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Research Article

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Treatment of Industrial Waste by Non-Thermal Technique – A Case Study

S Virapan[1*], R Saravanane[2] and V Murugaiyan[2]

[1]*Chief Operating Officer, CTPL Limited, Chennai, India*
[2]*Department of Civil Engineering, Pondicherry Engineering College, Pondicherry, India*

ABSTRACT

Zero liquid discharge (ZLD) of industrial wastewaters has become the order of the day in the war against pollution of and resurrection of contaminated environment. The reverse osmosis (RO) has come to stay as the technology of choice in recovering the water as a useable resource in ZLD practice. But the fact remains that the rejects of the RO process are typically concentrated in their dissolved solids (TDS) and its ingress into the environment endangers the aquatic sources almost irretrievably in terms of sustainable practices and costs of operation. This paper demonstrates the sustainability and viability of nature based net evaporator systems two identified wastewater streams one for textile spent dye bath with salt concentration at about 1.5 times of seawater and the other for RO rejects from a textile common effluent treatment plant (CETP). The study validates a design for these newer systems by a scientific application of the three phase mass transfer in natural falling film wetted surfaces and minimizes electrical energy.

Keywords: Wastewater; Zero liquid discharge; Reverse osmosis; Total dissolved solids

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INTRODUCTION

Almost all of the potable water required in the world today is supplied by surface water and groundwater resources. Higher demands for potable water has led to excessive use and thus lowered the levels of surface water and ground water availability in many areas. Increasing population particularly in coastal regions in different countries around the world has lowered the ground water table due to excessive pumping of ground water causing saline intrusion in countries such as Vietnam, Bangladesh, India and Florida State (US). Erratic weather patterns linked to global climatic changes seems to have affected rainfall volume and pattern causing drought conditions in some parts of the world such as Australia. The extreme shortage of potable water has made countries rethink their potable water supply policies; for example, US and Australia are both considering alternatives of potable water supply. A method exploited in many arid countries is desalination of seawater. Seawater is freely available and exists close to coastal lands where around 39% of the world's population resides; hence desalination of sea water can be an attractive and logical option for alternative potable water supply. Water desalination can be accomplished by different techniques that can be classified into two categories: thermal and membrane processes. The thermal processes can be subdivided into the following processes:(i) Multistage flash evaporation, (ii) Multiple effect distillation and (iii) Vapour compression. The membrane processes are subdivided into: (i) Reverse osmosis (ii) Electrodialysis and (iii) Nanofiltration. Some basic informations on these processes are shown in Figure 1.

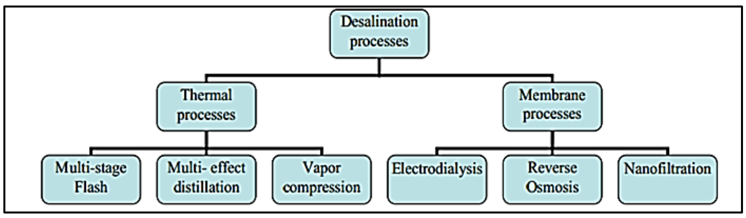

Figure 1: Industrial desalination processes

Limited studies were reported on treatment of waste water [1-6].

The Design of a Thermal Evaporator System for Wastewater

The design of a thermal evaporator system for wastewater RO rejects encompasses many variables as the viscosity, rugosity, temperature, concentration of dissolved salt and gases, heat transfer co-efficient of the materials of heat exchanger surfaces and most crucial is the almost always non-steady state of the equilibrium between these variables. The initial TDS in the feed gets continuously increased due to vaporization and whatever three phase mass transfer kinetics are sought to be applied get into a continuous change. This defies the development of a theoretically verifiable design equation to the system and implies the impossibility of sizing the material flow rates, the heat of reaction and the resulting TDS. If these evaporator systems are to be operated in a batch mode, that at least will permit a design basis but in actual practice, the multiple effect vaporization evaporators which uses the waste heat of the upstream vapour is the preferred choice in the field and hence, the batch operation gets ruled out. Perhaps the fairly comprehensive design approach and material specifications are contained in the design manual compiled by the Middle East Desalination Research Center (MEDRC) at Oman but that again is for a fairly steady state system of seawater RO and clearly is not applicable to the wastewater systems of the present context. It is logical not to pursue this approach because whatever is developed for a given wastewater will not be applicable to the other system due to inherent changes of the parameters listed out ante.

