AN OVERVIEW OF CASE STUDIES ON ZERO LIQUID DISCHARGE – INDIAN EXPERIENCE

27th January, 2014

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Abbreviation.. 1

ZLD	Zero Liquid Discharge
CETP	Common Effluent Treatment Plant
TWIC	Tamilnadu Water Investment Company Limited
GoTN	Government of Tamilnadu
GoI	Government of India
O&M	Operation & Maintenance
ZWD	Zero Waste Disposal
TDS	Total Dissolved Solids
MLD	Million Litre per Day
MoEF	Ministry of Environment & Forest

Abbreviation.. 2

PMC	Project Management Consultant
TNPCB	Tamilnadu Pollution Control Board
OCD	Optionally Convertible Debentures
MEE	Multiple Effect Evaporator
BDTRF	Brine Discharge Through Resin Filter
MVR	Mechanical Vapour Recompression
UF	Ultra Filtration
DST	Department of Science & Technology

CONTENTS

Section A: Introduction to TWIC

Genesis

- TWIC was formed to promote the first PPP in water Sector, namely the New Tirupur Water Project (185 MLD, 1000 Crore)
- Promoted by Infrastructure Leasing and Financial Services Limited (IL&FS) [54%] and Government of Tamil Nadu (GoTN) [46%]
- Over the last few years, TWIC has been in the forefront of a number of initiatives both in the urban water space as well management of industrial effluent

Focus Areas

Water Reuse

- Industrial Effluent
- Sewage Reuse
- Desalination

Urban Water

- Treatment Plants
- Urban Water Distribution

Life Cycle Approach to Projects

- Emphasis on Life Cycle Costs and Benefits (technology, O&M)
- Ability to structure and implement projects on a commercial basis

Project Development	Project Financing	Project Implementation	Project O&M
-Technology Solution, Development & Design -DPR Preparation -Procurement Services	-Financial Close -Investment -Lending	-Project Management -Implementation Supervision -Lenders Engineer	-Direct O&M -Supervision -Performance Audits -Energy Audits

Recognition

- Government of Tamilnadu (G.O 132 dtd 31.12.12)
  - Has nominated TWIC as PMA for implementing on behalf of the government for the following:
    - Dedicated agency for development and O&M of CETPs for GoTN
    - Industrial water supply through Reuse of Sewerage water and Desalination.

- Government of India
  - TWIC's technology for ZLD recognized by Ministry of Textiles and has been evaluated & accepted by the Dept. of Science and Technology (DST).
  - TWIC has been a Knowledge partner to the Ministry of Textiles.

Section B: Concept of ZLD

Concept of ZLD

- ZLD – meaning zero discharge of wastewater from Industries.
- A ZLD system involves a range of advanced wastewater treatment technologies to recycle, recovery and re-use of the ‘treated’ wastewater and thereby ensure there is no discharge of wastewater to the environment.
- A typical ZLD system comprises of the following components:
  - Pre-treatment
  - Reverse Osmosis
  - Evaporator & Crystallizer

Need for ZLD .. 1

- Most polluting industries such as Pharma, Pulp& Paper, Tanneries, Textile Dyeing, Chemicals , Power Plants etc generate wastewater with high salinity/TDS.
- Conventional ‘Physico-chemical-biological’ treatment does not remove salinity in the treated effluent. The TDS content is well above the statutory limit of 2100 mg/l.
- Discharge of saline but treated wastewater pollutes ground and surface waters.
- Several states in India including Tamilnadu are water stressed. Competing demands for water from agriculture and domestic use has limited industrial growth.

Need for ZLD .. 2

- TN has taken a lead on ZLD due to absence of fully flowing perennial river Most rivers originate from neighboring states and water sharing is enmeshed in disputes. Several landmark pollution cases and court battles have hastened this, such as the Vellore and Tirupur court cases. Other states such as Gujarat and Karnataka also are now are considering ZLD.
- Location of industries in ‘Inland areas’ and issues related to sea discharge of ‘treated’ wastewater.
- High cost of water (> Rs. 40) and statutory regulations are prime drivers for ZLD.
- **MAIN MOTIVATORS- Water Scarcity, water economics, regulatory pressure.**

International Context .. 1

- In the early seventies, increased salinity of the United States Colorado River, due to Power Plant discharges, created the regulatory context to push for ZLD in the US.

- For new industrial projects, where gaining an approval for a discharge agreement might traditionally take five years, with ZLD it could be a matter of 12 months. As a result, ZLD technology effectively evolved in the US and later grew globally.

- In Germany, stringent regulation in the 1980's resulted in ZLD systems for Coal Fired Power Plants.

- **(Source GWI)**

International Context .. 2

- In China, a chemical company Yunnan Yuntianhua (YTH Group)for a Coal-to-Chemicals plant in an environmentally sensitive location, one of the largest grasslands in China (inner Mongolia)has gone in for ZLD. This is paving the way for more such projects in the region.
- ZLD system for the tanning sector in Lorca, Spain is based on membrane techniques, designed to lower the water salinity to levels suitable for re-use at an agricultural and industrial level.

Benefits of ZLD

- Installing **ZLD** technology is beneficial for the plant's water management; encouraging close monitoring of water usage, avoiding wastage and promotes recycling by conventional and far less expensive solutions.
- High operating costs can be justified by high recovery of water (>90-95%) and recovering of several by products from the salt.
- A more sustainable growth of the industry while meeting most stringent regulatory norms.
- Possibility of use of **sewage** for recovery of water, for Industrial and municipal use, using ZLD technologies.
- Reduction in water demand from the Industry frees up water for Agriculture and Domestic demands.

Challenges in ZLD

- "Is the Holy Grail of Industrial wastewater Treatment..." Global Water Intelligence.
- ZLD results in generation of hazardous solid wastes creating disposal challenges- need to think of Zero Waste Disposal (ZWD) Plants. Generate products/ by-products out of the waste.
- Economic viability- cost and availability of water, regulatory pressure are the real driving force.
- High Carbon foot print- is this environmentally sustainable?
- High Operating cost and financial impact on the industry and its Regional/ National/Global competitiveness.
- Technology shortcomings.



