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SAMPLING, TESTING AND EVALUATION OF THE PILOT MEMBRANE SYSTEM (RO) UNIT FOR PROCESSING TREATED TANNERY EFFLUENT AT A.T.H. LEDER FABRIK, MELVISHARAM



FINAL REPORT



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CONTINUOUS OPERATION OF REVERSE OSMOSIS PLANT AT A.T.H. LEDER FABRIK, MELVISHARAM

Symbols and Abbreviations

ACF	Activated Carbon Filter
AVG	Average
BDL	Below Detectable Limit
BOD	Biochemical Oxygen Demand
CF	Cartridge Filter
COD	Chemical Oxygen Demand
СТ	Collection Tank
ETP	Effluent Treatment Plant
HDPE	High Density Poly Ethylene
H ₂ O ₂	Hydrogen Per Oxide
IST	Intermediate Storage Tank
IWT	Intermediate Water Storage Tank
kg	Kilogram
L	Litre
MAX	Maximum
mg/L	Milligrams per litre
MIN	Minimum
PCO	Photo Chemical Oxidizer
PSF	Pressure Sand Filter
RePO	Regional Programme Office
RO	Reverse Osmosis
SEP	Solar Evaporation Pan
SS	Suspended Solids
SST	Secondary Settling Tank
TDS	Total Dissolved Solids
UNIDO	United Nations Industrial Development Organisation

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SAMPLING, TESTING AND EVALUATION OF THE PILOT MEMBRANE SYSTEM AT A.T.H. LEDER FABRIK, MELVISHARAM (Contract No.98/181)

1. INTRODUCTION

Wastewater from the tanneries are treated by physical, chemical and biological treatment method for removal of organic and inorganic pollutants. The treated wastewater from Effluent Treatment Plant (ETP) contain high amount of Total Dissolved Solids (TDS) in the range of 4000 – 14000 mg/L. The ions that contribute towards TDS were Sodium, calcium, chloride, and sulfate. The treated effluent from ETP is not suitable for reuse in the process due to the presence of high TDS. Therefore to recover water from treated tannery wastewater and reuse it in tanning process a pilot scale Reverse Osmosis system was installed and commissioned during May'98 at A.T.H Leder Fabrik tannery, Melvisharam, Ranipet, India.

2. LOCATION OF A.T.H LEDER FABRIK TANNERY

The A.T.H Leder Fabrik tannery is located in Melvisharam on the Kathivadi road in North Arcot Ambedkar district. It is about 2 km from Vellore – Arcot main road in Melvisharam area. National highway NH 46 Bypass road is passing near Melvisharam as shown in Fig.1.

Melvisharam is about 120 kms from Chennai on the Chennai-Bangalore National Highway NH 46. Nearest railway junction is Katpadi and is about 20 kms from Melvisharam.

3. TANNING PROCESS

The A.T.H Leder Fabrik tannery is processing semifinished leather to finished leather at the time of pilot scale RO study. The RO system is fed with ETP treated tannery effluent of semi-finish to finished leather.

4. OBJECTIVE OF THE STUDY

The objective of the study is to investigate the suitability of applying Reverse Osmosis (RO) system for treated tannery effluent and reuse of recovered water in the tanning process.

5. UNITS OF OPERATION IN RO SYSTEM

The RO system consists of Multistage Pressure Filters, Photo Chemical Oxidizer, Softener and microfilters and two stage RO units. The functions of the units are described briefly. The schematic process flow diagram is given in Fig.2

5.1. Collection Tank (CT)

Raw wastewater from the secondary settling tank is pumped to collection tank of capacity 1000 L.

5.2. Pressure Sand Filter (PSF)

The effluent is pumped to pressure sand filter (PSF) for removal of suspended solids from the collection tank.

5.3. Photo Chemical Oxidizer (PCO)

The filtrate from PSF is admitted to PCO. H_2O_2 is added for about a month to oxidize organic matter. Subsequently RO module I membrane was ruptured. Addition of H_2O_2 was suspended presumably on a reason that H_2O_2 might impair the durability of membrane.

5.4. Intermediate Water Storage Tank (IWT)

PCO treated effluent is collected in a tank of capacity 400 L.

5.5. Activated Carbon Filter (ACF)

The effluent from IWT is pumped into ACF. ACF is packed with granular activated carbon.

5.6. Softener

There was no provision for softener from the start-up to till 26.05.98. Only after the membrane rupture in RO module I softener was introduced after ACF.

5.7. Dosing Units

Anti-scalent, anti-oxidant and acids are added online using dosing pumps.

5.8. Cartridge Filter

After online addition of anti-scalent, anti-oxidant and acid to softener wastewater is admitted into a cartridge filter (CF) for the removal of suspended solids of size close to 5 micron.

5.9. Intermediate Storage Tank-I (IST-I)

Before feeding into RO module I the wastewater is stored in IST-I with a capacity of 500 L.

5.10. RO module I

Water from IST-I is fed to RO module I with a hydraulic pressure of 10-14 kg/cm².

5.11. Intermediate Storage Tank-II (IST-II)

Permeate from RO-I module is collected in IST-II with a capacity of 500 L.

5.12. RO module II

Permeate from IST-II is fed to RO module II with a hydraulic pressure in the range of 12-16 kg/cm². Final permeate was stored in a Sintex tank of capacity 1000 L.

6. DESIGN OF PILOT RO SYSTEM

The processing capacity of the RO System is to treat 1 m³ of treated tannery wastewater per hour. The RO System was designed to operate with the influent characteristics as given in Table 1.

Table 1: Design Parameters of RO System

SL.No	Parameters	Value
1.	рН	7.0 – 9.0
2.	COD	< 400 mg/L
3.	Suspended Solids	< 150 mg/L
4.	Total Dissolved Solids	5600 8000 mg/L
5.	Silica	< 20 mg/L
6.	Permeate recovery	80 - 85 %
7.	Total Dissolved Solids in permeate	< 700

7. OPERATION OF THE RO SYSTEMS

7.1 Feed Characteristics

Treated effluent from the effluent treatment plant (ETP) of A.T.H. Leder Fabrik, Melvisharam was taken up for the study. During the study period, tannery was processing semi-finished to finished leather. Wastewater from the secondary settling tank is pumped to the collection tank (CT) of the RO system. The feed characteristics are given in Table 2. The pumping of wastewater to collection tank is intermittent. There is no provision for measuring the volume of effluent from secondary settling tank (SST) to collection tank.

PARAMETERS	TREATED WATER FROM ETP			
	MIN	МАХ	AVG	
Suspended Solids (SS)		646	265	
Total Dissolved Solids (TDS)	3372	7190	4965	
Chloride as Cl	762	2558	1387	
Sulfate as SO₄ ²⁻	809	2615	1645	
Sodium as Na [⁺]	534	2178	1184	
Calcium as Ca ^{⁺+}	52	438	238	
Magnesium as Mg ^{⁺+}	7	38	23	
Silica as SiO₂	5	25	12	
Chemical Oxygen Demand (COD)	150	354	229	

Table 2. Characteristics of treated water from secondary settling tank

Note: All values are expressed in mg/L

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7.2 Feed Pre-treatment

Wastewater from the collection tank is pumped to IWT through PSF and PCO. From IWT wastewater is pumped into IST-II through ACF, softener and cartridge filter. Softener was introduced during the first week of Aug'98. Anti-scalent, anti-oxidant and acid were added to softener using online dosing pumps before cartridge filter.

8.0 OPERATING PARAMETERS/CONDITIONS

8.1 Period

RO system is operated for 6 days a week from 9.30 to 17.00 hrs.

8.2 Temperature

The RO System was operated at ambient temperature of 28 – 35°C.

