Zero Liquid Discharge in Textile Sector

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Introduction to Zero Liquid Discharge

ZLD stands for Zero Liquid Discharge - meaning zero discharge of wastewater from Industries.

Zero Liquid Discharge is a process that is beneficial to industrial and municipal organizations as well as the environment because it saves money and no effluent, or discharge, is left over. 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 requirements, enabling your business to:[1][4]

- Treat and recover valuable products from waste streams.
- Better manage produced water.

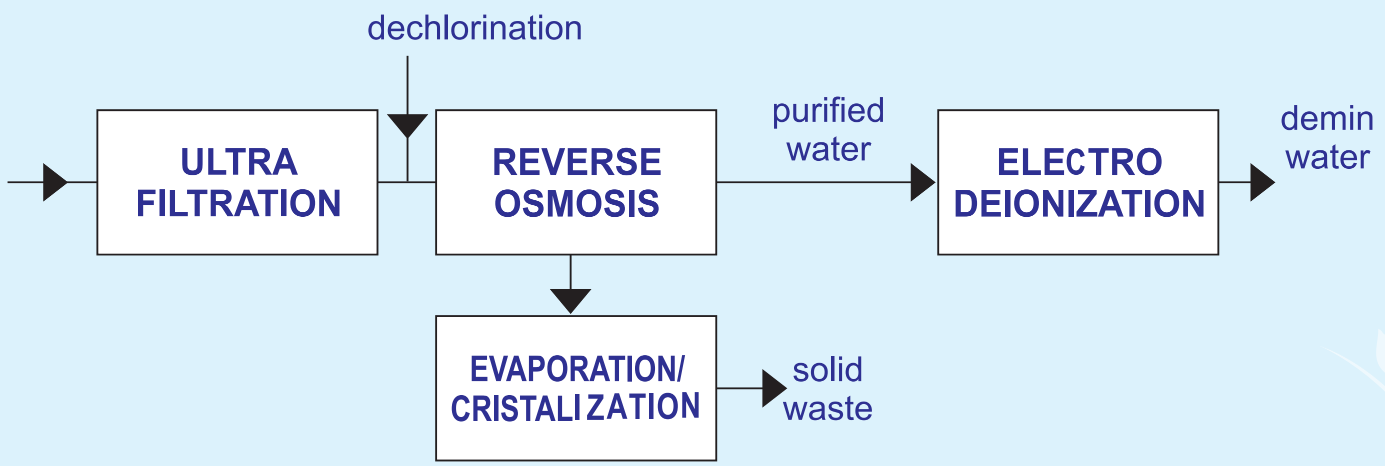

Fig. 1 : Diagram of Zero liquid discharge system

A **Zero liquid discharge facility** (ZLD), is an industrial plant without discharge of waste waters. Target ZLD is normally reached by

i) Quality of the waste water to be treated;

ii) Efficiency of the treatment system;

iii) Ability of the treatment system to withstand variability in the quality of waste water being treated over short-time (shocks) and long-time basis;

iv) Performance degradation of the machinery over a period of time;

v) Operation and maintenance issues such as backwash and cleaning operations;

vi) Mass-balance under different perceived operating conditions;

Need for ZLD

i) Industry uses huge volumes of pure water and is a major polluter of water courses;

ii) Conventional effluent treatment does not remove pollutants sufficiently - nutrients and salts are not well separated;

iii) Environmental regulation on discharge of specific solutes (salt, toxic elements, nitrate, nitrite etc);

iv) Water scarcity/water stress growing world, wide along with still negligible rate of waste water recycling;

v) Economics: recycled water becomes more affordable as the water supply from conventional sources becomes more expensive;

vi) Growing social responsibility and education towards awareness of environmental issues

vii) While ZLD cost is high in most cases, it might be a more economic solution; when waste needs to be transported in large volumes over long distances;

Zero liquid discharge treatment comprises of [3]

i) Primary Treatment

1. Equalization
2. Filtration
3. Mixers
4. Aeration
5. Anaerobic/Aerobic Digester and Biodegradability of Organics

ii) Secondary Treatment System

iii) Tertiary Treatment

However, the main objective in a zero discharge treatment system is to see that i) the processes utilized for waste water treatment does not generate any additional pollutants; ii) production of waste is minimized by suitable selection of unit processes and adjusting operating parameters; iii) as far as possible, pollutants in the wastewater are transferred to solid phase (sludge); iv) sludge is stored in a secured landfill; v) recovery of reusable materials, especially water, is achieved.

This article addresses how zero discharge can be achieved in a waste water treatment facility in textile sector. Article includes case study on zero liquid discharge at industrial level.

Arvind Santej Textile Dyeing - Closed Water Loop Concept, Gujarat, India[5],[6],[7]

Aravind Mills at Santej has one of the largest effluent recycle plants in Asia with recycling capacity 10,500 m^3/day. The latest & best of the technologies available in water / wastewater treatments can be seen in operation in this plant.

Procedure :

- Process : Bleaching, Neutralising, Washing, Primary Clarifier, Secondary Clarifier, Flocculator, Fixing & Softening.
- Sand filter to trap suspended solids.
- Pre-concentration in RO, recycle of water to process.
- Reject to MVR evaporation, recycle of condensate to process.
- Concentrate to FC-crystallization, recycle of condensate to process.
- Recovery of salts in centrifuge.