Section C- Case Studies for ZLD in Textile , Paper and Pulp



Tirupur Textile Effluent Management Project, Tirupur.. 1

- Project: TWIC has developed and established 9 Textile dyeing CETPs with a capacities ranging from 3 MLD to 11 MLD(Combined Capacity 53 MLD) in Tirupur based on Zero Liquid Discharge. The major components are BIOT, RO, Evaporator and Pipeline.
- Project Cost : Rs 540 Crores
- TWIC Role : TWIC has supported the Client in the following areas,
  - Preparation of Detailed Project Report
  - Selection of Technology & Preparation of Project Specification
  - Design Engineering, Procurement of contractor
  - Arranging Finance for the project
  - Implementation Supervision
  - O&M for 15 yrs as Independent Operator as advised by GoTN.

Tirupur Textile Effluent Management Project, Tirupur.. 2

- Benefits of this Project:

  The project for ZLD is perhaps the first of its kind in the world. Key benefits of the project are

  - Recycling >98% of the water.
  - Reuse of > 90% of the salt.
  - Cleaning of the local environment

- Current status

  - TWIC has also developed an alternate technology called “Treated Brine Reuse Technology” which substantially reduces the dependence on the evaporators.
  - Technology demonstration has enabled reopening of the dyeing units after closure by high court.
  - This has been successfully demonstrated at Arulpuram CETP and is now being implement in the remaining 6 TWIC developed CETPs. Modification cost of 7 CETP is Rs. 117.5 Crores.

Tirupur Textile Effluent Management Project, Tirupur.. 3

Pretreatment

Biological Treatment

Reverse Osmosis

Untreated & Treated Effluent

R.O reject – before treatment

R.O reject – after treatment

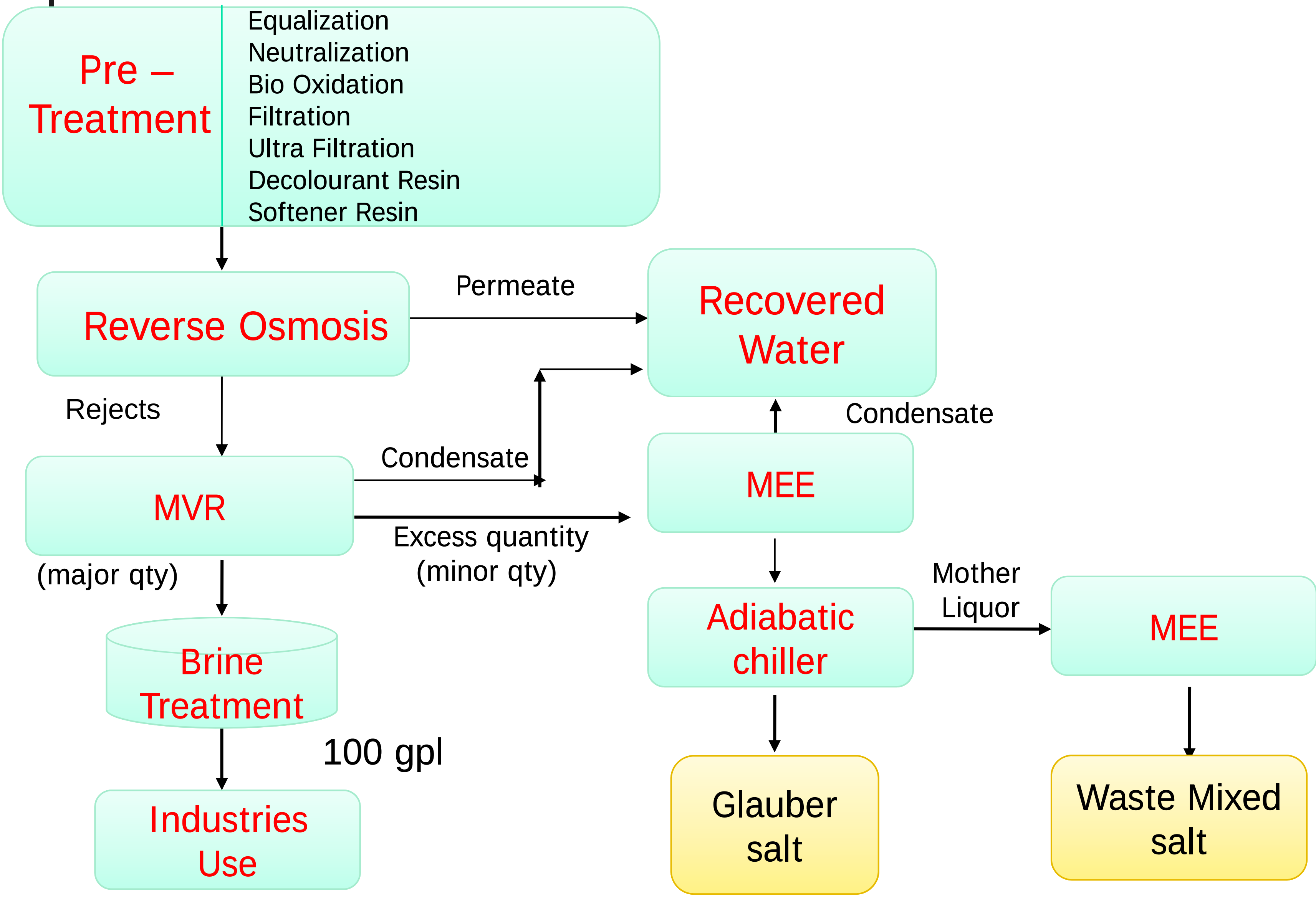
Lab trails using RO brine

O & M of Tirupur Textile CETP at Tirupur

Combined Effluent Characteristics

Sl.No	Parameters	Range
1	pH	8.5 - 10
2	BOD	400 - 500
3	COD	1000 -1200
4	TSS	200 - 300
5	TDS	6000 - 7000
6	Cl^-	400 - 700
7	SO_4^{2-}	2500 - 3100
8	Total Hardness as $CaCO_3$	100 - 150
All values are expressed in mg/l except pH		