The Experimental Setup at Jaipur

The Jaipur Integrated Textile Park (JITP) at Bagru, Jaipur, India is an integrated facility incorporating the textile dyeing and apparel making in a gated location with its own factories, sewage treatment plant and ZLD effluent treatment plant and is in operation forever three years. The climatic conditions of Jaipur are reported in Annexure III. The ZLD plant starts with an equalization tank for all waste waters be it from dye bath or apparel washing or bleaching. Thereafter, it has a biological extended aeration plant followed by chemical treatment and Oxidation reduction (OR) using freshly formed HOCl from chlorine gas fed through an ejector and then subjected to the OR in a HDPE closed container with catalyst chemicals and nascent air under turbulent conditions for breaking the bond of the dyes and thus getting a colorless treated effluent which is put through filters, cartridges and Reverse Osmosis (RO) membranes to recover close to 80% of reusable water. The RO rejects have a TDS in the range of about 20,000 to 25,000 mg/l and is put through a net evaporator. The RITP facilitates the centralization of textile units which were otherwise scattered in the state capital of Jaipur with scattered environmental pollution mainly from direct discharges into public drains. With the commissioning of JITP, a common effluent treatment plant has been set up with an equalization tank, biological aeration, fine filtration, oxidation-reduction, ultra filtration membrane (UF) and RO. The rejects are put passed through an ad-hoc wind and solar aided phase separation unit consisting of drapes of greenhouse nettings hung out over a sump and the RO rejects sprayed onto the drapes and back to the sump is shown in Figure 2.

Figure 2: Typical view of the facility

Nature of Operation of the JITP Net Evaporator

The JITP is in its intermittent operations as the full-fledged membership and design volume of effluents are still evolving. There are also spells during which there are practically no effluents and the biological treatment plant is sustained during these periods by feeding the carbon and nutrient sources from nearby textile effluents and supplementing with urea for nitrogen and phosphorous. The RO reject is received in a 11.6 m × 5.85 m × 0.8 m sump and sprayed over 22 numbers of 6 m × 6 m greenhouse net drapes hung over it and the drainages contained by kerbs. The spray is by a pipe grid with 30 mm holes at 30 cm c/c on both faces. The temperatures were (°C) ambient of 33-36 in day, 26-28 in night and RO reject 29-32. The humidity was a 45 to 51% low to 85-89% high. The wind speed was 3 m/s mean to 6 m/s maximum. The dew point in °C was 20-22 low to 25 high. There was no rainfall during the study period.

METHODOLOGY OF EVALUATION

The study evaluated the evaporation performance by measuring the elevation of the water surface in the sump below the net evaporator. The industry was in its repairs and renewals mode and thus it became easier to operate the Net Evaporator in batch mode. The sump below the net evaporator was already filled with the RO rejects from the plant operation before the imposed shutdown and this gave the opportunity to evaluate the performance under continuous mode as a corollary to the spent dye bath installation which was a daily but batch mode. The water surface elevation was recorded at the beginning of the six day period as also at the end of the period and the liquid depths in the sump. The RO installations in the region operate rather intermittently to match the varying demands of the market. Thus wastewater as RO rejects is equally intermittent. The upstream biological treatment plant is sustained in such periods by supplementing the wastewater and nutrients from elsewhere as slug additions frequently. Thus, the basic need is mostly to store the wastewaters and bring up the RO as and when needed especially for small plants who cannot afford mechanical thermal evaporators which otherwise become “dead investments” for major part of the time and which cannot be easily started on and off easily. Thus, the assessment of the unit was conducted as a batch operated exercise by filling up the RO rejects in the sump once and continuing the evaporation for a trial period of a week. The temperature of ambient and RO reject in sump were measured as they occurred. The TDS was tested by hot air oven drying and desiccator and analytical balance procedure. The humidity, temperatures, rainfall and wind force was taken out of meteorological records. The liquid depth in the sump was measured carefully.

RESULTS

The climatic conditions during the experiment and the other details are furnished in Table 1 and the operational results are shown in Table 2. TDS Theoretical is based on pro-rated concentration based on remaining water volume with respect to origin water volume in the sump for the starting TDS.

Table 1: Climatic conditions, infrastructure and liquid depth at net evaporator sump

Climatic Conditions	Day temperature 33 to 34°C, Night temperature 26°C, Daytime humidity 93%, Night time humidity-61%, Rainfall-nil, Daytime dewpoint-26°C, Nighttime dewpoint-23°C, Wind speed 3 to 5 m/s
Infrastructure	Sump length, width and depth -11.6 m, 5.85 m and 0.8 m, Number of Nettings-22, Netting height and width-6 m and 6 m, Circulation Pump 100 liters/minute

