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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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PROJECT REPORT

FINAL REPORT ON US/RAS/92/120/PDU/2A

OPERATION OF PILOT RO UNIT ATH TANNERY

MELVISHARAM, INDIA

Submitted by

AQUA CHEMICALS & SYSTEMS (MFG) LTD

42, FIRST STREET

KAMARAJ AVENUE

ADYAR

CHENNAI- 600020

INDIA

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LIST OF ABBREVIATIONS

BOD_5	:	Biochemical Oxygen Demand, 5 days, 20°C
COD	:	Chemical Oxygen Demand
CETP	:	Common Effluent Treatment Plant
CLRI	:	Central Leather Research Institute
cm	:	centimetre
°C	:	degree Celsius
d	:	day
dia	:	diameter
ETP	:	Effluent Treatment Plant
h	:	hour
HP	:	Horse Power
kg	:	kilogram
kWh	:	kilo Watt hour
l/s	:	litres per second
LDPE	:	Low Density Poly Ethylene
m	:	meter
m^3	:	cubic meter
mg/l	:	milligrams per litre
PDU	:	Pilot and Demonstration Unit
pH	:	Negative logarithm of hydrogen ion concentration
RO	:	Reverse Osmosis
RePO	:	Regional Programme Office
Rs.	:	Indian Rupees
s	:	seconds
TDS	:	Total Dissolved Solids
UNIDO	:	United Nations Industrial Development Organization
W	:	Watts
ACS	:	Aqua chemicals and systems (mfg) ltd

1. BACKGROUND

In arid countries and specifically in the tropical zone of South and East Asia scarcity of fresh water of good quality is emerging as a major challenge. For example, in Vellore district, Tamil Nadu state in the south of India where more than 50% of the tanning capacity of the country is located, Palar river flows only during monsoon for less than three months a year. For irrigation and drinking water, the population of this area depends entirely on ground water. Tannery effluent, even after treatment, contains TDS at levels more than 10,000 mg/l and when it is discharged on to the surface it contributes to degradation of ground water quality. In order to check such degradation, the pollution control authority in the state has prescribed, among norms for discharge of treated effluent to the surface, TDS at 2100 mg/l, Chlorides at 1000 mg/l and sulphates at 1000 mg/l.

To an extent TDS in tannery effluent can be controlled by adoption of cleaner technologies in tanneries. Alternative preservation techniques such as drying of hides and skins, cooling and chilling, etc. can help reduce or eliminate use of salt in preservation. However, these have not been found currently practical in India. Shaking and brushing of salted hides and skins can lead to reduction by 15 % in the impact of salt curing. Direct recycling of pickling/tanning floats may also reduce TDS in effluent. However, a significant part of the salinity in the effluent cannot be removed through such cleaner technologies.

In Tamil Nadu, natural solar evaporation is applied to process soaking effluent, containing maximum TDS, but the land requirement is high taking an average evaporation rate of 4-5 mm/d. Some attempts to accelerate the evaporation rate with sprinklers and inclined platform were successfully made. However, the drawback of such technologies is that water is not recovered.

Membrane technologies are increasingly applied to process saline water where the demand for fresh water is high. Since the beginning of 90's, 70% of the newly built desalination plants are using the reverse osmosis (RO) technology. The wider adoption of this technology has contributed to reduce the cost of the membranes. It was thus worthwhile to test the viability of the RO for primary and biologically treated tannery effluent.

One of the key issues in employing the RO technology is the satisfactory disposal of the reject from the system. It was therefore considered essential that while assessing the feasibility of the RO system for treating salinity in tannery effluent an appropriate course of action for dealing with the reject must also be specified.

2. OBJECTIVES

- To assess and demonstrate the feasibility of further treatment of treated tannery effluent containing upto 10000 mg/l of TDS by reverse osmosis for recovery of good quality water fit for reuse in tanneries.
- To minimise the rejected concentrate and demonstrate its treatment in the solar evaporation pan for salt recovery.
- To evaluate feasibility of re-use of rejects in relevant tannery operations.
- To evaluate the life of membranes used.

- To observe various operational parameters that influence the efficiency of the system.
- To optimise the cost of operation.

3. STRATEGY

As it was considered unwise to embark on a major investment without ascertaining the technical feasibility and the financial viability of the RO system for tannery effluent, UNIDO, under its Regional Programme, decided to adopt the following strategy:

- To lease a small system, with a capacity of 1 m^3 per hour and organise its operation by the supplier of the system for a period of about one year to evaluate its performance, cost of operation, quality of recovered water and filtrate.
- To install the system in a tannery with its own well functioning ETP producing treated effluent containing high level of TDS.
- To provide for external monitoring of the system by CLRI.
- Subject to satisfactory performance, to promote its upscaling and wider application in tanneries.

4. SELECTION OF INDUSTRY COUNTERPART

M/s ATH Leder Fabrik, Melvisharam was selected as the industry counterpart for this project on the following considerations:

1. The tannery has a well maintained ETP treating about 250 m^3/d of effluent.
2. All civil works, laboratory facilities and qualified operating personnel for operation and maintenance of the RO system were made available by the tannery.
3. It has the capacity to regularly and meticulously monitor and record the performance of the unit.

5. INSTALLATION OF THE PILOT RO SYSTEM

After evaluating the offers received, UNIDO has awarded the work of installation and operation of the pilot unit to us. (M/s Aqua Chemicals systems, Chennai.) The equipment remained the property of us and the contract was only for the purpose of evaluating the performance efficiency of the system for treatment of saline tannery effluent. We have provided all necessary inputs for regular operation of the system and also one plant-in-charge for operation and monitoring. The installation of the pilot RO unit of 1m^3 /h capacity was completed on 15 March 1998. Trial run started on 20 March, 1998. It took about 2 months for the plant to stabilise. Thereafter it has been operated continuously, until end of September 2000. Subsequently we were running the pilot unit in co-operation with the tannery as a demonstration project until the end of 2000.

6. SCHEME OF THE RO SYSTEM INSTALLED

Treated effluent collection system, effluent pump as well as complete civil and electrical works required for the system, including the building, were provided by ATH tannery. The tannery has also provided permeate water collection tank and pipeline to convey the permeate and the reject.

The system installed by ACS consisted of an inlet water tank (IWT), raw water pumps, an elaborate pre-treatment system comprising a multi grade filter (MGF), a photochemical oxidiser (PO), an activated carbon filter (ACF), chemical dosing system for dosing hydrogen peroxide, acid, antiscalant & antioxidant, an intermediate storage tank (IST-1), a high pressure pump-1, RO-1, intermediate storage tank (IST-2), high pressure pump-2 and RO-2. Necessary instrumentation such as pressure gauges, flow meters and on-line pH & conductivity analysers have also been provided.

Brief description of the technical features of the system components and the process are given in Annex-1& 2.

After the system commenced operation, its was augmented with more pressure gauges, flow meters and level controllers to facilitate better monitoring. A softener to take care of high hardness observed in the treated effluent was also provided by ACS at a later stage.

The P & I diagram of the pilot system is given in Annex-3.

7. MONITORING

In house monitoring of essential parameters (pH, TDS, hardness and COD) of the effluent was taken over by the tannery personnel while external monitoring of pH, TSS, TDS, Chlorides, Sulphates, COD, Silica and hardness was assigned to CLRI, Chennai, India for regular monitoring of the performance of the system.

Besides this, operational parameters such as flow rates, pressure readings, chemical dosages, cost factors and operational problems were kept both by the personnel of ACS and ETP in-charge of the tannery.

For recording flow rates, flow meters with totalisers were installed (total 8 nos.) in sections such as inlet, after IST, after softener, RO-1 reject to solar pan, RO-1 reject recycle, RO-1 outlet, RO-2 reject recycle and RO-2 permeate. But some of these flow meters were not giving correct reading even after multiple replacements. This was particularly the case with the important flow stream of reject line to solar pan and the explanation of the manufacturer was that since the flow rate was so low (as low as 100 l/h), such type of flow meters (with rotating wheels) could not function effectively. It was therefore decided to collect the reject in a centralised collection tank for measurement and necessary arrangements were made for the same in early 1999.

8. OPERATIONAL DETAILS

8.1 Flow pattern

<u>8.1.1. During the period March, 1998 to Dec 1998</u>

As per the contract, the pilot unit was operated 8 hours a day.

The operational pattern during the 8 h/d was generally as follows:

Time	Activity
9.00 A.M.	Feeding to raw water collection sump started
9.15 A.M..	Feeding to IST-1 using raw water pump through pressure filter and PO started
9.30 A.M.	Feeding to RO-1 started and
9.45 A.M.	Feeding to RO-2 started and permeate flowing out.
5.00 P.M.	Feeding to raw water collection sump was stopped and feeding to RO-1/2 continued.
5.30 P.M.	Feeding RO-1 was stopped.
5.45 P.M.	Feeding to RO-2 was stopped.
5.45-6.00 P.M.	A small quantity of water remaining in IST-1 and IST-2 was discharged and then the membranes were flushed with permeate water to preserve it until the next morning.
6.00 P.M.	The water remaining in the raw water collection tank and IWT were utilised for back washing of the pressure filter and activated carbon filter

8.1.2 During 25 December 1998 to 5 February 1999.

Continuous feeding was resorted to during this period. However, backwashing of filters as well as flushing of membranes were continued to be done once in 8 hours (as it was clarified by the supplier that the pilot system was designed for 8-hour continuous operation only based on the contract and therefore the capacity of filters was adequate only for this). In effect, the 24-hour continuous operation was a combination of three discrete 8- hour schedules. Due to this reason, achieving a steady state was never realised even during the continuous operation.

8.1.3 Operation from 5 February 1999 until end of September 2000.

The major operational parameters were similar to the initial 8-hour operation, except that for backwashing of filter only fresh effluent was used and the spent water was sent to the ETP. Analysis of this liquid was done only in terms of pollutants removed other than TDS and this stream was not considered for mass balance of TDS, as there was no carryover of TDS through this line.

The operation of the system was stopped at the end of September 2000 when the contract for the same ended. Thereafter, the system has been operated by the ACS in cooperation with the tannery.

