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Original Research Paper

# Zero Liquid Discharge Scheme in a Common Effluent Treatment Plant for Textile Industries in Tamilnadu, India

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## ABSTRACT

Perundurai Common Effluent Treatment Plant is one of the front runners in implementing ‘Zero Liquid Discharge’ concept in the treatment and management of effluents from a cluster of textile processing industries. The effluent is segregated into low TDS (< 2100 mg/L) and high TDS (> 2100 mg/L) streams at the individual member units itself and sent to treatment plant through separate pipelines. Low TDS effluent is subjected to primary, secondary and tertiary treatments to recover 77.7 % of the effluent for reuse by the member units. High TDS effluent is treated through Multiple Effect Evaporators and solar evaporation pans or salt recovery plant and converted into solid wastes. Out of a total pollution load of 48 kg/m$^3$ of effluent, only 6.0 kg/m$^3$ is removed through the treatment and the remaining is transferred to solid wastes. The capital investment to implement this scheme comes to Rs. 67,018/m$^3$ with recurring expenditure of Rs. 90/m$^3$.

## INTRODUCTION

Textile is one of the oldest and most important industrial sectors of the world in terms of employment and foreign exchange earnings but equally synonyms with high pollution and environmental degradation due to the presence of toxic/carcinogenic dyes and chemicals in its wastewater streams (Nosheen et al. 2000, Villegas-Navarro et al. 2001, Ghorishi & Haghighi 2003). Removal of these pollutants is a daunting task often met with failures which lead to severe water pollution problems in many parts of India including Tirupur and Erode in the state of Tamilnadu (Senthilnathan & Azeez 1999). Driven by legislation coupled with public outcry and judicial activism, Zero Liquid Discharge (ZLD) concept started gaining ground in recent years to overcome the pollution problems (Vishnu et al. 2007, Gozalvez-Zafrilla et al. 2008, Ramesh Kumar et al. 2009). This concept is very uncommon in India until few years back when many Common Effluent Treatment Plants (CETPs) located in Tamilnadu started incorporating/implementing ZLD due to its difficulty in meeting the standards for discharge of industrial effluents into natural aquatic systems. Present study deals with performance of one such scheme implemented by a CETP located at SIPCOT Industrial area (Perundurai) near Erode in Tamilnadu.

## TEXTILE PROCESSING

Textile manufacturing involves many dry and wet processes and the latter includes bleaching, dyeing and printing which is important from pollution point of view. Raw materials (woven cloth, cotton/polyester/acrylic/lycra yarn, etc.) are boiled in a vessel for 2-3 hours at 80°C to 130°C and then scoured after adding soap and caustic soda (5% strength) (Fig. 1). These materials are bleached either in hydrogen peroxide or hypochlorite solution by soaking (20-30 minutes) followed by washing and neutralization with alkali and acidic waters respectively. The washing operation is repeated if necessary before transferring material into a dyeing vat containing dyes, soda ash and salts such as sodium chloride/sodium sulphate depending upon the shade to be produced. In the case of polyester and acrylic materials salt is not used. Dyeing operations are carried out at 65°C to 130°C depending upon the type of materials and dyes to be used. Dyed cloth is washed with 1% soap solution to remove excess dyes and other contaminants followed by neutralization with acetic acid and treatment with dye fixing/softening agents. Then, the material is dried and sent for weaving, knitting or garment making. Depending on type of raw materials, the effluent generation due to processing of one kg of material varied from 10 to 16 litres for bleaching and 50 to 100 litres for dyeing.

Perundurai Common Effluent Treatment Plant (PCETP) was established in the year 2002 with a designed capacity of 4050 m$^3$/day at a capital cost of Rs. 27.14 crores (Table 1) to segregate and treat effluent from 14 textile processing units located in the SIPCOT Industrial Growth Centre, Perundurai, Erode district of Tamilnadu. It consists of (i) wash-water treatment plant (WTP) for effluent having TDS < 2100 mg/L (hereafter called as 'wash-water effluent') and (ii) Dyebath + RO reject treatment plant (DTP) for effluent having TDS > 2100 mg/L (hereafter called as 'dye-bath effluent'). The basic design and technical specifications are given in Table 2. WTP is designed to give primary (physico-chemical), secondary (biological) and tertiary (reverse osmosis) treatments so as to produce good quality treated effluent with TDS and chloride < 300 mg/L and < 200 mg/L respectively for reuse in the process. DTP consists of multiple effect evaporators (5 effect falling film evaporator), salt recovery plant (3 effect forced circulation evaporator) and solar evaporation pans where highly coloured effluent is concentrated to produce solid wastes/salts for further disposal. The condensate from DTP is mixed with RO condensate for reuse by member units.

