Global good practices in industrial wastewater treatment and disposal/reuse, with special reference to common effluent treatment plants

Central Pollution Control Board

(Ministry of Environment & Forests, Govt. of India)

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Executive Summary

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, especially with burgeoning small scale industrial sector in the country. To address the pollution coming out from industries, adoption of cleaner production technologies and waste minimization initiatives are being encouraged.

Common Effluent Treatment Plants (CETPs) are considered as one of the viable solution for small to medium enterprises for effective wastewater treatment. However, many of the operating CETPs are not performing optimally due to various technical and managerial reasons. This study has made an attempt to understand the issues related to the operating CETPs and provide information related to Best Available Techniques (BAT), along with economic feasibility.

The study has taken four prominent industrial sectors in the country, i.e. textile, tannery, pharmaceuticals and electroplating. For each of these sectors case studies which have adopted the BAT have been reported.

The textile industry is a water intensive sector and produces effluent with high levels of TSS and BOD. In the present report, a case study of a treatment plant in Germany is presented. The textile and clothing industry in Germany has oriented towards high quality and innovative products. This treatment plant is based on activated sludge process designed on low food-to-microorganism (F/M) ratio. The BOD is reduction is about 97%. Indian textile industries are also willing to upgrade technology and adapt technology to the Indian context. Many of the larger companies have already access to BAT. The report also documents a case study of Tirupur, Tamil Nadu, where zero liquid discharge (ZLD) system has been implemented. The BOD reduction is up to 98% and the Total Dissolved Solids (TDS) reduction is up to 97%. The water recovered has very low hardness, which is always demanded in textile sector for an improved finish and better quality dyeing.

Tannery sector in India has seen some advances in adoption of BAT, like adopting Zero Liquid Discharge (ZLD) technology by practicing reverse osmosis. Many countries are following the process of mixing tannery industry effluent with municipal waste water after some treatment for removal and recovery of heavy metals from the effluent. Some of the commendable case studies from Italy, Sweden and Netherland have been documented which efficiently remove nitrogen and sulphur from the effluent, along with main parameters COD. Special treatment to remove nitrogen from the effluent is generally not practiced in India. The reported Indian case study from Vaniambadi, Tamil Nadu is using BAT. Its performance has been analysed based on its trial operation results.

Pharmaceutical sector in India has taken a major leap after 1970. The pharmaceutical industry produces effluent having high concentration of organic matter. The high COD values and refractory nature of some organic compounds present are characteristics of pharmaceutical effluent. The report documents a case study of AstraZeneca effluent plant at Avlon Works, Avonmouth, United Kingdom. This plant has adopted anox Moving Bed Bio Reactor (MBBR) process which is a robust system followed by chemical phosphate removal and a Dissolved Air Flotation (DAF) plant. The plant uses plastic Bio carriers media which have high internal surface area and allow the biofilm to grow protected within these engineered plastic carriers. A case study of pharmaceutical sector in Patancheru CETP, Andhra Pradesh, India is also reported. In this plant the effluent is mixed with sewage to improve biological treatment amenability. The inlet parameters are regularly monitored and non-compliant tankers are rejected and sent back to the industries for further treatment of the effluent. This CETP has UF membrane bio reactor based treatment and the treated effluent is further polished at a public STP at Amberpet.

Electroplating sector discharges effluent with heavy metals like chromium and nickel. BEST Available Technologies (BAT) insists on recovering the metals and recycling the water. Technologies used for this purpose are Reverse Osmosis (RO), Ion-exchange, and Electro-dialysis and evaporation, etc. Documented case study from CETP in Ludhiana (India) is a Zero Liquid Discharge (ZLD) plant. Recovered water is reused by textile units. An innovative case of a Massachusetts company providing reagent based extraction of metals from effluent in a simple and cost effective manner is also reported. Based on the analysis, ion-exchange is evaluated to be effective in terms of efficiency and applicability.