8.2 Other operational parameters

8.2.1 Pressure

a. The inlet operating pressure before the pressure filter was around 3 bar. The pressure loss across the filters was approximately 0.5-1.0 bar depending on the solids accumulation in the filter. It was noted that after around 3 hours of operation, the pressure loss of 0.5 bar started and towards the end of operation, the pressure loss reached around 1.0 bar.

b. The overall pressure loss through activated carbon filter and softener was 0.5- 2.0 bar with inlet at 4.0 bar and outlet at around 2.0-3.5 bar depending on hours of operation.
c. The feed pressure of RO- 1 at the beginning of daily operation was around 11 bar reaching the maximum of 15 bar by the end of the operation with a pressure drop of around 0-1 bar across the membrane.
d. The feed pressure of RO 2 was around 12 bar in the beginning reaching the maximum of 16 bar by the evening. The pressure drop across the membrane was around 0-0.5 bar.

The variations in pressure levels noted in RO-1 & RO-2 are given in figure 1:

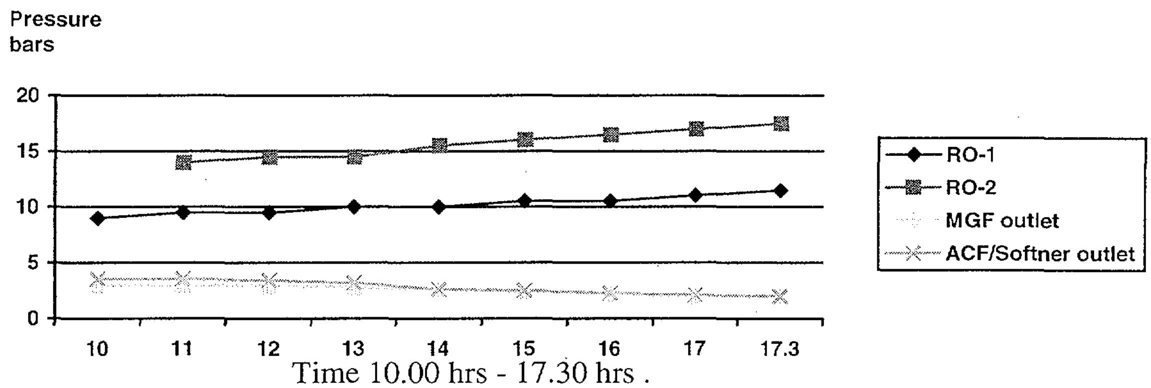


Figure 1: Pressure variation from 10 hrs to 17.30 hrs. in a day

8.2.2 Chemical consumption

The dosage of various chemicals maintained during the operation is in Table 1:

Table 1: Dosage of chemicals

Hydrogen peroxide	Nil
Hydrochloric Acid	Varied from 5 - 10 mg/l (depending on pH of feed water)
Antioxidant (Sulphite)	10 mg/l
Antiscalant (Hexa-meta phosphate)	10 mg/l

8.2.3 Power

The average power consumption per day as noted from the energy meter installed was maximum at 54 kWh and minimum at 16 kWh. The variation of average power consumption noted during the last fourteen months (without considering non operational periods and the continuous operation period) is given in figure 2:

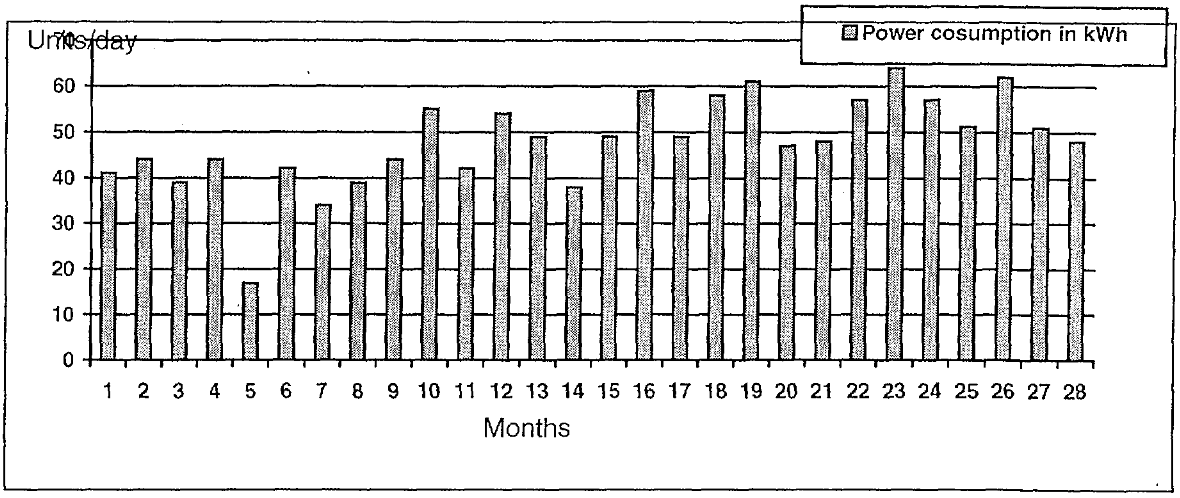


Figure 2: Power consumption during the project period

The average power consumption per day was 48 kWh.

The average power consumption during the 24-hour operation was 115 kWh/day.

8.2.4 Back washing & regeneration

Pressure filter

- The pressure filter (MGF) was back washed once in eight hours.
- Back washing was done by reversing the flow through the filter with water collected in the collection sump (at 5.15 PM) by the raw water feed pump. Part of this water was used for back washing and part sent to intermediate storage tank (IST-1).
- The pumping rate was set for 1 m^3/h and pumping continued till the collection tank was empty. Generally it took approximately 9-10 minutes to pump out the water.
- The water consumption during washing was around 150 l/cycle

Softener

- The softener was regenerated once a day.
- Approximately 100 l of sodium chloride solution (20%) was used for regeneration.
- Brine solution for regeneration was sucked in using inlet water tank (IWT) pump.
- Quantity of sodium chloride used was approximately 20 kg/d.
- Rinsing was done using water collected in the IWT and the quantity of water used was approximately 200 litres. Thus the total water consumption for regeneration of the softener was 300 l/d.

Activated carbon filter

- The activated carbon filter (ACF) was back washed once in eight hours.
- Back washing was done by reversing the flow through the filter with the remaining water in the IWT (at 5.30 PM) after regeneration of the softener.
- The pumping rate was set for 1 m^3/h and pumping continued till the collection tank was empty. Generally it took approximately 10-12 minutes to pump out the water.
- The water consumption during washing was around 200 l/cycle

RO membranes

- Cleaning of RO membranes using speciality chemicals was supposed to be done whenever the recovery came down or pressure drop across the membranes was higher than 2 kg/cm^2.
- Generally membranes were cleaned once a week at the site.
- The newly installed alternate membranes have been cleaned seven times till now.

8.2.5 Membrane flux

The RO-1 (nano membrane) was observed to be having a flux value of 14-15 $litre/m^2/h$. There was not much change observed during operation of the pilot system in the last seven months. (i.e. March-September 2000)

The RO-2 membrane was observed to be having a flux of 28-30 $l/m^2/h$. No change in flux was observed during operation between July to September 2000.

8.2.6 Temperature

The temperature in the pre-treated effluent fed to RO-2 increased by about 0.5°C when pumped at high pressure. Of course, the temperature levels varied with respect to the ambient temperature. The temperature variation pattern on a given day is presented in the figure 3:

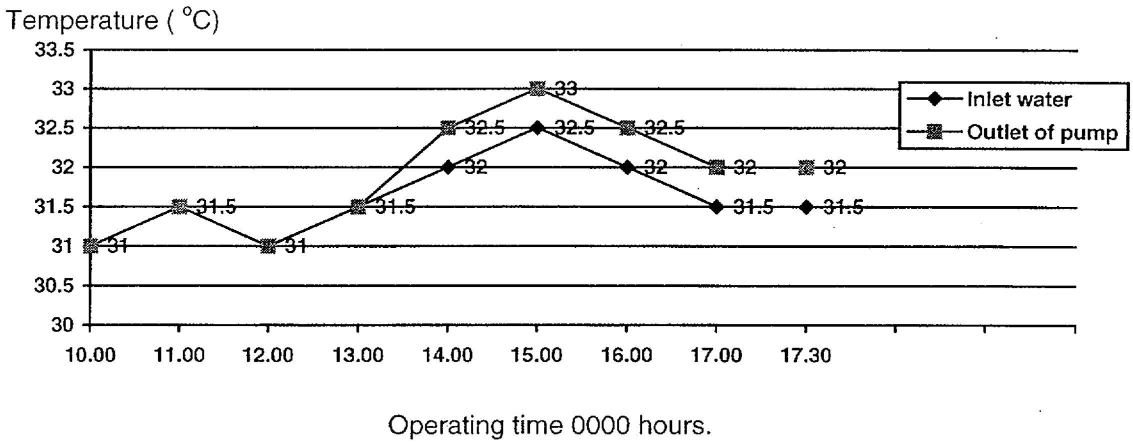


Figure 3: Temperature variation during a day of operation (typical)

9. DIFFICULTIES ENCOUNTERED

9.1 Maintenance problems

Initially during the stabilisation period of the pilot unit, quite a number of maintenance problems surfaced such as burning of fuses, shutdown of pumps, frequent choking of cartridge filter and activated carbon wash off etc. However after adopting necessary corrective measures, frequency of such complaints came down. From June 1998 onwards the main complaints related to failure of flow meters and frequent back washing of filters due to the high level of suspended solids in the treated effluent.

9.2 Failure of membranes

During the operation of the pilot system, three incidents of membrane failure occurred. The first one occurred immediately after the start-up during May 1998, when the RO membranes (RO-2) failed. Following inspection at the manufacturer's facility in the USA, it was confirmed that the failure was due to oxidation of sealants caused by excessive amount of hydrogen peroxide dosing. The pilot unit operation was re-started after replacement of this membrane within a month. But drawing from this experience, dosing of hydrogen peroxide was discontinued.

The second incident of membrane failure occurred during February 1999 following clogging of the nano membrane (RO-1) by a certain dye stuff in the effluent. This dye could not be removed in the ETP and thus got into the RO stream, finally resulting in clogging of nano membrane. While the logical action should have been to shut down the feed, the staff employed at the plant delayed the decision, which resulted in the problem. Their explanation was that it was done deliberately to see the effect of the red dye on the membranes. Since the increase in pressures occurred suddenly and not gradually, it has been concluded that the clogging was due to the dye and not the natural clogging of the membrane.

The nano membrane was replaced in July 1999 and the operation was restarted. But the replaced membrane (by a different manufacturer) was not of good quality and soon got blocked. This was changed with the membrane of original supplier (Osmonics, Inc, USA).

The two failures in nano and RO membranes are considered more due to insufficient plant control by the staff engaged by ACS than a genuine failure of the membrane itself.