## MATERIALS AND METHODS

Performance of PCETP was assessed during 24-25 November 2008. Composite samples from raw wash-water effluent, primary and secondary clarifier outlets, RO feed, evaporator feed and evaporator concentrate were collected on four hourly basis (for 24 hours). In addition, grab samples were also collected covering raw dye-bath effluent, RO permeate, RO reject and evaporator condensate. All the parameters were analysed following standard procedures (APHA 1998). Operational data including effluent inflow, capacity utilization and expenditure were collected from the company records.

## RESULTS AND DISCUSSION

Identification, characterization and segregation of different effluent streams from industrial processes are important prerequisites for selection and optimization of effluent treatment system as well as recovery-reuse of treated effluent, especially in textile sector where different processes generate different quality wastewaters (Le Rosi et al. 2007). Until recently very few attempts were made to segregate and treat the textile effluent in India. In the present case, the effluent streams generated by 14 member units are segregated by considering TDS limit of 2100 mg/L (max.) specified by the local (State) Pollution Control Board for land discharge as a criterion. Segregation is made with the help of a customised 'Automatic PLC Based Monitoring System' installed at individual member units. The 'low TDS effluent' with < 2100 mg/L (i.e. wash-water effluent) and 'high TDS effluent' with > 2100 mg/L (i.e. dye-bath effluent) are conveyed to the WTP and DTP respectively through dedicated PVC pipelines. Earlier studies emphasised that segregated wastewater treatment lead to better salt recovery, water reuse and up to 30% reduction in operational cost (Thakur et al. 1994, ElDefrawy & Shaalan 2007). While wash-water effluent showed pH of 7.60, conductivity of 3.19 mS/cm, TDS of 2194 mg/L, BOD of 397 mg/L and COD of 757 mg/L (Table 3), the dye-bath effluent is comparatively more alkaline (pH 9.95) with high TDS (44205 mg/L), conductivity (61.7 mS/cm) and COD (1249 mg/L) and low BOD (213 mg/L). Earlier studies carried-out in different countries showed a range of 5.5 to 15.0 for pH, 160 to 3606 mg/L for COD, 60 to 900 mg/L for BOD and 250 to 67500 mg/L for TDS for textile effluents (Nosheen et al. 2000, Yusuff & Sonibare 2004, Ramesh Babu et al. 2007, Arnal et al. 2008, Ramesh Kumar et al. 2009).

Wash-water effluent constitutes 86% of the total effluent generated from the present industrial cluster and needs to be treated to a quality so as to be reused for industrial purpose even though its contribution was only 6.2% in terms of total organic and inorganic pollution load. Accordingly, it is subjected to physico-chemical-biological treatment comprising coagulation (with the help of lime, ferrous sulphate/ferrous chloride and polyelectrolyte), clarification and activated sludge process which resulted in organic load reduction of upto 98%. The wash-water effluent BOD:COD ratio of 0.52 also indicated its amenability to biological treatment. Physico-chemical and 'Sequencing Batch Reactor' system were found reducing organic load up to 85 % in textile wastewaters (Arafat 2007). In PCETP, the MLVSS/MLSS ratio of 0.85 indicated the presence of mineralized sludge with 'Sludge Retention Time' of about 120 days which could be attributed to operation of the WTP at less than 50% capacity. However, the result indicated that the treatment system is meeting the design criteria (Table 2). Sludge generated in the primary and secondary treatment units is sent to sludge thickener/sludge drying beds and dried sludge stored for further safe disposal.