Plant capacity : 10,500 m^3/day

In operation since 2011

Closed Water Loop Concept, India

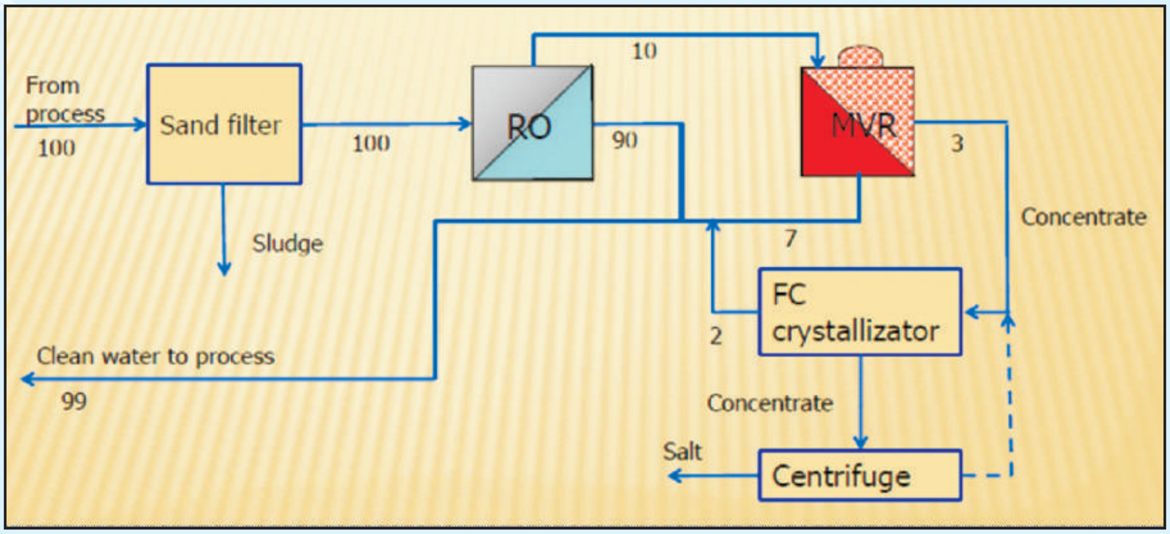

Fig. 2 : Diagram of Zero liquid discharge system

Note : Number refers to relative flow %

The MVR Plastic Evaporator

MVR's evaporation technique works in exactly the same way as conventional mechanical vapor recompression or multi-effect evaporators, but with a lower temperature difference. The MVR is designed to work efficiently at low temperatures without steam or coolants, reducing operating costs drastically.

Principle of Evaporation in an MVR Evaporator

The evaporator is based on the Mechanical Vapour Recompression principle. The energy source of the system is the latent heat released when the vapour evaporated from wastewater is condensed. This vapour is used as the heating medium after its pressure and temperature is increased using a high speed centrifugal fan as the vapour re-compressor. Preheated Effluent is pumped to the horizontal cylindrical vessel and uniformly distributed on the patented heat transfer element made of polymer. The polymeric heat exchanger modules are placed one after the other along the length of the vessel. As the water flows down, evaporation takes place. The vapours are sucked by a high speed centrifugal fan, which increases the pressure and saturation temperature. The saturated vapours condense on the inner surface of the polymeric heat exchanger and releases latent heat to the effluent. The clean condensate is then collected in a pipe connecting all the heat exchanger modules at the bottom. The concentrated effluent is pumped out for disposal or further treatment in a crystallizer. The entire system works under vacuum and the volatile gases, if any are removed by vacuum pump.

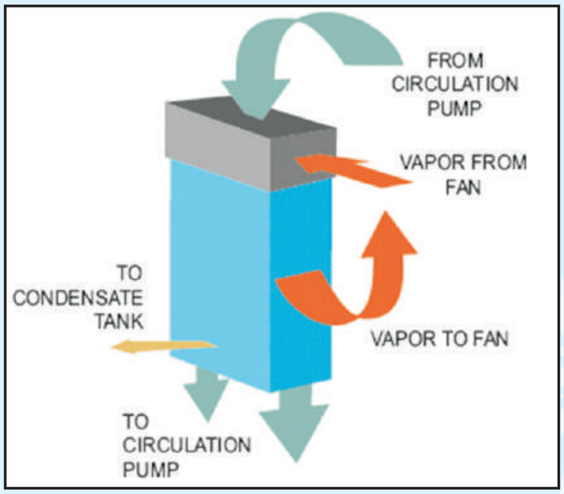

Fig. 3 : Polymeric Evaporative Heat Exchanger Cartridge

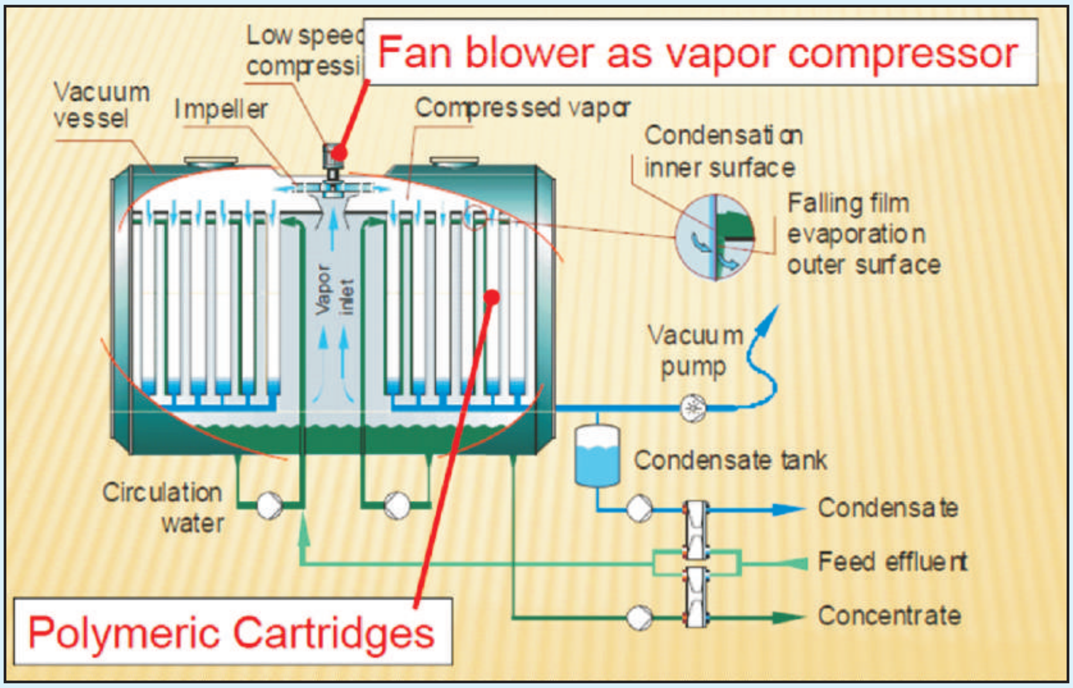

Fig. 4 : Schematic diagram of MVR system

Description of MVR evaporation

It is important before proceeding with a description of this technology to understand the production of steam or water vapor from liquid (boiling), this can be considered in two stages:

1. The liquid must be heated from room temperature to the boiling point. This process involves the addition of approximately 4,400 Joules/Kg for every degree Celsius the temperature raised. This amount of heat is known as the specific heat.
2. The liquid at boiling point is transformed into steam without an increase in temperature. This process requires the addition of very large amounts of heat - about 2,200,000 Joules/Kg of water vapor produced. This heat is known as the latent heat of vaporization. When water vapor condenses back into liquid it gives up the same latent heat.
3. Since every Joule of heat must be paid for in terms of fuel used, heating the water to boiling point (4,400 Joules) is a minor expense compared to the conversion to steam (2,200,000 Joules). Normal vapor-compression distillation is designed to allow latent heat to be "re-cycled" thus achieving far higher distillation production rates with lower energy input.

