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PERFORMANCE EVALUATION AND MODIFICATION OF ZERO LIQUID DISCHARGE PLANT IN PHARMACEUTICAL INDUSTRY

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Abstract

Rapid industrialization is adversely impacting the environment globally. Pollution by inappropriate management of industrial wastewater is one of the major environmental problems in India as well as in developing countries, especially with growing small scale industrial sector in the countries. The pharmaceutical industry produces effluent having high concentration of dissolved solids and organics. The present study is a case study in a zero discharge plant installed in a pharmaceutical industry for treatment of wastewater to carryout to improve the performance of Zero Liquid Discharge System. 1. Wastewater treatment by Stripper Column and its performance in removing organics from Wastewater. 2. Adding additional stripper in series to improve the performance for the removal of organics and moisture content from wastewater 3. Pilot plant studies with Tubular Filter Membrane for the removal of suspended solids from bio treated water for improving the performance of Reverse Osmosis System. There are two streams of wastewater generation from the plant activities. 1.High TDS Stream from process and washings.2. Low TDS Stream from utilities and domestic These effluents are treated in Zero Liquid Discharge System comprises of Stripper, MEE, ATFD, Bio ETP followed by Reverse Osmosis System. The treatment system for treating High TDS effluents consists of Oil and grease trap, Equalization, Neutralization, Primary clarifier, Stripper, Multiple Effect Evaporator followed by Agitated Thin Film Dryer (ATFD). The concentration generated from MEE is fed to ATFD to get dry Salt. These Salts are disposed to TSDF which is an authorized agency for disposal of hazardous waste In the present study, modifications in the stripping system & pilot plant studies with tubular filter membrane for bio treated water are carried and results are compared. Additional Stripper is added in series to the existing stripper to improve the performance of the existing stripper column with respect to MC of top distillate and also in removal of organics from wastewater. 1. It is found that the stripper top distillate generated is enriched with organics with an average moisture content of 9% .2. Stripper Top Distillate COD is 84.76% (8,47, 664 mg/l). A pilot plant study was carried on biotreated water (which is further treated in Reverse Osmosis) with Tubular Filter Membrane Process. It is observed that Tubular Filter Membrane is more effective in removal of suspended solids (91-95%). The advantages due to removal of suspended solids by Tubular filter membrane are 1. Bio fouling of Ro Membranes is reduced. 2. RO System efficiency is improved 3. RO System -CIP cycles are reduced.

Key words**:** Zero discharge plant, Stripper, Membranes, Evaporators, Dryers.

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Introduction:

The Indian pharmaceutical sector has witnessed exponential growth after the 70s to the current status and has emerged as a prominent provider of healthcare. The Industry today is in the forefront of India's science-based industries with multiple capabilities in the intricate field of drug manufacture. The organized sector of India's pharmaceutical industry consists of 250 to 300 companies, with the top 10 firm representing 30 %. However, the total sector is estimated at nearly 20,000 businesses, some of which are extremely small.

The pharmaceutical industry produces organic based wastewater, which requires treatment. These high strength industrial wastes are often difficult to break down in conventional wastewater treatment processes. The high COD values and recalcitrant nature of some of the organic compounds present are characteristic of Pharmaceutical wastewater streams. Its treatment poses one the biggest challenge to the industrial waste treatment system because of the lack of homogeneity of the effluent; there is no single approach or treatment method that applies to all. Generally depending on the type of chemicals that are used in the manufacturing processes, the COD value can vary considerably from as low as 100ppm up to 10000ppm with some even more than that.

Wastewater from pharmaceutical industry mostly contains organic compounds that includes solvents as well such isopropyl alcohol, ethanol and methanol. The wastewater can come from many streams originating from different stages of the production process. If those contain water soluble solvents, the COD value can reach as high as over 10000 ppm and that depends on the level of contamination carry over to the water. Usually in order to deal with this problem, the high COD stream should not be directly fed to the treatment system but instead, the wastewater should be diluted in order to lower the COD. This is important to prevent sudden shock to the biological system.

The wastewater usually contains chemical compounds with varying degree of organic composition but have very little to nil suspended solid materials. In line with these characteristics, choice of treatment processes that are selected will usually include the chemical precipitation as the first step before the wastewater is fed to the biological process

The chemical compound will be different in nature depending on the type of pharmaceutical products being produced and as such binding or chelating agents are used to attract and lump together the contaminants to be removed through floc formation.

Due to the wide variation in waste characteristics, it is indispensable that a comprehensive effluent assessment is carried out. This should be done through site survey covering all unit of operation over a period of time to get a complete idea of waste concentration, flow variation, balanced strength of combined waste streams.

Chemical analysis of effluent and assessment of waste composition will make it possible to calculate the strength of waste and accordingly arrive at a treatment plan. Treatability studies both chemical and biological studies will give foresight to the effectiveness of the treatment schemes for the pharmaceutical effluent.

Rapid advances made in the wastewater treatment technologies during the past one decade, particularly in the bulk drug sector. Now it is possible to reduce water consumption and wastewater generation considerably and even achieve the Zero Discharge Levels.

Major industrial establishments have established in-house wastewater treatment facilities. Small and medium scale industries might need to send the wastewater to common treatment facilities or to be recycle within the premises through ZLD (Zero Liquid Discharge) plant. As per local and national regulations, it is mandatory to establish ZLD plant, and treated water should be recycled within the premises. A ZLD-system can produce a clean stream from industrial wastewater suitable for reuse in the plant and a concentrate stream that can be disposed, or further reduced to a solid.

The systems available of treating industrial effluent are based on Physico-chemical and biological principles. The operation of effluent treatment plants requires technical skill and regular attention so to achieve compliance to standards. Standards for compliance have been notified under the Environment Protection Act, 1986. The notified standards permit industries to discharge the effluents only after compliance. However, statutory authorities are insisting industries to reduce water consumption and also take measures to not-to-discharge effluents. But, it has been observed that industries are not able to meet all time compliance standards

And as a result, rivers like Ganga and its tributaries is carrying high pollution load and it is the dilution available in river water which helps in minimizing pollution load. Hence Effluent Treatment Plants are used by industries to purify water by removing the pollutants from it for environmental protection.

The present study is related to wastewater treatment technologies for achieving zero liquid discharge concepts in industries for recycling the treated wastewater, technical need for ZLD and also a case study in a zero-discharge plant installed in a pharmaceutical industry for treatment of wastewater. The following studies have been carried to improve the performance of Zero Liquid Discharge System**.**

1. Wastewater treatment by Stripper Column and its performance in removing organics from wastewater.
2. Adding additional stripper in series to improve the performance for the removal of organics and moisture content from wastewater
3. Pilot plant studies with Tubular Filter Membrane for the removal of suspended solids from bio treated water for improving the performance of Reverse Osmosis System.

Zero Liquid Discharge (ZLD):

Zero Liquid discharge refers to installation of facilities and system which will enable industrial effluent for absolute recycling of permeate and converting solute (dissolved organic and in-organic compounds/salts) into residue in the solid form by adopting method of concentration and thermal evaporation.

After having recognition of problems that many industrial sectors are not able to achieve standards, and this ultimately necessitates to work towards Zero Liquid / effluent discharge standard.

Also, day by day the impact of water pollution has increased and also the ground water resources are gradually being depleted. In the present situation, it is required to recycle/reuse the wastewater generated from industrial outlets after suitable treatment. Environmental Authorities are also being directed to establish “Zero Liquid Discharge (ZLD) plants” in all industrial sectors.