8.3 Flow Rate

Wastewater from Secondary settling tank (SST) to collection tank in RO System is intermittent. The flow was controlled manually. No flow meter was provided to measure the reject I from RO Module I, part of the Reject I is mixed with the treated wastewater from SST in the collection tank and the remaining goes to solar evaporation pan. The volume of Reject I mixed in the collection tank was controlled manually. Online flow meter provided in the RO system were not working satisfactorily.

8.4 Pressure

Wastewater from IST-I is pumped using high pressure pump with a hydraulic pressure of 10-14 kg/cm² to RO module I. Water from IST-II is pumped using high pressure pump with a hydraulic pressure of 12-16 kg/cm² to RO module II.

8.5 Recirculation

Part of the wastewater from the collection tank is recirculated to maintain constant pumping rate. Part of the reject-I from RO module I continuously flows to collection tank. 100% Reject-II from RO module II is mixed with wastewater from PCO in IWT.

Recirculation of the Reject-I & II of RO Modules alters the concentration of TDS. This has to have a claim of change in quality of effluent right from IWT, ACF, Softener, dosing tanks filters etc to RO I. There should be a change in the performance of the pretreatment units. Recirculation details are given in Table 3.

Table 3. Recirculation details

SAMPLE NUMBER	FROM	то
Sample 1-4	No recirculation	
Sample 5-19	Part of reject from RO-I	Collection tank
	100% reject from RO-II	Intermediate water storage tank
	Part of liquor from	Collection tank (Effluent sump)
	Intermediate water	
	storage tank	

9. POINTS OF SAMPLING

The sampling points were fixed in consultation with UNIDO, RePO, Chennai. Till 26 May'98 system was operated without softener. After introduction of softener sampling points were changed.

Details of sampling points for the nineteen sets of samples collected from A.T.H. Leder Fabrik Tannery, Melvisharam are given in Table 4.

SL	TREATMENT UNITS	TREATMENT UNITS POINT OF		PERIOD		
No		SAMPLING	13.5.98- 26.5.98 (3 sets)	11.8.98- 12.2.99 (13 sets)	7.10-99- 13.11.99 (3 sets)	
1	Secondary Settling Tank (SST)	Outlet	Yes	Yes	Yes	
2	Photo Chemical Oxidiser (PCO)	Outlet	Yes	Yes		
3	Activated Carbon Filter (ACF)	Outlet	Yes	Yes		
4	Softener	Outlet		Yes	Yes	
5	Intermediate Storage Tank-I (IST-I)	Inlet	Yes	Yes	Yes	
6	RO module I	Outlet (Permeate-I & Reject-I)	Yes	Yes	Yes	
7	RO module II	Outlet (Permeate-II & Reject-II)	Yes	only for permeate- II	only for permeate -II	

10. ANALYSIS

Samples from various pretreatment units in the RO system were analysed for the parameters including pH, suspended solids, total dissolved solids, chloride, sulfate, sodium, silica, calcium, magnesium and COD by procedures recommended in the Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WPCF - 19th Edition, 1995).

pH of the samples were measured using WTW pH meter. COD was estimated using Thermoreactor 300. Sodium, calcium, magnesium and silica were determined using Perkin Elmer Atomic Absorption Spectrophotometer. Results of 19 sets of samples collected till 13.11.99 are given in Annexure I.

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11 PERFORMANCE OF REVERSE OSMOSIS PLANT

11.1 Solute removal efficiency

The overall removal efficiency observed during the study period is given in Table 5. Solute removal efficiencies are shown in Graphs 10-16.

$i a \mu e \sigma$, $i e i o i nance o i reverse osinosis \mu a n c$	Table 5.	Performance	of reverse	osmosis	plant
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COMPONENT	REMOVAL EFFICIENCY (%)			
	MIN	MAX	AVG	
Total Dissolved Solids (TDS)	69.1	98.3	92.4	
Chloride as Cl	31.1	99.1	87.1	
Sulfate as SO4 ²⁻	99.7	100.0	99.9	
Sodium as Na [⁺]	59.9	99.2	90.4	
Calcium as Ca ^{⁺⁺}	89.4	100.0	97.9	
Magnesium as Mg ^{⁺+}	90.9	100.0	96.5	
Silica as SiO₂	42.4	100.0	88.2	

11.2 Reject

Part of the reject from RO Module I was discharged into solar evaporation pan. The flow was controlled manually. Part of the Reject I was mixed with the treated wastewater from SST in the collection tank. The volume of reject goes to the solar evaporation pan is not constant. The characteristics of Reject collected during the study period are given in Table 6. Solute concentrations in the reject are shown in Graphs 1-7. Percentage of reject was calculated based on the manual flow measurement at the time of sampling and ions concentration in the permeate and reject is shown in Graph 17.

PARAMETERS	REJECT			
	MIN	MAX	AVG	
Total Dissolved Solids (TDS)	7961	27832	12830	
Chloride as Cl	1541	4285	2672	
Sulfate as SO₄²-	1855	13639	6062	
Sodium as Na [⁺]	1100	5920	2748	
Calcium as Ca ^{⁺⁺}	8	950	359	
Magnesium as Mg ⁺⁺	6	284	86	
Silica as SiO₂	6	100	33	
Chemical Oxygen Demand (COD)	283	401	326	

Table 6. Characteristics of reject

Note: All values are expressed in mg/L.

Increase in reject volume was observed due to fouling in the RO module I and this resulted in increasing the hydraulic pressure of RO module I. Due to the fouling of the membrane in RO module I permeate volume from RO module I was reduced drastically., This resulted in slow filling up of permeate in IST II. Therefore RO module II was operated intermittently.

11.3 Water Recovery

The total dissolved solids concentration in the treated tannery effluent during the study period was in the range of 3300-7200 mg/L against the design concentration of 8000 mg/L. TDS concentration in the permeate was about 88-1900 mg/L. Percentage of water recovery was calculated based on the manual flow measurement at the time of

sampling and ions concentration in the permeate and reject. The average recovery of permeate was 58%. Characteristics of permeate collected during the study period is given in Table 7. Water recovery rate is given in Graph 18.

PARAMETERS	PERMEATE CHARACTERISTICS			
	MIN	MAX	AVG	
Total Dissolved Solids (TDS)	88	1912	392	
Chloride as Cl ⁻	17	1131	182	
Sulfate as SO4 ²⁻	BDL	8.2	2	
Sodium as Na [⁺]	15	685	118	
Calcium as Ca ^{⁺⁺}	0.3	30	5.7	
Magnesium as Mg ⁺⁺	BDL	2.1	0.7	
Silica as SiO₂	BDL	3.2	1.7	

Table 7.	Characteristics	of permeate
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Note: BDL – Below Detectable Limit

All values are expressed in mg/L

11.4 Reuse of Recovered Water

Permeate collected from RO module II is stored in 1000 L syntex tank. The tannery draw the recovered water through the pipe line provided from the tank and used in the tanning process.

12 CLEANING OF PRE-TREATMENT UNITS

At the end of the day's operation, almost all the units in the RO system were washed. PSF and ACF are back washed with the wastewater in IWT tank to remove

the suspended solids. Both the RO modules are flushed with permeate water. Remaining wastewater in the collection tank was completely emptied daily before the operation. The collection tank was filled with treated wastewater from secondary settling tank daily. All the wash water from the system was let into drain.

Softener was regenerated with about 15-20 kg of commercial sodium chloride everyday. Brine liquor from softener after regeneration is discharged into solar evaporation pan. Removal efficiency of calcium and magnesium in softener is shown in Graph 8&9.

13 MEMBRANE FOULING

First fouling of the membranes in RO module I happened after the third set of sample collection on 27.05.98. This was due to the presence of H_2O_2 in the wastewater according to the membrane manufacture. H_2O_2 was added in PCO for the oxidation of organic matter in the wastewater. New membrane was installed during August 98. After the installation of the membrane the addition of H_2O_2 to PCO was stopped. The RO system was not operated due to failure of RO module stage 1 from February to September 99. The membrane was replaced during September 1999. Again fouling occurred due to clogging of pores due to dye used in the tannery. The dye could not be removed in the pre-treatment system. Frequent fouling of RO module I was observed during the study period. Due to clogging of RO I membrane the recovery rate has come down. Therefore RO module II could be operated with intermittent stoppage. Apart from dyes and organic matter another reason for fouling of RO Module I may be due to the presence of calcium and magnesium deposition, due to the poor removal efficiency of softener and continuos recycling of rejects which leads to increase in TDS and dye concentrations (Ref. Graph 8&9).