Barring the above incidents, the pilot unit operation had been relatively trouble free and seldom did the pressure levels reach the maximum fixed by the manufacturer (15 bar for nano and 20 bar for RO membrane).

A joint trial by CLRI and UNIDO was organised during November, 2000 to ascertain the recovery rate. The recovery rate observed during the joint trial was around 71%.

10. QUALITY OF PERFORMANCE

The analytical results at various points of the RO during 8-hour operation are given in Table 2 and 3. The various parameters at different sections of the RO unit varied from morning till evening from day to day. The analysis report is the average value of composite samples reported by the tannery and CLRI on representative conditions.

The variation of various parameters with respect to time is mainly due to the concentrate recycle and discharge of accumulated liquor in IST-1 & 2 after termination of operation at the end of 8-hour schedule.

The composite samples were collected at half hourly interval with respect to flow rate in individual streams and are the average of more than thirty sets of composite samples.

Table 2: Analysis reports of composite samples during 8 hours operation

#	Parameter	Unit	Inlet		Permeate		Reject	
			Range	Avg	Range	Avg	Range	Ave
1.	pH		6.6-8.2	7.8	5.4-6.2	5.7	5.2-6.0	5.9
2.	Total Suspended solids	mg/l	145-295	235	Nil	Nil	0-1.0	<1.0
3.	Total Dissolved solids	mg/l	3040-8335	5110	175-1200	395	16450-27310	19460
4.	BOD, 5 day 20° C	mg/l	36-89	68	Nil	Nil	12-190	106
5.	COD	mg/l	165-644	435	>2	>2	730-1925	932
6.	Chlorides	mg/l	810-2620	1215	90-710	204	2240-9410	5260
7.	Total Hardness	mg/l	1400-1904	1520	0-2.2	1.5	1420-4710	3420

The analytical values of water at intermediate stages are not given. Due to continuous re-circulation these values do not have much relevance in evaluating the system. For evaluating the efficiency of pre-treatment units to get realistic mass balance, separate analysis was done.

In order to assess the extent of TDS loss through other streams such as back wash and regeneration, water drained at the end of operation etc., representative samples of such streams were collected and the analysis report is reproduced in Table 3:

Table 3

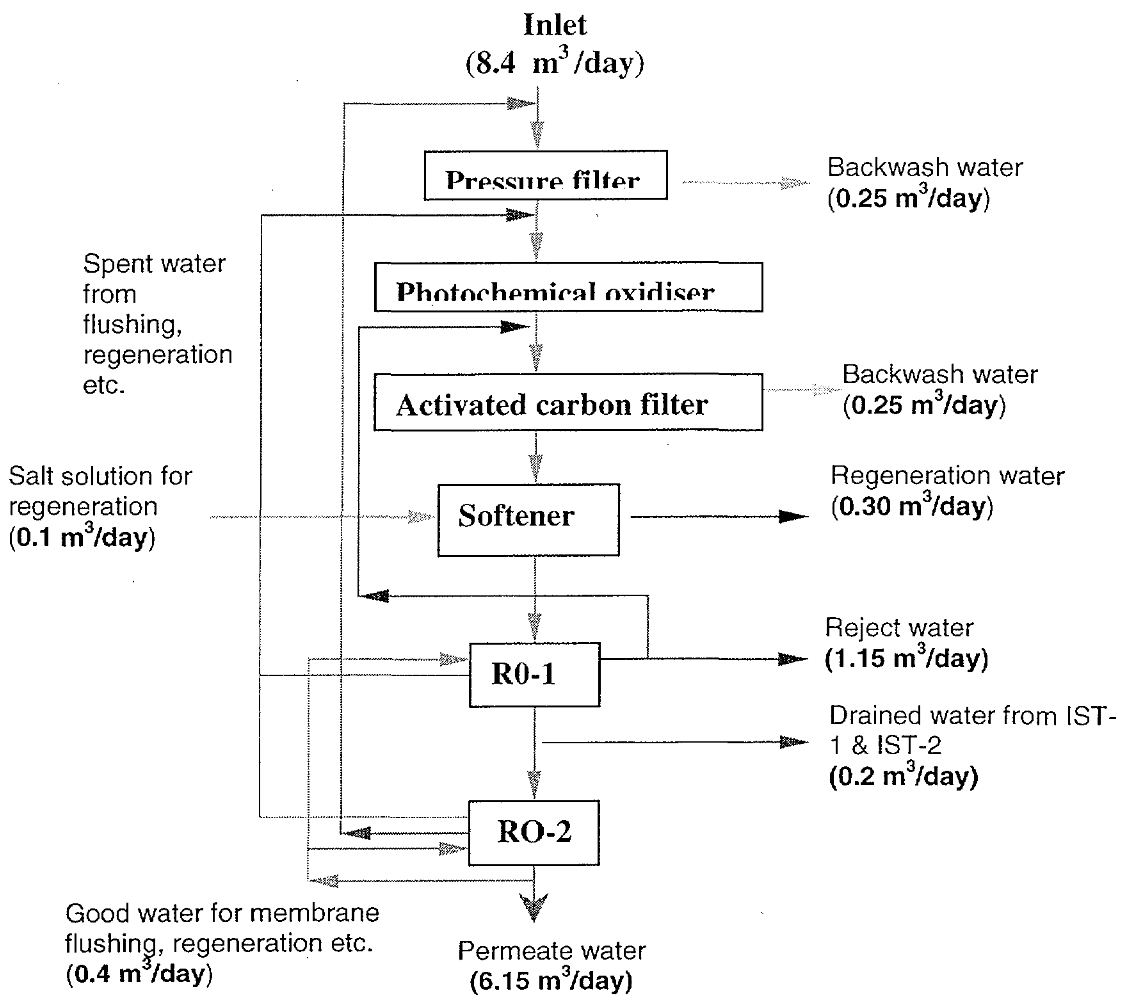
#	Parameter	Unit	MGF backwash	ACF back-wash	Softener re-generation	Water drained from IST-1	Water drained from IST-2
1.	pH		5.3-7.1	5.1- 7.1	5.2-7.1	5.1-7.2	5.1-7.2
2.	Total Suspended solids	mg/l	4480	980	210	17	ND
3.	Total Dissolved solids	mg/l	27775	25750	87750	29400	27600
4.	BOD, 5 day 20° C	mg/l	755	580	72	322	ND
5.	COD	mg/l	4975	3100	1010	980	375
6.	Chlorides	mg/l	5710	5080	51130	3980	5970
7.	Total Hardness	mg/l	350	5830	5110	5780	110

11. MASS BALANCE OF THE SYSTEM DURING 8 H/DAY OPERATION

11.1 Water balance:

The water balance through the system with the current 8 h/d operational pattern is given in Table 4 & figure 5:

Table 4



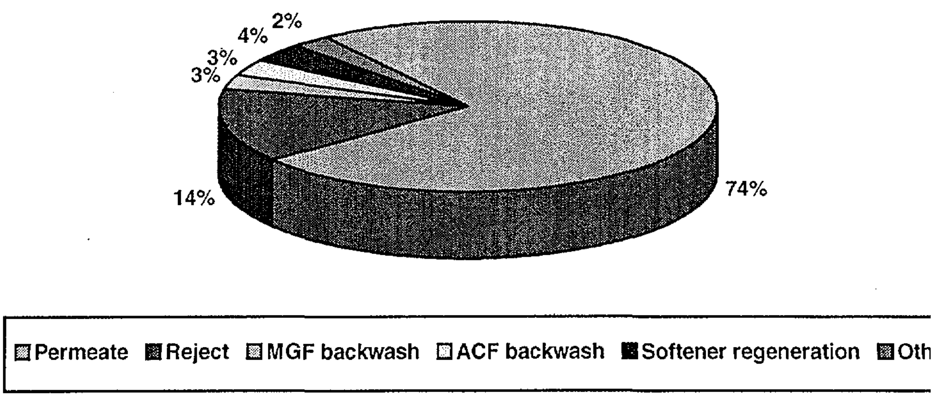
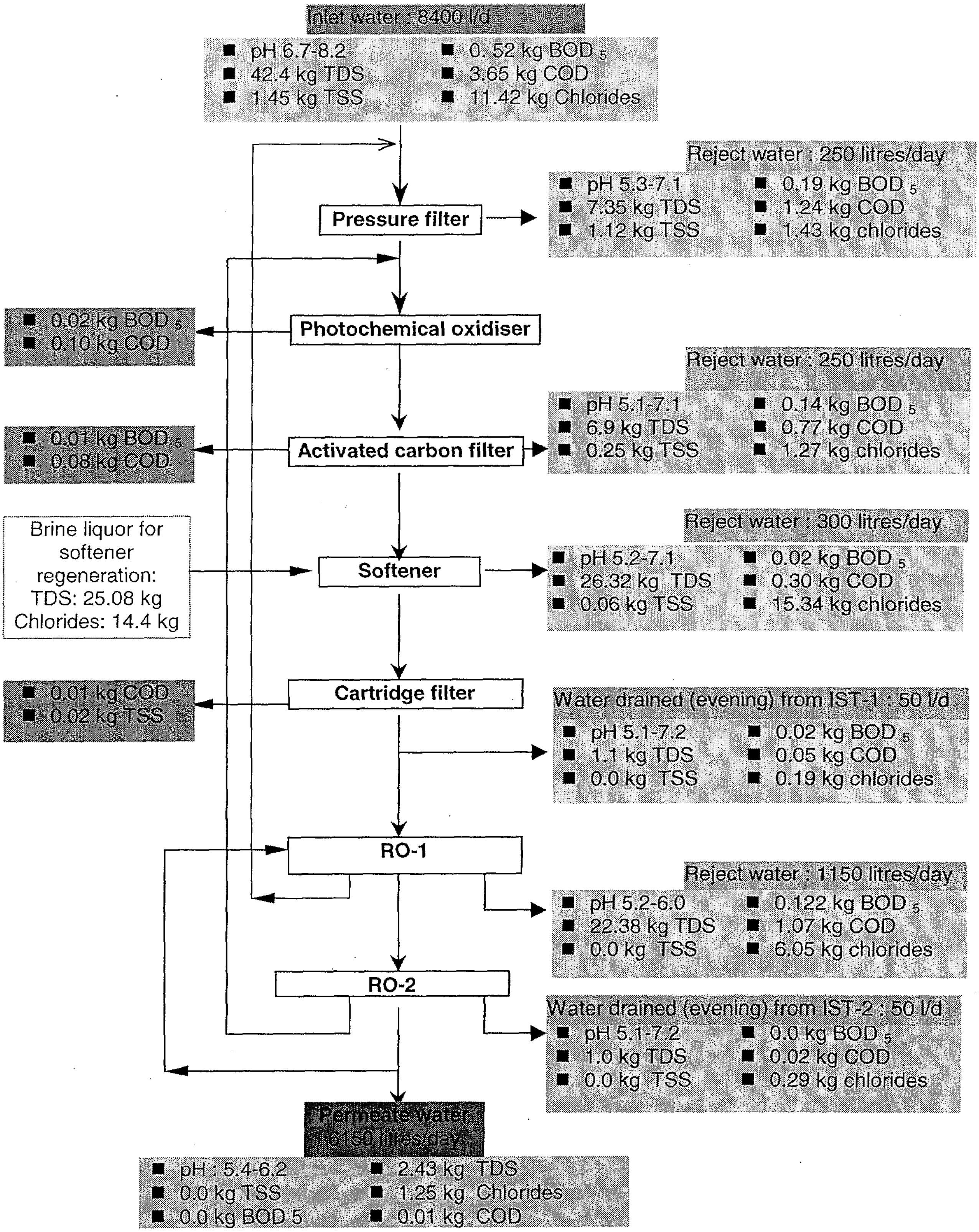


