Recovery of water for reuse from tannery wastewater and other advanced environmental protection measures – Asian scenario

Dr. S. Rajamani

Chairman - Asian International Union of Environment (AIUE) Commission No.18, First Street, South Beach Avenue, MRC Nagar, Chennai – 600 028, India. E-mail: dr.s.rajamani@gmail.com

Abstract

With a view to address the depletion of quality water resources, environmental challenges, control of Total Dissolved Solids (TDS) and salinity, a sustainable development of water recovery system has been developed and adopted in many tannery Effluent Treatment Plants (ETPs) in India, China and other leather producing countries. The tannery wastewater is initially treated by adopting conventional physiochemical and biological effluent treatment systems to reduce hazardous chemicals, BOD, COD, Suspended Solids, etc. Subsequently, high pressure membrane systems associated with tertiary treatment units have been implemented for recovery of water from tannery effluent and TDS management. Membrane Bio-Reactor (MBR) replaces secondary clarifier and sophisticated tertiary treatment units. Commercial-scale treatment systems with special technical units have been implemented in many locations for the capacities ranging from 500 to 10,000 m$^3$/day with an investment of more than 200 million US dollars. This paper deals with the recent developments on the environmental protection techniques in tannery wastewater treatment with focus on water-recovery for reuse, salt recovery, marine disposal of saline reject with proper bio-control system, etc. Case studies of innovative technological development and projects implemented in India, China and other countries are covered in this novel technical paper.

Keywords: Tannery Effluent Treatment Plant, Environment, Membrane System, Water Recovery.

1 – Introduction

Annual leather process in Asian Countries is estimated at 8 to 10 million tons of hides and skins which is more than 50% of the estimated World leather production of about 16 million tons per year. Wastewater discharged from world tannery sector is about 600 million m$^3$/annum. The tanneries in Asia discharge more than 350 million m$^3$ of wastewater per annum.

The ground and surface water resources in many locations in and around tannery cluster contain high Total Dissolved Solids (TDS) and not fit for domestic and industrial use. The conventional physiochemical and biological treatment systems are designed and implemented only to reduce Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), heavy metals etc. and not TDS and salinity which are mainly contributed by chlorides, hardness and sulphates. Due to inherent quality of wastewater from tanning industry, the treatment plants are unable to meet the prescribed standards in terms of TDS, chlorides in salinity in the treated effluent.

There is not much scope in mixing the treated tannery effluent with domestic sewage to achieve the TDS level in many locations in Asia in the absence of organized sewage treatment plants of required
capacity. Many polluting industries including tanneries are located in the land locked areas and there are constraints to discharge the treated effluent with high TDS in the Sea.

The TDS limit is being enforced in India and other parts of the World depending upon the final mode of disposal. In addition to the removal of TDS in the treated effluent, it is necessary to recover water for reuse to meet the challenge of water shortage. In many states in India, the pollution control authorities insist on water recovery integrated with Zero Liquid Discharge (ZLD) system. Different types of units such as Micro Filter (MF), Ultra Filtration (UF), Membrane Bio-Reactor (MBR), Nano Filtration (NF), Reverse Osmosis (RO) etc. have been developed for recovery of water from saline ground water, Sea water and domestic / tannery wastewater with high TDS. However, the achievement of Zero Liquid Discharge concept has got many technical challenges in addition to the application of various types of membrane systems. Management of the concentrated saline stream treatment by adopting energy intensive evaporation system seems to be one of the major issues in land locked areas. The marine disposal of saline reject from membrane system with high TDS over and above 40,000mg/l requires special development and provisions to safeguard the aquatic life.

2 – Technologies for Treatment of Salinity / TDS and Water Recovery

For recovery of quality water from tannery wastewater, the required treatment steps are (i) Conventional physiochemical and biological effluent treatment systems to reduce BOD, COD, SS etc. and (ii) Tertiary treatment systems including, micro-filter, low pressure membrane units such as ultra-filtration etc., before the application of single or multiple stage Reverse Osmosis (RO) system. A typical treatment process for recovery of water from wastewater is given in Figure 1.