Though the wash-water effluent meets the discharge standards after primary and secondary treatments, it is treated further to ensure reuse and attain ZLD goal in view of the public perception and judicial intervention rather than economics. Membrane technology found wide acceptance to produce high quality reusable permeates (Rozzi et al. 1999, Ciardelli et al. 2001, Fersi et al. 2005, Naveed et al. 2006). In PCETP, a combination of ultra filtration (UF) + organic scavenger (OS) + two stage reverse osmosis (RO) is used as tertiary treatment system. In RO plant, 5 micron cartridge filters are used with Stage I and Stage II working at a pressure of 14 $kg/cm^2$ and 40 $kg/cm^2$ respectively, resulting in 90% (max.) recovery. The RO treatment resulted in 86-97 % reduction of pollution load (mainly TDS), with permeates having TDS, COD, chloride and sulphate level of 204 mg/L, 5 mg/L, 74 mg/L and 10 mg/L respectively. Arnal et al. (2008) reported a 50% reduction of COD load with UF membrane. As the permeate quality is much better than the

Table 1: Project cost of 'Zero Liquid Discharge' treatment plant of M/s Perundurai Common Effluent Treatment Plant, Erode, Tamilnadu.

| Treatment system | Particulars | Cost in Indian rupees |
|---|---|---|
| Washwater Treatment Plant (Designed capacity: 3600 $m^3$/day) | Land* | 1,49,20,793 |
| | Physico-chemical treatment | 4,78,18,527 |
| | Biological treatment system | 1,62,34,489 |
| | Reverse osmosis system | 8,73,17,660 |
| | Flow meter, TDS monitoring system, Pipe lines and accessories* | 2,54,70,942 |
| | Capital cost for treatment of one $m^3$ of effluent | 53,267 |
| Dye bath + RO Reject Treatment plant (Designed capacity: 450 $m^3$/day) | Multi effect evaporators and Salt recovery plant | 7,24,53,089 |
| | Solar evaporation pans | 72,07,514 |
| | Capital cost for treatment of one $m^3$ of effluent | 1,77,024 |
| | Total capital expenditure | 27,14,23,014 |
| | Total capital cost Of ZLD scheme for one $m^3$ | 67,018 |

*Facilities common for both the plants and cost included only in washwater treatment plant; Data Source: M/s Perundurai Common Effluent Treatment Plant, Erode

Table 2: Basic design and technical specifications of treatment plant.

| Treatment units and specifications | Design criteria (mg/L) | | |
|---|---|---|---|
| | Parameter | Inlet | Outlet |
| **(A) Washwater Treatment Plant (WTP):** | | | |
| **Physico-chemical treatment units:** | | | |
| Washwater sump; Size: 8.0 m dia with 2.5 m SWD | TSS | 300 | <100 |
| Equalization tank; Size: 32.0 m dia with 4.0 m SWD | BOD | <350 | <200 |
| Clariflocculator-Flocculation; Size: 6.0 m dia with 3.0 SWD, RT = 30 min | COD | <1000 | <500 |
| Clariflocculator-Clarifier; Size: 16.5 m dia with 3.0 SWD; RT = 3.5 hrs | | | |
| Clarified water tank; Size: 10.0 m × 5.0 m × 3.0 m SWD | | | |
| Sand filter; Cap: 150 $m^3$/hr | | | |
| Sludge drying beds; Size: 11 m × 5 m × 1 m (five nos. ) | | | |
| Sludge thickener; Cap: 60 $m^3$/day | | | |
| Centrifuge; Cap: 5 $m^3$/hr | | | |
| **Biological Treatment units** | | | |
| Aeration tank (2 nos.); Flow: 150 $m^3$/hr; Size: 40m × 10 m × 4.5 m; | TSS | <100 | <30 |
| MLSS: 3500 mg/L; DO: 2 mg/L; Vol: 3600 $m^3$ | BOD | <300 | <10 |
| Secondary clarifier; Flow: 150 $m^3$/hr, Size: 20m × 3.0m SWD | COD | <600 | <100 |
| Tertiary clarifier; Flow: 150 $m^3$/hr; Size: 16 m × 3.0 m SWD | | | |
| **Reverse Osmosis Treatment:** | | | |
| Ultra filtration Plant; Cap: 3.6 MLD, Feed: 189 $m^3$/hr, | TDS | 2500 | <300 |
| Recovery: 95% | BOD | 10 | - |
| RO Plant-I Stage; Cap: 3.6 MLD, Feed:180 $m^3$/hr, | COD | 100 | - |
| Recovery: 75% | Hardness | <200 | - |
| RO Plant-II Stage; Cap: 3.6 MLD, Feed: 45 $m^3$/hr, | Silica | <20 | - |
| Recovery: 60% | Chloride | <1500 | <200 |
| **(B) Dye-Bath + RO Reject Treatment Plant** | | | |
| Multiple Effect Evaporator; Vol: 450 KLD, Reduction: 73%, No. of Effects: 5 effects falling film, Steam pressure: 8-9 bar, Steam required: 2452 kg/hr | TS | 80 g/L | 300 g/L |
| Salt Recovery Plant; Vol: 450 KLD, Reduction: 50%, No. of Effects: 3 effects forced circulation, Steam pressure: 3 bar, Steam required: 1495 kg/hr | TS | 300 g/L | Crystals with 10-15 % moisture |
| Solar Evaporation Pan; Solar evaporation rate: 5 mm/day, size: 122 m × 12.5 m, No. of solar pan: 7 nos. | Volume | 45 $m^3$/day | - |