Process Flow diagram of Textile CETPs



Brief Summary Performance of Arulpuram CETP

Raw effluent received (m3/month)	Recovered water sent to member units (m3/month)	Brine solution sent to member units (m3/ month)	Total recovery (m3/ month)	Wastage to solar pans (m3/ month)	Total Recovery %
85225	78708	3041	81749	453	**95.9%**

Average Raw effluent Salt concentration (gpl)	Average Brine concentration (gpl)	Salt received (Raw effluent received X Raw effluent concentration) (Tones/month)	Salt sent to member units as Brine (Brine solution sent to member units X Brine concentration) (Tones/month)	Salt in recovered water sent to member units (Recovered water sent to member unit X Recovered water concentration) (Tones/month)	Glauber salt produced with 55 % moisture (Total Glauber salt X 45%) (Tones/month)	Total Salt recovered (Tones/ month)	Salt recovery (Brine solution salt + Salt in recovered water + Salt without moisture) (%)
6.74	104	575	316	13	131	460	**80%**

Stage wise Quality Details .. 1

S.No	Parameter	Units	Influent	Recovered Water	Brine Solution (MVR Concentrate)
1	pH @ 25^0C		9.0	7.0	5.5
2	TDS	mg/l	6744	170	103972
3	Chloride as Cl^-	mg/l	734	34	11976
4	Sulphates as $SO_4 2^-$	mg/l	3142	19	56459
5	BOD @ 20^0C	mg/l	251	BDL	NA
6	COD	mg/l	1034	BDL	1820
7	TH as CaCO3	mg/l	111	BDL	129
9	Total Alkalinity as $CaCo_3$	mg/l	1538	48	178

Stage wise Quality Details .. 2

Quality of Recovered Glauber Salt:

S.NO	Parameter	Recovered Glauber Salt
1	Purity (%) as Sodium Sulphate @ 105^0C	98.5%
2	TH as $CaCO_3$ (mg/l)	Nil

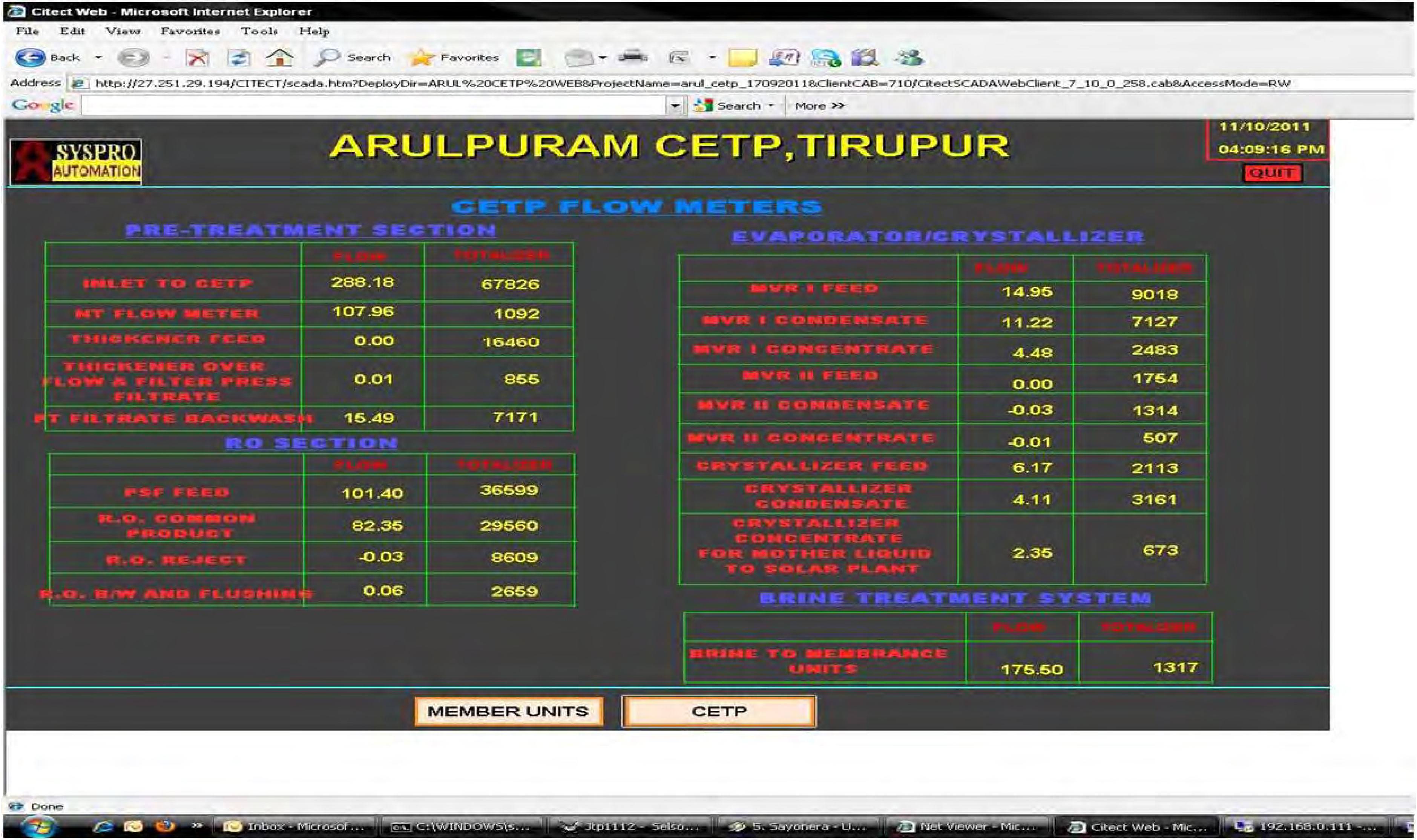
Approvals & Inspections done for the Arulpuram Demo .. 1

- DPR Approved by CES, Anna University
- Evaluation of the demonstration done by Anna University and report dated 31st Oct'11 Submitted to TNPCB.
- Evaluation also done by Secretary DST, GoI, who submitted his recommendation to MoT, GoI.
  - Also two members of the Technical committee constituted by MoT also visited and have submitted their satisfactory recommendations to MoT.
  - Following the above MoT advised all CETPs to follow TWIC Technology with TWIC as the Operator.