Figure 5: Water balance

11.2 Mass balance in terms of various components is given in Table 5

(Some minor deviations are made in figures to match the difference observed in analysis report to make the mass balance tally)

Table 5



Figures 6, 7, 8 & 9 provide distribution of TDS, chloride, BOD & COD in the system

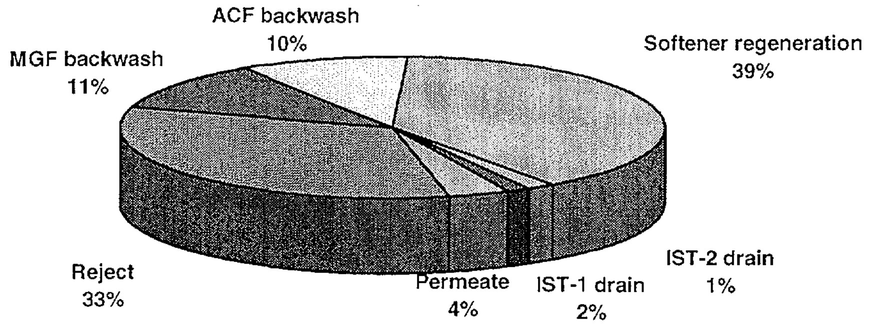


Figure 6: TDS distribution (Total inlet TDS 67.48 kg/d; 62.8% TDS from feed water and 37.2% from brine water for softener regeneration)

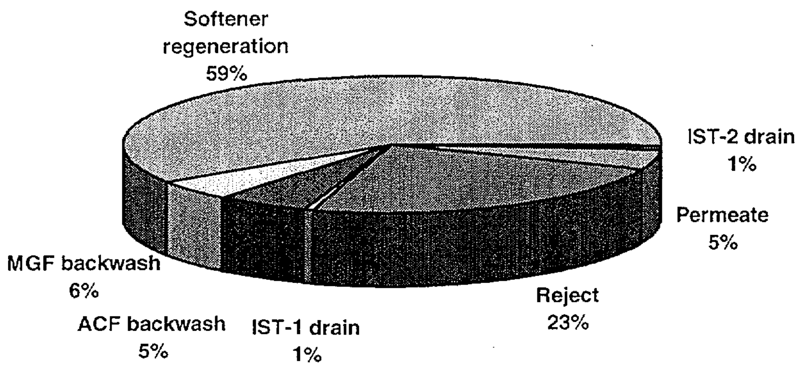


Figure 7: Chlorides distribution (Total inlet chlorides 25.82 kg/d; 44.23% Chlorides from feed water and 55.77% in brine water for softener regeneration)

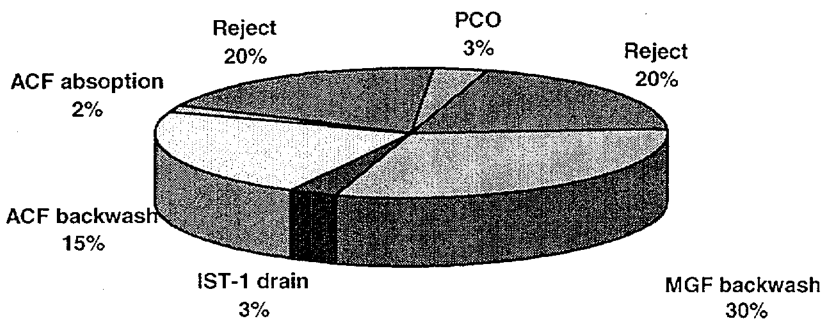


Figure 8: BOD Distribution (Total inlet BOD is 0.52 kg/d)

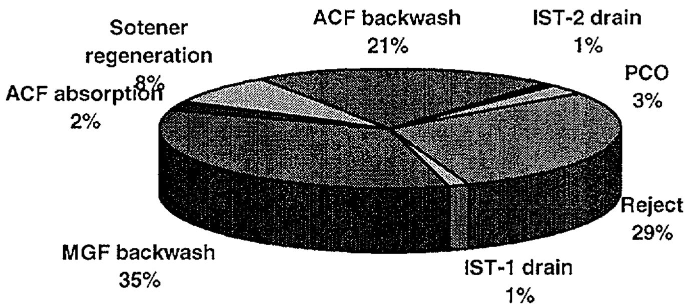


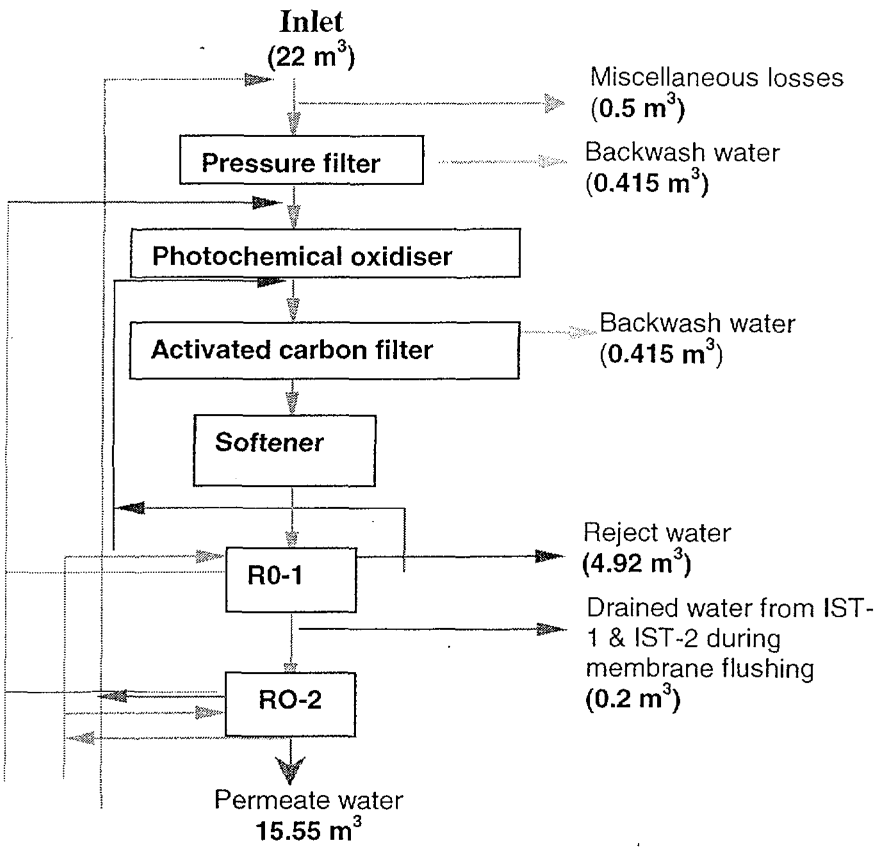
Figure 9: COD Distribution (Total inlet COD is 3.65 kg/d)

12. JOINT TRIAL CONDUCTED BY UNIDO &CLRI

As mentioned earlier, a joint trial was organised with CLRI to confirm the recovery rate. This was done from 25 to 26 October 2000. This result is considered more realistic, particularly due to the fact that the membranes had become quite old by then.

The water balance worked out during the trial period is in Table 6 and figure 10

Table 6



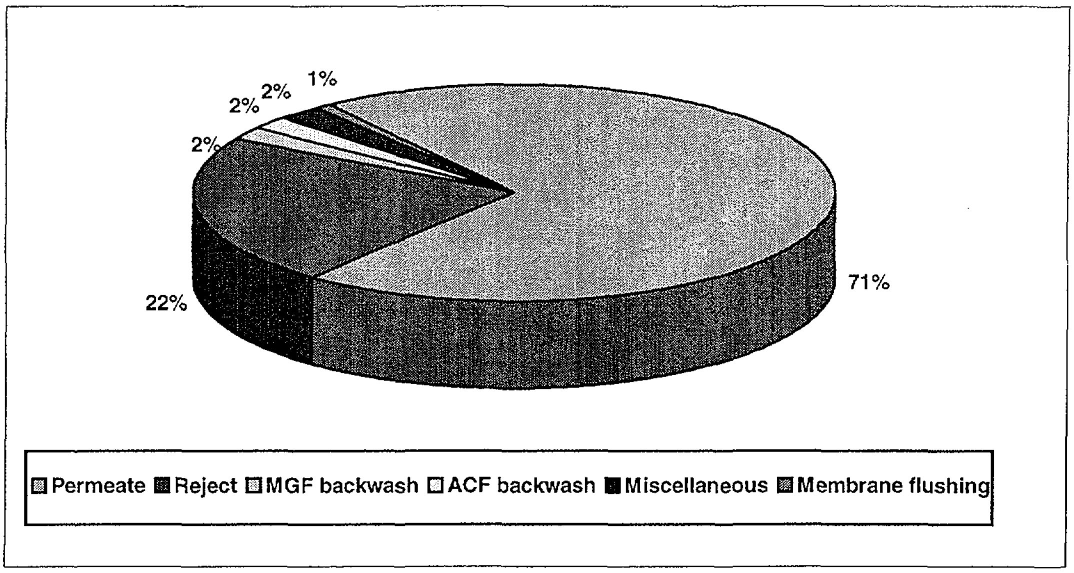


Figure 10: Water balance

13. EVAPORATION STUDIES

Disposal of reject from the RO system is the principal technical problem in application of RO for treating tannery effluent. It was felt that since the RO reject was free from suspended solids and other organics, it would evaporate faster and the dried up salt could be used in the tannery. It was expected to be purer than the salt obtained from solar evaporation pans. Evaporation studies were therefore carried out to ascertain the rate of evaporation and the purity of salt recovered. Since the volume of solar evaporation pans available in the tannery is much more than the small volume discharged by the pilot RO system, segregated loading of solar evaporation tank with rejects from the RO was found impractical. A sludge drying bed lying adjacent to the pilot RO unit was then emptied and made impervious by laying LDPE sheets. The evaporation of rejects from RO-1 and RO-2 was carried out in this makeshift tank. The average evaporation rate was observed to be 7-8 mm/day for a liquid depth of 30-50 mm. The salt obtained from reject from RO-1 was brownish with mostly sulphates as the major component. The salt obtained from RO-2 reject was pure transparent crystal with more than 95% of sodium chloride.