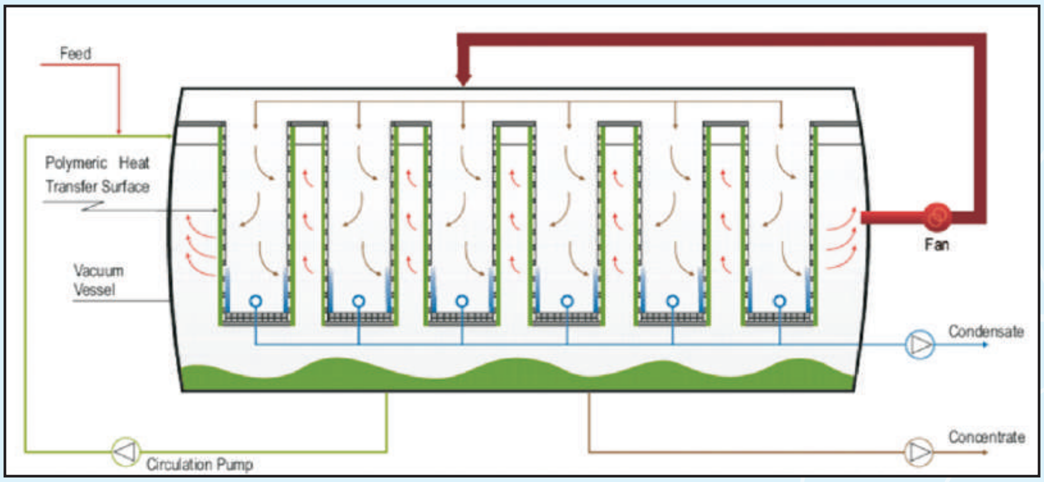

Fig. 5 : Mechanical vapour recompression cross sectional view

Fig. 6 : Polymeric film of an Evaporator

Table 1 : Analysis of Water parameters

Parameter	Unit	RO feed	Evaporator feed (MVR)	Condensate	Concentrate
pH		6-10	6 - 7	6 - 7	7-7,5
Temperature	ºC	35 - 45	35 - 45	45 - 55	50 - 55
TDS	mg/l	3.000 – 4.000	30.000 – 40.000	< 150	90.000 -120.000
BOD	mg/l	300 - 500			
COD	mg/l	1.000 -1.500			
Total Hardness	mg/l		500		

RO-recovery : 90%
Evaporator (MVR) recovery : 70%

Advantage of MVR Evaporator

1. Low cost evaporative surface results into
   - Large heat transfer surface
   - Small temperature difference
   - Simple, low speed fan as vapor compressor
   - Low power consumption
2. Polymer surface
   - Not prone for scaling
   - Can be operated in low pH
   - Corrosion resistant
3. Smooth surface
   - Easy cleaning
4. The major advantage of this technology is huge heat exchanger surface area can be Incorporated into the system at a very low cost.

Bombay Rayon Textile Dyeing - Closed Water Loop Concept, Bangalore, India [7],[9]

- Process:
  Bleaching, Neutralising, Washing, Dyeing, Acid washing, Washing, Soaping, Hot washing, Fixing & Softening.
- Effluent:
- Sand filter to trap suspended solids
- Pre-concentration in RO, recycle of water to process
- Reject to MVR evaporation, recycle of condensate to process
- Concentrate to ME evaporator for final concentration, recycle of condensate to process
- Concentrate to solar drying pond

Plant capacity 3 x 500 KLD

In operation since year 2006

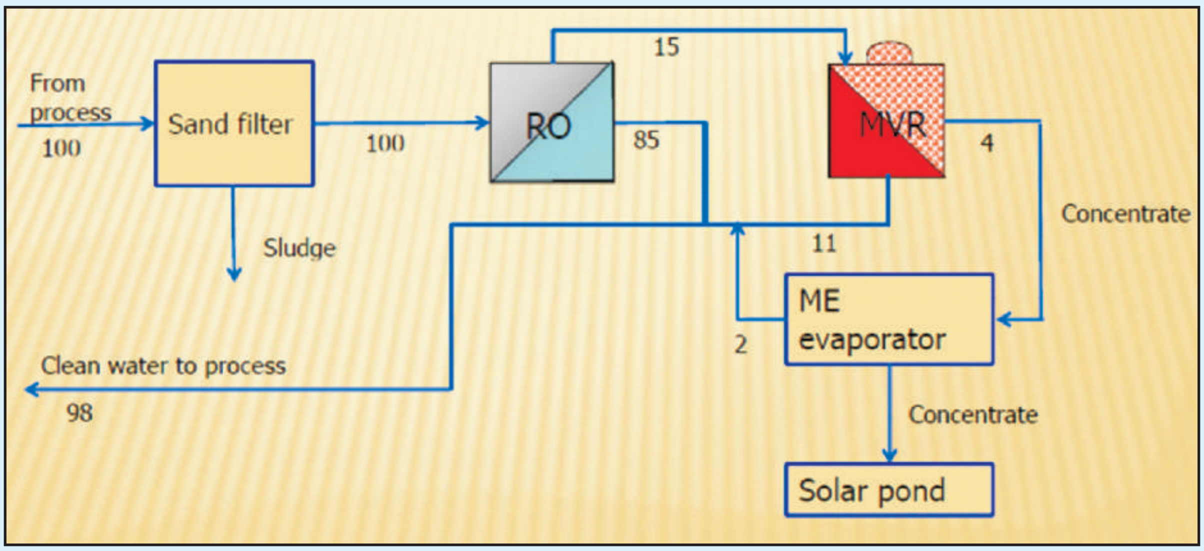

Fig. 7 : Water Balance diagram for Bombay Dying

Note : Number refers to relative flow %

Table 2 : Analysis of Water parameters

Parameter	Unit	RO feed	Evaporator feed (MVR)	Condensate	Concentrate
pH		6 - 10	6 - 7	7 – 7,5	7 - 7,5
Temperature	ºC	35 - 45	35 - 45	45 - 55	50 - 55
TDS	mg/l	3.000 – 4.000	25.000 – 30.000	< 125	100.000 - 120.000
BOD	mg/l	300 - 500			
COD	mg/l	1.000 -1.500			
Total Hardness	mg/l		200		

RO-recovery: 85%

Evaporator (MVR) recovery: 75%

Unique washing and dyeing industry limited, Gazipur, Bangladesh [11],[12]

Introduction

The textile and clothing industries provide the single source of economic growth in Bangladesh's rapidly developing economy. Exports of textiles and garments are the principal source of foreign exchange earnings. Agriculture for domestic consumption is Bangladesh's largest employment sector.