ZLD will be recognized and certified based on two broad parameters that is, water consumption versus waste water re-used or recycled (permeate) and corresponding solids recovered (percent total dissolved / suspended solids in effluents).

Technical needs for ZLD – The guidelines

Implementation of Zero Liquid Discharge system will be applicable to zero-down organic load, recover metals and other constituents.

Direct installation of ZLD facilities may have technical constraints to operate specialized system.

Pre-requisite for ZLD accomplishment would need physical and chemical treatment and followed by biological system to remove organic load. The treated effluents can be then subjected for concentration and evaporation. The concentration process as applicable can be adopted at appropriate stage. The concentration method quite often involves the adoption of

Reverse Osmosis (RO) and Nano Filtration (NF) methods. The evaporation methods involve incineration/ drying / evaporation of effluent in multi effect evaporators (MEE). In the process of achieving ZLD in pharmaceutical industries, solids recovered will have to be stored and disposed to Hazardous waste disposal sites.

Cost-wise, achieving ZLD will be costly proposition but, now becoming necessity because rivers need to be rejuvenated. A typical cost indicates that a CETP treating 1 MLD of waste water with conventional physicochemical and biological treatment is around Rs. 3.0 to 4.0 Crores with operation and maintenance cost of Rs. 300-350 per cubic meter (M3), Whereas, cost of combination of conventional ETP with ZLD facilities costs around Rs. 12.0 to 15.0 Crores per MLD. Now, the ZLD adoption is becoming essential rather than imposition.

Application of ZLD in Industries

The significant industrial sectors like Sugar, Distilleries, Pharmaceutical, Tanneries, Pulp & Paper, Textile, Dyeing, and Dairy would need special emphasis for enforcement of ZLD. It is important to mention that in the name of ZLD, no forceful injection into ground water table is to be tried nor utilizing effluents / permeate for irrigation / or horticulture. ZLD would strictly means recycling treated effluent back for re-use in industrial / or domestic purpose but, exclude use / disposed in ambient environment. ZLD is applicable to industries having high BOD and COD load, color bearing effluents, having metals, pesticides and other toxic / hazardous constituents.

1. The industries having high organic load and other refractory nature of pollutants will be requiring adopting ZLD system.
2. ZLD refers to a system which would enable and industry to recover clean water using back into industrial processes or domestic use and not subjecting to be disposed in ambient environment including use in industrial premises.
3. Industries will have options to select technical system facilitating to achieve ZLD.

Technical Route for Achieving ZLD

ZLD can be achieved by adopting conventional primary, secondary and tertiary effluent treatment and polishing by filtration and using clean water back into process / or domestic use. In some case, Reverse Osmosis, Micro/Nano Filtration and concentrating with Multiple Effect Evaporators (MEE) can be employed. It has been quite often debated that employing ZLD route is energy intensive and having exorbitant cost / financial burden. But, it cannot be denied that in the present circumstances when ground water table is getting depleted and there is diminishing flow in rivers, permitting industries to discharge even treated effluents, does not seems to be environmentally acceptable proposition. However, industries will be at their technical wisdom and expertise to search for better ZLD achieving practice but with a caution that there will stern actions if, on the name of ZLD, un-acceptable practices are adopted. In some cases, if any industry feels that a given process needs modification, stopped

or substituted, they can do so but, in longer run, treated effluents cannot be disposed. It is also to be understood that in absence of ZLD, industry has to meet compliance with standards and the results through on-line effluent monitoring devices will be available with regulatory authorities and also in public domain.

Zero Liquid Discharge System for Pharmaceuticals

In this sector most of the industries are operating based on partial ZLD system and partially treating effluent in the conventional way. In most of the cases domestic effluent is treated separately or mixed with either low or high TDS effluent. The mixed salt recovery and no takers of salt generated is one of the problems of the industry since there is no reuse of same by the industry. In pharmaceuticals the reuse of by products are not encouraged much since it is following very high-quality standards for each raw materials. The effluent is generally segregated based on the strength of the pollutants in the early stages itself.

Low TDS Effluent treatment system

Common collection tanks, Neutralization tanks, tubular settler, Aeration followed by clarifier, tertiary chemical treatment to reduce TDS followed by Pressure sand filter, Activated Carbon filter and filter press for dewatering of sludge generated from clarifloculation are the major components. The secondary treated effluent is being treated through Disk membrane type R.O. The R.O. permeate is utilized as cooling tower makeup water and R.O. reject is treated through Multi effect evaporator. In case of high COD and TDS in RO permeate the same is treated through Spiral type RO, to meet the requirement of cooling tower.

High TDS Effluent treatment system

The treatment of High TDS effluent consists of Common Collection tanks, Settling tank followed by filter press, stripper to remove VOC, Multi Effect Evaporator (forced circulation) and a Agitator Thin Film Drier (ATFD). The MEE condensate is being taken along with Low TDS effluent for further treatment. MEE concentrate is being dried through ATFD and salt is collected and stored in Hazardous storage yard and the same being sent to TSDF or stored in the industry for safe disposal.

MATERIALS AND METHODS

A case study was conducted in Hetero Drugs Limited which is an API (Active Pharmaceutical Ingredients) manufacturing industry located at Bonthapally village, Gummadidala Mandal Sangareddy District.

The objective of the study is to improve the performance of ZLD. For this the following studies are carried out in ZLD System.

1. Wastewater characterization, Segregation and treatment of wastewater by Zero Liquid Discharge system (Stripper, MEE, ATFD, Bio ETP and Reverse Osmosis system).
2. Studies with respect to additional stripper in series which is added to the existing stripper to improve the performance for the removal of organics
3. Studies & Trails with respect to Tubular Filter Membrane for the removal of suspended solids from bio treated water for improving the performance of Reverse Osmosis System.

Materials and Methodology for Wastewater Management:

Wastewater samples are collected and analyzed the samples for TDS and COD as per Standard Testing Procedure.

a. The chemicals used for analysis of effluents are sulphuric acid (98%), Ferrion Indicator, Silver sulfate, K_2Cr2O7 (0.25 N), Ferrous

Ammonium Sulfate (0.1 N), Mercuric Sulfate, pH Buffers and whatmann filter papers.

b. Alum was used for primary treatment of effluent.
c. Defoamer in Bio ETP for foaming control in Aeration tanks

Analytical Instruments in the ETP laboratory are:

1. Hot air oven &. Muffle furnace are used for determination of TDS (mg/l),
2. COD digesters are used for measuring COD of effluents (mg/l),
3. KF Titrator was used for calculating Moisture Content (%)
4. pH meter, Analytical balance are the analytical instruments used for effluents pH and weighing of chemicals required for analysis of effluents.
5. Desiccator

Determination of pH

pH meter is used for determination of pH of effluents.

Determination of COD:

Reflux procedure is used for determination of COD

Procedure for COD:

1. Taken 10 ml of sample in a 250 ml refluxing flask.
2. Added approximately 400 mg (a pinch) of Mercuric Sulphate and Silver Sulphate (40 mg).
3. Added 10 ml of Potassium Dichromate by pipette and 30 ml of concentrated Sulphuric acid by measuring cylinder. Acid added in controlled manner with regular mixing of the sample.
4. Connected the reflux flask through the condenser and reflux done for a period of 2 hours at 150^0C.
5. Added 80 ml of distilled water through condenser cool it to room temperature and titration carried with standard Ferrous Ammonium Sulphate solution using 4 drops of ferroin indicator.
6. End point observed from blue green to brick red, even though blue green may reappear within minutes. Titer value is V1 ml.
7. Performed the same procedure with distilled water 20 ml Titer value be V2 ml.