![Figure-1: Treatment System for Recovery of Water and TDS Management.](image)

The number of stages and types of RO system are based upon the TDS concentration in the feed water, estimated percentage of quality water recovery and reduction in volume of saline reject. High pressure Sea water membrane is adopted for handling treated effluent with TDS concentration more than 10,000 mg/l. The quality water recovery rate could be achieved to the level of 70 to 90% depending upon the feed water TDS level, type and stages of membrane system etc. In addition to recovery and reuse of quality water by the industry, the additional benefits are savings in chemical usage in the tanning process and reduction in pollution load in the effluent. The reject saline stream from RO system needs to be managed by adopting the options of forced / thermal evaporation system or disposal into Sea wherever feasible with suitable control.

Many full scale membrane systems have been installed for recovery of water from domestic and tannery wastewater with capacities ranging from 100 to 20000m³/day.
3 – Membrane Bio- Reactor (MBR) integrated with RO system

Membrane Bio- Reactor is a low pressure membrane unit integrated with aeration unit. It requires continuous recirculation cum backwash facility. MBR system is developed using ultra filtration type membranes with high recirculation provision in the aeration unit along with bio-mass to maintain required mixed liquor suspended solids (MLSS). The MBR replaces the secondary clarifier and sophisticated tertiary treatment units prior to RO system. The process flow diagram of MBR is given in Figure – 2.

![Process Flow Diagram of Membrane Bio Reactor](image)

Membrane Bio Reactor (MBR) system is commonly adopted in many countries to remove the residual BOD, suspended solids / coliform, etc. from the effluent. After treatment with MBR, the water is applied through RO system for removal of TDS and salinity to get drinkable quality water with TDS less than 500mg/l. A Common Effluent Treatment Plant (CETP) in Spain with MBR and RO system for water recovery was established in 2005. Recent times many CETPs in India have adopted MBR and other membrane system for water recovery and reuse from the tannery effluent. After MBR / UF treatment, the suspended solids and BOD values in the effluent are below detectable level and taken for treatment with RO system for recovery of water after the removal of TDS and salinity. Figure - 3 shows the installation of RO system for water recovery from tannery effluent.

![Reverse Osmosis system following MBR / UF](image)

In China also water is becoming a scarce commodity in many locations. Expansion of high water consuming industries is allowed only if they are provided with water recovery system in the effluent.
treatment plants. To recover water from the tannery wastewater, submerged MBR linked with activated biological treatment is provided in the first stage. Following MBR system an RO plant in “Christmas Tree” configuration has been installed and operated at 12–16 bars. The RO plant produces about 70% permeate and 30% concentrate. The quality of the recovered water meets the drinking water standards. The saline water concentrate stream is further treated with Fenton process before disposal.

A view of the submersible MBR in one of the tannery effluent treatment plants in China is shown in Figure – 4.

![Submerged Membrane Bioreactor](image)

The Nano Filtration (NF) is adopted for removal of colour and salts such as sulphates from the treated effluent after ultra filtration or MBR stage. Nano-filtration membranes are operated under low pressure with high yield of about 90%. Adopting NF will improve the efficiency of RO in water recovery and to decrease the volume of saline reject.

### 4 – Techno Economical aspects of Residual Saline Streams

The disposal of the concentrated saline stream from the membrane system is one of the important issues to be addressed in land locked areas. The conventional method for disposal of saline stream is to adopt open solar evaporation pans. The average evaporation rate in solar pans ranges from 4 mm to 6 mm depending on the locations. These evaporation pans occupy large land area. The sprinkling system linked with solar warming developed under UNIDO assisted programme improves the evaporation rate by 300%. However, the spreading of aero salt from the sprinklers is one of the limiting factors. To overcome the problems, a forced evaporation system in a closed unit is designed, developed and implemented as a demonstration unit. This system improves the evaporation rate of saline stream by about 800%. Condensed saline stream is discharged in the solar pan and the dried salt is collected periodically. The process flow diagram of the forced evaporation system is shown in Figure - 5.
Multiple stage evaporators using thermal and electrical power have been installed for evaporation of the reject saline stream from RO system. However, there are many technical issues such as constrains in continuous operation of the system, meeting the required quality of the condensate water from the evaporator for reuse, management/ utilization of the recovered salt with impurities etc., The capital and operational costs are also high. Further techno economical review and modified options are required on the sustainability of the system particularly in land locked areas.

