Zero Liquid Discharge ETP – A Case Study (Part II)

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Abstract
The various treatment steps required to get the complete textile ZLD ETP were already discussed. Primary, secondary and tertiary treatments followed by advanced filtration are the important steps of ETP. Understanding the principles of each process, effluent retention time in each step, and the necessity of proper sizing of equipment are the main key factors and performance assuring things in ETP. The filtration system and TDS mass balance along with permeate water quality is discussed with facts and figures.

Key words
Textile, ZLD, ETP, Effluent retention time, primary treatment, secondary treatment, filtration system, TDS mass balance, activated carbon filter, reverse osmosis

1.0 Introduction

In part I of this article series, we have understood the characteristics of the influent and basic effluent treatment scheme. Here, as we are discussing a case study of 600KLD (600000 liters of the effluent/day) effluent from a yarn dyeing plant. The described treatment scheme is as per the case study and plant provided by us. A complete treatment scheme to achieve Zero liquid discharge was shown and the theoretical aspects, the principle of each treatment, and the information on processes were shortly described in part I already. Now, in part II of this article series, We will be discussing the details about each component of ZLD ETP.

2.0 Components of ZLD plant

ZLD ETP plant consists of four major parts i.e. Primary treatment, Secondary treatment, Tertiary treatment, and advanced filtration with salt recovery to get ZLD. Each part is explained below.

2.1 Primary treatment process and it's component

Mainly primary treatment consists of the following component

- Bar screen
- Oil and grease trapper
- Collection tank
- Equalization tank or homogenization tank
- Anaerobic digester (may be recommended for COD > 2500 ppm
- Flash mixer with mixing channel and dosing system
- Primary clarifier

The Working and purpose of these components are explained below;

- ❖ Here, we are treating the effluent coming out from the yarn dyeing process. The yarn dyeing process takes place at higher temperatures around 90-95°C.
- ❖ Effluent from process house contains high temperature and variable in pH Value.
- ❖ Two different raw effluent storage tanks are provided called collection and Equalization tanks.
- ❖ Before the collection tank, one screening system is provided called Bar Screen, Oil & Grease Trap.
- ❖ Bar screen - to screen flubs, dust, other heavy metals from the process house.
- ❖ Oil & Grease Trap – generally oil & Grease having lower density nature, it will float over effluent. We can easily screen oil & Grease with Over Flow tee pipes.
- ❖ The necessity of oil & Grease removal – without removal of Oil & Grease, it forms a layer over effluent and prevent contact between atmospheric air and water. It will lead to reducing the effluent treatment process efficiency.
- ❖ Selection of Collection & Equalization tank capacity:
  - ➢ Generally, the exhaust yarn dyeing process takes a maximum 6-8 hours per batch.

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- Thus, on of average 3 batches per day are dyed. Here, in this case, due to high temperature, the collection and equalization tanks are provided with the capacity of 12 Hours retention time.
- The coarse bubble diffusion mechanism is provided in the collection tank for temperature reduction as well as effluent homogenization.

❖ Raw Effluent transfer pump and Selection

- Here, in this case, the effluent transfer rate is calculated based on 20 Hours of operation and head calculated from vertical sump depth of collection tank and anaerobic tank height from ground level.
- Equalization blower and diffuser selection are based on tank volume, Oxygen transfer and type of bubbling. We have provided a snap cap diffuser for the higher oxygen discharge rate.

❖ Acid Dosing System

- Before the anaerobic inlet, we need to correct the pH to the range of 7, because bacteria development achieves only in a neutral base.
- Hydro chloric acid dosing is given for pH correction.

❖ Anaerobic Digester tank

- This treatment is in the absence of oxygen and is used where COD values are very high i.e. > 2500
- we have given a retention time of 48 hours for the anaerobic process to reduce COD, BOD and Colour removal up to the limit.
- The feeding of cow dung, enzymes will increase the population of bacteria in an anaerobic tank. It will lead to getting better efficiency in COD, BOD reduction.