Calculated COD (mg/l) = <u>(V2-V1) x NFAS x 8000</u>

Volume of Sample (ml)

. **Determination of TDS:**

1. Checked the sample label to ensure collect 250 ml of sample to a clean plastic/glass sampler, label and deliver it to the laboratory.
2. Transferred the sample to a clean and pre-weighed evaporating dish and evaporate to dryness in a oven at 180± 2 ^{0}C.
3. Dish cooled in a desiccator to ambient temperature and reweighed.
4. Calculated TDS in mg/l ;

TDS mg/l = <u>(Final Wt. of dish-Initial Wt. of dish) x 1000 x 1000</u>

Volume of the sample taken

Effluents Treatment Scenario:

Effluents generated in the plant activities are being segregated based on TDS and COD. It is observed that effluents generated from process are High TDS effluents (TDS>5000 mg/l and COD>15000 mg/l).

Wastewater generated from utilities such as CT bleed off; boiler blow down and wastewater generated from domestic activities are Low TDS effluents.

Samples are collected on daily basis for wastewater characterization and the results of analysis of treatment system are presented in Results and Discussion.

ZLD system comprises of Stripper followed by MEE, ATFD, Bio ETP and Reverse Osmosis System.

a) After neutralization, the high TDS effluents are fed to Stripper Column for removal of low boiling organics from wastewater. Stripper top distillate (mixed solvents) generated is being disposed to authorized agencies.
b) Stripper bottom is fed to 5 effect Multiple Effect Evaporation (MEE) followed by Agitated Thin Film Drier (ATFD).
c) The condensate (distillate) generated during evaporation of high TDS effluents are treated in Bio ETP (Two Stage Aeration) along with low TDS effluents which are generated from utilities and domestic activities
d) The left-over concentration from MEE is fed to ATFD to get dry salts
e) Bio treated effluent is further processed in Reverse Osmosis System (3 Stage Module System).
f) The Permeate generated from RO system is reused as makeup water in utilities and the RO rejects are treated in MEE along with High TDS effluents.
g) Dry Salts generated from ATFD are being disposed to TSDF

Facilities for High TDS wastewater Management:

1) Stripper followed by MEE (5 effects) of capacity: 200 KL
2) ATFD of capacity 15 TPD

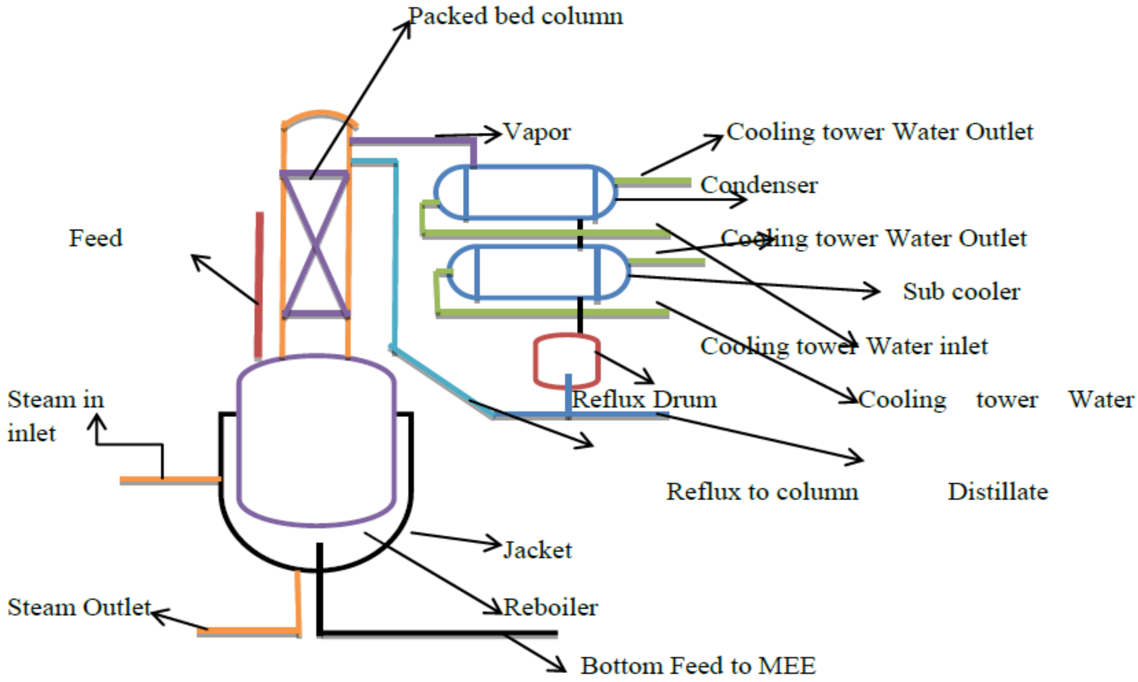

Figure 1: Stripper Column:

Table 1: Specification of Stripper Column (Existing):

S, No	Description	Specification
1	Stripper top temperature	98 ^{0}C
2	Stripper Bottom temperature	105^{0}C
3	Packing of stripper column	Random
4	Stripper Column height	12 m
5	Stripper Column diameter	600 mm
6	Type of reboiler	Thermo siphon
7	Type of heat exchanger	Shell and Tube
8	Specific gravity of stripper	0.98 gm/ml
9	Area of primary condenser	16 m^2
10	Area of secondary condenser	10m^2

Multiple Effect Evaporator

1) Five effects are provided. It is a forced circulation system in which high TDS effluents are evaporated under vacuum (vacuum distillation)
2) Temperatures and vacuum profile (Effect wise):**Table:2**

Description	Effect 1	Effect 2	Effect 3	Effect 4	Effect 5
Temperature (^{0}C)	105	85-90	75-80	65-70	55-60
Vacuum (mm of Hg)	50	150	300	450	550

3) Steam is given to I effect, vapors generated during evaporation of I effect is a heating source to second effect and so on.
4) Axial flow pumps are provided for circulation of effluent through effects.
5) Condensate generated during evaporation (5 effects) is being treated in Bio ETP.
6) Plant is designed to get an output of 30% dissolved solids

