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A Study on Zero Liquid Discharge Plant for Dyeing Industry

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Abstract: ***Dyeing industry is one of the most and second largest polluting industries in India. Generally dyeing process produces mixed waste water in large quantities up to 600m^3 per kg of fabric characterized by high organic load up to 1000mg/l COD, 7000 mg/l TDS, 2400 mg/l alkalinity. The release of coloured compounds and salt into the environment is undesirable not only because their colour, which may affect the photosynthesis of aquatic plants, but also because many dyes and their breakdown products may be toxic and/or mutagenic to life. The Zero liquid Discharge (ZLD) system removes dissolved solids from the wastewater and returns distilled water to the process (source). Reverse osmosis (membrane filtration) may be used to concentrate a portion of the waste stream and return the clean permeate to the process. This process may include pre-treatment, membrane filtration, evaporation, crystallization and solids recovery. Each module can be executed in parallel to expedite the design and implementation process. In this paper the effluent parameters should be analyzed and reduce the colour using oxidation reduction reactor. The treated water is recovered from the Reverse Osmosis Plant (RO) process during tertiary treatment phase and Salt is then recovered by Multiple Effect Evaporation (MEE) with Crystallization during reject management phase. In this process TDS removal efficiency of >90% resulted in permeate having average TDS of <500 mg/l and total hardness of>20 mg/l. This coupled with the high water recovery of 80 to 90% made the RO process and reject management both technically and economically viable for recovery and reuse of the waste water. 80- 85% of the water can be recovered and re-used back in the process.***

Keywords: Aeration, Oxidation Reduction, Reverse Osmosis, Hrsc Clarifier, Multiple Effect Evaporation, Crystallization

1. Introduction

In order to minimize environmental pollution due to the small and medium-scale industries, cleaner production technologies and formation of waste minimization circles are being encouraged in India. Besides, collective treatment at a centralized facility, known as the CETP is considered as a viable treatment solution, to overcome the constraints associated with effluent treatment in small to medium enterprises. Till 1990, only one CETP at Jeedimetla, Hyderabad was in operation. In 1991, the Ministry of Environment & Forests (MoEF), Government of India initiated an innovative financial support scheme for CETPs to ensure the growth of the small and medium entrepreneurs (SMEs) in an environmentally compatible manner.

While this scheme is designed for an initial period of 10 years, considering the need, extended further. Besides, the MoEF, the Ministry of Commerce and other funding schemes supported in establishment of new and augmentation of the existing CETPs. The concept of CETP was adopted as a way to achieve end-of-the-pipe treatment of combined wastewater to avail the benefit of scale of operation. In addition, the CETP also facilitates in reduction of number of discharge points in an industrial estate for better enforcement and also to make available the skilled man power for proper treatment of effluent.

Tirupur is a main hub of knit wear and textile industries which contributes 90% of the knit wear exports from India. Noyyal River is one of the historical rivers which are now completely dead because of the uncontrolled release of textile dye industry and bleaching industry waste waters to the river. At one stage Tamil Nadu Pollution Control Board took action against the industries those who are all releasing the untreated effluents to the river. Further Tamil Nadu Pollution Control Board strictly announced about Zero Liquid Discharge (ZLD). Based on the rules and regulations of ZLD, the industries are not allowed to release a single drop of effluent to the water bodies.

ZLD systems employ the most advanced wastewater treatment technologies to purify and recycle virtually all of the wastewater produced. Also Zero liquid discharge technologies help plants meet discharge and water reuse. In order to achieve Zero Liquid Discharge, we have to recover the water and salt separately from the effluent and reuse it in the dyeing process. This is a very complicated, tedious and expensive process, in terms of investment and running costs. As a simple explanation, the effluent is treated in an Effluent Treatment Plant (ETP) comprising Primary, Secondary and Tertiary and rejects management Treatment steps. The treated water is recovered from the Reverse Osmosis Plant (RO) process during tertiary treatment phase and Salt is then recovered by using Multiple Effect Evaporation (MEE) with Crystallization. 80- 85% of the water can be recovered and re-used back in the process. The cost of this recovered water recycled into the process is always much higher than the cost of input water used from other sources. The ZLD technology converts a high volume of liquid waste to distilled water for reuse, and solid salts that can be land filled or used as raw material for the chemical industry. It is applicable for industrial plant effluent treatment, wastewater reclamation and industrial recycling applications.

Scope of the project

- No impact on surrounding soil salinity, groundwater pollution or ecology of river bodies.
- Conservation of water resource through recovery and re-use of treated effluent,
- Recover and re-use of salt and water used in the dyeing process.