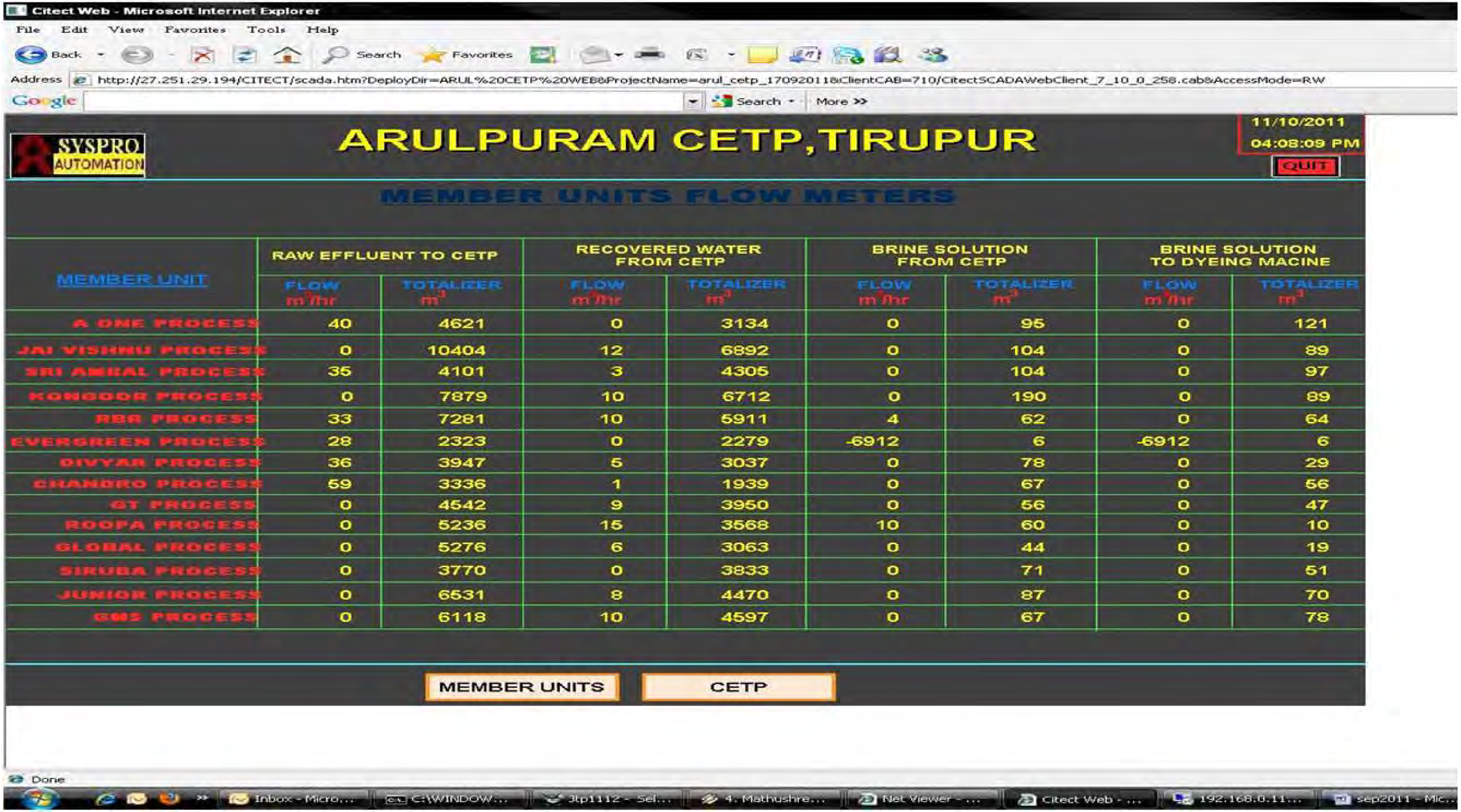
Approvals & Inspections done for the Arulpuram Demo .. 2

- Inspections were also done by court appointed Monitoring Committee and the Flying Squad and other officials of TNPCB.
- **Monitoring by PCB:** 24 hrs online Flow metering of raw, recovered water, brine and freshwater (4 Nos) in each dyeing member units & over 20 flow meters in the CETP uploaded continuously to a dedicated website / CETP Server.

Monitoring With SCADA – Arulpuram CETP.. 1



Monitoring With SCADA – Arulpuram CETP.. 2



ARULPURAM CETP,TIRUPUR

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MEMBER UNITS FLOW METERS

MEMBER UNIT	RAW EFFLUENT TO CETP		RECOVERED WATER FROM CETP		BRINE SOLUTION FROM CETP		BRINE SOLUTION TO DYEING MACINE	
	FLOW m^3/hr	TOTALIZER m^3	FLOW m^3/hr	TOTALIZER m^3	FLOW m^3/hr	TOTALIZER m^3	FLOW m^3/hr	TOTALIZER m^3
A ONE PROCESS	40	4621	0	3134	0	95	0	121
JAI VISHNU PROCESS	0	10404	12	6892	0	104	0	89
SRI AMBAL PROCESS	35	4101	3	4305	0	104	0	97
KONGOOR PROCESS	0	7879	10	6712	0	190	0	89
RBR PROCESS	33	7281	10	5911	4	62	0	64
EVERGREEN PROCESS	28	2323	0	2279	-6912	6	-6912	6
DIVYAR PROCESS	36	3947	5	3037	0	78	0	29
CHANDRO PROCESS	59	3336	1	1939	0	67	0	56
GT PROCESS	0	4542	9	3950	0	56	0	47
ROOPA PROCESS	0	5236	15	3568	10	60	0	10
GLOBAL PROCESS	0	5276	6	3063	0	44	0	19
SIRUBA PROCESS	0	3770	0	3833	0	71	0	51
JUNIOR PROCESS	0	6531	8	4470	0	87	0	70
GMS PROCESS	0	6118	10	4597	0	67	0	78