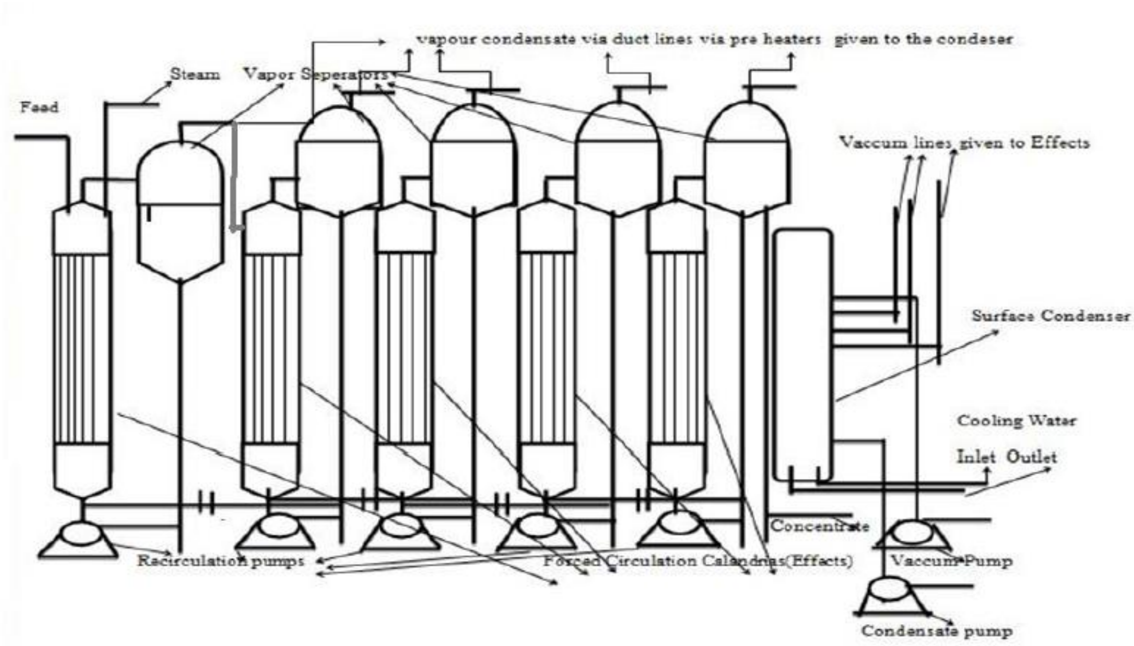

Figure 2 :Multiple Effect Evapourater (Five Effects)

Agitated Thin Film Dryer:

1. MEE concentrate (30% solids) is fed to ATFD to get dry Salts
2. The dry salts generated are being disposed to authorized agency (TSDF which is a Ramky facility)
3. Condensate generated during ATFD evaporation also being treated in Bio ETP.

Low TDS wastewater Management:

Cooling tower bleed off, boiler blow down, condensate from MEE and ATFD are being treated in primary treatment (consisting of equalization, neutralization, and primary sedimentation) followed by biological treatment

Bio ETP:

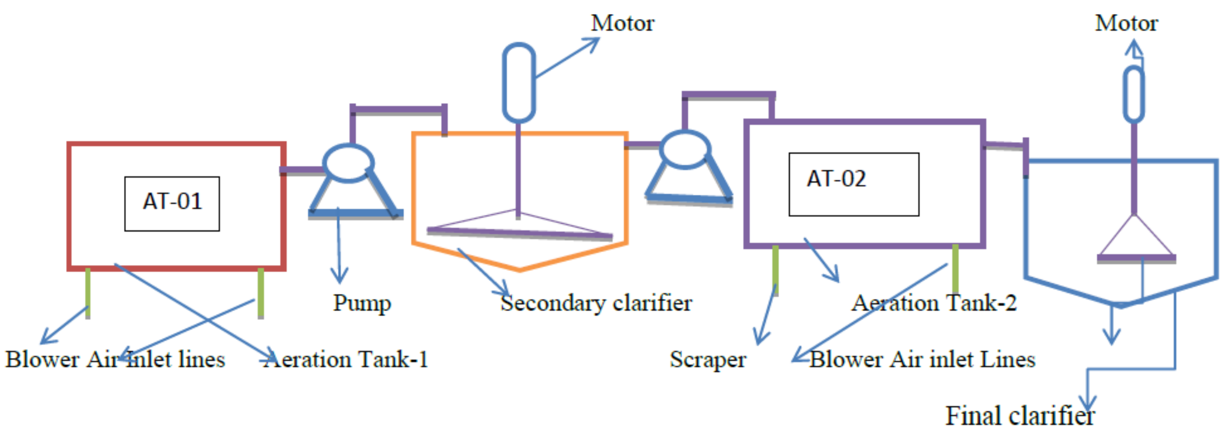

Figure 3: Two stage Diffused Aeration Tank System

The primary treated effluent is taken to Aeration tanks of capacity (1500 KL & 1000 KL) in which the effluents are treated by biologically (Conventional Activated Sludge Process). The treated effluents after biological treatment are being filtered in sand and carbon filters for removal of suspended solids. After filtration the treated effluents are further processed in Reverse Osmosis System.

3.6.2 RO System:

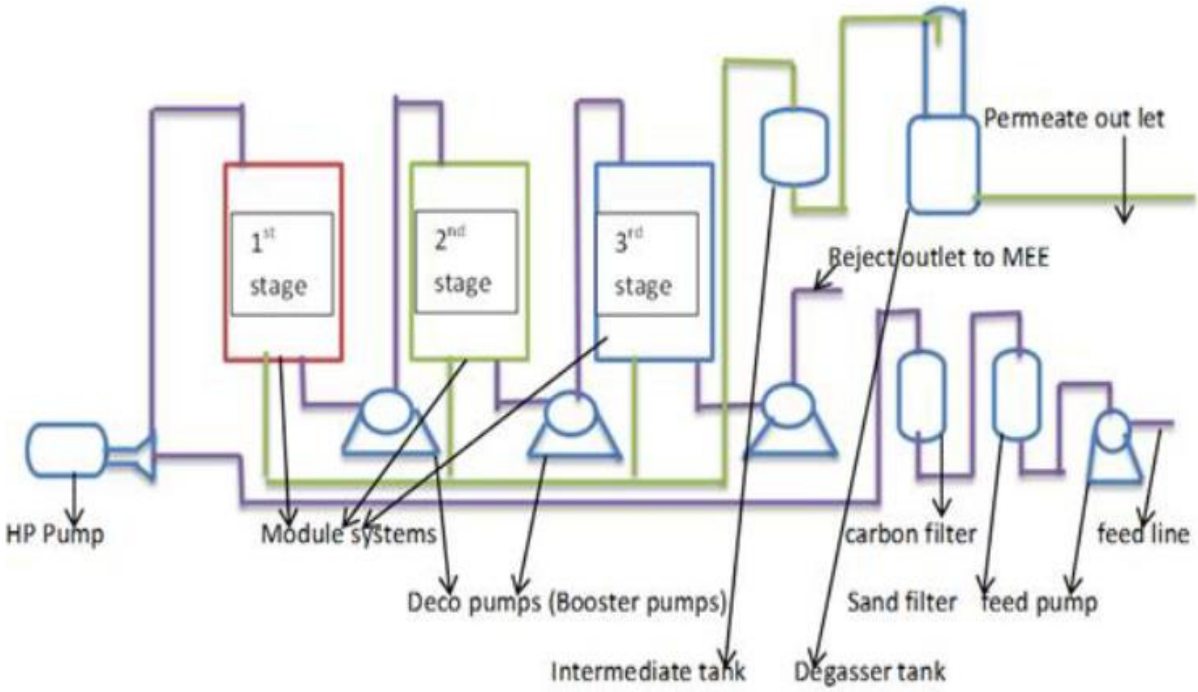

Figure 4 :Reverse Osmosis System

Reverse Osmosis is a membrane filtration process in which the treated effluent is passed through membrane at high pressure (20-50 bar)

Disc type membrane with 3 stage module system is provided.

I stage reject is being passed through second stage and second stage reject is passed through third stage by using booster pumps for maximum recovery of water (Permeate).

Permeate is reused in utilities and rejects are being sent to MEE and are being evaporated along with High TDS effluents.

Domestic effluents generated are being treated in Bio ETP along with low TDS effluents.

Secondary sludges are dried in sludge drying beds and the dried sludge is disposed to Hyderabad Waste Management Project (Treatment Stabilization Disposal Facility).