Water Consumption in Textile Processing

10-15% textile industries in Bangladesh adopted internationally acceptable water-treatment procedures, the remaining 60-70% or more industries lack or do not run such well-practiced technology, resulting in the harmful effluents release to the water bodies in order to save their factory cost.

The production of textile products is widely related to spinning, weaving / knitting, wet processing, and apparel manufacturing. The majority of the water consumption (60-70%) takes place in the wet processing of textiles.

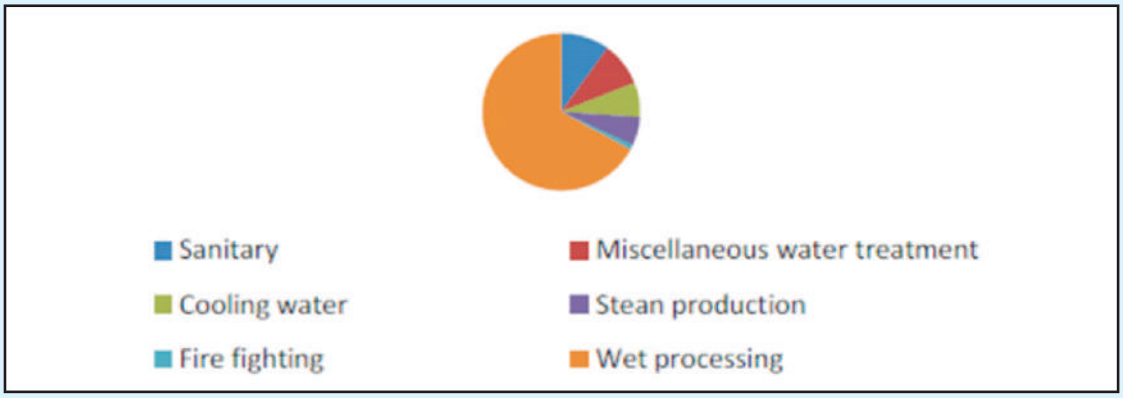

Fig. 8 : Bangladeshi textile industry water usages percentages

There are many dyeing industries in Bangladesh which are mainly located at Gazipur and Narayanganj industrial area. The garment sector now accounts for about 77% of the country's foreign exchange earnings, and 50% of its industrial work force. Textile is the most important sector of Bangladesh's economy. Textile industry uses large quantity of water in its production processes and highly polluted and toxic waste waters are discharged into sewers and drains without any kind of treatment.

Below table shows properties of Shitalakkhya river water sampled in the vicinity of the dyeing and garments washing activities. The tests were conducted by collecting river water at the adjacent point of several textile dyeing and garments washing plants from the Shitalakkhya River and compared with the river water standards.

Table 3 : Comparison of the Shitalakkhya river water with river standard forms

Parameters	River water (standard form)	Shitalakkhya River water (close to the Textile Mills
pH	6.5-8.5	10.5
DO (Dissolved Oxygen)	6 mg/l	3.5 mg/l
TDS (Total Dissolved Solids)	< 13 mg/l	44 mg/l
Conductivity	32 µS/cm	95 µS/cm

This study was aimed at the dyeing industries to assess the present situation of environmental impacts arising from the activities of dyeing industries in Bangladesh. The samples were collected from effluent water of a renowned and international buyer recognized industry named UNIQUE Washing and Dyeing industry Limited in Gazipur. [12]

The textile dyeing industries of Gazipur and Narayanganj generate large amount of effluents, sewage sludge and solid waste materials everyday which are being directly discharged into the surrounding channel, agricultural fields, irrigation channels, surface water and these finally enter in to Turag and Shitalakkhya River.

Effluent Treatment Technologies

All the dyeing industries should have the authentic waste water treatment plant but unfortunately there are many dyeing industries in Bangladesh which are running without any ETP. Only a few of them have ETP like Unique dyeing industry.

Textiles are dyed using reactive, dispersed, indanthrene or other kinds of dyes. These dyes use various types of chemicals. The concentrations of chemical substances in the effluent from this process always vary because of compound chemical reactions taking place and the effluent is colored. In the printing process high color impurities are generated. This is the last step of wet processing. The inducted coloring process uses various dyes depending on the buyer's wishes, including:

- For cotton: Reactive dye, direct dye, vat dye (Maximum efficiency 55%-65%);
- Basic dye, Acid dye;
- Sulpher dye (more useful for black shed), azoic dye, pigments; and
- For polyester: Dispersed dye (Efficiency 95%).

Unique has authentic waste water treatment plant which is designed by Techno economic service (from India). Their waste water from dyeing and washing section is refined to dispose in Turag River. The sludge produced from ETP is disposed in city corporation waste disposal center. Moreover the lime, alum from sludge is used as chemical fertilizer in local farm. The effluent flow chart layout collected from Unique is given in the Fig 8.

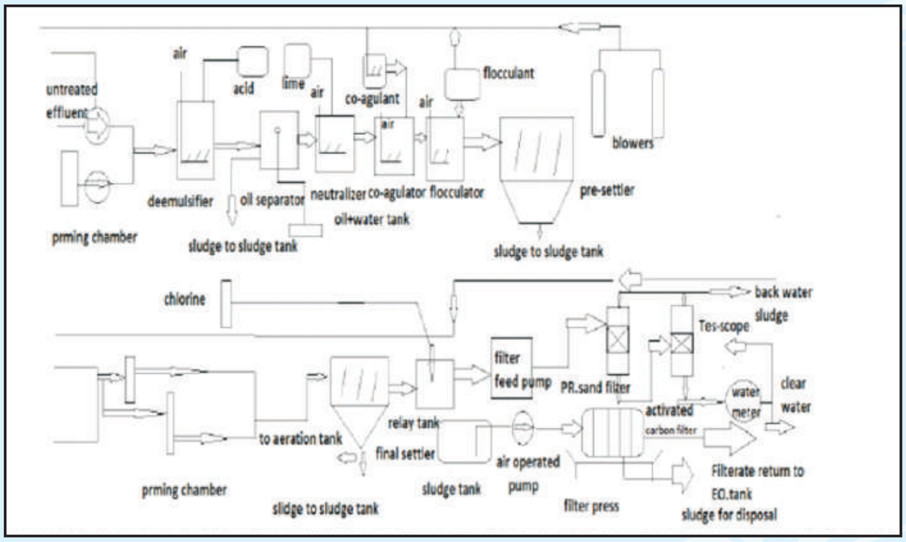

Fig. 9 : Effluent flow chart layout of Unique Washing and Dyeing industry Ltd.