14 CONTINUOUS OPERATION OF RO SYSTEM

The RO system at A.T.H Leder Fabrik Tannery, Melvisharam was operated on continuous basis to observe the problems faced during continuous operation and to

assess the recovery rate. The observations made during the study is reported in Annexure II.

15 OBSERVATIONS

- 1. RO system was operated to a maximum of 8 hours a day
- 2. Flow from secondary settling tank is not continuous for the RO system. The flow was controlled manually.
- 3. On line flow meters provided were not working satisfactorily.
- 4. Softener was regenerated with about 15-20 kg of commercial sodium chloride everyday and wastewater was discharged into solar evaporation pan.
- 5. At the end of the day's operation, almost all the units in the RO system were washed. PSF and ACF are back washed with the wastewater in IWT tank to remove the suspended solids. Both the RO modules are flushed with permeate water. Remaining wastewater in the collection tank was completely emptied daily before the operation. The collection tank was filled with treated wastewater from secondary settling tank daily. All the wash water from the system is let in to drain.
- Frequent fouling of RO-I membrane was observed. Due to frequent fouling in the RO module-I a reduction in membrane permeability was observed which results in intermittent operation of RO Module II.
- 7. Treated wastewater from secondary settling tank was pumped intermittently.
- 8. Volume of reject discharged into the solar evaporation pan was controlled manually which resulted in flow variation.
- 9. Average permeate volume during the study period was 58% based on the manual flow measurement and ions concentration in the permeate and concentrate at the time of sampling.

ANNEXURE - I

PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	IST-I	IST-II	REJECT-I	PERMEATE-II	REJECT-II
рН	6.72	7.30	7.13	5.65	5.86	5.93	5.46	6.17
Suspended Solids (SS)	404							
Total Dissolved Solids (TDS)	5992			5876	3186	10256	322	4188
Chloride as Cl ⁻	1742			1778	1679	1679	190	2148
Sulfate as SO ₄ ²⁻	2443			2413	50	5411	8.2	108
Sodium as Na [⁺]	1470			1350	932	2280	110	1140
Calcium as Ca ⁺⁺	254			242	68.2	552	4.4	102
Magnesium as Mg ⁺⁺	38			41	9.6	118	0.6	15
Silica as SiO ₂	5.76			7.7	8.27	10.65	BDL	15.5
Chemical Oxygen Demand (COD)	252	• 331	529					
Biochemical Oxygen Demand (BOD ₅ , mg/L)	7.0		-					

1.	Date of sample collected by CLRI	:	13.05.98
2 <u>.</u>	Date of sample received by CLRI	•	14.05.98
3.	Ref. & Date	•	US/RAS/92/120/PDU/2A dt.13 May'98
4.	Code No. of the set	:	1

PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	IST-I	IST-II	REJECT-I	PERMEATE-II	REJECT-II
рН	7.43	7.2	7.10	3.91	5.83	5.26	5.80	6.02
Suspended Solids (SS)	272							
Total Dissolved Solids (TDS)	5800			4852	3044	10194	1712	4482
Chloride as Cl	1605			1770	1783	2107	937	2445
Sulfate as SO ₄ ²⁻	2357			1356	7	4511	4.1	16.5
Sodium as Na [⁺]	1480			1290	992	2070	538	1410
Calcium as Ca ⁺⁺	220			176	65	490	21.7	87
Magnesium as Mg ⁺	27			20	4	73.8	2.14	5.4
Silica as SiO ₂	5.57			7.31	6.66	8.70	3.21	7.52
Chemical Oxygen Demand (COD)	181	205	243					
Biochemical Oxygen Demand (BOD₅, mg/L)	11							

1.	Date of sample collected by CLRI	:	23.05.98
2.	Date of sample received by CLRI	:	23.05.98
3.	Ref. & Date	:	US/RAS/92/120/PDU/2A dt.13 May'98
4.	Code No. of the set	:	2

PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	IST-I	IST-II	REJECT-I	PERMEATE-II	REJECT-II
рН	7.32	7.53	7.45	6.20	6.15	6.25	6.20	6.46
Suspended Solids (SS)	366							
Total Dissolved Solids (TDS)	6182			6132	3172	10036	1912	4218
Chloride as Cl ⁻	1641			1815	1770	1833	1131	2316
Sulfate as SO ₄ ²⁻	2424			2429	9.2	5606	3.8	21
Sodium as Na ⁺	1710			1730	1070	2450	685	1470
Calcium as Ca ⁺⁺	284			260	77	554	30	97
Magnesium as Mg⁺⁺	21.22			19.6	2.55	59	1.46	3.01
Silica as SiO ₂	4.50			4.91	4.14	5.82	2.44	5.27
Chemical Oxygen Demand (COD)	222	249	248					
Biochemical Oxygen Demand (BOD ₅ , mg/L)	15							

1.	Date of sample collection	:	26.05.98
2.	Date of sample received by CLRI	:	27.05.98
3.	Ref. & Date	:	US/RAS/92/120/PDU/2A dt.13 May'98
4.	Code No. of the set	:	3

PARAMETERS	ETP TREATED EFFLUENT	PCO	SOFTNER	IST-I	IST-II	REJECT-I	PERMEATE	REJECT-II
рН	7.23	7.36	7.24	6.27	6.43	6.91	5.54	6.71
Suspended Solids (SS)	204							
Total Dissolved Solids (TDS)	5584	5402	5326	5816	3944	8176	174	6192
Chloride as Cl	1460			2226	1947	2019	77	3055
Sulfate as SO ₄ ²⁻	2271			1401	27	3829	1	58
Sodium as Na [⁺]	1260	1860	1800	1720	1020	1830	55	2470
Calcium as Ca ⁺⁺	311	296	294	304	27	325	11	35.7
Magnesium as Mg ^{⁺+}	29	35	36	41	12	70	0.6	27
Silica as SiO ₂	5.76	8.3	8.23	9.34	7.91	9.04	BDL	13.05
Chemical Oxygen Demand (COD)	154	156	242					-

Note: All values except pH are expressed in mg/L. First set of samples were collected after the installation of new RO membrane.

1.	Date of sample collected by CLRI	:	11.08.98
2 .	Ref. & Date	:	US/RAS/92/120/PDU/2A dt.13 May'98
3.	Code No. of the set	÷	4

3. Code No. of the set

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-II
рН	6.81	6.98	7.31	7.02	6.13	6.00	5.04	6.33
Suspended Solids (SS)	276							
Total Dissolved Solids (TDS)	4232			4312	3832	2158	114	3650
Chloride as Cl	1162			1369	1216	1126	43	1865
Sulfate as SO ₄ ²⁻	2020			1657	1440	16	0.83	33
Sodium as Na [⁺]	1080			1590	1380	855	48	1410
Calcium as Ca ^{⁺⁺}	300			21	19	9	2	14
Magnesium as Mg ^{⁺⁺}	21			3.4	2.8	0.73	0.52	1.39
Silica as SiO ₂	7.29			12.43	10.84	9.94	BDL	19.56
Chemical Oxygen Demand (COD)	153	131	128					

Note : All values except pH are expressed in mg/L.

- Date of sample collected by CLRI 1. 21.08.98 :
- Ref. & Date 2.