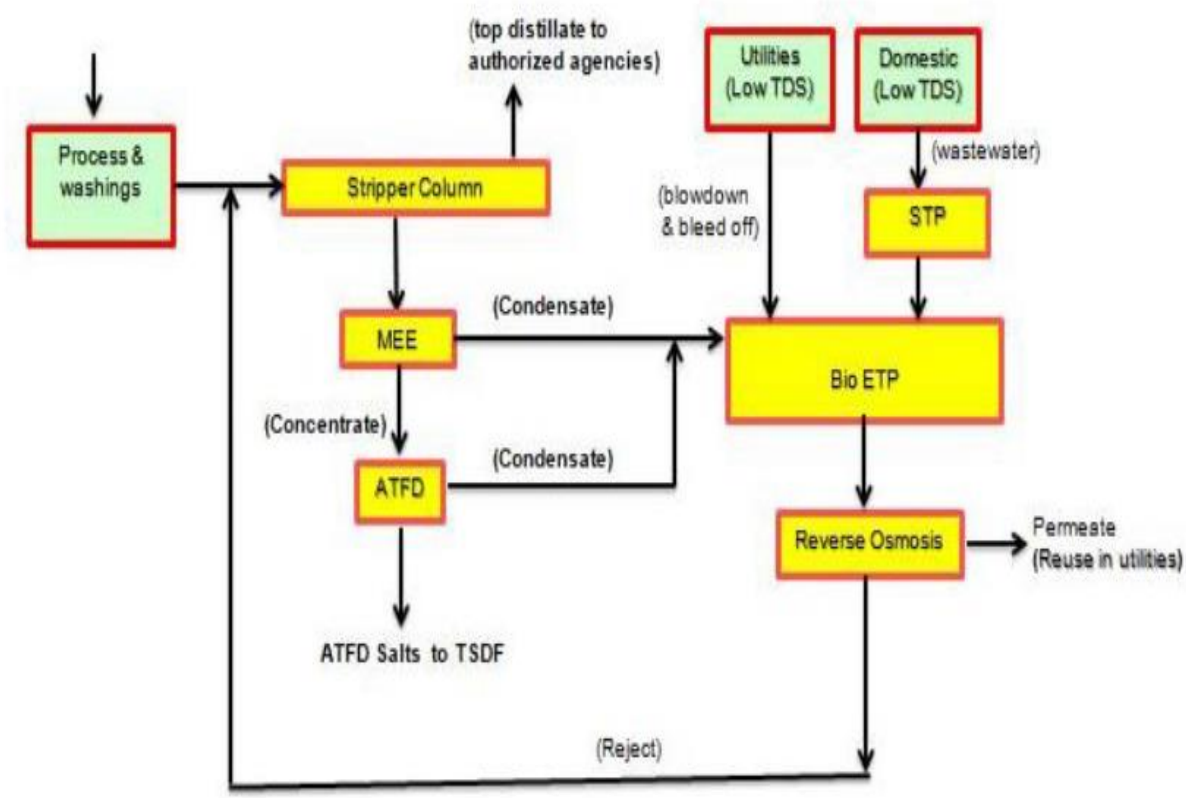

Figure 5:Schematic Diagram of Zero Liquid Discharge System

Studies carried in the existing system:

a) In order to improve the performance of stripper, additional Stripper is added to the existing stripper system and the results of the stripper studies are presented in chapter 4 (Results and discussion)

b) In order to improve the performance of Ro System, a pilot plant study is done on bio treated water with Tubular Filter Membrane and the results are presented in chapter 4 (Results and discussion).

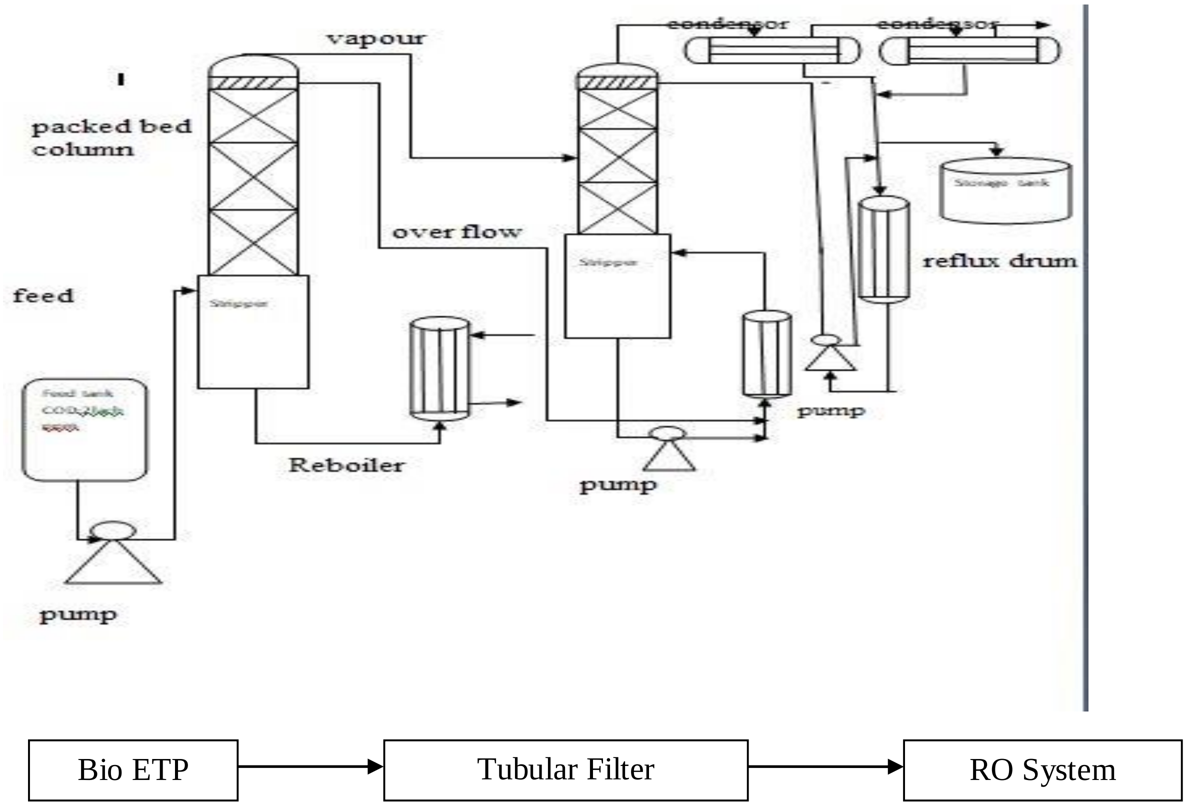

Figure 6: Stripper process -After Modification

RESULTS AND DISCUSSIONS

All the process effluents including washings from production blocks are being considered as high TDS (TDS >5000 mg/l & COD > 15000 mg/l) and the effluents generated from utilities & domestic are considered as low TDS (TDS <5000 mg/l and COD > 15000 mg/l.

Zero Liquid Discharge system is provided to treat the effluent generated ZLD system comprises of Stripper followed by MEE, ATFD, Bio ETP and Reverse Osmosis System.