5 – Novel Marine disposal of treated saline streams

A novel technological development has been made for the drawl of Seawater of 30,000 m$^3$/day from nearby Sea for the desalination plant integrated with a major leather complex in South India. Out of the total water quantity, freshwater of about 10,000m$^3$/day will be generated and the remaining 20,000m$^3$/day will be discharged into Bay of Bengal with special bio-control and dispersion system to safe guard the aquatic life. The leather complex will be using the freshwater generated by desalination plant for its process requirements and 9,000m$^3$/day wastewater will be treated, mixed with saline reject of the desalination plant, stored in a water tight pond for a capacity of about 10 days and discharged into the Sea by laying 5 km pipeline using high pressure HDPE pipe and special sprinkling system. The combined treated saline stream with a quantity of about 29,000m$^3$/day will be discharged once in a week under the overall control of environmental protection authorities.

With the support of many National Institutes and other organizations, model studies were carried out in finalizing the novel marine outfall. The spreading of an effluent cloud released in a marine environment is governed by advection caused by large scale water movements and diffusion caused by comparatively small scale random and irregular movements without causing any net transport of water. Hence, the important physical properties governing the rate of dilution of an effluent cloud in coastal waters are bathymetry, tides, currents, circulation and stratification.

A five port diffuser systems with 0.18 m diameter is planned with a jet velocity of 2.5 m/sec, for the release of treated effluents and reject water from the proposed desalination plant.

The Environmental Clearance (EC) has been accorded to this unique integrated project with water recovery using desalination process, tannery wastewater treatment, novel and safe saline reject disposal into Sea without affecting the marine life which is first of its kind in India.
6 – Recent technological developments in Asian and other leather producing countries

The recent developments in cleaner production and waste management in Asian and other selected leather producing countries are given in Table 1.

<table>
<thead>
<tr>
<th>Country</th>
<th>Research &amp; Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITALY</td>
<td>Total aerobic biological oxidation system without the use of chemical is adopted in major CETPs for reduction of COD and sludge generation. Thermal treatment of sludge, energy generation from volatile organic matter and overall sludge management are followed. Central chrome recovery and reuse system are being adopted in many locations.</td>
</tr>
<tr>
<td>NEW ZEALAND</td>
<td>Enzymes and unhairing process is becoming more popular. Elimination of salting of skins by introducing chilling process in selected areas, Sulphide oxidation, pH &amp; settleable solids control and discharge of effluent into public sewer system.</td>
</tr>
<tr>
<td>SPAIN</td>
<td>The tannery clusters with CETP are located in Igualada near Barcelona and Lorca near Murca a coastal town in the southern part of Spain. The CETP in Igualada with a capacity of 9 MLD has been established with a capital cost of 13 million Euros. Membrane Bio Reactor with Reverse Osmosis (RO) for water recovery has been established in the CETP near Lorca. The water recovery system from a tannery CETP is first of its kind in the World and was commissioned during 2004-2005. The system has faced with some technical and economical issues in saline water evaporation system in the landlocked area. R &amp; D activities on cleaner production and waste minimization are being carried out by the institutions in Spain: INESCOP, AIICA and EEI (UniversitatPolitècnica de Catalunya)</td>
</tr>
<tr>
<td>TAIWAN</td>
<td>Currently there are about 50 tanneries in operation in Taiwan. The tanneries are having individual treatment plants with capacities ranging from 300 m3–2000 m3/day. They adopt conventional physio-chemical and biological treatment systems.</td>
</tr>
</tbody>
</table>