1

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US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set 5 :

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-II
рН	7.09	6.89	7.07	6.98	6.27	6.21	5.25	6.48
Suspended Solids (SS)	246							
Total Dissolved Solids (TDS)	4584			5450	5490	3448	162	5570
Chloride as Cl	1238				1835	1745	66	2919
Sulfate as SO ₄ ²⁻	1556				1955	31	3.9	64
Sodium as Na [⁺]	1280			1990	1950	1410	38	2260
Calcium as Ca ^{⁺+}	243			114	127	35	1.1	57
Magnesium as Mg ^{⁺+}	24			24	23	7.1	0.8	11
Silica as SiO ₂	9.30			13.29	15.17	14.06	1.69	17.29
Chemical Oxygen Demand (COD)	165	214		156				

- 1. Date of sample collected by CLRI : 27.08.98
- 2. Ref. & Date : US/RAS/92/120/PDU/2A dt.13 May'98
- 3. Code No. of the set : 6

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-II
рН	6.60	6.53	6.62	6.59	6.05	6.00	5.45	6.40
Suspended Solids (SS)	240							
Total Dissolved Solids (TDS)	3734			6834	6636	4196	216	6702
Chloride as Cl	1175			2106	2206	2188	72	3489
Sulfate as SO ₄ ²⁻	1423			2957	2259	22	0.13	46
Sodium as Na [⁺]	1020			2260	2330	1550	48	2460
Calcium as Ca ⁺⁺	235			173	156	44	1.6	82
Magnesium as Mg ^{⁺⁺}	13			15	14	3.6	0.6	6.1
Silica as SiO ₂	9.45			17.16	17.89	16.03	0.64	26.7
Chemical Oxygen Demand (COD)	150	357	266					

Note : All values except pH are expressed in mg/L.

Date of sample collected by CLRI : 03.09.98
Ref. & Date : US/RAS/92/120/PDU/2A dt.13 May'98
Code No. of the set : 7

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.86	6.48	6.50	6.47	6.26	6.47	6.44	6.21
Suspended Solids (SS)	274							
Total Dissolved Solids (TDS)	4794	9200	9146	9100	8990	5694	254	17032
Chloride as Cl	1012	1817	2947	3064	2829	2829	118	2875
Sulfate as SO ₄ ²⁻	1534	5630	3059	2989	2996	84	4.5	10000
Sodium as Na ⁺	967	2360	2800	2760	2740	2070	99	2370
Calcium as Ca ⁺⁺	219	264	198	194	180	77	2.74	377
Magnesium as Mg ⁺⁺	20	36	29	. 33	31	10	0.5	75
Silica as SiO ₂	11.4	22	20	19.7	18.6	10.5	2.14	35.4
Chemical Oxygen Demand (COD)	259	807	466					

Note : All values except pH are expressed in mg/L.

- 1. Date of sample collected by CLRI : 10.09.98
- 2. Ref. & Date : US/RAS/92/120/PDU/2A dt.13 May'98

- 3. Code No. of the set :

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	7.62	6.83	6.94	7.01	6.64	6.64	6.60	6.53
Suspended Solids (SS)	68							
Total Dissolved Solids (TDS)	4744	6532	6820	6362	6274	3970	208	11802
Chloride as Cl ⁻	1275	1528	2278	2260	2133	2007	81	2296
Sulfate as SO ₄ ²⁻	1404	2706	1432	1399	1288	23	0	5600
Sodium as Na [⁺]	1240	1910	2210	2280	2240	1590	62	2800
Calcium as Ca ^{⁺+}	255	199	134	73	70	19	1.3	133
Magnesium as Mg ⁺⁺	16	16	11	14	13	5	1.1	30
Silica as SiO ₂	13.95	16	22	21.49	25.22	20.51	1.29	27.09
Chemical Oxygen Demand (COD)	215	317	236					

Note : All values except pH are expressed in mg/L.

1.	Date of sample collected by CLRI	:	18.09.98	

US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set

Ref. & Date

2.

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PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	SOFTENER	IST-I	- IST-II	PERMEATE	REJECT-I
pН	7.13	6.79	6.88	6.91	6.22	6.31	6.47	6.11
Suspended Solids (SS)	220							
Total Dissolved Solids (TDS)	4612	6724	6324	6248	6256	3936	242	11448
Chloride as Cl	1220	1510	2188	2079	2079	1971	68	2332
Sulfate as SO ₄ ²⁻	1526	3184	1409	1269	1413	17	0	5746
Sodium as Na ⁺	892	1490	1560	1620	1570	1260	58	1570
Calcium as Ca ⁺⁺	267	171	106	16	16	7	0.6	35
Magnesium as Mg ⁺⁺	22	18	12	10	10	4	0.9	23
Silica as SiO ₂	18.4	21	29	28.9	29.1	27.7	3.0	30.3
Chemical Oxygen Demand (COD)	207	337	276					

Note : All values except pH are expressed in mg/L.

1. Date of sample collected by CLRI : 23.09.98

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10

2. Ref. & Date

US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set :

PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.52	6.35	6.37	6.31	6.02	6.11	6.68	6.40
Suspended Solids (SS)	124		i					
Total Dissolved Solids (TDS)	3580	5622	5412	5250	5288	3194	190	10138
Chloride as Cl ⁻	762	986	1252	1470	1478	1431	52	1541
Sulfate as SO ₄ ²⁻	989		1150		1010	24	0	4515
Sodium as Na ⁺	896	1630	1880	1930	1790	1310	51	3650
Calcium as Ca ⁺⁺	261	165	58	4	4	2	0.26	8
Magnesium as Mg⁺⁺	19	13	8	3	3	0.72	0.20	6
Silica as SiO ₂	15.53	19	29	29.49	29.38	27.17	1.39	29.74
Chemical Oxygen Demand (COD)	354	593	302					

Note : All values except pH are expressed in mg/L.

- 1. Date of sample collected by CLRI : 08.10.98
- 2. Ref. & Date

US/RAS/92/120/PDU/2A dt.13 May'98

- 3. Code No. of the set
- : 11

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PARAMETERS	ETP TREATED EFFLUENT	РСО	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.62	6.24	6.28	6.22	5.81	6.08	7.02	5.69
Suspended Solids (SS)	106							
Total Dissolved Solids (TDS)	3372	7126	7974	7950	7924	5392	290	14010
Chloride as Cl	768	1365	2414	2396	2432	2368	.99	2295
Sulfate as SO ₄ ²⁻	1185	3533	1881	2188	1867	39	0	5714
Sodium as Na [⁺]	534	1500	2110	2280	2010	1660	74	3125
Calcium as Ca ^{⁺+}	206	216	149	149	118	64	3	416
Magnesium as Mg ⁺⁺	29	64	25	26	27	10	0.09	143
Silica as SiO ₂	20.96	34	53	53.1	53.21	51.04	2.31	38.96
Chemical Oxygen Demand (COD)	225	432	336					

Note : All values except pH are expressed in mg/L.

Date of sample collected by CLRI 1. 15.10.98 :

2. Ref. & Date

US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set

12 :

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PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.00	5.57	5.60	5.56	5.36	4.88	6.89	5.03
Suspended Solids (SS)	122							
Total Dissolved Solids (TDS)	4020	9700	10274	10150	10570	7892	440	19684
Chloride as Cl	904	1636	3155	3164	3164	3290	145	3064
Sulfate as SO ₄ ²⁻	1199	4857	2655	2634	2794	139	1.1	10230
Sodium as Na ⁺	778	1990	2620	2880	3360	2270	112	4400
Calcium as Ca ⁺⁺	245	394	335	276	281	144	5	727
Magnesium as Mg ⁺⁺	28.52	90	54	52	50	19	0.52	284
Silica as SiO ₂	11.66	25	42	40.31	38.55	38.91	0.58	43.58
Chemical Oxygen Demand (COD)	225	500	445					

Note : All values except pH are expressed in mg/L.

- Date of sample collected by CLRI 1. 16.10.98 :

:

13

Ref. & Date 2.