It is inferred that for each case, with its unique set of issues, different technological solutions are needed. Moreover, technological solution is not the only factor. A survey was conducted with CETP operators and other stakeholders and it was concluded that operation and management issues plays an equally important role. In India, even though several CETPs have implemented latest and advanced technologies, but issues like, operation and maintenance, untrained staff, intermittent power supply, high operation cost, inappropriate design capacity, inadequate penalties for non-compliance, lack of regular monitoring of inlet and outlet parameters etc. are some major issues for the underperformance of CETPs. Therefore to solve the problem a holistic approach that take into account use of viable technologies as well as the support mechanisms and good management and business models, is required.

1. Introduction

This chapter discusses evolution of Common Effluent Treatment Plants (CETPs) in Indian context and their performance evaluation. A section in the report also presents the rationale for selecting industry sectors for this study, in particular to understand the best case studies. Since CETP case studies are not widely available, the study also discusses the treatment technologies in ETPs for various industries.

1.1 Background and evolution of CETP

The process of industrialization is adversely impacting the environment globally. Pollution due to inappropriate management of industrial wastewater is one of the major environmental problems particularly in India. With burgeoning numbers of Small Scale Industries (SSIs), concern towards the ever increasing volume of the effluent generated has tremendously increased. The volume of effluent generated by a cluster of SSIs at times surpasses the volume of wastewater generated by a single large industry. Also due to lack of space, technical manpower, and often finances, individual SSI cannot install and operate captive wastewater treatment plant, which constraints their ability to control pollution.

To address the pollution coming out from industries, adoption of cleaner production technologies and waste minimization initiatives are being encouraged across the globe. Developing economies have encouraged small scale industries for employment generation although they are known to be highly polluting. Common Effluent Treatment Plants (CETPs) are considered as one of the viable solution for small to medium enterprises for effective wastewater treatment.

In India, Ministry of Environment and Forest (MoEF) in 1991 initiated an innovative financial support scheme for CETPs to ensure growth of the small and medium entrepreneurs (SMEs) in an environmentally compatible manner. The provision of the scheme for fund is as follows;

- Central Government matching grants-25% of the project capital cost

  (this has been increased to 50% since 2012)
- State Government subsidy- 25% of the project capital cost
- Loans from financial institutions- 30% of the project capital cost, and
- Contribution from the SMEs-20% of the project capital cost

While initially the scheme was launched for first ten years, but considering the need, it was extended further. Accordingly the MoEF instructed various State Pollution Control Boards (SPCBs) to examine the possibilities of establishing CETPs in various industrial estates in the respective states. In India more than 150 CETPs have been set up so far under this scheme.

The concept of CETP was adopted as a way to achieve end-of-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 by environmental regulatory agencies and the investment of substantial government finances in the CETP scheme was justified on the basis of potential benefits in terms of pollution reduction and environmental improvements.

The main objective of establishing CETP is[1]:

- To reduce the treatment cost for individual units while protecting the environment.
- To achieve 'Economies of scale' in waste treatment, thereby reducing the cost of pollution abatement for individual factory.
- To minimize the problem of lack of technical assistance and trained personnel as fewer plants require fewer trained personnel.
- To solve the problem of lack of space as the centralized facility can be planned in advance to ensure that adequate space is available.
- To reduce the problems of monitoring for the pollution control boards.
- To organize the disposal of treated wastes and sludge and to improve the recycling and reuse possibilities as once individual units are required to pay for waste treatment/disposal, they tend to adopt means to reduce waste generation.

1.2 Status of CETPs in India

In the Indian context, given the small investment in establishing SMEs, provision of individual effluent treatment plants is not feasible due to high capital and operating cost. The disposal of treated effluents is also problematic as every individual industry cannot reach the water body through pipeline nor can it purchase land for inland irrigation.

MoEF therefore instructed the various SPCBs to examine the possibilities of establishing CETPs in various industrial estates. In response to the directive issued by the Central government, the State governments started identifying the locations for establishing CETPs. Work carried out in this context till 1990 was very limited. Till 1990, India had only one CETP in Jeedimetla near Hyderabad (Andhra Pradesh). Till 2005, around 88 CETPs had been established across the nation. The number of CETPs rose to more than 150 by the year 2011.