14. COST BENEFIT ANALYSIS

14.1 Operation cost

Table 7: During 8-hour operation

#	Item	Consumption	Value (INR)	Cost (INR)/day
1.	Power	48 kWh/day	4/kWh	192
2.	Labour	1 Technician	50/day	50
3.	Chemicals			0
	(a) Hydrogen peroxide	0	60/litre	0
	(b) Hydrochloric acid	0.5 litre	6/litre	3
	(c) Anti-oxidant	200 g	60/kg	12
	(d) Anti-scalant	300 g	70/kg	21
	(e) Salt	20 kg	1/kg	20
	Total			298

Cost analysis

Parameter	Unit	Quantity
Average quantity of water treated	m^3/day	8.4
Average quantity of water recovered	m^3/day	6.15
Cost of operation	INR/day	298
Cost operation /quantity of water treated	INR/m^3	35.47
Cost operation /quantity of water recovered	INR/m^3	48.45

Table 7: During continuous operation

#	Item	Consumption	Value (INR)	Cost (INR)/day
4.	Power	115 kWh/day	4/kWh	460
5.	Labour	3 Technicians	50/day	150
6.	Chemicals			0
	(a) Hydrogen peroxide	0	60/litre	0
	(b) Hydrochloric acid	1.0 litre	6/litre	6
	(c) Anti-oxidant	500 g	60/kg	30
	(d) Anti-scalant	500 g	70/kg	35
	(e) Salt	50 kg	1/kg	50
	Total			731

Cost analysis

Parameter	Unit	Quantity
Average quantity of water treated	m^3/day	22.1
Average quantity of water recovered	m^3/day	16.46
Cost of operation	INR/day	731
Cost operation /quantity of water treated	INR/m^3	33.08
Cost operation /quantity of water recovered	INR/m^3	44.4

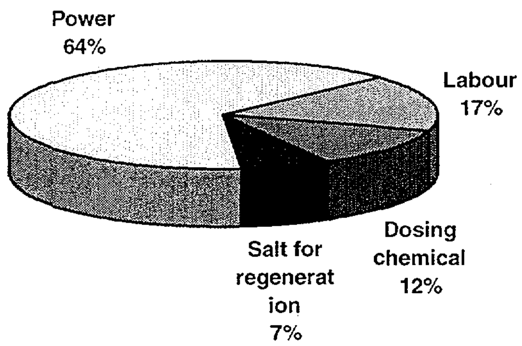


Figure 11: Distribution of cost – 8 h/d operation

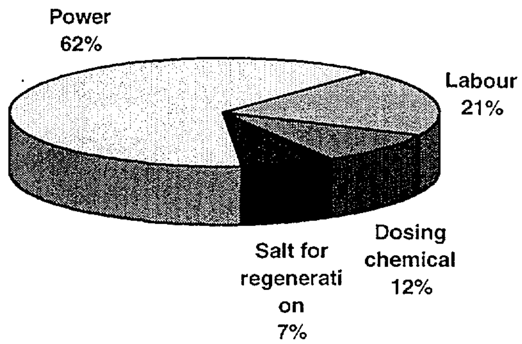


Figure 12: Distribution of cost – continuous operation

Note

The above figures do not include the depreciation on capital investment, monitoring / analytical cost etc. and also the membrane replacement cost, due to the following reasons:

- The capital cost and depreciation are quite high for the capacity of the pilot system. If these figures are taken for calculation of depreciation, the projected figure will not be representative of those of a large-scale unit.
- For normal RO unit, no regular analytical monitoring is required as, the operational parameters (pressure readings, pH, conductivity, ORP, chemical dosing etc.) are generally measured on-line. For the pilot system, however, very close analytical monitoring was needed to verify the suitability of the technology.

- The membrane replacement cost is not calculated as presently the life of the membrane is unknown. The manufacturer claimed it to be 3 years. However, the first set of membranes could hardly be operated for two months. It was of course confirmed by the suppliers that this was due to oxidation of sealants. Nevertheless, this aspect had to be left unverified due to inadequate duration of the pilot system operation.

15. EVALUATION OF PILOT SYSTEM PERFORMANCE

Based on the 18-month operation of the pilot RO unit, following observations may be made:

- The pilot unit, which was operating with treated tannery effluent with TDS of around 5000 mg/l could provide around 70-75% recovery of permeate, without much operational problems, except for the incidents of membrane failures described.
- The photochemical oxidiser provided was not very helpful, as the COD removed in this unit was not at all commensurate with its capital & operational cost.
- To achieve good performance of the RO, adequate pre-treatment is critical. The high level of hardness of the effluent, unexpected, necessitated the inclusion of a softener at a later date.
- The residual organics in the tannery effluent may not be easily oxidisable like any other effluent. Dosage of oxidising agents to reduce COD should however be done with caution.
- Continuous re-circulation of RO rejects results in gradual increase of TDS in intermediate stages during various hours of the day. The impact of re-circulation of reject could not be fully known even during the 24-hour continuous operation as this was again a discrete operation.
- The softner provided for the removal of hardness was not very helpful. Besides low efficiency, this unit introduced additional salt to the system. It is considered better to opt for some other system for hardness removal, if the same were considered necessary (as the membranes are used in many cases for removal of hardness too, proper choice of membranes could avoid this problem).
- The quantity of reject could be reduced by utilising the same for various applications like backwashing, regeneration etc. The reject from second stage RO, though rich in salt, is free from impurities and could be used as mother liquor for pickling float after supplementing the salt concentration.
- The mechanical problems encountered in the beginning of the trial operation could be due to lack of awareness of the system as, later, such complaints were seldom reported.
- Though the extent of damage occurred to the membrane due to the trial operation so far is largely unknown, the almost steady level of membrane flux and absence of any unusual pressure build up in the RO units indicate that deterioration of the membrane quality, if any, should be within the normal wear and tear levels.

16. FEASIBILITY OF UP-SCALING

16.1 General considerations

The main objective of the pilot unit was to verify the technical feasibility of the RO system for recovery of clean water from tannery effluent. While the performance of pilot unit could be taken as the basis for evaluating the technical feasibility of a larger RO unit, capital & operational cost of the pilot unit cannot be taken as representative. Based on the performance of the pilot unit, the following inferences may be drawn:

1. The RO technology can be applied to recover clean water from treated tannery effluent, provided necessary and appropriate, site-specific, pre-treatment is instituted.
2. The pilot plant has achieved between 70% & 75% recovery. However, this figure includes all backwashing, regeneration etc. When the RO unit is made an integral part of an ETP, all such waste liquor will generally be sent back to the inlet of the ETP. It is therefore felt these streams need not be considered as reject in an up-scaled plant. Without these washings, the average quantity of reject as observed in the pilot unit was only around 15-20%, indicating the possibility of achieving upto 80-85% recovery. However, based on the pilot unit performance, it is advisable to assume the rate of recovery in the range of 70-75% while planning upscaling.
3. In the ATH tannery, suspended solids, COD and colour were found to be high in the inlet. For tannery effluents in general, these may not be as high as in most of the good (C)ETPs, the level of suspended solids is less than half of the TSS reported in the ATH tannery.
4. The photochemical oxidiser had been suggested by the manufacturer as an ideal method of reducing the organics in the treated effluent. However, this claim was not proved right in the field. It may be assumed that for the present system, where the RO membrane is protected by nano membrane (which is less vulnerable to organics), the photochemical oxidation can be avoided in a larger unit. It has also been noted that the cost of a bigger photochemical oxidiser is prohibitively high. (Rs. 1.5 to 2 million for an RO unit of 11 m^3/h capacity). This unit has not been suggested or taken in the cost calculation for a larger unit.
5. In the pilot unit, the softener was added as the project was in small scale. For a bigger unit, a softener may not be required as generally in the tannery effluent the total hardness is much less than that reported in the ATH tannery. For the ATH tannery, instead of a softener, tertiary precipitation and settling using lime (temporary hardness was found to be around 60% of total hardness) would have been the easier solution, which could also have controlled the suspended solids. Avoiding softener would also reduce the quantity of reject and reduce operational cost. Accordingly, this has not been considered in the cost for up-scaling the system.
6. The supplier of the pilot system felt that it was not even necessary to have a nano filter pre-treatment for a larger plant as it may contribute substantially to power and membrane replacement requirements. It was pointed out that as the nanofilter did not show much of a scaling problem, it should be possible to run the plant without it.
7. An ORP meter should control the dosing of antioxidant to control the risk factor to membrane. Dosing could be reduced if and when needed. This control can prevent such damages as had happened with the RO membranes originally installed.
8. The flushing of membranes, as done now may not be required if the unit operated continuously.
9. The design of pressure filter and activated carbon filter should be done such that only one back washing should be adequate in 24-hour operation.

10. The power requirement, which is the major cost factor for the pilot system, will be less for a bigger unit.
11. It is preferable to modify operation with a programmable logic controller (PLC) for a bigger unit to make it simpler than the manually controlled operation as was done in the pilot unit.
12. A degassifier tower after the RO membranes may be required for the permeate.
13. Proper operation of the unit depends a lot on the effective control by the plant operators. Properly qualified and experienced staff should be employed in such units.