Table 2: Operational results of JITP net evaporator

No.	Days	Time	Total Interval (hrs)	Sump water depth, (cm)	TDS actual	TDS Theoretical	TDS actual / 1000	TDS Theoretical/1000
1	Day-1	3.00 pm	0	50	9850	9850	9.85	9.85
2		4.30 pm	1.5	49.6	9760	9929	9.76	9.93
3		6.00 pm	3	49.3	10200	9990	10.2	9.99
4		7.30 pm	4.5	49	10030	10051	10.03	10.05
5	Day-2	8.30 am	17.5	45.5	10780	10824	10.78	10.82
6		11.30 am	20.5	44	10950	11193	10.95	11.19
7		4.00 pm	25	41.5	11900	11867	11.9	11.87
8	Day-3	9.30 am	52.5	36.8	12830	13383	12.83	13.38
9		1.00 pm	56	35.2	13200	13991	13.2	13.99
10		4.30 pm	59.5	33.4	13900	14746	13.9	14.75
11		6.30 pm	61.5	33	14100	14924	14.1	14.92
12	Day-4	10.00 am	77	28.7	15900	17160	15.9	17.16
13		1.00 pm	80	27.1	16450	18173	16.45	18.17
14		6.00 pm	85	24.8	18200	19859	18.2	19.86
15	Day-5	10.00 am	101	20.7	22300	23792	22.3	23.79
16		1.30 pm	104.5	18.9	23900	26058	23.9	26.06
17		5.00 pm	108	18.2	24300	27060	24.3	27.06
18		7.30 pm	110.5	17.8	26200	27669	26.2	27.67
19	Day-6	9.30 am	124.5	13.5	35850	36481	35.85	36.48
20		1.30 pm	128.5	12.1	41020	40702	41.02	40.7
21		6.00 pm	133	10.4	43560	47356	43.56	47.36

DISCUSSION

The pattern of actual TDS compares well with the theoretical TDS except that the actual TDS is marginally lesser than the theoretical. This can be conceived as due to salts crystallizing on the netting and getting trapped there. This was also observed as a thin film at times but then it also gets sloughed off at times. A graphical relationship of these is presented in Figure 3.

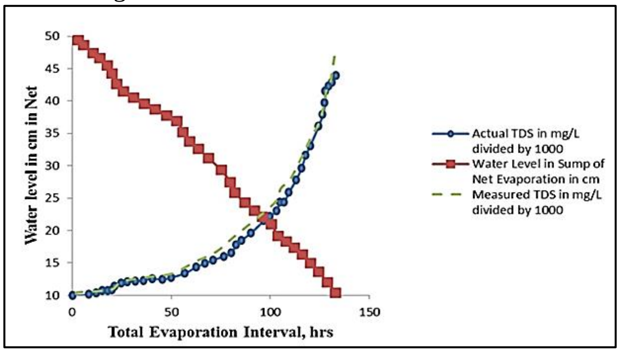

Figure 3: Variation of water level w.r.t. actual and measured TDS

It may be possible that in due course of continuous operation, the salt adhered with the netting may pose a physical problem of undue weight on the net hanging beams and may even cause the netting to break free of the beam supports. This is an importance aspect of in choosing the appropriate netting which are hydrophobic and the structural design of the beams in strong tubular yet strong synthetic material. The classical problem in the present study location is the wind carried blow of finest sands which may tend to settle on the wet net layers. This however can be easily overcome by growing two peripheral layers of the tall and lean variety of Poplar trees.

The novel features of the validated system are found to be as under:

- Eliminates steam generators as induced thermal evaporative operation
- Eliminates complicated mechanical and electrical infrastructure
- Eliminates metal scaling and corrosion problems
- Eliminates dependence on specialist trained high-skill operators
- Eliminates dependence of vendors for equipment repairs and renewals
- Eliminates back up high energy diesel generator sets
- Eliminates need to keep the set-up “warm” even during “no-Reject” periods
- Eliminates O&M costs as close to about INR 200/kilolitre of RO Rejects
- Eliminates random specifications as there is no BIS code of practice
- Completely nature based system with two phase fluid-air mass transfer
- Permits switch-on and switch-off as and when needed
- System uses only an ordinary centrifugal foot mounted pump set
- The nettings are readily available off the shelf green-house nettings
- Efficiency can be maximized using spray nozzles for application on nettings
- Rainy days also bring about evaporation and does not need shut down
- Temporary roofing using tarpaulins over truss work protects from direct rainfall
- O&M cost is a maximum of INR of only about Rs 15/kilolitre of RO Rejects
- System can be fabricated by locally available masons and fabricators
- Permits preventive maintenance by removing and re-erecting the nettings easily
- Above all can be locally designed, built and operated even in remote locations

CONCLUSION

The present quandary of many a liquid waste generating industry like the textiles and tanneries are even now not able to come out of the ZLD crisis. It is a fact that almost all tanneries and textiles are operating at highly curtailed operation of partial production and some have also closed down and gone out of business. On the other hand, the practice of ZLD requires a cost intensive investment and sophisticated equipmental specialties which are just not affordable financially even by the high profile industries. The pity is the benthic end industries which suffer because they are the people tackling the dyeing and bearing the brunt of the pollution control issues of ZLD. It is this core sector that needs to be helped out to sustain the industry per se. Accordingly, the present pilot on-hand study has brought out a simple system which can be erected by these small scale industries on their own with juxtapositions based on season to season demands of the industry.

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