Data Source: M/s Perundurai Common Effluent Treatment Plant, Erode

Table 3: Performance analysis of various treatment units during 24-25th November 2008.

| Parameters | Details of samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dye Bath raw effluent) | Washwater (raw effluent) | Primary Clarifier outlet | Secon-dary Clarifier outlet | RO inlet | RO permeate | RO reject | ME Evaporator inlet | ME Evaporator concentrate | ME Evaporator condensate |
| pH | 9.95 | 7.60 | 8.10 | 7.50 | 6.40 | 6.20 | 6.80 | 10.50 | 10.46 | 9.51 |
| EC, mS/cm | 61.70 | 3.19 | 2.95 | 3.06 | 3.07 | 0.29 | 31.10 | 90.50 | 189.10 | 0.19 |
| TSS, mg/L | 170 | 136 | 58 | 22 | 22 | 8 | 28 | 382 | - | 2 |
| TDS, mg/L | 44205 | 2194 | 1678 | 1594 | 1506 | 204 | 18176 | 62640 | 206780 | 60 |
| BOD, mg/L | 213 | 397 | 153 | 9 | < 1 | BDL | 17 | 1413 | 4010 | 43 |
| COD, mg/L | 1249 | 757 | 375 | 62 | 55 | < 5 | 429 | 4138 | 8355 | 164 |
| Chloride, mg/L | 18989 | 800 | 611 | 659 | 824 | 74 | 8597 | 21923 | 35980 | 26 |
| Sulphates, mg/L | 1421 | 129 | 125 | 229 | 300 | 10 | 818 | 1670 | 1116 | BDL |
| Amm. Nitrogen, mg/L | 5 | 17 | 20 | 4 | 2 | - | 21 | 25 | 37 | - |
| Copper, mg/L | 0.29 | 0.06 | - | - | - | 0.02 | - | - | 2.23 | 0.02 |
| Lead, mg/L | 0.21 | BDL | - | - | - | BDL | - | - | 1.11 | BDL |
| Zinc, mg/L | 0.21 | 0.09 | - | - | - | 0.23 | - | - | 0.95 | 0.14 |
| Nickel, mg/L | 0.16 | BDL | - | - | - | 0.02 | - | - | 1.40 | 0.02 |
| Total chromium, mg/L | 0.22 | BDL | - | - | - | BDL | - | - | 1.88 | BDL |
| Cadmium, mg/L | 0.14 | 0.01 | - | - | - | BDL | - | - | 1.19 | BDL |

MLSS = 4004 mg/L, MLVSS = 3394 mg/L, SVI = 146 mL/g, MLVSS/MLSS = 0.85, DO = 3.25 mg/L, F/M ratio = 0.02

Table 4: Capacity utilization and expenditure incurred at PCETP during February-October 2008.