Textile waste water can be handled by using evaporation and solid separation process. The technology is based on basic principle of reduction of quantity by concentrating the effluent and subsequently separation of salt and water.

1) The evaporation system :

Textile Effluent is fed to the vacuum evaporator to concentrate up to 40% solids concentration. The total process is under vacuum and the vapors generated in the system are re-used to economize steam consumption in multiple effect evaporation system with thermal vapour recompression system. The thermal vapour recompression system use Vapours generated in the evaporator and compress it by steam and the compressed vapours are used as heating

medium in the evaporator, in this way steam consumption is reduced. Water recovered from the evaporator has low COD/BOD value and can be recycled in the plant.

2) The separation process (Zero Liquid Discharge Section) :

The resultant slurry (concentrate) is fed to the thickener and centrifuging section for converting the liquid concentrate to solid waste. The mother liquor from thickener and centrifuge is recycled back to evaporator. The water separated out from evaporator is good enough in quality to recycle in the plant for Dyeing. The machinery used in separation process is shown in Fig 9.

Fig. 10 : Machinery used in separation process

Designing of Zero Discharge System

The designing of zero discharge system can also be helpful for textile effluent water. The zero discharge system can be implied to dyeing and bleaching operation. In this method the waste water is recovered from dyeing and bleaching operation and it is reused again in these two operations. So the environment has zero liquid discharge. The solid waste generated from this process should be stored in a secured landfill. It can minimize the effect of waste water on the environment as far as possible. Any zero discharge treatment system design should consider the following facts/requirements:

1. Quantity of the effluent to be treated.
2. Variability in time of the quantity as well as quality of the effluent.
3. Unit processes suitable for achieving desired purposes for the given nature of the effluent.
4. The upper and lower limits of performance of each unit process.
5. The durability of the system to be adopted.
6. The feasibility of establishing suitable collection and conveyance system in the case of a common treatment facility.

Treatment of textile dyeing and printing industry located in GIDC Pandesara, Surat, Gujarat, India Textile Dyeing using Semi conductor Photocatalysis [12],[13]

Introduction

Dyes are extensively used in the textile industry. The colour which dues impart to water bodies is very undesirable to the water user for aesthetic reasons. Due to high concentration of organics in the effluents and higher stability of modern synthetic dyes, their discharges into rivers are harmful to aquatic life. To minimize the harmful effects of the waste water a comparatively new method can be used like semiconductor photocatalysis.

Semiconductor photocatalysis is an attractive treatment for industrial wastewater. Semiconductor photocatalysis can be defined as the reaction in which the decomposition of organic substances in an aqueous solution by means of semiconductor likes TiO_2 or ZnO in presence of light.

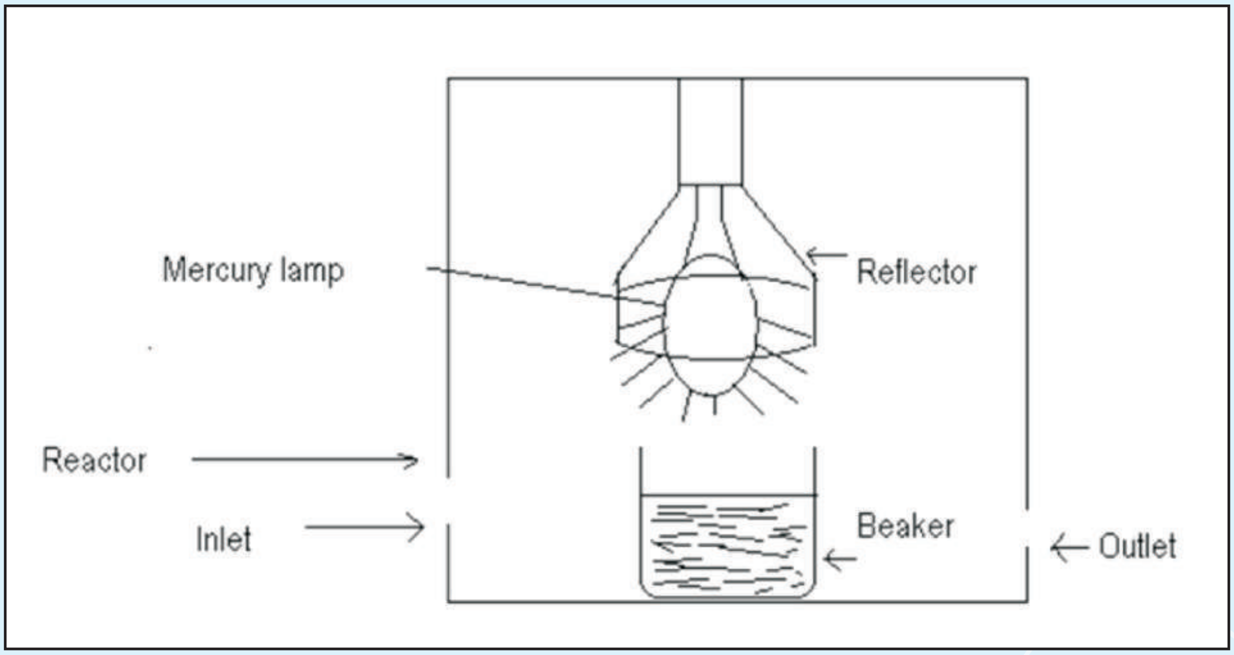

Fig. 11 : Schematic diagram for experimental set up.

Semiconductor photocatalysis is an aqueous process where the water is integral part of the reaction. Residence time may vary from 100 to 150 minute, and the Chemical Oxygen Demand (COD) removal may typically about 50-60 % insoluble organic matter is converted to soluble organic compound which are turn in oxidizing and eventually converted to CO_2 and water, without emission of NO_2, SO_2, HCl, furans, fly ash etc. Semiconductors are used to degrade the organic pollutant in water to less harmful materials. The removal of colour from wastewater is often more important than the removal of other organic colourless chemicals. Decolourization of effluent from textile dyeing and printing industry was regarded important, because of aesthetic and environmental concerns. The TiO_2 and ZnO have photocatalytic properties to be promising substrate for photodegradation of water pollution and show appropriate activity in the range of solar radiation. The overall benefits of the decolourization of textile industrial wastewater may include very interesting subject saving huge amount of water because textile dyeing industries are regarded as chemical intensive and water intensive. This type of industry has more pollutants and consumes a huge amount of water.