16.2 Planning an up-scaled unit

Based on the pilot unit performance, some reputed suppliers of RO system in India were requested to submit a proposal for a plant with capacity to treat around 220 m^3/d. Three firms viz, Ion Exchange India Ltd, Thermax Limited and Aqua Chemicals & System Mfg. Co. Ltd indicated their interest. Since the overall viability was not comprehensively demonstrated in the pilot unit operation, the preference was to get a proposal on BOOT (build-own-operate-transfer) basis. According to this arrangement, the supplier would set up the RO unit with its own resources, operate the same with its own personnel and sell the water to the client at a pre-fixed mutually agreed rate, which will cover the operational expenses and capital repayment charges. While Ion Exchange and Thermax were interested in offering the system on out right sale basis, Aqua chemicals (based on the experience from their pilot unit) was willing to offer the plant for outright purchase as well as on BOOT basis provided the capacity of the unit was high enough to make such an arrangement feasible. The cost of water to be purchased by the client as quoted by Aqua for a 500 m^3/d RO unit was Rs.38/m^3 (US $ 0.85/m^3) for five years. The break-up of cost made by Aqua was Rs.24/m^3 for all operational cost of RO (including depreciation, membrane replacement etc.) and Rs.14/m^3 towards capital repayment. All civil works would be in the scope of the client. The finer details of the agreement between the client and supplier may include guarantee clauses (from the client as well as the supplier) for the purchase of water and provision for collecting capital repayment charges at a mutually agreed rate during low/non operational periods.

16.3 Features of the larger unit

As indicated by the companies offering the RO unit, the system will have a collection tank where all the effluent after treatment in a full-fledged ETP will be collected and pumped to the lime-soda softening cum tertiary treatment intended to reduce hardness and TSS/silt density Index in the effluent. The softened effluent will be collected in another tank and then pumped to the pre-treatment units comprising pressure filter, activated carbon filter, online chemical dosing arrangement etc. (The offer of Thermax envisages an organic resin-based scavenger too). The pre-treated effluent is then pumped to the RO unit and while the permeate will be collected for re-use in the tannery, the reject will be sent to the solar evaporation pan (with or without improved solar evaporation methods). The recovery assured is more than 75%.

It has been suggested not to discharge the concentrated pickle float with the effluent from the tannery so that the sulphate concentration in the influent could be brought down. This however has not been indicated as a pre-condition for the installation of RO system.

17. COST BENFIT ANALYSIS OF AN UPSCALED SYSTEM

Two cases, one about an RO system for a medium scale individual tannery, with an effluent flow of 200 m^3/d and another, larger one, for a cluster of tanneries (effluent flow 4000 m^3/d) have been considered for making cost benefit analysis. Figures of operational cost were calculated based on the offers submitted by the suppliers of RO system.

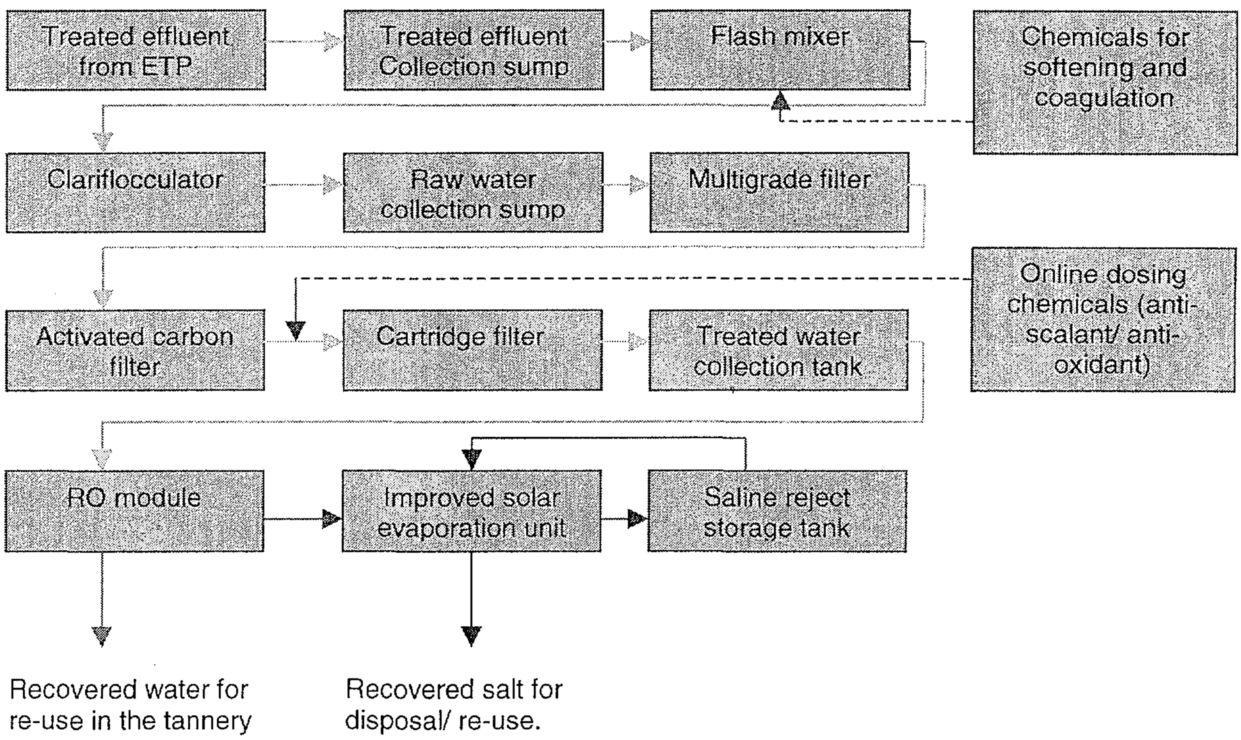
An improvised solar evaporation system equipped with sprinklers has been assumed for the treatment of reject. Since the reject from RO will be free of suspended solids, no pre-treatment unit is considered. Further, as the reject from RO is coming out at a higher pressure (15-20 bar) than that required for the sprinkler system (2-3 bar), no inlet pumping of the reject is required. Only the re-circulation of saline liquor is required in the improved solar evaporation. As the solar evaporation is not feasible during rainy days, sufficient storage capacity of reject liquor (equivalent to 45 days) is assumed and the quantity of evaporation per day is calculated as 10 months over 12 months.

For the bigger unit for a cluster of tanneries, a back up mechanical evaporator with 4 stages, complete with boiler unit has been assumed for evaporation of reject liquor from RO unit during rainy days.

17.1 RO Unit for individual tannery with a maximum effluent flow of 200 m^3/d

The scheme suggested is given in Table 8.

Table 8



17.1.1 Basic assumptions:

- Inlet flow 11.0 m^3/h,
- Permeate flow 7.7 m^3/h.
- Reject flow: 3.3 m^3/h.

17.1.2 Treatment units

Unit	Capacity	Nos.	Price (Rs.)
Treated effluent collection tank	15 m^3	2	80,000
Treated effluent pump	20 m^3/h, 1.5 kW	2	40,000
Flash mixer	1 m^3 , 0.75 kW	1	55,000
Clariflocculator	4 m dia, 0.75 kW	1	260,000
Chemical preparation & dosing	1 set, 1.5 kW		65,000
Tertiary treated effluent collection tank	15 m^3	2	80,000
Raw water pump	20 m^3/h, 1.5 kW	2	40,000
Multigrade filter	20 m^3/h	1	135,000
Activated carbon filter	20 m^3/h	1	180,000
Online dosing of chemicals	1 set 1.5 kW		175,000
Micron/cartridge filter	20 m^3/h	1 set	220,000
Pre-treated water collection sump	20 m^3	1	90,000
RO feed pump	7.5 kW, 30 bars	2	180,000
RO unit	1 set	1 set	800,000
Degassifier	20 m^3/h	1	230,000
ORP meter, flow meters, pressure gauges and PLC control unit	LS	Set	580,000
Improved solar evaporation unit with re-circulation pumps	1700 m^2 sprinkler area, 2500 m^2 crystallisation area	1	2,300,000
Reject storage ponds	1400 m^3	2	2,900,000
			8,410,000

- Cost of the RO unit: Rs.32.1 million
- Cost of improved solar evaporation system and reject storage tank: Rs. 52 million
- Total cost including civil works = Rs. 84.1 million ($ 1.83 million)

17.1.3 Operational costs

1. Power: Pre-treatment: 6 (4.5 + 1.5) kW, RO pump (7.5 kW) and other equipment (1.5 HP); Total: 15 kW = Rs. 66/h = Rs. 1320/day (20 h/d).

2. <u>Chemicals</u>:

Item	Dosage	Consumption	Total consumption	Cost per day (Rs).
Lime	200 ppm	2.2 kg/h	44 kg/d	92.4
Sodium carbonate	150 ppm	1.65 kg/h	33 kg/d	198.0
PE	1 ppm	11 g/h	0.22 kg/d	60.5

Acid	10 ppm	110 g/h	2.2 kg/d	13.2
Antiscalant	10 ppm	110 g/h	2.2 kg/d	132
Antioxidant	8 ppm	88 g/h	1.76 kg/day	105.6
Total				601.7

3. Labour: 4 nos. (3 technician + chemist) = Rs. 300/day.
4. Miscellaneous: Rs.200/day
5. Membrane replacement cost: (assuming Rs. 700,000 for membranes and 300 days membrane life, equivalent to 100% depreciation) - Rs. 2333/day *

* Though 3 year membrane life is claimed by the manufacturers, based on the experience in the pilot unit and considering that there is nano unit here, it is considered realistic to assume membrane life of 300 days only.