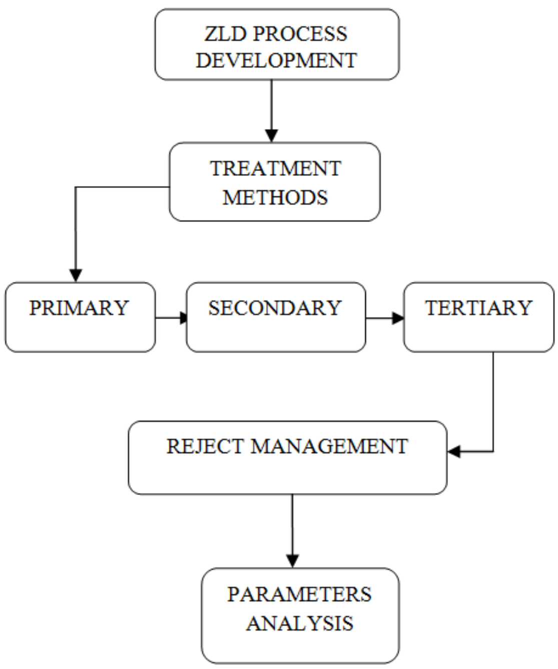
Objective of the Study

- ZLD - stands for Zero Liquid Discharge – meaning zero discharge of Industries.
- To increase the efficiency of colour removing using oxidation reduction technique in the waste water.
- To recover valuable ingredients from effluent waste water for reuse onsite.
- Reduce the scale formation for brine preparation

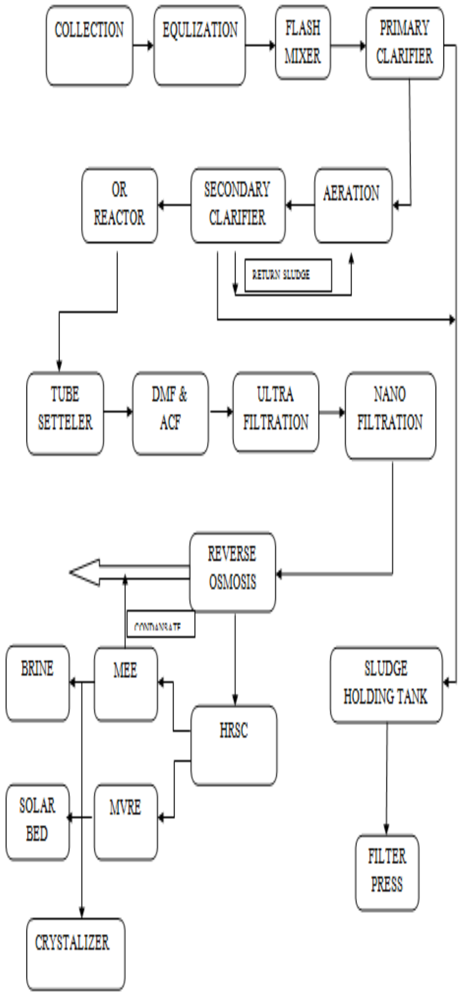
2. Methodology

Zero Liquid Discharge is a wastewater treatment process developed to completely eliminate all liquid discharge from a system. The goal of a zero liquid discharge system is reduce the volume of wastewater that requires further treatment economically process wastewater and produce a clean stream suitable for reuse. Industries may being to explore ZLD because of ever tightening wastewater disposal regulations, industry mandated green initiatives ,public precipitation of industrial impact on the environment and concern the quantity and quality of water.

Methodology Flow Chart



ZLD Process Development Flow Chart



Treatment Methods

- PRIMARY TREATMENT
- SECONDARY TREATMENT
- TERTIARY TREATMENT

Primary Treatment

In this process used to Removal of floating and settleable materials such as suspended solids and organic matter.

1. Screen chamber: Remove relatively large solids to avoid abrasion of mechanical equipments and clogging of hydraulic system.
2. Collection tank: The collection tank collects the effluent water from the screening chamber, stores and then pumps it to the equalization tank.
3. Equalization tank: The effluents do not have similar concentrations at all the time; the pH will vary time to time. Effluents are stored from 8 to 12 hours in the equalization tank resulting in a homogenous mixing of effluents and helping in neutralization. It eliminates shock loading on the subsequent treatment system. Continuous mixing also eliminates settling of solids within the equalization tank

Table: The Characteristics of Effluent for Primary Treatment

S. NO	Parameters	Units	Primary Treatment	
			Raw Effluent	Homogenization
1	pH	_	9.3	8.2
2	TSS	mg/l	113	110
3	TDS	mg/l	7400	7600
4	Total Hardness	mg/l	260	260
5	Total Alkalinity	mg/l	2400	2400
6	COD	mg/l	1097	900
7	Turbidity	NTU	120	110
8	BOD	mg/l	290	256

Secondary Treatment

Biological and chemical processes are involved in this level. To remove, or reduce the concentration of organic and inorganic compounds. Biological treatment process can take many forms but all are based around microorganisms, mainly bacteria.