Material & Method[13]

The samples were analyzed for the various physico-chemical parameters as per standard methods. The samples were found to contain high COD and colour. The pH value of the wastewater sample varies from 5.9 to 9.2 .The samples were characterized for operational parameters such as pH, contact time, COD and BOD during the period of study. In this study TiO_2 powder (anatase) form and ZnO were used as supplied. The methodology consist of fabrication of reactor for semiconducting photocatalysis process, characterization of coloured wastewater and conducting preliminary studies to evaluate the effect of pH (4, 6, 8, 10), catalyst dosage (1, 2, 3, 4, and 5gL-1) and residence time (150minutes). In this study experiment were carried out in photocatalytic reactor which was made up of tin, the reactor consist of reflector (tin),400 watt Mercury lamp ,and water container with outlet and inlet due to temperature control. The experimental studies were performed to study the effect of pH, catalyst dosage, contact time on semiconductor photocatalysis .For coloured wastewater treatment initially the liquid solution was blended with catalyst (TiO_2 and ZnO) then put into the reactor under mercury lamp (400watt) for 30 minutes contact time and finally measured COD by standard methods up to residence time 150 minutes. The samples were taken at regular interval of 30 minutes during the course of semiconductor photocatalysis.

Results and Discussion

The samples were withdrawn periodically from the reactor and analyzed for COD. The results are presented in fig.12. The COD removal was increasing gradually as time proceeds, from the results it was observed that the sample can be treated up to 40% in terms of COD removal without the presence of catalyst. This confirms needs of catalyst for treating the coloured wastewater sample by semiconductor photocatalysis.

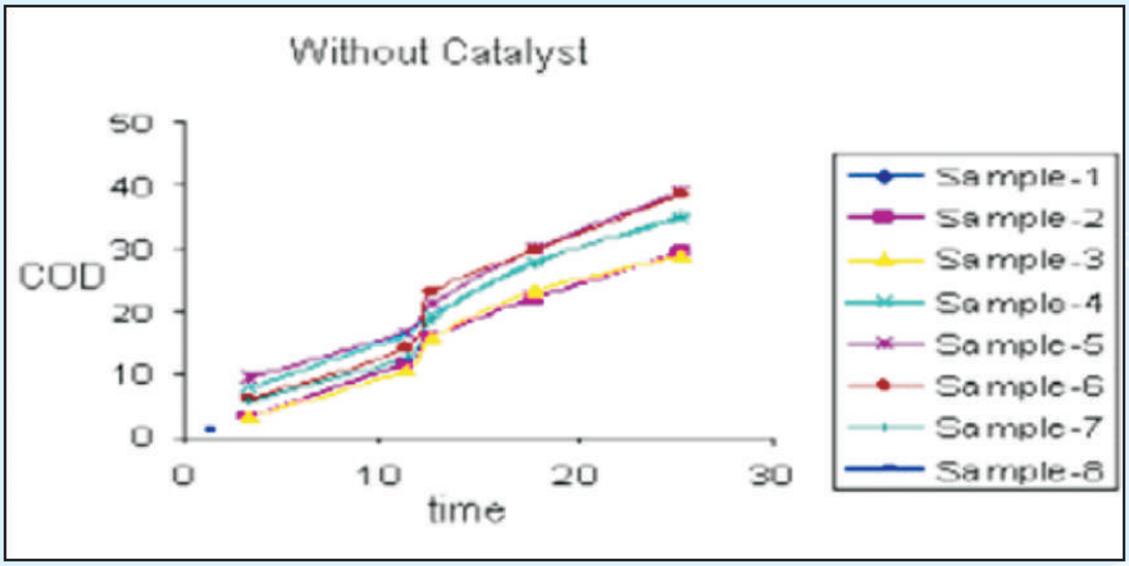

Fig. 12 : Plot shows experiment performed without catalyst

Effect of catalyst dosage

The influence of catalyst charged into reaction vessel on COD & colour removal has to be analyzed for studying the effect of catalyst dosage on degradation of coloured wastewater. The studies were carried out with the catalyst such as TiO_2 and ZnO separately to study effect on degradation.

The maximum COD removal achieved was 50% for TiO_2 and 60% for ZnO of semiconductor photocatalysis. From the results it was observed that the concentration of 5gL-1 for both TiO_2 and ZnO has the maximum effect on degrading the coloured wastewater.