US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set :

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
pH ^{TI}	6.18	5.65	5.67	5.65	5.58	4.96	5.85	5.47
Suspended Solids (SS)	72							
Total Dissolved Solids (TDS)	5000	13986	13092	13250	12510	8090	406	27832
Chloride as Cl	1085	2260	3706	3706	3544	3525	154	4285
Sulfate as SO_4^{2-}	1994	6220	4640	4705	3975	76	2	13639
Sodium as Na [⁺]	1120	3120	3550	3570	3390	2720	122	5920
Calcium as Ca ^{⁺+}	309	570	389	398	414	149	5	950
Magnesium as Mg ^{⁺+}	21	60	30	40	35	10	0	162
Silica as SiO ₂	18	40	56	56	51	48	3	70
Chemical Oxygen Demand (COD)	299	862	612					

Note : All values except pH are expressed in mg/L.

- 1. Date of samples collected by CLRI 05.11.98 : Ref. & Date 2. :

US/RAS/92/120/PDU/2A dt.13 May'98

14

3. Code No. of the set :

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	5.85	5.77	5.72	5.69	5.02	5.42	5.66	5.38
Suspended Solids (SS)	646							
Total Dissolved Solids (TDS)	4300	9408	10214	10612	9406	6832	296	18978
Chloride as Cl	1335	2795	4177	4350	3078	2434	94	3471
Sulfate as SO4 ²⁻	1339	2664	1674	1883	1227	38	2	10599
Sodium as Na [⁺]	646	1704	1920	2040	1752	1152	62	2760
Calcium as Ca ^{⁺+}	277	386	376	394	370	248	5	381
Magnesium as Mg⁺⁺	33	101	71	76	65	19	0.3	175
Silica as SiO ₂	25	44	72	71	67	59	0.43	100
Chemical Oxygen Demand (COD)	310	450	427					

Note : All values except pH are expressed in mg/L.

- Date of sample collected by CLRI 1. 25.12.98 :
- Ref. & Date 2.

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- US/RAS/92/120/PDU/2A dt.13 May'98
- Code No. of the set 15 3. :

PARAMETERS	ETP TREATED EFFLUENT	PCO	ACF	SOFTENER	IST-I	IST-II	PERMEATE	REJECT-I
рН	5.49	6.19	5.93	5.9	4.98	5.63	5.49	5.07
Suspended Solids (SS)	578							
Total Dissolved Solids (TDS)	5926	7176	6972	7112	6980	4092	212	9474
Chloride as Cl	1960	2383	2552	2556	2579	2199	70	3023
Sulfate as SO ₄ ²⁻	2615	2420	2100	2005	1939	25	0	2998
Sodium as Na [⁺]	857	890	910	920	876	605	19	1100
Calcium as Ca ^{⁺+}	438	489	454	456	452	217	6.51	554
Magnesium as Mg ⁺⁺	35.97	78	74	71	73	20	0.41	109
Silica as SiO ₂	8.7	35	46	46	47	45	0	55
Chemical Oxygen Demand (COD)	286	198	225					

Note : All values except pH are expressed in mg/L.

- 1. Date of sample collected by CLRI : 12.02.99
- 2. Ref. & Date

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US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set 16 :
| PARAMETERS | ETP TREATED
EFFLUENT | SOFTNER | IST-I | IST-II | PERMEATE | REJECT-I |
|---------------------------------|-------------------------|---------|-------|--------|----------|----------|
| рН | 6.73 | 6.63 | 6.31 | 5.80 | 6.87 | 5.88 |
| Suspended Solids (SS) | 166 | | |] | | |
| Total Dissolved Solids (TDS) | 5676 | 5204 | 5156 | 1970 | 96 | 8572 |
| Chloride as Cl ⁻ | 1908 | 1926 | 1908 | 854 | 21 | 3000 |
| Sulfate as SO4 ²⁻ | 809 | 662 | 844 | 176 | BDL | 1527 |
| Sodium as Na [⁺] | 1773 | 1630 | 1610 | 712 | 15 | 2550 |
| Calcium as Ca ^{⁺+} | 65 | 66 | 64 | 29 | BDL | 77 |
| Magnesium as Mg ⁺⁺ | 11 | 11 | 11 | 3 | 1 | 18 |
| Silica as SiO ₂ | 8 | 11 | 10 | 4 | BDL | 18 |
| Chemical Oxygen Demand
(COD) | 165 | 140 | | | | 283 |

CHARACTERISTICS OF RO TREATED WASTEWATER AT A.T.H TANNERY, MELVISHARAM

Note : All values except pH are expressed in mg/L.

1. Date of sample collected by CLRI : 7.10.99

2. Ref. & Date : US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set : 17

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CHARACTERISTICS OF RO TREATED WASTEWATER AT A.T.H TANNERY, MELVISHARAM

PARAMETERS	ETP TREATED EFFLUENT	ACF	SOFTNER	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.68	6.57	6.54	4.53	4.75	5.79	4.16
Suspended Solids (SS)	370						
Total Dissolved Solids (TDS)	5015		5050	5321	1754	88	7961
Chloride as Cl ⁻	1541		1693	1683	696	17	2756
Sulfate as SO ₄ ²⁻	879		886	816	144	BDL	3682
Sodium as Na [⁺]	1317		1462	1466	560	18	2170
Calcium as Ca ⁺⁺	81		84	81	33	0.44	94
Magnesium as Mg ⁺⁺	7		. 7	9	5	0.63	11
Silica as SiO ₂	12		14	14	5	BDL	17
Chemical Oxygen Demand (COD)	203	167					295

Note : All values except pH are expressed in mg/L.

- 1. Date of sample collected by CLRI :
- 2. Ref. & Date

26.10.99

18

:

: US/RAS/92/120/PDU/2A dt.13 May'98

- 3. Code No. of the set

CHARACTERISTICS OF RO TREATED WASTEWATER AT A.T.H TANNERY, MELVISHARAM

PARAMETERS	ETP TREATED EFFLUENT	ACF	IST-I	IST-II	PERMEATE	REJECT-I
рН	6.57	6.51	4.34	4.99	4.85	5.36
Suspended Solids (SS)	274					
Total Dissolved Solids (TDS)	7190		6770	2442	123	9687
Chloride as Cl ⁻	2558		2633	1032	24	4170
Sulfate as SO4 ²⁻	1297		844	136	BDL	1855
Sodium as Na ⁺	2178		2113	832	19	2915
Calcium as Ca ^{⁺+}	52		54	29	0.50	78
Magnesium as Mg ⁺⁺	16		15	3	BDL	23
Silica as SiO ₂	14		16	7	BDL	27
Chemical Oxygen Demand (COD)	323	241				401

Note : All values except pH are expressed in mg/L.

- 1. Date of sample collected by CLRI 13.11.99 :
- Ref. & Date 2. :

US/RAS/92/120/PDU/2A dt.13 May'98

3. Code No. of the set : 19

GRAPHS

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TDS CONCENTRATION IN FEED, REJECT & PERMEATE



CHLORIDE CONCENTRATION IN FEED, REJECT & PERMEATE





SULFATE CONCENTRATION IN FEED, REJECT & PERMEATE

SODIUM CONCENTRATION IN FEED, REJECT & PERMEATE



CALCIUM CONCENTRATION IN FEED, REJECT & PERMEATE





MAGNESIUM CONCENTRATION IN FEED, REJECT & PERMEATE

SILICA CONCENTRATION (SiO₂) IN FEED, REJECT & PERMEATE



CALCIUM REMOVAL EFFICIENCY IN SOFTENER



CALCIUM

MAGNESIUM REMOVAL EFFICIENCY IN SOFTENER



TDS REMOVAL EFFICIENCY



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CHLORIDE REMOVAL EFFICIENCY



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SULFATE REMOVAL EFFICIENCY







CALCIUM REMOVAL EFFICIENCY



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MAGNESIUM REMOVAL EFFICIENCY

SILICA (SiO₂) REMOVAL EFFICIENCY



PERCENTAGE OF REJECT





PERCENTAGE OF PERMEATE

ANNEXURE - II

REPORT ON CONTINUOUS OPERATION OF REVERSE OSMOSIS SYSTEM INSTALLED AT A.T.H LEDER FABRIK, MELVISHARAM ORGANISED BY UNIDO, RePO, CHENNAI

To recover water from treated tannery wastewater and reuse it in tanning process a pilot scale Reverse Osmosis system was installed and commissioned during May'98 at A.T.H Leder Fabrik Tannery, Melvisharam, Ranipet, India. The RO system was operated to a maximum of 8 hours a day. TDS level in the recovered water from the RO system was in the range of 90-440 mg/L and the recovered water was reused in tannery for wet finishing operations. The average permeate recovery during the study period was around 60% against the designed value of 80-85%.