Figure 7: Aerobic oxidation using diffused aeration in Italy
Figure 8: SPAIN - New CETP in Igualada
Figure 9: Elevated aerobic biological treatment system
7 – Conclusion

The leather production activities especially raw to semi-finishing process are being shifted from the developed nations such as United States, West European Countries, to Asian, North African and Latin American Countries. The major tanneries in leather producing Countries such as China, Italy, India etc. have to develop and adopt new environmental protection measures such as adoption membrane system, water recovery, etc. due to enforcement of stringent environmental regulations. The sustainability of the small-scale units is becoming a serious issue to meet the environmental requirements. Major investments are being made for environmental protection and resettlement of tanneries from the urban areas to the industrial parks with common effluent treatment plants. New regulations and restrictions such as REACH on the use of certain chemicals, salinity and water recovery under zero discharge concept, disposal/management of chrome containing sludge etc. envisage continued Research & Development activity. Innovative tanning processes which will greatly reduce the water and chemical usage and minimize solid waste generation are needed together with overall environmental planning and management.

8 – Acknowledgement

The contributions of Asian International Union Environment (AIUE) Commission and IUE Commission members from various countries, IULTCS, UNIDO and European Union are acknowledged. Special efforts and inputs from Mr.Ivan Kral, UNIDO, Ms.Catherine MONEY, Ms.Patricia CASEY, Prof.Dr.Mariliz Gutterres, Ms.Katia Fernanda Streit, Mr.Chen ZHANGUANG, Mr.Su CHAOYING, Mr.Liyuzhong, Mr.Thomas Yu, Mr.Vera Radnaeva, Mr.Gokhan Zengin, Ms.Eylem Kilic, Dr.Campbell Page, Mr.Jakov BULIAN, Dr.Wolfram SCHOLZ, Mr.Elton Hurlow, Dr.Shi Bi, Dr.MaJianzhong, Dr.Volkan Candar, Prof.Altaf AFSAR, Dr.Keiji Yoshimura, Mr.M.Aihara, Mr.Juan Manuel SALAZAR, Dr.Dietrich Tegtmeyer, Mr.Arnab Jha, Ms.Suliestiyah Wiryodiningrat, Dr.LuminitaAlbu, Mr.Gustavo Gonzalez, Mr.Y.K.Luthra, Mr.Goeff HOLMES, Mr.Dylan BALL, Dr.Mwinyikione Mwinyihija, Mr.Arnold Mulder, Mr.Mohammad Aslam Mia and other technical committee members are greatly acknowledged.

The support and contributions of COTANCE, European Union (EU), National Research & Development Institute for Textile and Leather (INCOT), Division Leather & Footwear Research Institute (ICPI), Leather Research Institute by name “Asociación Española de lasIndustrias del Curtido y Anexas (AIICA)” located in Igualada, particularly by Dr.Agustí Marshal, Dr.Ms.Luisa F.Cabeza and
Mr. Daniel Sanchez Esteve from Spanish Leather Chemists Association (SLCA) are greatly acknowledged.

Central Leather Research Institute (CLRI), China Leather Industry Association (CLIA), Taiwanese Leather Industry Association (TLIA), Indian Leather Technology Association (ILTA), Latin American Congress Federation of Leather Industry Chemists and Technicians (FLAQTIC), Japanese Association of Leather Technology (JALT) is acknowledged.

9 – References

1. S. Rajamani – Sustainable Environmental Protection System for tanning industry with viable sludge and saline stream management, Leather News India – 2014
3. S. Rajamani – Concept and guidelines for Environmental Footprint for World Leather Sector, Leather News India – 2013
4. S. Rajamani – Environmental update in Leather producing countries, Taiwan, Leather News India – 2012
5. S. Rajamani & Patricia Casey – Environmental update in Leather Producing Countries – Argentina, Leather News India – 2010
7. LL. Milá, X. Doménc et al., Use of LCA in the procedure for the establishment of environmental criteria in the catalan ecolabel of leather – 2002