1. Initially the effluents are collected in collection and neutralization tanks.
2. After neutralization, the high TDS effluents are fed to Stripper Column for removal of low boiling organics from wastewater. Stripper top distillate (mixed solvents) generated is being disposed to authorized agencies.
3. Stripper bottom is fed to 5 effect Multiple Effect Evaporation (MEE) followed by Agitated Thin Film Drier (ATFD).
4. The condensate (distillate) generated during evaporation of high TDS effluents are treated in Bio ETP (Two Stage Aeration) along with low TDS effluents which are generated from utilities and domestic activities
5. The left-over concentration from MEE is fed to ATFD to get dry salts
6. Bio treated effluent is further processed in Reverse Osmosis System (3 Stage Module System).
7. The Permeate generated from RO system is reused as makeup water in utilities and the RO rejects are treated in MEE along with High TDS effluents.
8. Dry Salts generated from ATFD are being disposed to TSDF which is a Hyderabad waste management project for hazardous waste disposal

Table-3: Wastewater Characteristics-Zero Liquid Discharge System

Description	pH	TDS (mg/l)	COD (mg/l)
Stripper Feed	7.2-8.1	24648-32468	68482-84284
Stripper top distillate	8.62-9.42	212-324	428342-518242
MEE Condensate	7.1-7.5	112-224	10284-16218
MEE Concentrate	6.1-6.5	237900-289900	35000-40000
ATFD Condensate	7.1-7.	424-558	15282-22412
Bio ETP outlet	7-7.2	2752-4248	2842-3872
RO Permeate	6.5-6.8	452-728	224-248
RO Reject	6.8-7.2	6000-7142	4242-5840

Figure 7:Graph showing the performance of waste water Characteristics-ZLD

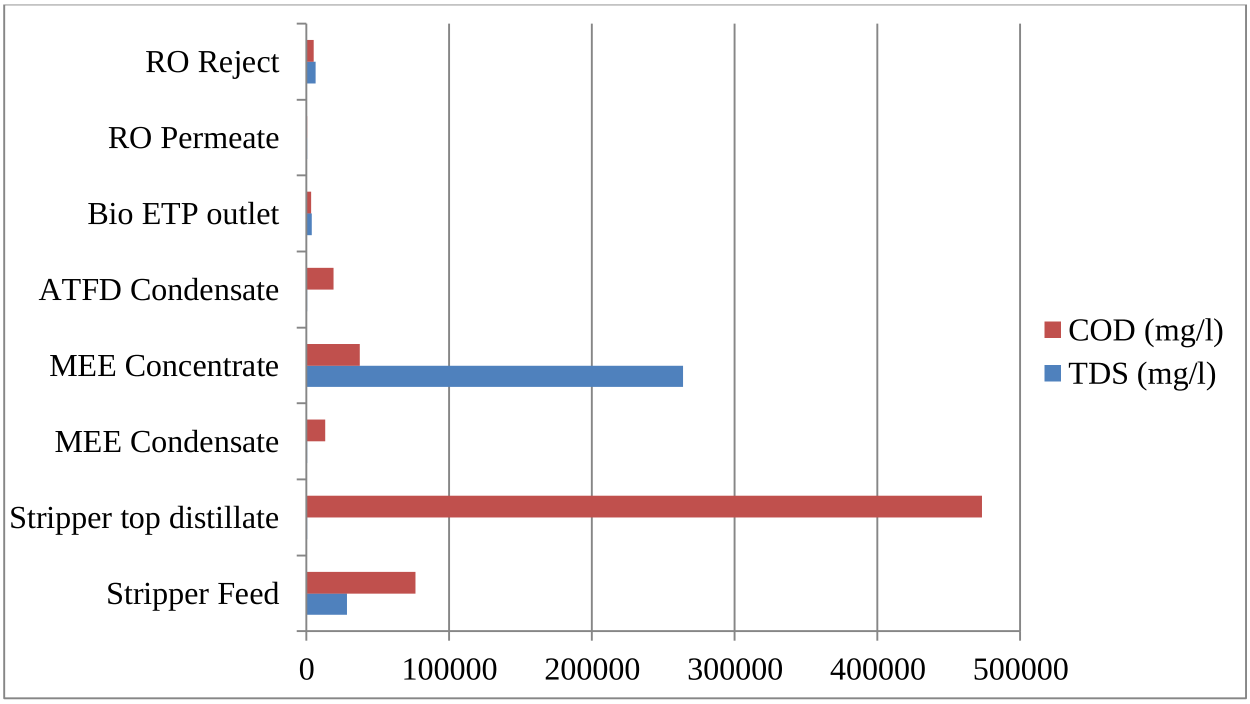

Table 4 : Characteristics of Stripper Top distillate

S.No	Stripper feed COD (mg/lit)	Stripper top distillate COD (mg/lit)	Moisture content (%)
1	84284	518242	76.2
2	73248	482348	74.6
3	74346	478248	72.4
4	68842	428342	78.1
5	76348	478348	72.8
6	72340	468228	74
7	78240	512348	78.4
Avg			75.2

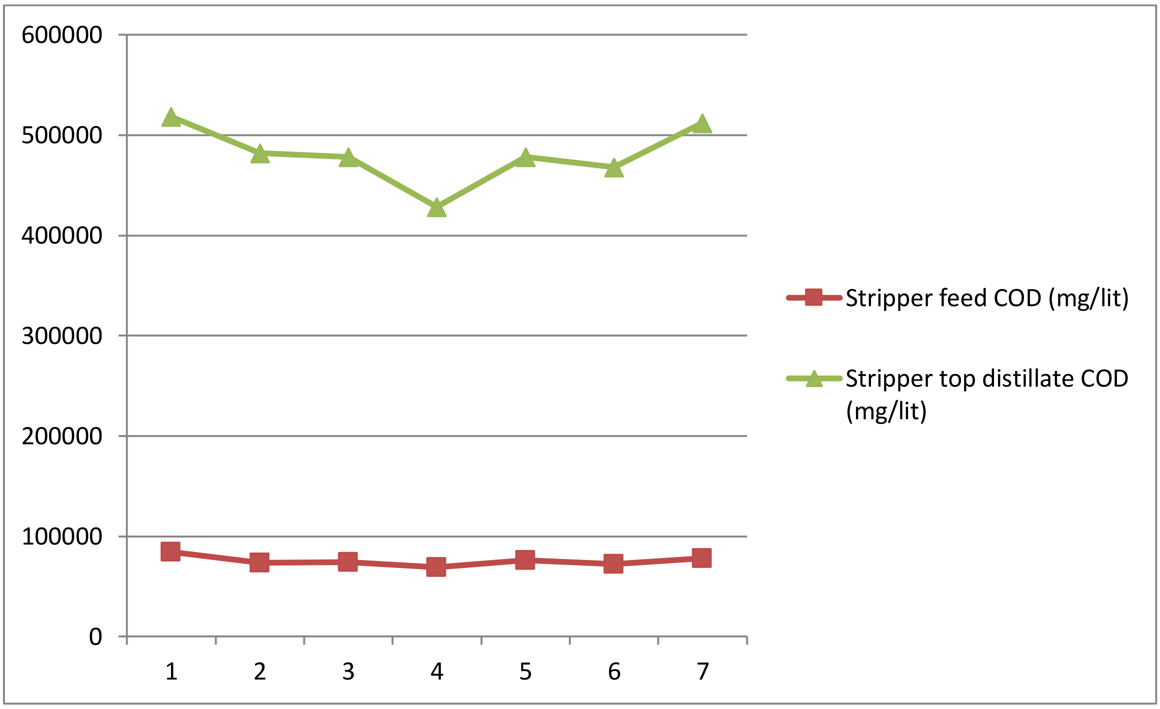

Figure 8:Graph Showing the Performance of output Stripper before modification

Average Moisture content (%) : 75.2

The top distillate generated is further processed in distillation column for removal of moisture content and to enrich the stripper top distillate with mixed solvents.