To study the general and operational problems in continuous operation of RO system and to improve the recovery rate of permeate a trial run was organized during 25-26th October 2000. The plant was started at 10:00 am on 25th October 2000.

OBSERVATIONS

1. Feed characteristics

Treated wastewater from secondary settling tank was pumped into collection tank. The feed characteristics during the study period are given in Table 1.

DADAMETEDS	FEED				
FARAMETERS	MIN	MAX	AVG		
Suspended Solids (SS)	308	590	404		
Total Dissolved Solids (TDS)	7618	8474	7883		
Chloride as Cl ⁻	3088	3440	3252		
Sulfate as SO ₄ ²⁻	683	1429	1005		
Sodium as Na+	2461	2845	2606		
Calcium as Ca++	21	22	22		
Magnesium as Mg++	39	45	42		
Silica as SiO ₂	16	21	18		
Chemical Oxygen Demand (COD)	172	187	180		

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Note: All values are expressed in mg/L.

The pumping of wastewater to collection tank is intermittent. Volume of effluent pumped from secondary settling tank (SST) to collection tank was measured using flow meter. Quantity of treated tannery effluent pumped in to the RO system is given in Table 2.

DATE & TIME	FEED FLOW METRE READING	CUMULATIVE VOLUME IN LIT
23/10/00 10:00	82.6	0
23/10/00 15:40	86.1	3500
23/10/00 17:05	87.5	4900
23/10/00 17:37	87.6	5000
23/10/00 21:30	89.2	6600
23/10/00 22:45	90.6	8000
23/10/00 23:30	91.6	9000
24/10/00 3:40	93.5 ,	10900
24/10/00 4:00	94.1	11500
24/10/00 4:30	95	12400
24/10/00 5:00	95.5	12900
24/10/00 5:30	96.2	13600
24/10/00 6:00	96.9	14300
24/10/00 6:45	97.5	14900
24/10/00 7:20	97.8	15200
24/10/00 8:00	99.3	16700
24/10/00 10:30	101.5	18900
24/10/00 10:55	101.9	19300
24/10/00 12:15	102.9	20300
24/10/00 12:40	103.3	20700
24/10/00 13:10	103.6	21000
24/10/00 13:35	104.3	21700
24/10/00 14:00	104.7	22100
24/10/00 14:40	105.7	23100

Table 2. Treated Tannery Effluent Pumping Rate

2. Sampling

Samples from secondary settling tank, various pre-treatment systems and RO units (16 set of samples) were collected on 23.10.2000 and 24.10.2000 and analysed in the Lab. The details of sample collected during the study period and time of collection are given in Table 3.

SAMPLE SET NO.	SAMPLE NAME	DATE	TIME	REMARKS		
BATCH OPERATION NO. 1						
1.	Treated Tannery Effluent Reject I, Permeate	23/10/2000	15:30	Plant started at 10.00		
2.	Reject I Treated Tannery Effluent Permeate	23/10/2000	17:00			
3.	Treated Tannery Effluent Collection Tank, IWT, IST – I IST – II, Permeate, Reject I Reject II, Softener Outlet RO I – Flush, RO II – Flush	23/10/2000	17:35	Plant stopped at 17.35 due to pressure increase in RO Membrane		
BATCH OPERATION NO. 2						
4.	Treated Tannery Effluent Permeate, Reject I	23/10/2000	21:30	Plant started at 21.30		
5.	Treated Tannery Effluent Permeate, Reject I Collection Tank, IWT, IST – I IST – II, Reject II Softener Outlet	23/10/2000	22:40			
6.	Permeate, Reject I Treated Tannery Effluent IST – I, IST – II, Collection Tank, IWT	23/10/2000	23:30	Plant stopped at 23:30 due to pressure increase in RO Membrane		
BATCH OPERATION NO. 3						
7.	Treated Tannery Effluent Permeate, Reject I	24/10/2000	04:00	Plant started at 03:40		
8.	Treated Tannery Effluent Permeate, Reject I Collection Tank, IWT IST – I, IST – II, Reject II	24/10/2000	05:00			
9.	Treated Tannery Effluent Permeate, Reject I Collection Tank IWT, IST – I, IST – II, Reject II	24/10/2000	06:30			

Table 3. Details of samples collected from RO Syste

SAMPLE SET NO.	SAMPLE NAME	DATE	ТІМЕ	REMARKS
10.	Treated Tannery Effluent Permeate, Reject I Collection Tank IWT, IST – I, IST – II, Reject II	24/10/2000	07:30	Plant stopped at 8:00 due to pressure increase in RO Membrane
11.	PSF & ACF Backwash	24/10/2000	08:15	
	BATCH OPER	ATION NO.	4	
12.	Treated Tannery Effluent Collection Tank, IWT, IST – I, IST – II, Permeate Reject I, Reject II	24/10/2000	10:30	Plant started at 10:30
13.	Reject II, Permeate, Reject I	24/10/2000	10:55	
14.	Treated Tannery Effluent Collection Tank, IWT IST – I, IST – II, Permeate Reject I, Reject II	24/10/2000	12:40	
15.	Treated Tannery Effluent Collection Tank IWT, IST – I, IST – II, Permeate, Reject I, Reject II	24/10/2000	13:35	
16.	Treated Tannery Effluent Collection Tank IWT, IST – I, IST – II Permeate, Reject I Reject II Reject Composite from Storage Tank	24/10/2000	14:40	Plant stopped at 14:40 due to pressure increase in RO Membrane

3. RO Operating Pressure

Wastewater from IST-I is pumped using high pressure pump with a hydraulic pressure of 7-8 kg/cm² to RO module I. Water from IST-II is pumped using high pressure pump with a hydraulic pressure of 16-25 kg/cm² to RO module II. If the operating pressure exceeds more than 25 kg/cm² in RO module II the system was stopped, cleaned then restarted. Hydraulic pressure to RO module I & II were monitored and given in Table 4.

DATE & TIME	OPERATING PRESSURE (kg / cms)							
	RO – I	RO – II						
BATCH OPERATION – 1								
23/10/00 15:55	7.5	21.5						
23/10/00 17:05	7.5	22						
23/10/00 17:45	8	23						
BATCH OPE	BATCH OPERATION - 2							
23/10/00 21:30	8	18						
23/10/00 22:45	8	22.5						
23/10/00 23:30	8	24						
BATCH OPERATION – 3								
24/10/00 4:00	7	16.5						
24/10/00 4:30	7.5	18.5						
24/10/00 5:00	7.5	20						
24/10/00 5:30	7	22						
24/10/00 6:00	• 7	23						
24/10/00 6:45	7.5	24						
24/10/00 7:20	7.5	24.5						
24/10/00 8:00	8	25						
BATCH OPE	RATION – 4							
24/10/00 10:30	7	17.5						
24/10/00 10:55	7	19.75						
24/10/00 12:15	7	20						
24/10/00 12:40	7	22						
24/10/00 13:10	,7.5	23						
24/10/00 13:35	7.5	24						
24/10/00 14:00	7.5	24.25						
24/10/00 14:40	7.5	25						

Table 4. Hydraulic Pressure In RO – I and RO - II during the Study Period

Both the RO modules were flushed with permeate water or cleaned using chemicals if the hydraulic pressure in RO module II increased to 25 kg/cm². Cleaning details are given in Table 5.