❖ Chemical treatment system

- We have provided one mixing channel system along with the flash mixer setup for better agitation.
- Primary treating chemicals are lime, ferrous for colour removal and precipitation, poly for the sludge settling process.
- alternately we can use CRP, Alum for colour removal and precipitation, poly for sludge settling. Consumption of CRP and Alum will reduce the sludge generation in the ETP system.
- Low HP installed Chemical mixing agitators with a speed ratio of 25:1 provided based on chemical consumptions for chemical mixing.

❖ Primary Clarifier

- Floculators having a speed ratio of 40:1 are provided for better agitation in the flash mixer.
- Flash mixer is having a capacity of 20 Minutes retention time of average daily flow.
- A primary clarifier system is provided for the settling of suspended solids and turbidity, it is designed based on flow velocity and surface area.
- Primary clarifier is equipped with MS Bridge, gear box with a speed ratio of 70:1, worm reduction drive, center shaft, A frame, Scrubber arm, chequer plates and accessories.
- Sludge from the primary clarifier will discharge out to sludge thickener for the sludge handling process.
- Sludge handling will do with the help of a decanter, Screw press, or filter press to convert sludge into dry sludge.

To achieve the better efficiency of pollution removal from the effluent, the hydraulic retention time (HRT) of every process is important and they are as mentioned in below Table 1.

Table 1: Component wise HRT (hours), parameter control and purpose

Sr. No.	Component	HRT	Purpose of treatment	Critical parameters
1	Bar screen chamber	Online	To screen flubs, dust, other heavy metals	
2	Oil grease trapper	Online	Floating oil and grease screening	
3	Collection tank	12 Hrs	To collect the effluent from the process	Ensure no bigger suspended solids and fibrous material in it
4	Equalization tank	12 Hrs	Proper mixing and homogenization of the effluent	Temperature < 38°C with the help of aeration, pH 7-8 by HCL dosing
5	Anaerobic digester	48 Hrs	To reduce colour, COD and BOD	Temperature - < 38 pH - 7.5 to 8
6	Flash mixer	20 minutes	To coagulate and flocculate the suspended solids/pollutants	Based on jar test, optimized Dosing of PAC, decolourant and polyelectrolyte
7	Primary clarifier	6 Hrs	Settling of suspended solids as sludge	Flocculator speed ratio

2.2 Secondary treatment process and its component

This treatment is mainly biological and carried out in presence of oxygen.

2.1.1 Biological Aeration tank

- Biological aeration is also called an activated sludge process and is the Heart of the ETP Process, where the COD and BOD reduction takes place up to 90%.
- Here the aeration tank is designed with a retention time of 36 Hours.
- Aeration blowers with fine bubble diffuser provided for better oxygen transfer efficiency.
- Generally, the Standard oxygen transfer efficiency rate is only 23% from atmosphere air and only 18% of them were utilized for MLSS development. The remaining 88% is considered as a loss.
- Identifying of good aeration process is based on MLSS level and DO level.
  - Taking a jar of 1000 ml effluent from the aeration tank contains 300-400 mg of MLSS will be considered as good aeration efficiency.
  - Maintaining DO in between 1-2 ppm.
  - Maintaining the temperature between 25-38 Deg Celsius.

2.1.2 Secondary Clarifier

- The secondary clarifier is mainly designed to re-circulate aged bacteria to the aeration tank.
- The design of the mechanism is similar to the primary clarifier mechanism.
- The flow rate of recirculation bacteria is kept at half of the average daily flow rate.

2.1.3 Add ons

- Change Over for Aeration blower
  - It is used to change each blower for an operation of 10 Hours per day cycle.
  - Auto ON/OFF Control.
- Online DO Meter
  - Dissolved Oxygen meter. (DO) : It is used to measure the level of DO in the aeration tank to increase or decrease the oxygen rate with the help of VFD Control Drives.
  - Case-1: DO level < 1: Need to Increase oxygen transfer efficiency by increasing Hz in VFD control.
  - Case-2: DO level >2 : Need to reduce oxygen transfer efficiency by decreasing Hz in VFD Control.
  - VFD controlling will be done automatically with the DO meter analyzer.
- pH, TDS meter for regular parameter analysis.
- Electromagnetic flowmeter : To measure average flow per hour.