4.1 Stripper Column Modification:

1) An addition stripper column is added to the existing stripper column in series.
2) The vapour generated from Stripper I is passed through Stripper II.
3) A temperature controller is provided at top of Stripper Column (II) to monitor vapour temperature. The vapour generated during stripping process is being condensed and collected in receiver, If the mixed solvent temperature is <77^0 C, the solvent is being collected in storage tank. If the temperature >77^{0}C the collected solvent in the receiver is being again refluxed in Stripper-II for reducing Moisture Content and to enrich the solvent (%) in top distillate.

Table-5 Characteristics Stripper Top Distillate -After Modification

S.No	Stripper feed COD (mg/lit)	Stripper top distillate COD (mg/lit)	Moisture content (%)
1	68482	782348	9.4
2	72842	842422	8.6
3	74868	852684	8.2
4	80242	889462	9.2
5	76248	869246	9.8
6	74268	848248	9.2
7	76567	849242	8.6

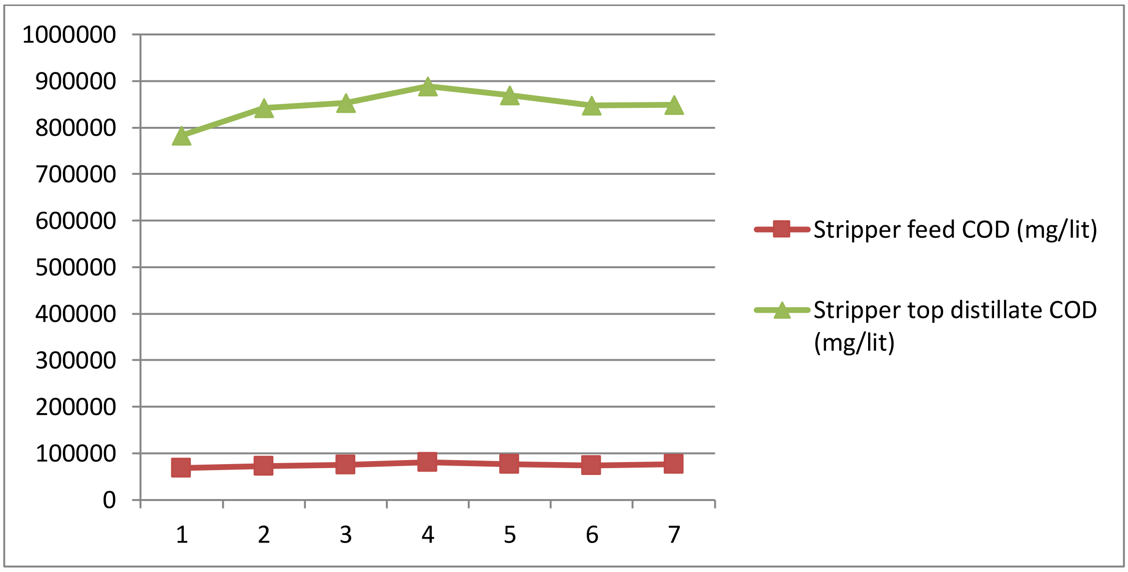

Figure 9:Graph Showing Performance output of Stripper after modification

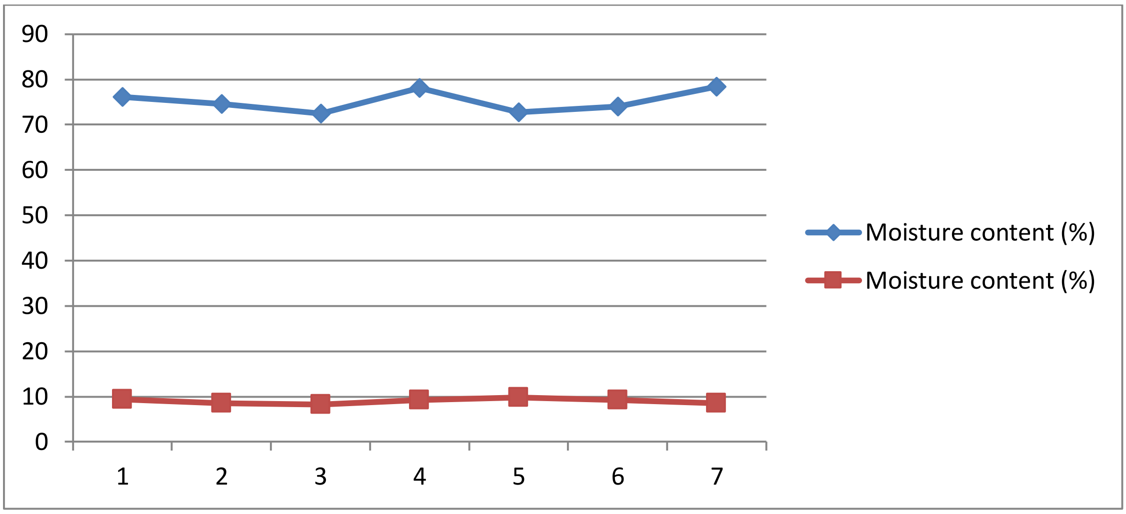

Fig10:Graph showing the performance of Stripper moisture content (%) output profile

Moisture content in the stripper distillate is reduced (average:9%) and the top distillate is enriched with mixed solvent with a COD of 84.7%

Pilot study on Bio treated water with Tubular Filter Membrane:

The low TDS effluents (cooling tower bleed off, Boiler blowdown and condensate from evaporation systems and Domestic waste are being treated in Bio ETP followed by RO System.

A pilot study is conducted on bio treated water with tubular filter membrane with respect to suspended solids. The results of the pilot study are

Table :6

Description	Inlet of TFM (mg/l)	Out let of TFM (mg/l)
TDS	2830	2100
COD	3412	2700
SS	232	10

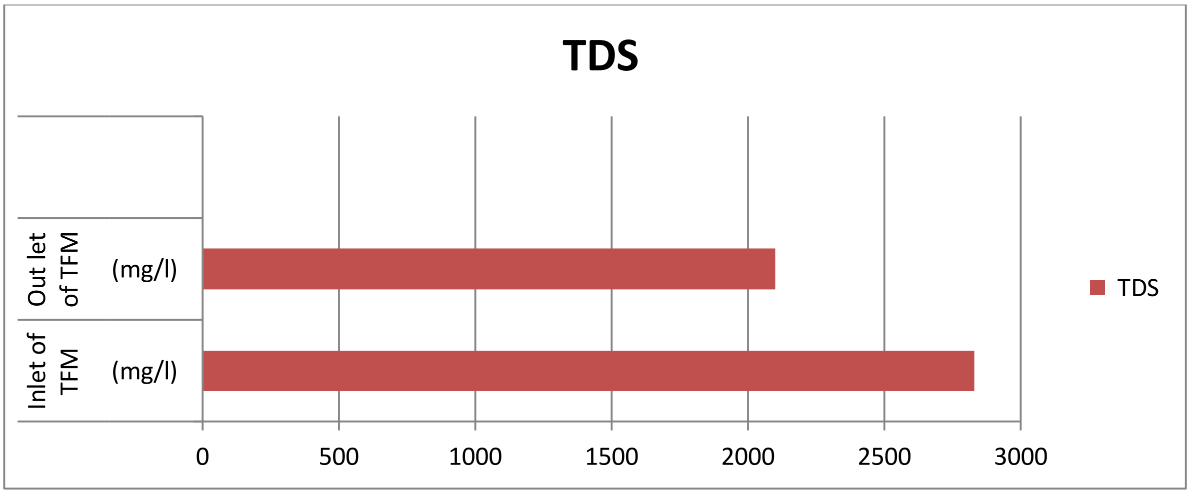

Figure 10: Graph Showing the performance of TDS (mg/l)