| Month/Year | Total monthly inflow ($m^3$/month) | | CETP Capacity utilization (%) | | Expenditure incurred (Rupees) | | Cost of treatment per $m^3$ of wastewater (Rupees) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Washwater Treatment Plant | Dye-bath+ RO Reject Treatment Plant | Washwater Treatment Plant | Dye-bath Treatment Plant | Washwater Treatment Plant | Dyebath+ RO Reject Plant | Wash water | Dye-bath+ RO reject | Overall cost |
| Feb-08 | 37919 | 6902 | 36 | 53 | 1945970 | 2126118 | 51 | 308 | 91 |
| Mar-08 | 40695 | 6554 | 36 | 47 | 2065942 | 2054738 | 51 | 314 | 87 |
| Apr-08 | 40199 | 5728 | 37 | 42 | 2285356 | 1954487 | 57 | 341 | 92 |
| May-08 | 43103 | 6368 | 39 | 46 | 2329421 | 2039048 | 54 | 320 | 88 |
| Jun-08 | 38630 | 5974 | 36 | 44 | 2006434 | 1916917 | 52 | 321 | 88 |
| Jul-08 | 37520 | 5771 | 34 | 41 | 1897652 | 2005413 | 51 | 347 | 90 |
| Aug-08 | 37609 | 6292 | 34 | 45 | 1836018 | 2168198 | 49 | 345 | 91 |
| Sep-08 | 40978 | 6691 | 38 | 50 | 2161008 | 2124029 | 53 | 317 | 90 |
| Oct-08 | 37734 | 5696 | 34 | 41 | 2242439 | 1911994 | 59 | 336 | 96 |
| Average | 39376 | 6220 | 36 | 45 | 2085582 | 2033438 | 53 | 328 | 90 |

standards prescribed for process water (pH = 6.0-8.5, chloride = 100 mg/L, sulphate = 100 mg/L) in textile industries (IS 201: 1992), all the 14 members of the PCETP started reusing the permeate to the tune of about 35438 $m^3$/month (i.e. 77.7 % of total effluent quantity) in their processes.

Dye-bath effluent comprises 14% of total effluent quantity generated but contributes 93.8% of pollution load. The combined stream of RO reject (TDS = 18176 mg/L; COD = 429 mg/L) and dye-bath effluent (TDS = 44205 mg/L; COD = 1249 mg/L) is first concentrated in multiple effect evaporators and the concentrate having COD of 8355 mg/L is converted into solids either through solar evaporation or salt recovery plant. Out of total pollution load of 48.60 kg/$m^3$ of (TDS = 94.6%, COD = 4.1%, BOD = 1.2%) untreated (combined) textile effluent, only 6 kg/$m^3$ equal to 99 % of BOD, 83% of COD and 8% of TDS is removed during the entire treatment and the remaining load (42.60 kg/$m^3$) is transferred into solid wastes, possibly having lot of biologically resistant organic pollutants (non-biodegradable nature) with deleterious effects on the environment and demands scientific handling and disposal as against the haphazard approach practiced at present.

An attempt has been made here to analyse the cost of the

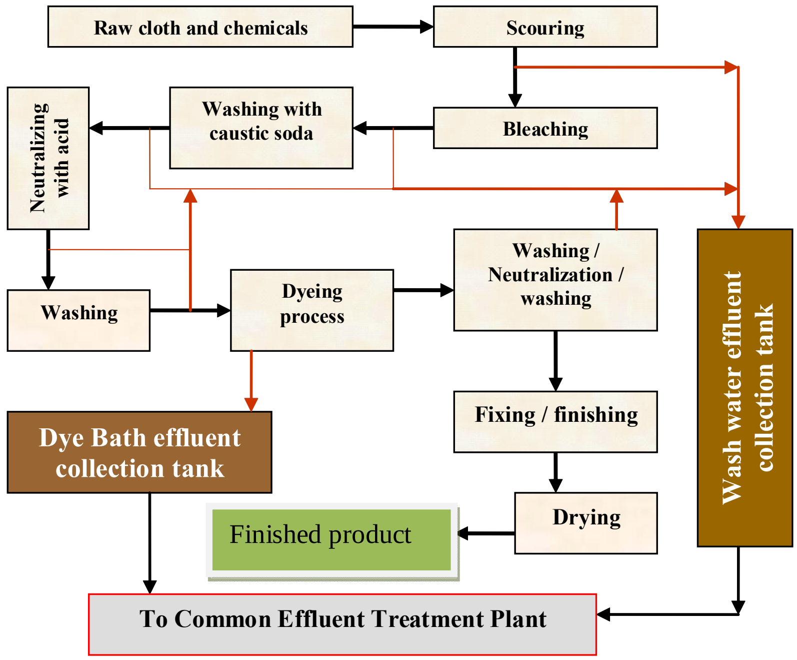


Fig. 1: Basic flow-chart of textile wet processing and wastewater generation in the SIPCOT Industrial Growth Centre, Perundurai (Erode District), Tamilnadu.