6. Depreciation: (considering a depreciation rate of 10% for mechanical components other than the membranes which are already covered under item 5 above and assuming 5% for the civil works): Rs. 753 + Rs. 42 = Rs.792/day

(a) Total for RO unit operation: **Rs. 5547/day**

Cost of operation of improved solar evaporation unit

1. Power (for re-circulation): 12.5 kW/h = 100 units = Rs. 400 per day.
2. Depreciation @ 5% : Rs. 866 per day
3. Manual labour for collection of salt: Rs. 180 per day (3 x 60 per person)

(b) Total for evaporation of reject: **Rs. 1446/day**

Total cost of operation: (a) + (b) = **Rs. 6993/day**

17.1.4 Cost analysis

Parameter	**Unit**	**Quantity**
Average quantity of water treated (20 h operation)	m^3/day	220
Average quantity of water recovered (20 h operation)	m^3/day	154
Cost of operation	Rs./day	6993
Cost operation /quantity of water treated	Rs./m^3	31.78
Cost operation /quantity of water recovered	Rs./m^3	45.41

Note: If the tannery is situated in a water scarce area, assuming that fresh water is purchased @ Rs. 30/m^3 (as commonly noted in tanneries of Tamilnadu), the effective cost of operation will be Rs. 6993 – Rs. 4620 = Rs. 2373/d, which works out to a cost of Rs. **10.78/m^3.**

Note

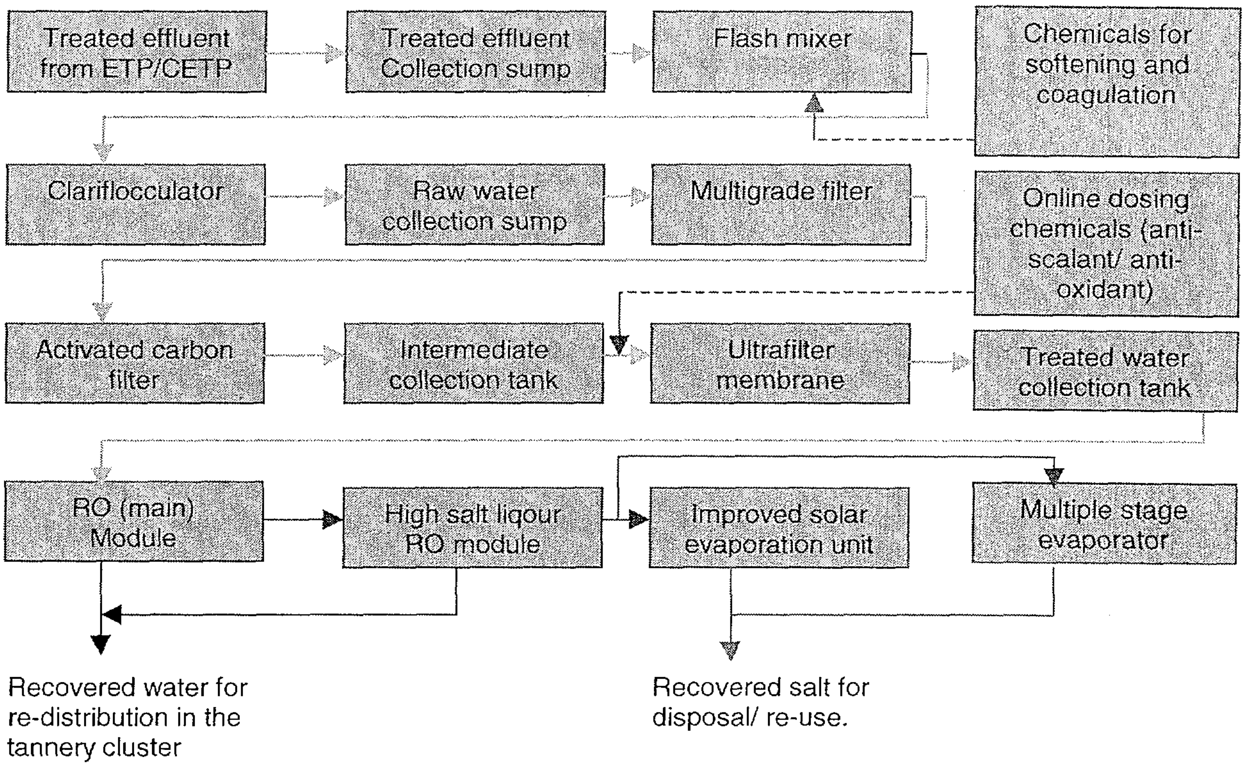
1. Additional benefits such as (a) avoiding effluent discharge causing serious damage to agricultural fields, (b) possibility of assured supply of water, (c) obtaining good quality water (water purchased by the tannery is having TDS 1500-1750 mg/l where as TDS in the recovered water from RO unit is only 300-400 mg/l) which is expected

to provide savings due to better uptake of chemicals used in tanning process etc. and (d) better image for the industry are not considered in the above cost benefit analysis.
2. The value of recovered salt has not been included in the above.
3. The above does not include the capital repayment cost which would work out to Rs. 7.13/m^3, assuming 12% rate of interest and a repayment schedule of 10 years.

17.2 RO Unit for a tannery cluster with an effluent flow of 4000 m^3/d

The scheme suggested is given in Table 9.

Table 9



Projected recovery: 65% in RO main module and 50% in RO high salt module.

17.2.1 Basic assumptions:

- Inlet flow 200 m^3/h.
- Permeate flow, RO main: 130 m^3/h.
- Permeate flow, RO high salt: 35 m^3/h
- Reject flow: 35 m^3/h.

17.2.2 Treatment units

17.2.2.1 Pre-treatment and RO units

(a) Civil

The civil components in the unit, their dimensions as well as the cost is given in table below:

Unit	Unit dimensions	Capacity m^3	Nos.	Price (Rs.)
Treated effluent collection tank	10 m x 20 m x 2 m	400	2	1,000,000
Flash mixer	1m x 1 m x 1 m	1	1	50,000
Clariflocculator	16 m dia x 2.5 m SWD	500	1	900,000
Lime preparation tank	1.5 m x 1.5 mx 2 m	4.5	2	55,000
Soda preparation tank	1.5 m x 1.5 mx 2 m	4.5	2	55,000
PE preparation tank	1 m x 1 m x 1 m	1	2	40,000
Tertiary treated effluent collection tank	10 m x 20 m x 2 m	400	1	500,000
Intermediate collection tank	8 m x 12 m x 2 m	192	2	440,000
Pre-treated water collection sump	8 m x 12 m x 2 m	192	2	440,000
Permeate collection tank (overhead tank)	15 m x 20 m x 2 m	600	2	2,000,000
Reject collection tank	8 m x 10 m x 2 m	160	2	400,000
Administrative building, control room and laboratory	15 m x 20 m		1	400,000
Miscellaneous				800,000
Total				7,080,000

(b) Mechanical

The mechanical components, capacity, operating power as well as the price is given below:

Unit	Capacity m^3/h	Nos.	Unit power kW/h	Operating power kW/h	Price (Rs.)
Treated effluent pump	200	3 (2+1)	15	30	300,000
Flash mixer	200	1	1.5	1.5	90,000
Clariflocculator	200	1	1.5	1.5	800,000
Lime preparation and		2	0.75	0.75	120,000
Soda preparation and		2	0.75	0.75	120,000
PE preparation and dosing		2	0.75	0.75	120,000
Lime dosing pump		2	0.75	0.75	80,000
Soda dosing pump		2	0.75	0.75	80,000
PE dosing pump		2	0.75	0.75	140,000
Raw water pump	200	3 (2+1)	15	30	300,000
Multigrade filter	200	1	0	0	950,000
Activated carbon filter	200	1	0	0	1,200,000
Online dosing of chemicals	200		4.5	4.5	1,150,000
Ultrafilter pump	200	3 (2 + 1)	22.4	44.8	660,000
Ultrafilter unit	200	3 (2 + 1)	0	0	9,200,000
RO feed pump	200	5 (3 +2)	44.7	134	1,220,000
RO unit	200	3	0	0	10,500,000
Reject RO feed pump	35	5 (3+2)	12	36	700,000
Reject RO unit	35	3	0	0	1,40,000
Degassifier	200	3	0	0	900,000

ORP meter, flow meters, pressure gauges and Computer based DCS control unit with all accessories.	Set	1 set	7.5	7.5	3,900,000
Miscellaneous including piping, valves, membrane cleaning system and testing facilities.	Set				3,500,000
				294.3	36,030,000

(c) Pipe line network for distribution of recovered water back to the cluster:

1. No. of tanneries assumed : 80
2. Total length of pipeline: 9.2 kilometers
3. Size and material of pipeline: 90 mm 8 bar pressure PVC pipes
4. Distribution and measurement: Solenoid valve controlled from DCS and flow meter logged on to DCS for quantity measurement, individual water meters installed at each tannery inlet.
5. Total cost of piping: Rs. 6,200,000
6. Total cost of measurement units: Rs. 1,400,000

Total cost for distribution network: Rs. 7,600,000

17.2.2.2 Improved solar evaporation unit

Total quantity of reject per day : 700 m^3
Total area required for sprinklers : 18000 m^2
Total area required for crystallisation : 26,000 m^2
Slat collection equipment : 2 mini trucks, equipped with mechanical shovel type rake
Total cost of installation: Rs. 21,600,000

17.2.2.3 Multiple stage evaporator

Pumping rate: 35 m^3/h
No. of evaporators: 2
Concentration of thermal evaporation: from 50-60 g/l to 220 g/l
Removal of salt: by centrifugation
Stages of evaporation: 5 stages, final two stages work under 26" Hg columns.
Steam requirement: 8 tonnes steam at 2 bar pressure/hour
Boiler capacity: 10 tonnes x 1 No..
Cost of evaporation: Rs. 180/m^3

Cost: Rs. 22,420,000 including all accessories and boiler.

Summary of costs

- Cost of the RO unit: Rs. 36,030,000 + 7,080,000 = Rs. 43,110,000
- Cost of improved solar evaporation system: Rs. 21,600,000
- Cost of multiple stage evaporator: Rs. 22,420,000

- Cost of distribution and measurement units: Rs. 7,600,000
- Total cost: **Rs. 94,730,000 (US $ 2.06 million)**

17.2.3 Operational costs

17.2.3.1 RO unit

1. Power: 294 units per hour: 5880 units per day = **Rs. 25,872 per day**

2. Chemicals:

Item	Dosage	Consumption	Total consumption	Cost per day (Rs).
Lime	200 ppm	40 kg/h	800 kg/d	1680
Sodium carbonate	150 ppm	30 kg/h	600 kg/d	3600
PE	1 ppm	200 g/h	4 kg/d	1100
Acid	10 ppm	2 kg/h	40 kg/d	240
Antiscalant	10 ppm	2 kg/h	40 kg/d	2400
Antioxidant	8 ppm	1.6 kg/h	32 kg/d	1920
Total				10,940

3. Labour: 16 nos. (1 Plant Manager, 2 chemists, 4 operators, 2 technician + 7 workers) = **Rs. 2500/day.**

4. Miscellaneous: **Rs.2000/day**
5. Membrane replacement cost: (assuming Rs. 14,000,000 for all membranes and 300 days membrane life, equivalent to 100% depreciation) - **Rs. 46,666/day** *

* Though 3 year membrane life is claimed by the manufacturers, based on the experience in the pilot unit, it is considered realistic to assume only 300 days membrane life.