1. Flash mixer: Coagulants were added to the effluents:
Lime: (800-1000 ppm) to correct the pH up to 8-9
Alum: (200-300 ppm) to remove colour
Poly electrolyte: (0.2 ppm) to settle the suspended matters & reduce SS, TSS.

The addition of the above chemicals by efficient rapid mixing facilitates homogeneous combination of flocculates to produce microflocs.

2. Clarriflocculator: In the clarriflocculator the water is circulated continuously by the stirrer. Overflowed water is taken out to the aeration tank. The solid particles are settled down, and collected separately and dried; this reduces SS, TSS. Flocculation provides slow mixing that leads to the formation of macro flocs, which then settles out in the clarifier zone. The settled solids i.e. primary sludge is pumped into sludge drying beds.

3. Aeration tank: The water is passed like a thin film over the different arrangements like staircase shape. Dosing of Urea and DAP is done. Water gets direct contact with the air to dissolve the oxygen into water. BOD & COD values of water is reduced up to 90%. Activated sludge process used to convert non-settleable solids to settleable solids. Activated sludge refers to a mass of micro-organisms cultivated in the treatment process to break down organic matter into carbon dioxide, water, and other inorganic compounds. The activated sludge process has three basic components:

- An aeration tank in which oxygen supplied to effluent.
- Clarifier in where sludge is separated to supernatant.
- Sludge recirculation mechanism

4. Secondary Clarifier: The clarifier collects the biological sludge. The overflowed water is called as treated effluent and disposed out. After completion of the bio-oxidation, the contents of the aeration tank flow by gravity to the secondary clarifier for separation of the carry-over biomass from the treated effluent. The clear supernatant water overflows to the holding tank. The clarifier is designed to crate right conditions of quietness to allow the settling of the sludge flocs. The sludge is recycled to aeration tank to maintain balance between the micro-organisms and incoming food.

5. Oxidation reduction reactor: Oxidation-reduction process use to remove colour from the supernatant. Most of the organics are removed in biological treatment. The biologically treated effluent will be drawn by pump sets into colour removal systems of HDPE pipe line. As soon as the reactor gets filled, the recirculation pump sets are started to re circulate the reactor contents and for homogenizing the colour removal system. Intense mixing of chlorine gas and the effluent drawn by booster pumps occurs and the oxidation reaction takes place at the throat of the venture of the ejector. During the addition of chlorine one or more electrons transfer from chlorine to the supernatant, causing its destruction. It destroys pollutants such as bacteria, viruses and some pesticide active ingredients. The end point of the reaction is detected by matching the measured readings with the present valves of ORP.

Table: The Characteristics of Effluent for secondary Treatment

S. NO	*Parameters*	*Units*	*Secondary Treatment*		
			BIO-OXIDATION	*SUPERNATANT*	*OXIDATION REDUCTION*
1	pH	_	7.7	7.6	7.6
2	TSS	mg/l	90	28	15
3	TDS	mg/l	7480	7420	7360
4	Total Hardness	mg/l	280	280	220
5	Total Alkalinity	mg/l	2060	2040	1540
6	COD	mg/l	440	320	202
7	Turbidity	NTU	1	15	12
8	BOD	mg/l	125	91	58
9	DO	Mg/l	2	2	2

Tertiary Treatment

Final cleaning process that improves waste water quality before it is reused, recycled or discharged to the environment.
Mechanism: Removes remaining inorganic compounds, and substances, such as the nitrogen and phosphorus. Bacteria, viruses and parasites, which are harmful to public health, are also removed at this stage.