The hydraulic retention time (HRT) and critical parameter to be controlled in the biological tank (secondary treatment) are important and they are as mentioned in the below table 2

Table 2:- HRT and critical parameter to be controlled in the biological tank

Sr. No.	Component of treatment	HRT in hours	Purpose of treatment	Critical parameters to be controlled
1	Aeration tank	36 Hours	To reduce Cod and BOD with the help of bacteria	DO level 1-2 pH- 6.5 – 7.5 Temperature < 35°C MLSS - 3000 to 4000 ppm
2	Secondary clarifiers	6 Hours	To clarify the water	
3	Holding tank	24 hours	To hold treated water	-

2.3 Tertiary treatment

- Tertiary treatment is like river water treatment; here we can control individual parameters like hardness, colour removal, Silica, Suspended solids and turbidity control.
- Chemical mixing is based on the type of treatment to be obtained.
- Caustic and Soda ash will reduce hardness.
- Alternately we can use Lime and Soda Ash for hardness control. It is named lime soda softening.
- Lime/CRP, Ferrous sulphate/ALUM/PAC, and Poly for Colour removal and control of suspended solids and turbidity
- A tertiary clarifier is used to clarify the water which is sent to a duel media filter and activated carbon filter

2.3.1 Dual media filter

A sand-anthracite filter or dual media filter/multi-media filter is primarily used for the removal of turbidity and suspended solids as low as 10-20 microns. Dual media filters provide very efficient particle removal under the conditions of a high filtration rate. Inside a sand-anthracite filter is a layered bed of filter media [1]. Sand is used to remove the suspended particles and anthracite is used to removing the odor and color from the effluent. Gravels and pebbles are provided for supporting both the media. To maintain the filtration efficiency, periodically an automatic back-washing technique is used.

2.3.2 Activated carbon filter

Here, the principle of adsorption is used. The filter medium adsorbs or reacts with pollutants in the effluent and filtered water is drained. The medium used is the natural material derived from coconut shell, lignite etc. the volatile organic matters, chlorine and disinfectants are removed from the effluent with the help of this filter. The removal of such impurities is important before the further filtration process like Reverse osmosis. The COD reduction upto the stage of an activated carbon filter is tabulated in below table 3.

Table 3 : COD& BOD reduction stage wise

Treatment	Reduction	BOD (mg/l)	Final BOD
Combined Effluent	---	800.00	800.00
Anaerobic Digester	45%	360.00	440.00
Primary Clarifier	20%	88.00	352.00
Biological Aeration	90%	316.80	35.20
Tertiary	20%	7.04	28.16
Dual Media Filter	5%	1.40	26.75
Activated Carbon Filter	5%	1.33	**25.00**

Treatment	Reduction	COD (mg/l)	Final COD
Combined Effluent	**---**	3000.00	3000.00
Anaerobic Digester	**45%**	1350.00	1650.00
Primary Clarifier	20%	330.00	1320.00
Biological Aeration	90%	1188.00	132.00
Tertiary	20%	26.40	105.60
Dual Media Filter	5%	5.28	100.32
Activated Carbon Filter	5%	5.01	**95.31**

2.4 Membrane filtration process:

After the secondary (biological) and tertiary (fine-tuning) treatment the effluent is subjected to the filtration system. The filtration system used here is micro-filtration, Reverse Osmosis (RO), and nano-filtration in series. Here, RO filtration is the heart of the system and to sustain its efficiency the pre-treatment of the effluent is a must and is done through the micro-filtration system. RO filtration separates the TDS or salts (both monovalent and divalent salts) from the effluent. Further to separate mono-valent salt (sodium chloride, sodium acetate etc) from divalent salt (Glauber salt) the technique of nano-filtration is used. Thus we can recover sodium chloride (in the form of brine solution) and Glauber salt solution (reject of nano-filtration) separately. The requirement, functions of each filtration system is described below.