MEMBER UNITS | CETP

O&M Cost (Rs/m3) for 5.5 MLD capacity

S.No	Description	Operating Cost
I	**Variable Cost (**Power, Diesel, Chemicals, Cartridge Filter, Sludge Handling Charges, Maintenance & Firewood Cost)	**125-150**
II	**Fixed Cost (**Power, Manpower Cost, Replacement, Standard Maintenance, Lab Chemicals, Admin & Statuary)	**25-50**
	Total Operating Cost (Rs/m3) **(** Excluding Depreciation &Finance Cost **)**	**150 - 200**
III	**Recovery Cost (Rs/m3)**	
1	Cost of recovered Water(Including brine), Rs.70/Kl @98% recovery	68.6
2	Cost of recovered Sodium Sulphate salt @ Rs.10/Kg for 90% recovery of salt	63.0
	Total Recovery Cost (Rs /m3)	**131.6**
	Net Operating Cost (Rs/m3)	**30 - 70**

Financial Impact of ZLD for a Textile CETP

S.NO	Items	Value
1	Capacity of CETP	5500 m3/d
2	Water consumption for dyeing	50 L/Kg of Fabric
3	Total production capacity per day	110 tonnes
4	Processing cost of dyed fabric –	80 Rs/Kg
5	Processing Cost per day	Rs. 88Lakhs
6	Cost of ZLD system @ Rs. 30 - 70 Rs/KL net for 5.5 MLD	Rs. 1.65 – 3.85 Lakhs
7	Cost of ZLD per Kg of dyed fabric	1.5 to 3.5 Rs/ Kg
8	% of ZLD cost on Processing Cost of dyed fabric	1.9 – 4.37%

Basis

Liquor Ratio	1:3.5	1:5	1:8
Water Consumption	40	50	80
Hrs of Operation	6-8	8-10	10-12

Shade	L	M	D
Processing Rs/Kg	40-60	80	100

LARGE PULP& PAPER ETP

Technical and Commercial Feasibility for Development, Financing, Implementation and Operation of Zero Liquid Discharge Effluent Project for A Pulp & Paper Mill ..1

- Project:. In order to meet its environmental obligations, a major paper and newsprint manufacturer in South India has decided to implement a 10 MLD project for reuse of water.

- TWIC Role : Implementation and operation of the pilot plant and preparation of technical and commercial feasibility report as a precursor to development, financing, implementation and operation of Zero Liquid Discharge facility

- Benefits of this Project:

  The project would enable the Pulp mill in reducing its water consumption and further improve on the quality of treated wastewater used for irrigation.

- Current Status: Currently the 120 m3/day pilot plant has been successfully demonstrated. A full scale plant is now proposed.

Technical and Commercial Feasibility for Development, Financing, Implementation and Operation of Zero Liquid Discharge Effluent Project for a Pulp & Paper mill ..2