DATE & TIME	OPERATION	PROCEDURE				
23/10/00 17:45	RO – I Flushing	About 200 L of Permeate was used for flushing operation.				
23/10/00 17:45	RO - II Flushing	About 200 L of Permeate was used for flushing operation.				
23/10/00 23:30	RO – I Chemical Cleaning	About 200 L of Permeate + 1.5 L 5050 chemical run for 45 minutes.				
23/10/00 23:30	RO – II Chemical Cleaning	About 200 L of Permeate + 1.5 L 5050 chemical run for 45 minutes.				
23/10/00 23:30	PSF Backwash	About 100 L of IWT water was used for backwash				
23/10/00 23:30	ACF Backwash	About 100 L of IWT water was used for backwash				
24/10/00 08:15	RO - I Chemical Cleaning	About 200 L of Permeate + 1 L 5090 chemical run for 45 minutes.				
24/10/00 08:15	RO - II Chemical Cleaning	About 200 L of Permeate + 1 L 5090 chemical run for 45 minutes.				

Table 5. Cleaning	Of	RO	System
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5. Reject

Part of the reject from RO Module I was discharged into a storage tank. The flow was controlled manually. Part of the Reject I was mixed with the treated wastewater from SST in the collection tank. The volume of reject goes to the storage tank is not constant. Volume of reject was calculated based on the height difference in the storage tank. Volume of reject collected during the study period is given in Table 6.

DATE & TIME	HEIGHT (m)	DIA (m)	REJECT VOL. (L) CUMULATIVE
23/10/00 10:00	0	2.18	0
23/10/00 17:40	0.3	2.18	1119
23/10/00 22:30	0.46	2.18	1716
23/10/00 23:25	0.54	2.18	2015
24/10/00 3:30	0.54	2.18	2015
24/10/00 5:45	0.74	2.18	2761
24/10/00 7:00	0.84	2.18	3134
24/10/00 8:10	0.97	2.18	3619
24/10/00 10:30	0.98	2.18	3656
24/10/00 10:55	1.04	2.18	3880
24/10/00 12:12	1.06	2.18	3954
24/10/00 13:10	1.13	2.18	4216
24/10/00 13:35	1.17	2.18	4365
24/10/00 14:00	1.22	2.18	4551
24/10/00 14:45	1.32	2.18	4924

Table 6. Volume of Final Reject I collected at Storage Tank

The characteristics of Reject collected during the study period are given in Table 7.

DADAMETEDS	REJECT						
FARAMETERS	MIN	МАХ	AVG				
Total Dissolved Solids (TDS)	12784	21118	16875				
Chloride as Cl ⁻	3861	7967	5810				
Sulfate as SO ₄ ²⁻	4728	6290	5532				
Sodium as Na+	3376	6182	4632				
Calcium as Ca++	24	33	29				
Magnesium as Mg++	61	142	97				
Silica as SiO₂	18	49	33				
Chemical Oxygen Demand (COD)	246	435	376				

Table 7. Characteristics of Reject I collected during Study Period

Note: All values are expressed in mg/L.

Increase in reject volume was observed due to increase in hydraulic pressure which resulted frequent cleaning of RO system.

5. Permeate Recovery

The total dissolved solids concentration in the treated tannery effluent during the study period was in the range of 7600 - 8475 mg/L. TDS concentration in the permeate was 200-400 mg/L. Characteristics of permeate collected during the study period is given in Table 8.

DADAMETERS	PERMEATE						
PARAMETERS	MIN	MAX	AVG				
Total Dissolved Solids (TDS)	200	400	294				
Chloride as Cl ⁻	74	218	124				
Sulfate as SO₄²-	BDL	BDL	BDL				
Sodium as Na+	45	152	85				
Calcium as Ca++	0.06	0.24	0.13				
Magnesium as Mg++	0.08	0.66	0.36				
Silica as SiO ₂	BDL	BDL	BDL				

Table 8. Characteristics of Permeate Water

Note: BDL – Below Detectable Limit

All values are expressed in mg/L

Analytical results of 4 batches of samples collected on 23.10.2000 and 24.10.2000 are given in Tables 9 a - 9 i. The average recovery of permeate was 55-60 %. Percentage of water recovery was calculated based on the ions concentration in the permeate and reject.

23/10/2000 23/10/2000 23/10/2000 23/10/2000 23/10/2000 23/10/2000 24/10/2000 PARAMETERS 15:30 17:00 17:35 21:30 22:40 23:30 4:00 6.35 6.37 6.64 6.75 рΗ 6.29 6.19 6.29 Suspended Solids (SS) Total Dissolved Solids (TDS) Chloride as Cl⁻ Sulfate as SO42-Sodium as Na+ Calcium as Ca++ Magnesium as Mg++ Silica as SiO₂ Chemical Oxygen Demand (COD)

Table 9a. Characteristics of samples collected from Secondary Settling Tank (Treated Tannery Effluent) (Contd.)

Table 9a. Characteristics of samples collected from Secondary Settling Tank (Treated Tannery Effluent)

	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000
PARAIVILIERS	5:00	6:30	7:30	10:30	12:40	13:35	14:40
рН	6.76	6.72	6.60	6.69	6.25	6.42	6.32
Suspended Solids (SS)	374	392	308	408	318	358	420
Total Dissolved Solids (TDS)	7646	7670	7730	7662	7768	7972	8290
Chloride as Cl ⁻	3440	3299	3299	3369	3299	3299	3339
Sulfate as SO ₄ ²⁻	1025	990	704	1025	683	983	1088
Sodium as Na+	2513	2646	2659	2652	2698	2662	2845
Calcium as Ca++	22	22	22	21	22	22	22
Magnesium as Mg++	40	41	40	41	41	40	39
Silica as SiO ₂	18	17	17	17	17	16	16
Chemical Oxygen Demand (COD)	184	184	184	187	181	174	177

PARAMETERS	23/10/2000	23/10/2000	23/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000
	17:35	22:40	23:30	5:00	6:30	7:30	10:30	12:40	13:35	14:40
рН	5.12	5.04	5.00	5.73	5.52	5.54	5.37	5.40	5.46	5.16
Total Dissolved Solids (TDS)	12526	10362	10294	9532	10392	11146	9846	10050	10268	11642
Chloride as Cl ⁻	4562	3930	4071	3720	4141	4352	3439	3861	4001	4773
Sulfate as SO4 ²⁻	2573	2231	2266	2001	1785	1576	1604	1409	1443	1736
Sodium as Na+	3640	3015	3027	2884	309	2777	3355	3227	3041	3463
Calcium as Ca++	28	25	24	24	24	25	22	24	24	25
Magnesium as Mg++	97	68	53	47	56	57	44	46	56	61
Silica as SiO₂	34	27	27	23	24	27	20	22	22	25

 Table 9b. Characteristics of samples collected from Collection Tank

PARAMETERS	23/10/2000	23/10/2000	23/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000
	17:35	22:40	23:30	5:00	6:30	7:30	10:30	12:40	13:35	14:40
pН	5.49	5.63	5.59	5.83	5.72	5.67	5.66	5.75	5.60	5.74
Total Dissolved Solids (TDS)	14238	12962	14904	11074		18396	10098	11964	15084	15664
Chloride as Cl ⁻	6212	5580	6458	4983		7159	4071	4633	7054	7265
Sulfate as SO4 ²⁻	2224	1966	2629	1806		2169	1750	2043	1548	1771
Sodium as Na+	4621	4070	4751	3772		5097	3093	4219	5260	5365
Calcium as Ca++	22	20	20	20		23	17	20	21	21
Magnesium as Mg++	64	50	46	42		56	37	46	45	48
Silica as SiO ₂	43	40	45	50		41	22	30	38	38