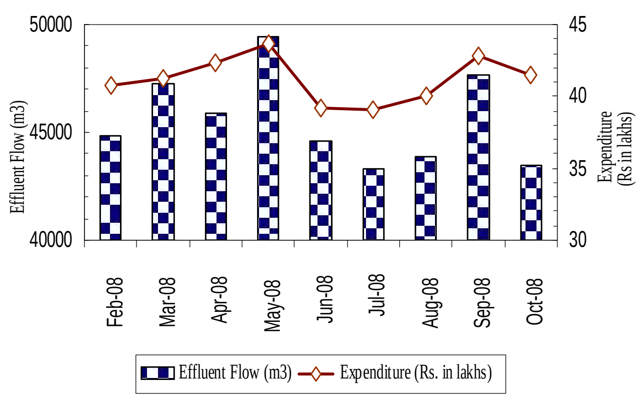


Fig. 2: Monthly effluent inflow and expenditure incurred at M/s. Perundurai CETP, Erode, Tamilnadu.

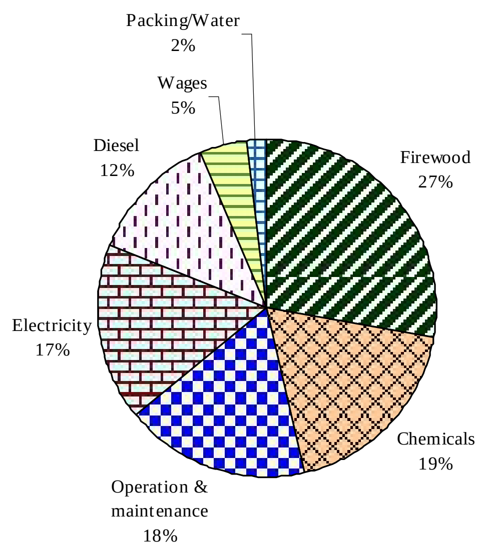


Fig. 3: Percentage of expenditure from various sources at M/s Perundurai CETP, Erode, Tamilnadu.

treatment by taking into account the expenditure incurred for establishment, operation and maintenance of the PCETP which is running on 'no-loss no-gain basis' with expenditure being reimbursed by member units. It was established with a capital investment of Rs. 27.14 crores, indicating an investment of Rs. 53,267/$m^3$ of wash-water effluent treatment and Rs. 1,77,024/$m^3$ of dye-bath + RO reject effluent treatment. The overall investment cost comes to Rs. 67,018/$m^3$ (Table 1). The monthly expenditure varied from Rs. 39.03 lakh to Rs. 43.68 lakh (Fig. 2), with an average of Rs. 41.19 lakh during February-October 2008. Out of the total expenditure incurred, firewood accounts for 27% followed by chemicals (19%), operation & maintenance (18%), electricity (17%) and diesel (12%) (Fig. 3). While the overall cost comes to Rs. 90/$m^3$ of effluent, the expenditure of WTP is Rs. 53/$m^3$ and DTP is Rs. 327/$m^3$. However, the operational expenditure can be further reduced with full capacity utilization as the present utilization is in the range of 36 %

(WTP) to 45 % (DTP) (Table 4). Earlier study reported treatment cost of Rs. 72.30/m$^3$ (Vishnu et al. 2007).

In conclusion, ZLD scheme can be achieved in textile industries with segregation of effluent followed by treatment comprising primary (screening, equalization, coagulation, sedimentation, filtration), secondary (activated sludge process, sedimentation, filtration) and tertiary (reverse osmosis) treatments for 'low-polluted effluent' and with evaporators/concentrators, salt recovery plant or solar evaporation pans for 'high-polluted effluent'. The high quality RO permeate and evaporator condensates can be reused in the process by industries. The capital investment (Rs. 67,018/m$^3$) and recurring expenditure (Rs. 90/m$^3$) may go up with incorporation of solid waste disposal facilities, life of RO membranes and cleaning of scales in tube walls of evaporators among others. On the other hand, the recurring expenditure can be reduced with full capacity utilization and recovery and reuse of salt. Further, sustaining the high operation and maintenance cost of RO plant and evaporators are going to be an uphill task in a system operating on 'no-loss-no-gain' principle.

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