Aeration Tank

Ultra Filtration

Nano Filtration

Reverse Osmosis

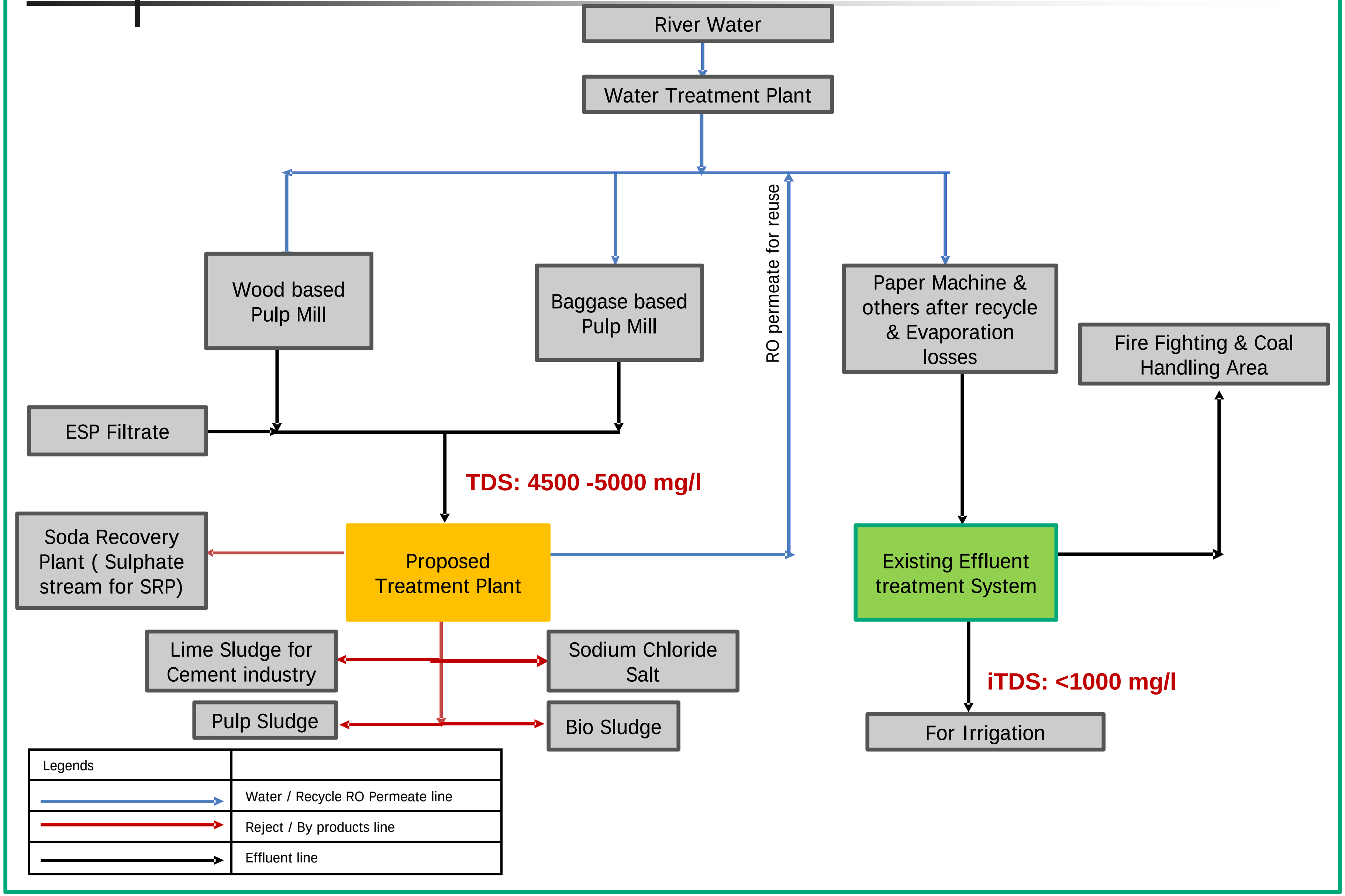
Background of The Project

- The Pulp & Paper Mill entered into a contract with TWIC with a view to improve the overall characteristics of the treated effluent being discharged. The Mill also was desirous of exploring the possibility of using treated water in the process

- TWIC recommended the setting up of a pilot plant for this purpose in order to evaluate various options

- The pilot plant was designed and commissioned in October 2011 and was operated for a period of 8 months

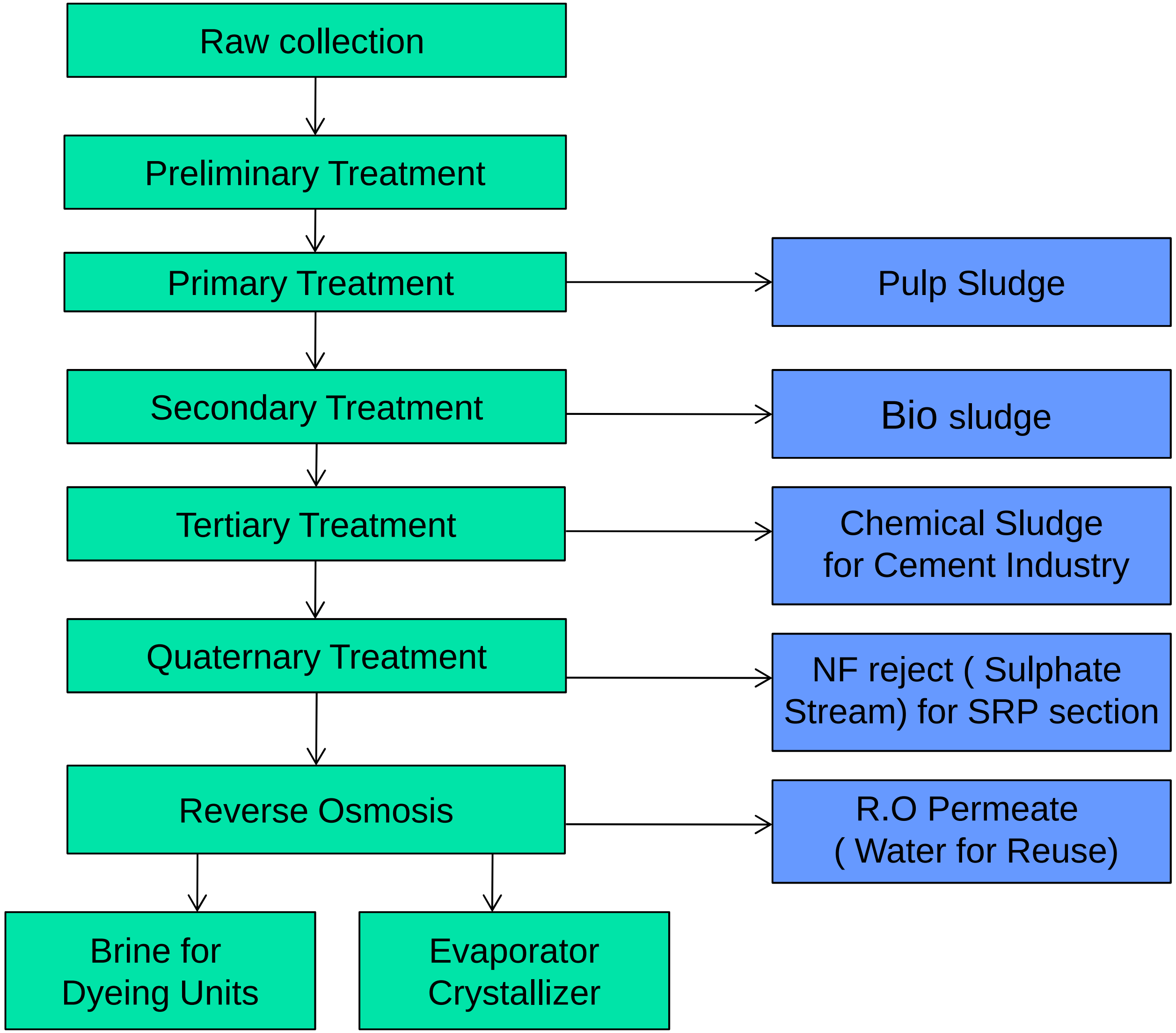
Proposed Treatment Scheme for Bleaching Effluent & Existing ETP



Effluent characteristics of Bleach Liquor at the Pulp & Paper Mill

Sl.No	Parameters	Range
1	pH	5.0 – 6.0
2	BOD	900-1100
3	COD	2000 - 3400
4	TSS	450 - 1000
5	TDS	4500 - 5800
6	Cl^-	1500 - 2000
7	SO_4^{2-}	500 - 600
8	Total Hardness	900 - 1200
All values are expressed in mg/l except pH.		