2.4.1 Micro-filtration process:

- Used as a pretreatment for the reverse osmosis process.
- Operating pressure : 0.1-2.5 bar.
- Membrane pore size : 0.1-0.22 Micron
- Controlling parameters:Suspended solids and Turbidity < 1.
- Type of process:
  - Flushing :30 Sec,
  - Filtration :28 Min,
  - Backwash/Air Scouring : 60 Sec,
  - Valve actuation : 30 Sec.
- Input parameters required to be within the below limits
  - Total Suspended solids : < 10 ppm
  - Turbidity : < 10 NTU
  - Oil & Grease : < 2 ppm.
- Cleaning process:
  - Clean in Place – general : once in 15 days.
  - Chemical backwash : once in a day.
  - Cleaning Chemicals : Caustic 25%, Hypo 12%, Citric 2% and 98% Concentration.
- Microfiltration usually serves as a pre-treatment for other separation processes such as ultra-filtration, and a post-treatment for granular media filtration. The typical particle size used for microfiltration ranges from about 0.1 to 10 µm. In terms of approximate molecular weight, these membranes can separate macromolecules of molecular weights generally less than 100,000 g/mol. The filters used in the microfiltration process are specially designed to prevent particles such as sediment, algae, protozoa or large bacteria from passing through a specially designed filter. More microscopic, atomic or ionic materials such as water (H_2O), monovalent species such as Sodium (Na^+) or Chloride (Cl^-) ions, dissolved or natural organic matter, and small colloids and viruses will still be able to pass through the filter.
- The suspended liquid is passed through at a relatively high velocity of around 1–3 m/s and at low to moderate pressures (around 100-400 kPa) parallel or tangential to the semi-permeable membrane in a sheet or tubular form. A pump is commonly fitted onto the processing equipment to allow the liquid to pass through the membrane filter. There are also two pump configurations, either pressure-driven or vacuum. A differential or regular pressure gauge is commonly attached to measure the pressure drop between the outlet and inlet streams. The schematic diagram of the microfiltration process is as shown in the figure1 below.