Table 9c. Characteristics of samples collected from Intermediate Water Storage Tank (IWT)

PARAMETERS	23/10/2000	23/10/2000	23/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/200
	17:35	22:40	23:30	5:00	6:30	7:30	10:30	12:40	13:35	14:40
рН	4.83	4.41	4.87	5.09	4.87	4.86	5.02	4.81	4.76	4.91
Total Dissolved Solids (TDS)	13970	12046	13180	10104	13996	14932	9980	11236	13666	15274
Chloride as Cl ⁻	6317	5440	6177	4562	6738	7019	3896	5194	6387	7230
Sulfate as SO₄²-	1220	893	1813	1681	1959	2092	1611	1890	2050	1973
Sodium as Na+	4885	4082	4860	3570	5120	5380	2750	3990	4770	5540
Calcium as Ca++	24	21	21	20	22	24	19	21	21	22
Magnesium as Mg++	78	59	58	46	61	69	41	51	58	60
Silica as SiO₂	22	21	31	26	31	41	22	27	35	29

Table 9d. Characteristics of samples collected from Intermediate Storage Tank-I (IST – I)

Note : All values except pH are expressed in mg/L

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DADAMETEDS	23/10/2000	23/10/2000	23/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/200
FARAMETERS	17:35	22:40	23:30	5:00	6:30	7:30	10:30	12:40	13:35	14:40
рН	4.82	4.57	4.97	5.24	5.04	4.90	5.14	4.79	4.51	4.78
Total Dissolved Solids (TDS)	10824	9192	11070	8292	11968	12934	7088	10700	11342	12998
Chloride as Cl ⁻	5826	4176	5896	4282	6247	6879	3474	7042	3673	6935
Sulfate as SO ₄ ²⁻	36	36	30	88	84	87	63	59	86	91
Sodium as Na+	4040	350	4210	3030	4420	4840	250	3470	4350	4870
Calcium as Ca++	19	14	17	20	24	25	16	18	20	23
Magnesium as Mg++	13	9	11	18	22	23	14	13	16	18
Silica as SiO ₂	34	22	32	19	29	31	14	19	25	29

Table 9e. Characteristics of samples collected from Intermediate Storage Tank-II (IST – II)

PARAMETERS	23/10/2000	23/10/2000	23/10/2000	23/10/2000	23/10/2000	23/10/2000	24/10/2000
	15:30	17:00	17:35	21:30	22:40	23:30	4:00
рН	4.97	4.98	4.93	5.10	4.73	4.92	5.15
Total Dissolved Solids (TDS)	15824	16960	19536	14240	16262	18066	12784
Chloride as Cl ⁻	5264	6001	6773	4966	6001	6808	3861
Sulfate as SO ₄ ²⁻	5969	5704	6011	5000	5551	5620	5007
Sodium as Na+	4227	4721	5791	3879	3777	4828	3408
Calcium as Ca++	28	30	30	31	31	30	24
Magnesium as Mg++	84	87	142	93	122	130	70
Silica as SiO ₂	42	45	49	30	41	46	24
Chemical Oxygen Demand (COD)	312	411	419	337	427	427	246

 Table 9f. Characteristics of Reject I samples collected from RO system (Contd.)

PARAMETERS	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000
	5:00	6:30	7:30	10:30	10:55	12:40	13:35	14:40
рН	5.13	4.91	4.88	4.85	4.40	4.59	4.55	4.63
Total Dissolved Solids (TDS)	15550	18444	20692	13306	14294	16546	19510	21118
Chloride as Cl ⁻	4913	6317	7545	3861	4492	5510	6879	7967
Sulfate as SO4 ²⁻	5523	5718	5843	5244	4728	5007	6290	5774
Sodium as Na+	4260	5591	5881	3376	3743	5402	4417	6182
Calcium as Ca++	30	29	30	26	27	28	28	33
Magnesium as Mg++	84	95	125	74	76	98	114	61
Silica as SiO ₂	28	36	36	18	20	24	30	33
Chemical Oxygen Demand (COD)	328	370	402	427	BDL	352	435	BDL

Table 9f. Characteristics of Reject I samples collected from RO system

DARAMETERS	23/10/2000	23/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/200
	17:35	22:40	5:00	6:30	7:30	10:30	10:55	12:40	13:35	14:40
рН	4.67	4.48	5.22	4.96	4.91	5.18	4.95	`4.71	4.54	4.84
Total Dissolved Solids (TDS)	19112	16922	18032	20890	23034	11988	12810	17460	20800	22824
Chloride as Cl ⁻	9932	7370	8739	10845	11722	5791	6668	8493	10704	11827
Sulfate as SO ₄ ²⁻	81	81	202	205	98	61	76	105	109	88
Sodium as Na+	4157	4669	8355	7654	6010	4751	4101	8296	7724	5082
Calcium as Ca++	30	25	31	38	36	27	27	28	31	33
Magnesium as Mg++	23	13	30	31	39	22	20	18	29	26
Silica as SiO₂	77	61	48	69	74	33	37	50	59	68

Table 9g. Characteristics of Reject – II samples collected from RO System

PARAMETERS	23/10/2000	23/10/2000	23/10/2000	23/10/2000	23/10/2000	23/10/2000	24/10/2000
	15:30	17:00	17:35	21:30	22:40	23:30	4:00
рН	5.09	5.09	5.15	5.05	5.04	5.03	5.04
Total Dissolved Solids (TDS)	280	312	340	240	300	320	200
Chloride as Cl ⁻	. 87	118	135	79	108	129	76
Sulfate as SO ₄ ²⁻	BDL						
Sodium as Na+	60	81	94	50	74	91	48
Calcium as Ca++	0.08	0.15	0.16	0.08	0.1	0.13	0.06
Magnesium as Mg++	0.58	0.56	0.49	0.41	0.55	0.53	0.47
Silica as SiO ₂	BDL						

 Table 9h. Characteristics of RO Permeate Samples (Contd.)

Table 9h. Characteristics of RO permeate samples

PARAMETERS	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000	24/10/2000
	5:00	6:30	7:30	10:30	10:55	12:40	13:35	14:40
рН	5.06	5.05	5.25	5.27	5.21	5.09	4.98	5.18
Total Dissolved Solids (TDS)	230	280	394	230	250	310	324	400
Chloride as Cl ⁻	96	153	180	74	97	127	180	218
Sulfate as SO4 ²⁻	BDL							
Sodium as Na+	67	108	127	45	66	91	128	152
Calcium as Ca++	0.1	0.18	0.23	0.07	0.1	0.15	0.2	0.24
Magnesium as Mg++	0.4	0.66	0.17	0.13	0.11	0.08	0.09	0.27
Silica as SiO ₂	BDL							

	PSF & ACF Backwash	Reject From Storage tank	RO I – FLUSH	RO II – FLUSH	Softner outlet	Softner outlet
PARAMETERS	24/10/2000	24/10/2000	23/10/2000	23/10/2000	23/10/2000	23/10/2000
	8:15	14:40	17:35	17:35	17:35	22:40
рН	5.48	5.09	5.54	5.23	5.48	5.57
Total Dissolved Solids (TDS)	13004	16832	632	1088	17452	16492
Chloride as Cl ⁻	5615	5615	174	515	7581	5650
Sulfate as SO ₄ ²⁻	2448	5571	223	78	2231	2280
Sodium as Na+	4591	4747	135	396	6355	7135
Calcium as Ca++	26	31	0.95	1.26	28	25
Magnesium as Mg++	54	121	1.33	1.03	66	49
Silica as SiO ₂	BDL	24	0.58	25	49	39
Chemical Oxygen Demand (COD)		230	······································		255	234

Table 9i. Characteristics of samples collected during Cleaning Operations