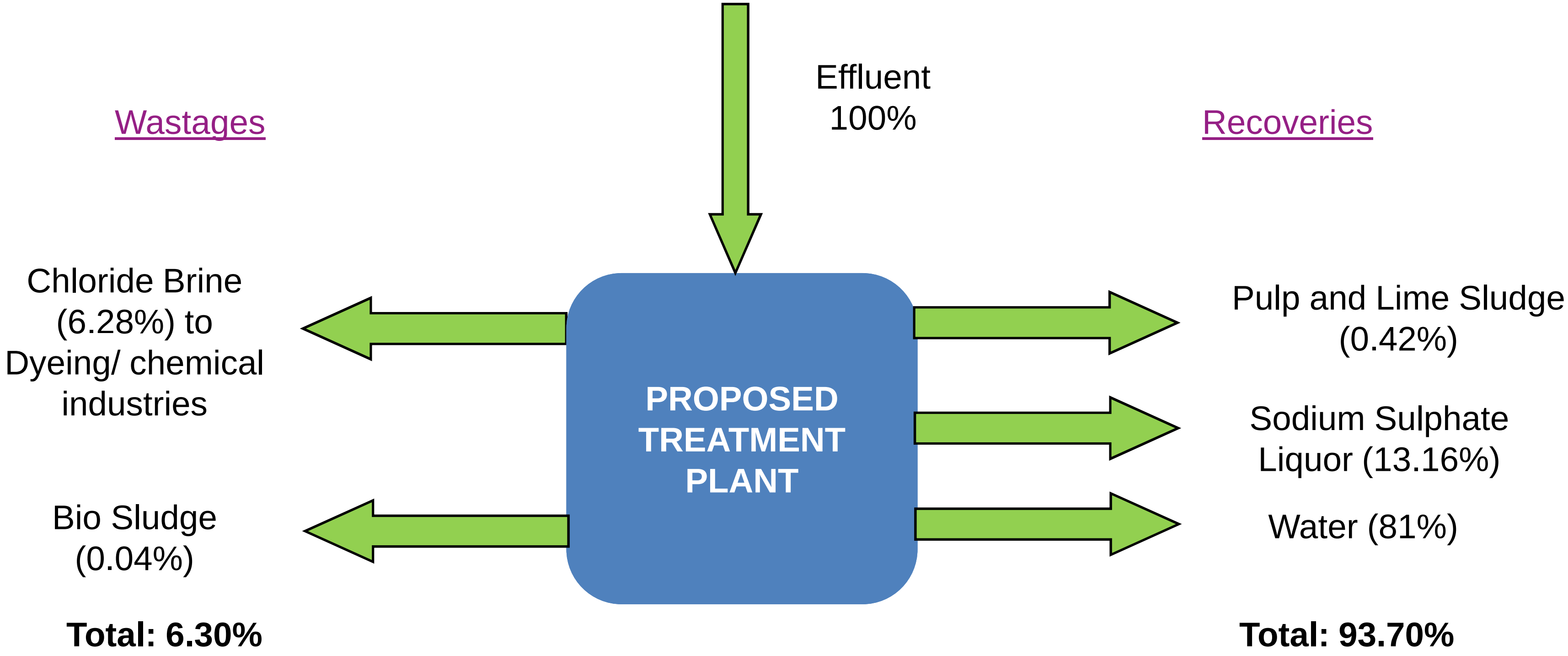
Simple Schematic of Proposed Process



Demonstration of Concept through a Pilot Plant

- Based on the schematic and discussions with client ,a detailed design & engineering was undertaken by TWIC
- The pilot plant was erected & commissioned in October 2011
- Pilot plant performance were evaluated for 6 months with hard wood bleach effluent ,further evaluations were carried out for another 2months
- Data generated based on the piloting provided inputs for designing of full scale plant

Summary of recoveries and wastages



Pilot Plant Stage wise Samples

Samples collected at different Point

Quality Of Various Recovered By-products

S. No	Parameters	units	Recovered Water (RO Permeate)	Sulphate stream (NF Reject)
1	pH		6	7.1
2	TSS	mg/l	0	21
3	TDS	mg/l	177	31328
4	Turbidity	NTU	0	8
5	COD	mg/l	1	1587
6	BOD	mg/l	1	3
7	Total Hardness	mg/l	0	51
8	NaCl	mg/l	134.4	5286
9	Total Silica	mg/l	0	29
10	Na_2SO_4	mg/l	0	16543

Lime sludge for cement plant

Description	Composition in % (Dry wt basis)
$CaCO_3$	75%
$MgCO_3$	12.6%
SiO_2	0.7%
Organic matter	9.15%
Moisture	1.8%

Quality of Chloride brine

Parameters	Purity in %
NaCl	90% - 95%
Na_2SO_4	**3 %- 4%**
Inert	**1%**

Robustness of the Technology

- During the piloting quality was changed due to change in the production process from high acidic bleaching process to low acidic bleaching process, which again reversed after a short period and then again low acidic pulping process was established.
- Parameters such as pH, sulphates, chlorides , hardness ,etc ,varied drastically during this period.
- However the performance of the pilot was more or less stable which proves the flexibility and robustness of the technology.

Benefits of the Project

- **Reduced TDS load**

  TDS level of the treated discharge effluent will be reduced

- **Production of high quality R.O Water**

  About 81 % of the effluent will be recovered as R.O permeate which saving water considerably

- **Generation of useful by products**

  By-products generated, such as, Sulphate and Lime sludge can be used within the paper mill. The high quality brine generated can be sold off to other industries, such as, dyeing industries or industrial salt manufacturers. For a 10 MLD plant 21.8 Tonnes/day of Na_2SO_4 and 36.3 Tones/day of lime sludge is expected.

- **Improving effluent Management Efficiency**

  Due to segregation ,treatment & recycling of these waste streams, the pollution load on the remaining composite effluent will be reduced. Therefore ,performance of the existing ETP will also improve.

- **Water Conservation**

  Due to recovery of about 81% of influent to ZLD plant, water consumption of the pulp mill will come down from 50 m3/ MT to 43 m3/ MT .