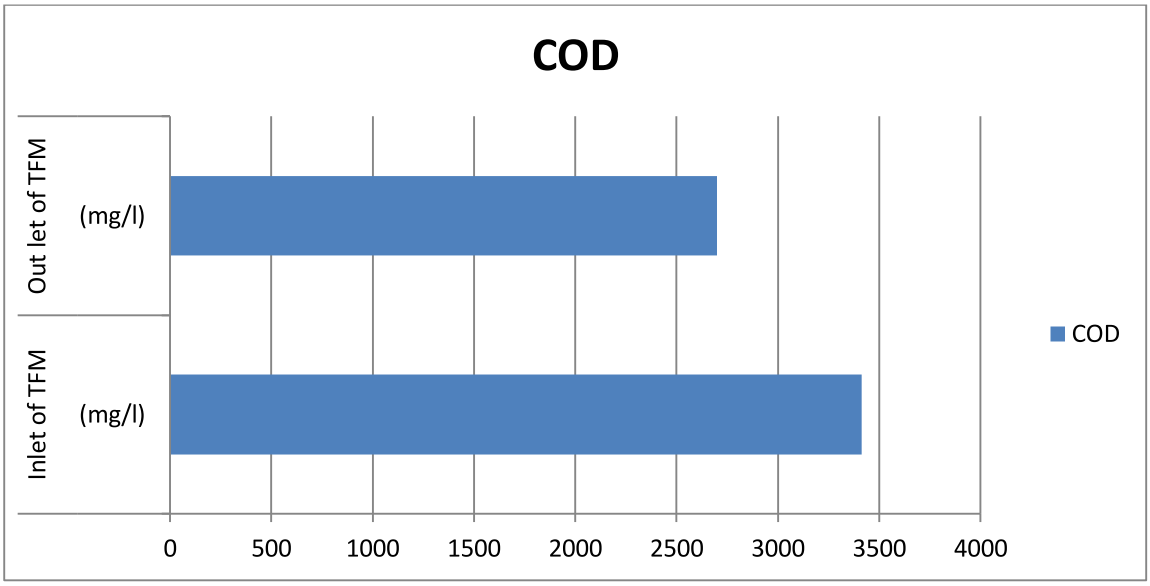

Figure 11: Graph showing the performance of COD (mg/l)

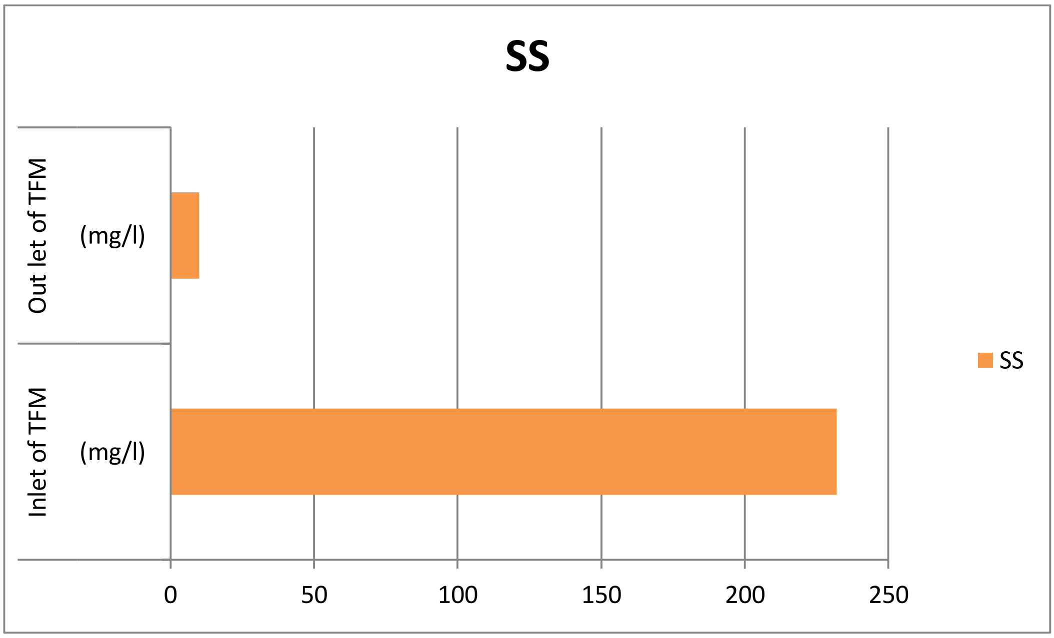

Figure 12: Graph Showing the performance of suspended solids (mg/l)

CONCLUSIONS

Based on results in the present work, it is concluded that Zero Liquid Discharge System ((Stripper, MEE, ATFD, Bio ETP & Reverse Osmosis) is more effective method for treating wastewater generated from pharmaceutical industries.

The following conclusions are drawn based on studies done in Zero Liquid Discharge (ZLD) System and pilot plant studies on bio treated water.

1) Wastewater treatment by ZLD in pharmaceutical industries is an effective method in recovering water from wastewater treatment. Reuse of treated water in utilities as makeup reduces the freshwater

intake helps in resource saving potential

2) Studies have been carried out on wastewater by stripping process.
3) Reduction of moisture content is observed in stripper top distillate by adding additional stripper in series to the existing stripper column. It is also observed the stripper top distillate is enriched with mixed solvents after addition of stripper column to the existing stripper.
4) As the initial stripper top distillate MC is more (74-78%), in order to reduce MC and to enrich solvents in stripper top distillate, added one more stripper column in series with vapour cutoff temperature 77^0C at the Stripper II outlet
5) Stripping process in ZLD discharge system reduces the organic load on subsequent treatment systems
6) Pilot plant study is carried on low TDS wastewater with Tubular Filter Membrane
7) Tubular membrane filtration works by feeding water under pressure into the membrane tube. This pressure forces water though membrane and tube substrate, but does not allow suspended particles to pass through the membrane. The filtered water (permeate) passes through the membrane and substrate (support) tube. The suspended particles (retentate) exit the tube and return to a concentration tank in preparation for another pass through the membrane tube filter. This process allows for effective, efficient filtration requiring less space than traditional clarifying filter systems.
8) Filtration systems that utilize a pretreatment step (including chemical precipitation) along with TMF technology in front of RO ultrafilters can yield more efficient RO performance with longer RO module life. With high water recovery rates and a long service life, industrial facilities implementing a pre-RO TMF filtration system are able to operate at the most efficient level possible.
9) It is observed from pilot plant studies that reduction of suspended solids from treated water is 91-95% after passing it through Tubular Filter Membrane.
   Due to Suspended solids reduction in the bio treated water,
   a. The performance of RO is improved with respect to recovery of permeate from RO System.
   b. Bio fouling in RO Membranes is reduced
   c. Membranes Life increased from 3 to 5 years.
   d. Treatment capacity of RO is increased with respect to water recovery as the Disc Type Membrane is more effective for SS of wastewater <100 mg/l.

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