6. Depreciation: (considering a depreciation rate of 10% for mechanical components other than the membranes which are already covered in item 5 above and assuming 5% for the civil works): Rs. 7343 + Rs. 1180 = **Rs. 8523/day**

(a) Total for RO unit operation: **Rs. 85561 /day**

17.2.3.2 Improved solar evaporation unit

1. Power (for re-circulation): 85 kW/h = 1700 units = **Rs. 7480 per day.** Assuming 10 months operation in year, average operating cost per day: **Rs. 6233 per day**
2. Depreciation @ 5%: **Rs. 3600** per day
3. Manual labour for collection of salt: **Rs. 600 per day** (10 x 60 per person)

(b) Total for evaporation of reject: **Rs. 10433/day**

17.2.3.3 Multiple stage evaporation

Total quantity to be evaporated: 700 m^3/day
Total cost of evaporation: Rs. 180/m^3: Rs. 126,000 per day
Assuming two months operation in a year,
(c) Average operating cost: **Rs. 21,000/day**

17.2.3.4 Distribution network

Depreciation @5% : Rs. 1267/day
Operating charges: two technicians: Rs. 180 per day
(d) Total operating charges: **Rs. 1447/day**

Total operating cost: (a) + (b) + (c) + (d) = **Rs. 118441/day, say Rs. 118500**

17.1.4 Cost analysis

Parameter	Unit	Quantity
Average quantity of water treated (20 h operation)	m^3/day	4000
Average quantity of water recovered (20 h operation)	m^3/day	3200
Cost of operation	Rs./day	118500
Cost operation /quantity of water treated	Rs./m^3	29.63
Cost operation /quantity of water recovered	Rs./m^3	37.03

Note: If the tannery cluster is a water scarce area, assuming that fresh water is purchased @ Rs. 30/m^3 (as commonly noted in tanneries of Tamilnadu), the effective cost of operation will be Rs. 118500 – Rs. 96,000 = Rs. 22500/day, which works out to a cost of **Rs. 5.63/m^3.**

<u>Note</u>

1. The above cost does not include the value of recovered salt. Assuming a value of 75 paise per kg of salt recovered (the average price of recovered salt ranges between Rs. 1-1.5/kg), the savings will be Rs. 30,000 per day and if this saving is taken into account, the net operating cost per day will be Rs. – 7500/day i.e., a saving of Rs. 7500 per day.
2. The above cost does not include capital repayment cost which could, depending on the repayment period, amount to **Rs. 4.4 – Rs. 5.8/m^3** (calculated @ 12% p.a. interest).
3. Additional benefits such as (a) avoiding effluent discharge causing serious damage to agricultural fields, (b) possibility of assured supply of water, (c) obtaining good quality water (water purchased by the tannery is having TDS of 1500-1750 mg/l where as TDS expected in the recovered water from RO unit is only 300-400 mg/l) which is expected to provide savings due to better uptake of chemicals used in tanning process etc. and (d) better image for the industry, are not considered in the above cost benefit analysis.

18. COMPARISON OF RO WITH OTHER ALTERNATIVES

At the moment, a number of alternatives have been considered by the tanning industry for tackling the problem of TDS in treated tannery effluent in Tamilnadu, India. The serious options among them were:

(a) To discharge the entire treated tannery effluent from Vellore district to the sea through a pipeline, which can carry 30,000 –35,000 m^3 per day, running along the banks of river Palar.
(b) To construct sewage treatment plants in individual tannery clusters and combine the effluent from the tannery (C)ETPs, so as to dilute the tannery effluent and possibly creating greenbelts in the otherwise arid areas of Vellore district.
(c) To apply Reverse Osmosis system for recovery of water.

A fourth alternative, i.e, applying high rate transpiration system (HRTS) for disposal of these effluents has also been discussed. However, since there is no data available regarding the cost and viability of this technique, the same is not listed here.

The first option listed above, i.e., the pipeline is projected to have a tentative installation cost of Rs. 3000,000,000 and as per the feasibility report prepared by an agency of the Tamil Nadu government, the operating cost is estimated at Rs. 32/m^3 without the capital repayment charges and Rs. 50.66/m^3 with the capital repayment charges.

Regarding the second option, no clear data is available, as no project proposal has been made so far. None of these clusters at present has a piped sewerage network. Considering that the population of clusters like Ambur, Vaniyambadi and Ranipet is approximately 100,000 each an approximate volume of 2500 m^3/d of sewage could be expected to be generated in each cluster. Assuming a minimum of 500 mg/l TDS in this sewage (the actual value of TDS is well above 3000 mg/l in some of these clusters), and tannery effluent of 30,000 m^3/day at 10,000 mg/l, the net TDS in the combined treated effluent could be around, which, though not within the limit prescribed by TNPCB, may be good enough for afforestation using saline resistant plants. Considering the average population of 100,000, the cost for sewerage and the treatment plants (using thumb rule of TWAD board @ Rs.3000 per capita) could be Rs. 300,000,000. The operating cost of sewage treatment plant could be Rs.437500+ Rs. 250000 =687500 (assuming Rs. 7/m^3 of sewage treated and 5% depreciation), which works out to a cost of Rs. 22.91/m^3 of tannery effluent without capital repayment and Rs. 32.24/m^3 with capital repayment charges.

The RO unit for the effluent volume of 30,000 m^3/d may be cheaper than the projected cost based on the estimate for 4000 m^3/d, as with the increase in capacity, the cost of RO unit tend to be lower. However, if the RO option is considered, a split installation would be more realistic. The estimated cost of RO option for a capacity of 30,000 m^3/d would be Rs.710,475,000 and operating cost Rs. 5.63/m^3 without capital repayment and Rs. 10.03/m^3 with capital repayment over 20 years with 12% interest.

In general, an overview of the comparison between the above three options is given below:

Option	Major advantages	Major disadvantages	Installation cost Rs.	Operating cost (Rs./m^3)
Pipeline	(1) A simple & effective option. (2) Permanent solution (3) Least additional operational requirement	(1) No water recovery (2) Possible objections from community and fishermen. (3) Possible draining of the area, contributing to further water scarcity.	Rs. 3000 million	Rs. 50.66
RO unit	(1) Water recovery (2) Assured supply of good quality water (3) Better image for the industry (4) Least damage to environment.	(1) Requirement of good operation and control (2) Many operational difficulties are largely unknown and hence the high level of risk. (3) Viability depending on sale of recovered water.	Rs. 710 million	Rs. 10.03
Sewage treatment plant	(1) Improve the locality's environment (2) Least risk for tanners (3) Possibility of greening the area.	(1) The TDS limit may still not achieved (2) Viability of laying sewerage line in some locations is doubtful. (2) Depends on progress of construction in several areas which may be time consuming	Rs. 1500 million	Rs. 32.24

* The above comparison is based on very sketchy estimates for options other than the RO system and therefore should be considered only as a very rough guide. Detailed study of all options is required for a proper comparison of advantages/disadvantages as well as economics of each option.

19. CONCLUSION

In view of the encouraging results from the pilot RO system, it will be of interest if a private tannery with its own ETP were to install a RO unit of about 200 m^3/d capacity, preferably on BOOT basis.

Details of units in pilot RO unit at ATH tannery, Melvisharam

Unit	Details	Design
Raw water collection tank	No. of units : one Capacity : 1000 litres Type : Custom built HDPE tank, sintex make.	Storage capacity :1 hour.
Raw water pump	No. of pumps : one Capacity of motor : 1.0 HP Type : centrifugal, closed impeller. Make : Kirloskar	Pumping rate: 2 m^3/h.
Inlet water tank	No. of units : one Size : 800 mm dia x 1000 mm height Capacity : 500 litres MOC : mild steel rubber lined.	Storage capacity : 10 min
Raw water pump	No. of pumps : One Capacity of motor: 2 HP Type: centrifugal, closed impeller Make : Kirloskar	Pumping capacity: 3 m^3/h
Multi-grade filter	No. of units : one MOC : Fibre reinforced plastic Size : 330 mm dia x 1400 mm height Back washing : programmable Fill media : garnet & anthracite.	Max flow : 4.0 m^3/h Design pressure : 3.5 bars.
Photochemica l oxidiser	No. of units : Two, series operation Size: 40 mm dia x 540 mm height. MOC : Stainless steel Type of lamp : Ultraviolet, tubular No. of lamps : two	Detention time : 20 sec.
Activated carbon filter	No. of units : one MOC : Fibre reinforced plastic Size : 330 mm dia x 1400 mm height Back washing : programmable Fill media : granular activated carbon	Max flow : 4.0 m^3/h Design pressure : 3.5 bars.
Softener	No. of units : one MOC : Fibre reinforced plastic Size : 330 mm dia x 1400 mm height Regenerant : sodium chloride Regeneration : programmable Fill media : strong acid cation resin.	Max flow : 6.0 m^3/h Design pressure : 1.5 bars.
Chemical dosing system	No. of dosing systems : 4 Components: Chemical preparation tank, dosing pump, mixer (only in antioxidant preparation tank) MOC of chemical preparation tank : Fibre reinforced plastic Capacity of chemical preparation tanks : 100 litres	Chemicals dosed : hydrochloric acid, antioxidant, antiscalant and hydrogen peroxide. Capacity of dosing pumps : 1 litres per hour.

	Make of dosing pump : Milton Roy	
Cartridge filter	No. of units : one No. of elements : six MOC : ploy propylene Size : 300 mm dia x 400 mm height Type of cartridges: polypropylene hollow fibre, custom built Cartridge pore size : 5 micron	Max flow: 3.0 m^3/h Design pressure: 2.0 kg/cm^2
Intermediate storage tank-1	No. of units : one MOC : Fibre reinforced plastic Size : 800 mm dia x 1000 mm height Level control : automatic	Storage capacity : 25 minutes
High pressure pump-1	No. of units : One MOC : SS 316 Capacity of motor : 3 HP Make : Oasis. Type : Triplex, Qunitaplex Plunger	Capacity : 3 m^3/h Rated pressure : 15 kg/cm^2.
RO-1	No. of pressure tubes: Two No. of elements : 3 in each Membrane MOC : thin film composite Pore size : 10 Angstrom units	Membrane type : Spiral wound Designed pressure : 15 kg/cm^2 Flux : 15 $l/m^2/h$.
Intermediate storage tank-2	No. of units : one MOC : Fibre reinforced plastic Size : 800 mm dia x 1000 mm height Level control : automatic	Storage capacity : 20 minutes
High pressure pump-2	No. of units : One MOC : SS 316 Capacity of motor : 5 HP Make : Oasis. Type : Triplex, Qunitaplex Plunger	Capacity : 3 m^3/h Rated pressure : 35 kg/cm^2.
RO-2	No. of pressure tubes: Two No. of elements : 3 in each Membrane MOC : thin film composite Pore size : 0.2 Angstrom units	Membrane type : Spiral wound Designed pressure : 24 kg/cm^2 Flux : 30 $l/m^2/h$.
Permeate collection tank	No. of units : one Capacity : 1000 litres Type: Custom built HDPE tank, sintex make.	3 hours storage capacity.

MOC : material of construction