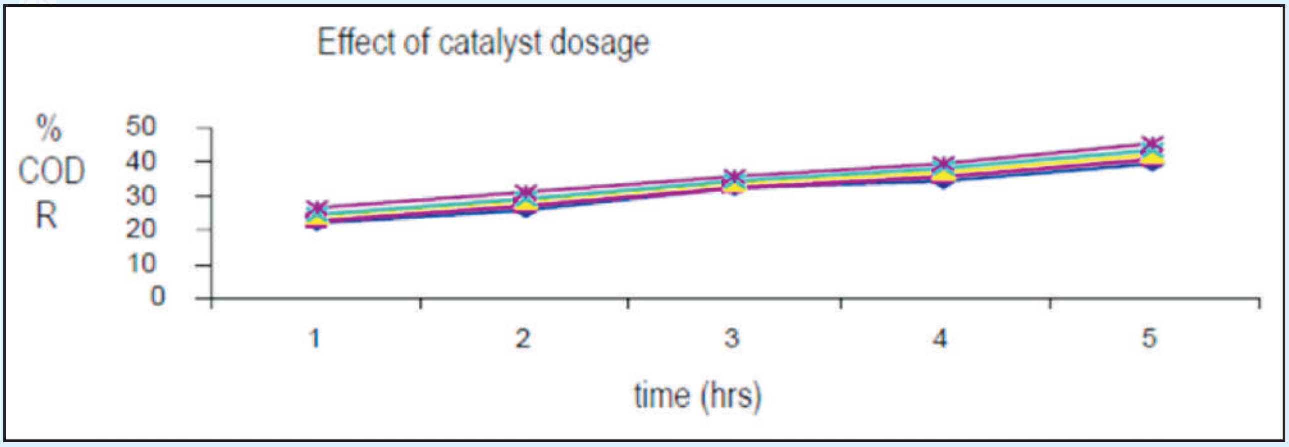

Fig. 13 : Effect of TiO_2 on wastewater sample

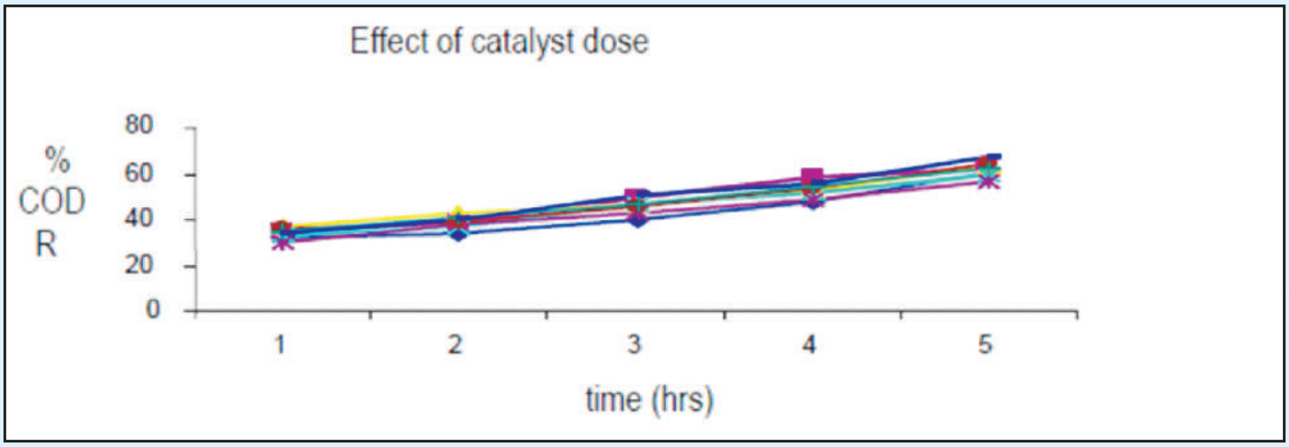

Fig. 14 : Effect of ZnO on wastewater sample

Effect of pH

The effect of pH was studied 4, 6, 8 and 10 using the catalysts TiO_2 and ZnO. The catalytic dosage was kept at the optimum concentration 5 g/L-1 for both TiO_2 and ZnO.

The experimental results are presented in (Fig.14) and (Fig 15). The results shows that maximum COD removal was found to be 50% for TiO_2 and 60% for ZnO at pH 8.

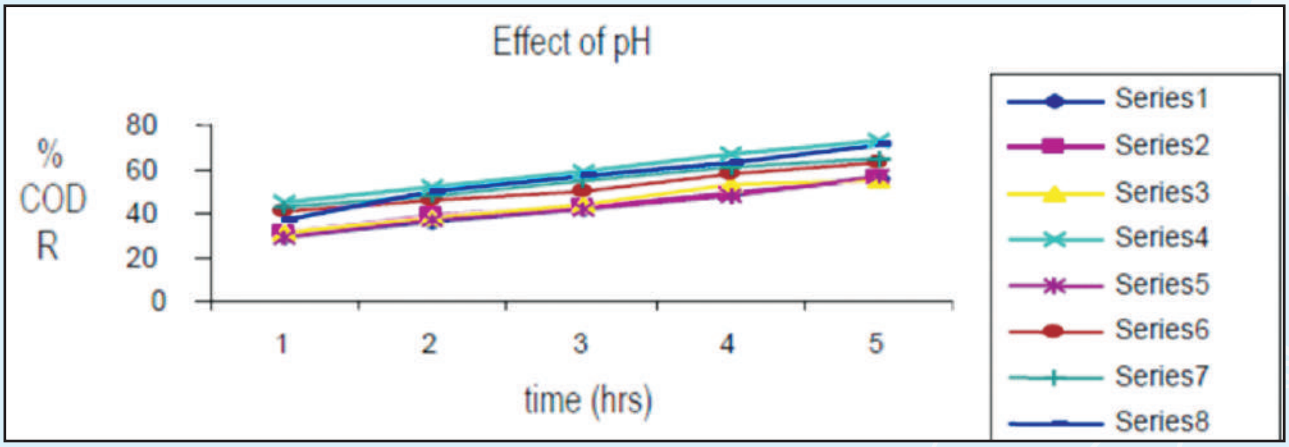

Fig. 15 : Effect of ZnO catalyst at pH 8.

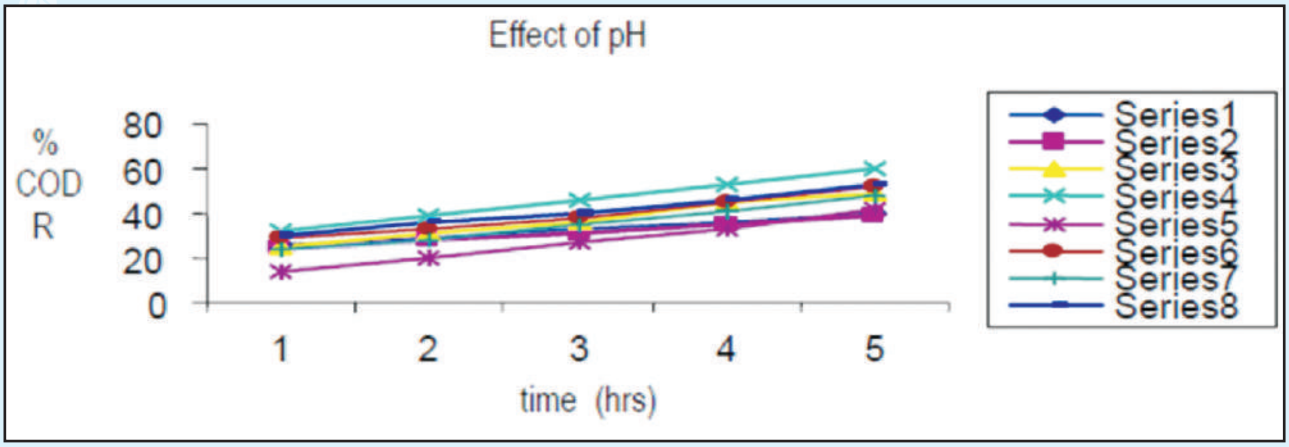

Fig. 16 : Effect of TiO_2 catalyst at pH 8

Effect of contact time

The effect of contact time on the degradation of coloured wastewater was studied at optimum pH 8 for both catalyst and optimum dosage 5 gL-1 for both TiO_2 and ZnO. Samples were taken at regular intervals and analyzed for COD removal to check the degradation of wastewater. From the results maximum COD removal was found 45% for TiO_2 and 50% for ZnO in 150 minutes of process duration.

BOD

The BOD test was carried out by diluting the sample with oxygen saturated de-ionized water, inoculating it with a fixed aliquot of seed, measuring the dissolved oxygen (DO) and then sealing the sample to prevent further oxygen dissolving in. The sample is kept at 20 °C in the dark to prevent photosynthesis (and thereby the addition of oxygen) for five days, and the dissolved oxygen is measured again. The difference between the final DO and initial DO is the BOD. The apparent BOD for the control was subtracted from the control result to provide the corrected value.