1. Flocculation& tube settlers: flocculation process is to remove colloidal and settlable particles by using flocculants. It reduces total hardness of an effluent. The purpose of flocculation is to accelerate the pace at which the particles collide, causing the agglomeration of

electrolytic ally destabilized particles into settable and filterable sizes

2. Media filter: to remove suspended solids and to reduce turbidity present in an effluent.
3. Ultra filtration: to remove colloidal silica and to reduce turbidity. Uf membranes will remove high molecular-weight substances, colloidal materials, and organic and inorganic polymeric molecules.
4. Nanofiltration: Nanofiltration separates sodium chloride particles from effluent. The Nanofiltration is capable of removing hardness elements such as calcium or magnesium together with bacteria, viruses, and colour. Nanofiltration filter has pore size around 0.001 microns. Nanofiltration operated on lower pressure than reverse osmosis and as such treatment cost is lower than reverse osmosis treatment. Nanofiltration is preferred when permeate with TDS but without colour, COD and hardness is acceptable. Feed water to Nanofiltration should be of similar qualities as in case of reverse osmosis.
5. Activated carbon filter: To remove turbidity and fine particles present in an effluent. It is pre treatment of reverse osmosis process. Activated carbon's adsorptive properties are used to remove organics. Activated carbon can remove and destroy residual disinfectants (chlorine and chloramines) through a catalytic reduction reaction.
6. Reverse osmosis is a pressure driven cross flow membranes process, which is employed normally for removal of dissolved solids from the water. Reverse osmosis membranes being very finer in pore size, they also reject all the impurities like organic matter, colloidal matter, heavy metals, etc.RO is continuous process in which contaminated feed enters the membrane at pressure and two streams – one of good quality permeate and other being concentrated stream called reject are generated. Reverse osmosis filters have a pore size around 0.0001 microns. After water passes through a reverse osmosis filter, it is essentially pure water. In addition to removing all organic molecules and viruses, reverse osmosis also removes most minerals that are present in the water. Reverse osmosis removes monovalent ions, which means that desalinates water.

Table: The Characteristics of Effluent for secondary Treatment

S.NO	Parameters	Units	Tertiary Treatment				
			FLOCCULATION	DMF	UF	ACF	RO
1	pH	_	11.2	6.5	6.5	6.5	6.9
2	TSS	mg/l	15	8	5	1	Nil
3	TDS	mg/l	7360	7300	7260	7200	240
4	Total Hardness	mg/l	160	150	140	140	1
5	Total Alkalinity	mg/l	1360	860	820	740	74
6	COD	mg/l	110	90	70	40	24
7	Turbidity	NTU	10	4	Nil	Nil	Nil
8	BOD	mg/l	32	25	20	16	3

Reject Management System

Processes capable of reducing the concentrate, either directly from the conventional RO or the volume-reducing processes to zero liquid discharge. Its sufficiently dry salt or other solid were evaluated as a means for final concentrate disposal. Specifically, the analysis focused on mechanical evaporation, solar evaporation, multi effect evaporation and crystallization.

1. Softening process (HRSC clarifier): to reduce hardness of low brine and to neutralize ph.

Process:

The low brine from low brine tank is pumped to softening process. the softening process is done by the addition of caustic soda. the caustic soda is added in hrscc tank. hrscc are designed to treat different type of water for a verity of application for solid settling and separation. for optimum operation effective solid separation hrscc employs use of flash mixer, and stilling chamber prior to clarifier. Typically chemical treatment using alum, zinc and polyelectrolyte are used to aid coagulation &flocculation and enhance removal of solids. high rate solids contact clarifier can both perform the chemical conditioning function and sedimentation function in one tank. High rate Solids contact clarifier overcomes some of the problems exhibited in the sludge blanket clarifier. It basically controls the chemical reactions taking place, flocculation, and the sedimentation phenomena more positively than in a sludge blanket clarifier and is not as readily affected by changes and flows or by process. The high rate Solids-Contact Reactor Clarifier operates with the low brine being brought into immediate contact with a large circulating volume of relatively dense previously formed flocculate and precipitate. The mixture of Low brine and re circulated slurry is sent upward into the reaction cone with 75-90% being returned to recirculation with the incoming low brine. The remaining 10-25 % passes under the cone and into the clarification zone. Once in the clarification zone, the solids settle to the tank floor with the clarified liquid moving into the MVRE and MEE.

Table: The Characteristics of Effluent for HRSC clarifier

Parameters	Units	Feed	Permeate
pH	-	7.8	6.5
TDS	mg/l	39400	65000
Total Hardness	mg/l	1100	250
Total Alkalinity	mg/l	1360	120

2. Multi Effect Evaporators: Multi effect evaporators is a process of mechanical in which essentially a heat exchanger to boiled a water to give a vapour. Water is boiled in sequence of vessels each held at a lower pressure than the last. The use of steam for further in industrial Process. Multi effect evaporators in feed are generally transferred from the one effect to another. Multi effects evaporators well establish technology for

concentration up to 40% solid which can result in substantial solid waste volume reduction.