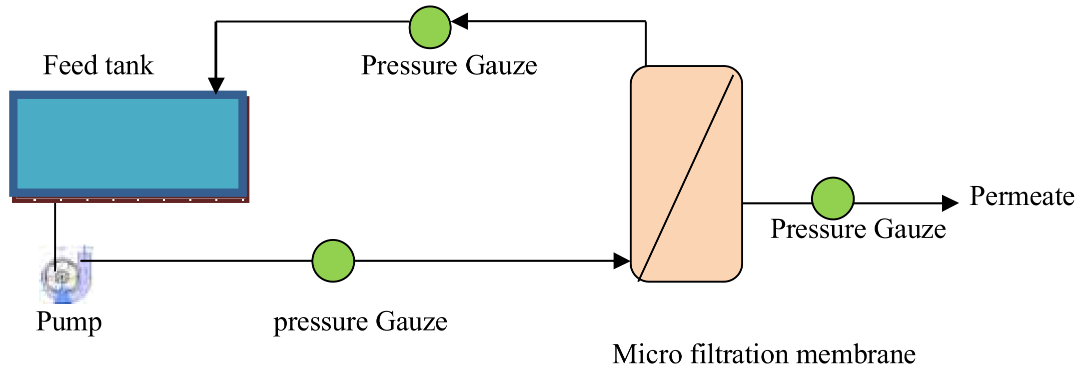

Figure 1 : Microfiltration process line diagram

2.4.2 Reverse osmosis process(RO)

24.2.1 RO process information

- Reverse Osmosis is the finest level of filtration available The RO membrane act as a barrier to all dissolved salts [2]. Reverse osmosis is a process that industry uses to clean water, whether for industrial process applications or to convert brackish water, to clean up wastewater or to recover salts from industrial processes.
- Reverse osmosis will not remove all contaminants from water as dissolved gases such as dissolved oxygen and carbon dioxide are not being removed. But reverse osmosis can be very effective at removing other products such as trihalomethanes (THM's), some pesticides, solvents and other volatile organic compounds (VOC's).
- In the reverse osmosis process cellophane-like membranes separate purified water from contaminated water. RO is when pressure is applied to the concentrated side of the membrane forcing purified water into the dilute side, the rejected impurities from the concentrated side being washed away in the reject water.
- RO can also act as an ultra-filter removing particles such as some micro-organisms that may be too large to pass through the pores of the membrane.
- The performance of a system depends on factors such as membrane type, flow control, feed water quality, temperature, and pressure.
- Also, only part of the water entering the unit is useable; this is called the % recovery. For example, the amount of treated water produced can decrease by about 1-2% for every 1 degree Celsius below the optimum temperature.
- Systems must be well maintained to ensure good performance with any fouling requiring cleaning maximizing the output of water.
- Biocides may be needed and the choice of biocide would depend on the membrane type, alternatively, other filters may be required to remove chlorine from water to protect the life of the membranes.
- To this end a good treatment regime is needed and knowledge of the specific foulants so the optimum cleaning and maintenance chemicals can be chosen.

2.4.2.2 Reverse osmosis plant: Designed for 600 KL/day.

Here, 4 stages RO is designed to get maximum water recovery i.e. 91.5%. The inlet and outlet parameters in the RO plant in totality are given below

Table 4 :Inlet and outlet parameters in RO plant

Parameter	Treated water to RO	RO product water (average)	Unit
PH	6.5 – 7.5	6.0 – 7.0	-
Total suspended solids	< 1	Nil	Ppm
Total dissolved solids	6000	< 350	Ppm
Total Iron as Fe	< 0.1	Nil	Ppm
Calcium as $CaCO_3$	75	< 10	Ppm
Total hardness as $CaCO_3$	100	< 15	Ppm
Chlorides as Cl	4000	< 200	Ppm
Sulphates	1000	< 50	ppm
Total silica as SiO_2	< 20	< 5	Ppm
Oil & Grease	Nil	Nil	Ppm
Organics	Nil	Nil	Ppm
Colour	Colourless	Nil	Ppm
Turbidity	< 1	Nil	Ppm
Heavy metals	Nil	Nil	Ppm

Table 5 : The stage-wise RO feed rate, TDS, % recovery and other parameters are given in the below table.

Particulars	unit	RO stage				Nano- filtration
		I	II	III	IV	
Designed capacity	KL/Day	600				75
Operating hours	Hours	20	17-18	13-14	17-18	20-21
Feed flow rate	KL/Day	30	12	8	4	3
Permeate flow rate	KL/Hr	19.5	6	2.8	1	1.5
Recovery	%	65	50	35	25	50
Reject flow rate	KL/Hr	10.5	6	5.2	3	1.5
Feed pressure required	PSI	450	600	800	900	600
Feed TDS	Ppm	6000	17000	33600	51300	68000
Permeate TDS	Ppm	< 300	< 400	< 400	< 400	60000
Reject TDS	ppm	17000	33600	51300	68000	73000

Thus, the overall recovery of good water (TDS < 400 ppm) is 91.5%

2.4.3 Nano-filtration (NF) plant

RO and NF are both membrane technologies that use a semi-permeable medium to remove certain ions and particles from a liquid stream, they can be distinguished based on the size of particulates that each can remove. Comparatively, RO and NF are capable of removing finer contaminants than micro-filtration and ultra filtration [3]. Nano-filtration membrane has pore sizes from 1-10 nano-meters, smaller than that used in microfiltration and ultra-filtration, but just larger than that in reverse osmosis. Membranes used are predominantly created from polymer thin films. The original uses for nano-filtration were water treatment and in particular water softening

The reject effluent quantity of 68-70 KL from 4^{th} stage RO, which is having a TDS value of 51000-52000 ppm is fed to a nano-filtration system to separate and recover sodium chloride, sodium acetate and any other mono-valent salt brine solution from Glauber salt solution. The plant running parameters are shown in the above table along with RO parameters. From the 70 KL RO reject is fed to using the nano-filtration and the permeate 35 KL with 60 grams/lit salt in it called as brine solution is gain used in the dyeing department with required top of the fresh salt.

In next part III, we will be discussing the multiple effect evaporation, mass balance, salt recovery, Sludge generation and disposal part so that complete ZLD is achieved

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