The loss of dissolved oxygen in the sample, once corrections have been made for the degree of dilution, is called the BOD5. BOD can be calculated by:

- Undiluted: Initial DO - Final DO = BOD
- Diluted: ((Initial DO - Final DO)- BOD of Seed) x Dilution Factor

Table 4 : Effect of catalyst performance

Sample	COD (mgL-1)	BOD (mgL-1)
1.	1808	250
2.	1824	200
3.	1512	345
4.	1592	260
5.	1432	330
6.	1584	315
7.	1612	380
8.	1740	270

Table 5 : Percentage of removal of COD by adsorbent dose TiO_2 5gL-1

Sample	30	60	90	120	150
1	26.5	30.8	35.8	39.5	45.0
2	23.1	26.4	30.4	37.1	43.8
3	20.4	28.1	31.4	39.1	45.7
4	30.1	37.6	43.0	48.9	56.2
5	14.9	20.1	26.7	34.2	42.5
6	24.1	26.8	36.1	41.9	46.5
7	22.4	29.2	37.2	44.4	51.4
8	21.6	29.4	34.2	40.9	48.7

Note : Time is taken in minute

Table 6: Percentage of removal of COD by adsorbent dose ZnO 5gL-1

Sample	30	60	90	120	150
1	19.2	24.1	27.7	30.6	37.5
2	17.6	22.6	27.8	32.9	39.1
3	24.0	30.3	36.9	45.6	51.6
4	35.4	42.2	47.1	51.4	56.7
5	17.3	244.3	30.3	36.4	44.8
6	24.5	26.1	38.1	44.1	49.3
7	31.1	33.4	43.6	47.8	52.5
8	28.1	35.9	38.9	45.2	49.7

Note : Time is taken in minute

The treatability studies focus that the semiconductor photocatalysis process could be used as alternative techniques from the degradation of textile dyeing and printing wastewater. By using semiconductor such as ZnO and TiO_2 removal of COD was achieved. The catalytic performance ZnO has been found to be more effective in degradation of the wastewater compared to TiO_2 with the operating parameters.

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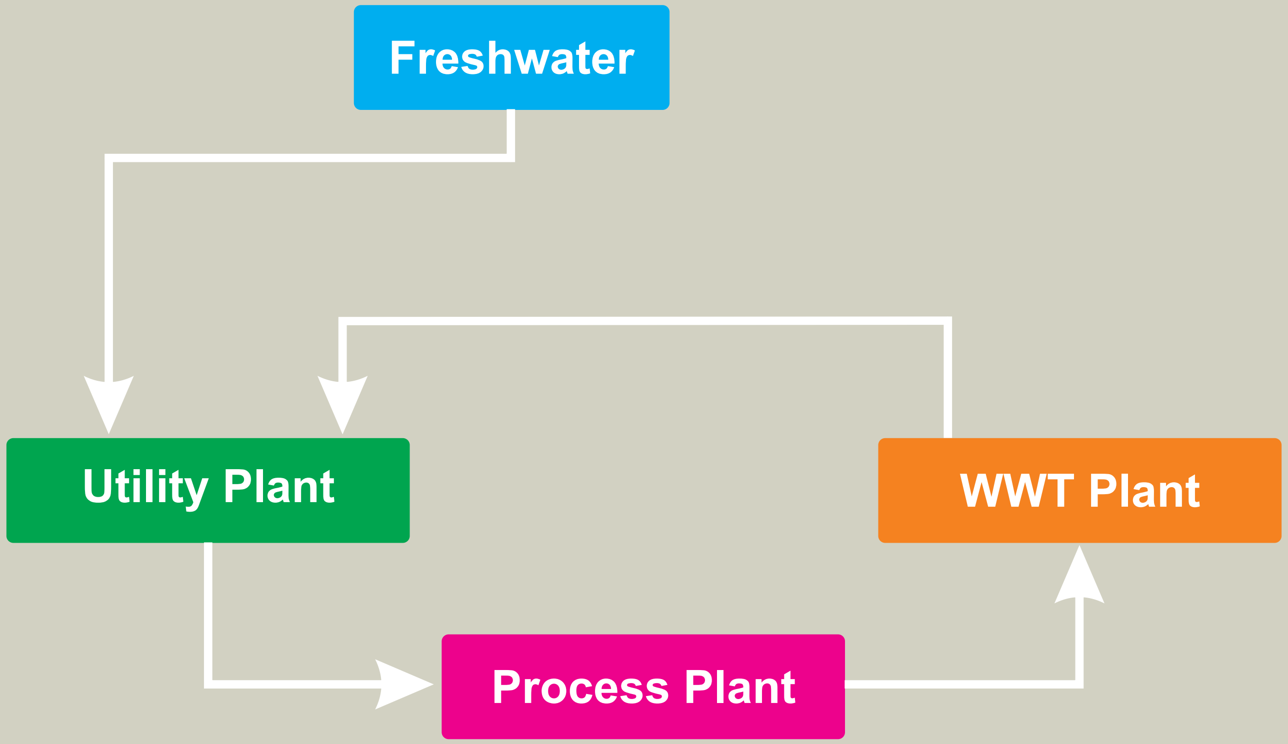

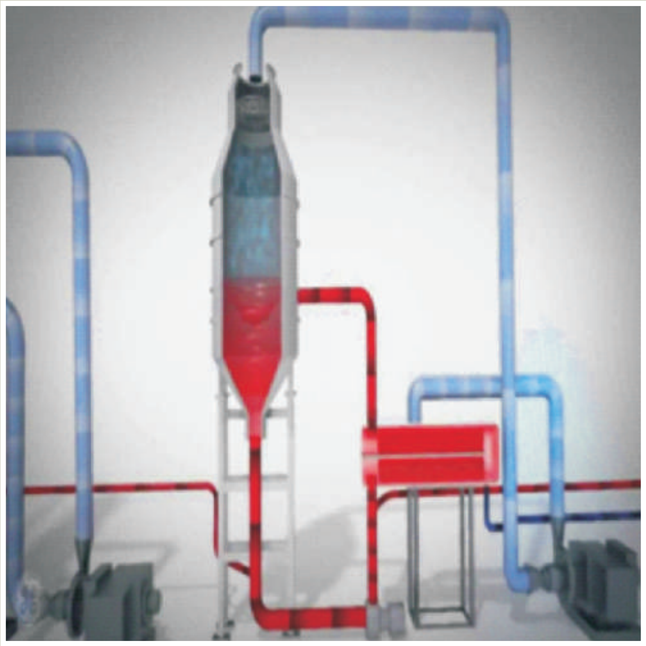

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