3. Mechanical vapour recompression evaporator: Mechanical Vaporised Recompressed Compression (MVRE) is the evaporation method by which a compressor is used to compress and thus increase the pressure of the steam produced. Since the pressure increase of the steam also generates an increase in the steam temperature, the same steam can serve as the heating medium for the liquid being concentrated from which the vapour was generated to begin with. This makes this evaporation method very energy efficient. When this compression is performed by a mechanically driven compressor, the evaporation process is referred to as MVRE (**Mechanical Vapour Recompression Evaporator**). The main components of evaporation system are vacuum vessel, evaporative heat transfer surface installed inside the vessel and vapour recompression fan. The polymeric heat transferred surface has element square, double side structure. The solution to be concentrated is circulated to the top of the element and distributed on both of the outer surface of element. The feed concentration is around 6%. As the solution treated with saturation stage, it begins to evaporate when heated. The vapour generated flow into a fan, which adds energy by increasing the pressure and temperature of the vessel. After the fan, the compressed vapour is introduced inside the heat transfer element. Here the vapour condenses latent heat is released and transferred to through the polymeric surface causing the solution on the exterior surface to release more water vapour. The condensate vapour, the product of the process is then discharged from inside the element as clean condensate. The concentrated liquid is discharged from the bottom of the vessel to brine storage tank.
4. Sludge thickener: thickening is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction. To illustrate, if waste activated sludge, which is typically pumped from secondary tanks with a content of 0.8% solids, can be thickened to a content of 4% solids, then a fivefold decrease in sludge volume is achieved.
5. Filter press: A filter press is a tool used in separation processes, specifically in solid /liquid separation using the principle of pressure drive, provided by a slurry pump. In the thickened sludge is injected into the center of the press and each chamber filled. The filling time maintained as quick as possible in order to avoid cake formation in the first chamber before the last chamber is filled. While the chambers are being filled up, the pressure inside the system will increase due to the formation of thick sludge. Then the liquid is filtered out through the filter cloths by adding streams of compressed air or water. The use of pressurized water required more time to pass into the chamber compared to pressurized air, however this method is much more cost efficient.
6. Crystallization: In crystallization, solid crystals are obtained from a homogeneous solution. It is a solid–liquid separation technique. Crystallization occurs only when a solution is super saturated. Super saturation of a solution is its state in which the solvent has higher concentration of solute than what can be dissolved in it at that temperature. By using this method, salts can be recovered from the mother liquor. Crystallizers are of two types, namely single-stage and multi-stage. The common chemicals removed from the effluent by crystallization include calcium sulphate, sodium chloride, calcium chloride and sodium sulphate. Therefore, the scale causing chemicals can be removed from wastewater and this can be used a pre-treatment method for wastewater being used for membrane purification and evaporation.
7. Solar pan**:** solar evaporation ponds are shallow artificial ponds designed to evaporate brine and to get salt from it.
8. Final recovery of water & brine: direct salt recovery from the dye effluent offers the advantage of treating water quantity as compared to the water amount coming from the whole dyeing process. the textile industry is characterized by high water use, and this water must be of high quality. Water used, whether obtained from the distribution network or from other sources, is subjected to purification, normally softening, process. Moreover, high salt concentrations are required in the medium used for textile fibber dyeing process to ensure that the pigment is fixed to the fabric. These dyeing waters have a high salt content even after treatment. The treated water and brine used for the dyeing units.

Table: The Characteristics of Final Recovery Water & Brine

S.NO	Parameters	Units	Final Recovery	Brine
1	pH		6.5	6.5
2	TDS	mg/l	350	180000
3	Total Hardness	mg/l	1	240
4	Total Alkalinity	mg/l	35	450

3. Result and Discussion

The textile industry in India faces environmental issues due to color and non usable high TDS brine solutions present in its effluent. The major issue for plant operation is the mixed salts coming out of the systems, as those salts cannot be reused in the dyeing process. . The reject of the existing RO system is first preheated and then feed to the evaporation system in a forward feed manner. The present technique represents a unique solution for the selective crystallization and recovery of salt followed by mixed salts, which can then be reused in the dyeing process. The recovery and reuse of salts and water results in hand some pay backs for the evaporation system. The final end products are process condensate and salts of reusable quality.

4. Conclusion

In this chapter toward achieving ZLD have been discussed. Primarily current ZLD developments are based on recycle and reuse of waste water. This chapter also discusses recent advances in efficient treatment methods and rejects management systems as well as the use of better things in ZLD processes. In these studies included in this chapter clearly demonstrate the possibility of implementing such solutions in practice. There are several opportunities to use effluent treatment technologies discussed in this book in a synergistic fashion to enhance the effectiveness and efficacy of remedies proposed for ZLD.

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