Estimated O&M Cost for 10 MLD ZLD Plant at Pulp Mill

S.No	Description	Operating Cost
I	**Variable Cost (Rs /m3)**	
	Energy, Steam, Chemicals & Consumables	59
II	**Fixed Cost (Rs /m3)**	
	Energy Cost, Manpower Cost, Lab Chemicals & Consumables, Maintenance Cost, Replacement Cost for Resins & Membranes	28
	Total Operating Cost (Rs/m3)	**87**
III	**Recovery Cost (Rs/m3)**	
1	Recovered Water	4.92
2	Pulp	0.40
3	Lime Sludge	2.16
4	Sodium Sulphate to Soda recovery	11.68
5	Chemical sludge to Cement Manufacturing	8.76
	Recovery Cost (Rs /m3)	**28**
	Net operating cost (Rs/m3)	**59**

Note: Depreciation and Financial costs not included. Cost of brine transportation extra.

Section D : Challenges with ZLD

Technology issues with thermal evaporation in ZLD systems for industrial wastewater

While the technology for conventional treatment and wastewater recycling R.O has more or less stabilized, the major issue has been with evaporation of R.O rejects in thermal evaporators. In fact several ZLD CETPs have failed due the failure of these Evaporators.

The major issues are:

- Very high evaporation costs (highly energy intensive 20-40 kWh/m3 as against 2-4 kWh/m3 for desalination).
- Technical limitations in evaporating mixed salts, which is typical for such industrial wastewaters due to problems in crystallization.
- The mixed salt is contaminated due to concentration of pollutants in the R.O rejects and even further during the Evaporation process. The mixed salts are unfit for reuse and create a serious storage and disposal issue. Typical contaminants which make it unfit for reuse are purity of salts, colour, organics (COD), nutrients, silica, heavy metals, hardness caused by calcium and Magnesium salts etc. The salt cake in most cases cannot be disposed off to landfills and require hazardous waste disposal facilities.
- Corrosion and scaling of the evaporators resulting reduced life and efficiency.
- Frequent interruptions and downtime affect processing capacity.

Some technology options and need for further research

- Extensive pre-treatment (preferably before R.O) to reduce hardness, silica, Colour and organics to reduce scaling and improved efficiency of Evaporator systems. Removal of contaminants will also make the salt crystallized fit for reuse.
- Segregation or separation of salts improving crystallization and possibility of reuse. E.g. separation of Chloride and Sulphate salts from a mixed wastewater.
- Possible reuse of salts within the same industry (e.g. salt in Textile dyeing) or as raw material for other industries (sulphate for pulp & paper industries).
- As Sodium Chloride (typically present in most wastewaters) is cheap and easily available disposal or transportation to the other industries in not cost effective. Production of by-products such as caustic, hypochlorite, Chlorine etc could be an option. However, the quality of salt required for such production is very high and therefore would require further research and implementation in pre-treatment technologies.
- Removal of nutrients, through biological methods, from the saline R.O concentrates brine could be tried before sea disposal. Possible options could be through Nitrification and denitrification, however limitations due to salinity concentrations and contaminants need to be understood and researched well for industrial application. Possibilities of use of algae for brine treatment also exist and could also be source of bio fuel.
- Other alternatives to thermal evaporation including solar evaporation (land area could be a limitation) needs to be explored further. Deep well disposal is an option so far not considered in India. This too may be worth studying as there are several such cases abroad.
- Need for the ZLD technology’s O&M cost to be low, typically less than one $.

Approach to ZLD.. 1

- Technology
  - Need for extensive piloting before implementation to demonstrated Techno-commercial feasibility.
  - One Size does not fit all: Need to remember "not all Textile dyeing effluent are same" or "not all Tannery effluent are same" or "not all paper industries are same" or "not all ZLD are same".
  - Since almost no EPC company provides 'in-house' all components of ZLD, there is an extensive need for integrating the complete process components to avoid problems. Therefore the Consultant should assure process performance guarantees.
  - Not just water balance but material balance for several critical parameters (not just TDS!)a must for correct process design.
  - Internal recirculation: Quality and quantity of backwash/ regeneration/ CIP /cleaning on the entire treatment process to be carefully accounted for in process design.
  - System design should be based on high 'Reliability Index'.
  - High Process Flexibility to be built in for various components to handle variations in effluent quality/ individual component performance. Design should be based on multiple process streams including standby and downtime.

Approach to ZLD…2

- Must focus on reduction of brine concentrate to reduce the need for evaporation and crystallization. Higher recovery in R.O possible subject to osmotic pressure limitations, but with elimination of Hardness, silica, foulants. High Pressure R.O systems available and are cost effective such as DTRO (90 – 160 bar).
- Avoid Evaporator usage due to high Carbon foot print (cannot justify the environmental gains of ZLD) and associated technical issues with evaporation of mixed salts in wastewater, as far as possible.
- Think "Zero Waste Discharge" to achieve Zero Liquid Discharge". Focus on salt recovery and reuse, salt separation and reduced sludge generation.

- O&M
  - Need for independent (for CETPs) and Professional O&M.
  - Most CETPs /ETPs are poorly managed and there is complete lack of certified ETP operator courses and dearth of well trained manpower.
  - Expenditure on O&M is an issue.
- Role of regulator
  - The PCB has essentially been a regulator without offering any "Technical Solutions" or advice. In some cases instead of applying standards based on 'Best Available Technology", the environmental standards have exceeded them. The result is that the PCB is not only battling against pollution but is also facing a slew of court cases. Monitoring 'round-the-clock' such a large number of industries are also not practical. Unequal application of law results in shifting of pollution to neighboring states or even districts.

CONCLUSIONS

- ZLD is a Technological Challenge, and the focus must be on Zero Waste Disposal (ZWD).
- Extensive research and piloting necessary for every single case for Technology selection and financial viability.
- Brine Concentration, Evaporation and Crystallization and disposal still a major issue. Focus must be on recovery and reuse of salts.
- Water Scarcity, Water economics and regulatory pressure are the main drivers of ZLD and will determine financial viability.

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THANK YOU