Table 1.1 Effluent treatment capacity of CETPs in different states of India (in MLD)

Sl. No.	State	CETPs in	Combined	CETPs in 2011	Combined
1.	AP	3	12.75	4	13.5
2.	Delhi	11	133.2	13	211.8
3.	Gujarat	16	156.3	26[1]	374
4.	Haryana	1	1.1	9	48.3
5.	Karnataka	2	1.3	7	7
6.	Maharashtra	11	63.25	25[2]	186.9
7.	MP	1	0.9	1	0.9
8.	Punjab	2	1.535	5	6.9
9.	Rajasthan	8	57.7	11	117.2
10.	Tamil Nadu	29	71.15	44	148
11.	UP	3	44.4	7	56.3
12.	WB	1	10	1	20
13.	Total	88	559.770	153	1191

[1]Two CETPs contribute to a final CETP (FETP), [2]One CETP contributes to another CETP

[1] Performance Status of Common Effluent Treatment Plants in India, CPCB, 2005

It can be seen on Table 1.1 that even though Tamil Nadu has the highest number of CETPs, Gujarat treats the highest amount of wastewater. Tamil Nadu has the distinction of being the state that has the maximum number of CETPs. This is due to large concentration of small scale garment and the leather processing units. Delhi, Maharashtra, Rajasthan and Uttar Pradesh also have a large number of CETPs and also treat a high volume of wastewater.

1.3 CETPs Performance

The technologies used in various CETPs all over India have been built on the best available technology[2]. In many cases, the CETPs have been upgraded to adopt better technology, but the overall performance of the CETPs in many cases is sub optimal. Central Pollution Control Board (CPCB) evaluated the performance of 78 operating CETPs in the year 2005 and came out with a status report[3] with following main observation:

- Unsatisfactory performance of CETPs is largely due to poor operation & maintenance.
- Meeting the design inlet quality to the CETPs that inter alia depends on effluent quality from contributing industries is key to achieving the standards for CETP effluent quality.
- High TDS in the raw influent reaching CETPs, and as a result in treated effluent of CETPs, is a widespread problem.

The CPCB report had suggested that the performance of CETPs has been largely unsatisfactory because of poor operation and maintenance therefore the SPCBs should conduct their regular monitoring of CETPs and take action against wilful defaulters. It further reiterated the fact that the SPCBs are required to prescribe specific set of pre-treatment standards for influent to CETP from each industrial sector and enforce them diligently. The report also recommended for need for area specific approach to tackle the problem of Total Dissolved Solids (TDS). Attempt should be towards reduction in use of TDS contributing chemicals in industries by adopting cleaner production technologies and recovery and recycling of chemicals from the waste streams.

1.4 Need for this study

In view of the underperformance of CETPs in India, this study has been envisioned to find and document global best practices of wastewater treatment in specific context of CETP. For this study industry specific cases have been analysed and documented in the report, along with some good sludge management and disposal practices.

1.4 Rationale for selection of industry for case study

Textile processing is the leading industry in terms of number of CETPs. This is followed by tanneries, which can be considered as the second highest industrial type in reference to number of CETPs catering to them. Based on this analysis, these two industries types have been taken up along with other two key industry types i.e. pharmaceuticals, and electroplating. Each of the four selected industry sectors are described in the upcoming chapters which details out the associated problems in terms of effluent characteristics, Best Available Techniques (BAT), and some case studies exemplifying the adoption of BAT.

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[2]Waste-water treatment technologies: A general review., United Nations, 2003

[3] Performance Status of Common Effluent Treatment Plants in India, A CPCB report, 2005

2. An Overview of Effluent Treatment Technologies

This chapter discusses in brief various treatment technologies involved in the process of wastewater treatment. In-depth knowledge of all these technologies and factors regulating the treatment mechanism is important for better management of CETPs or ETPs.

Wastewater depending on its characteristics is subjected to different treatment options. Basic wastewater treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter and, sometimes, nutrients from wastewater. General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary and/or advanced wastewater treatment. These are described below in brief.

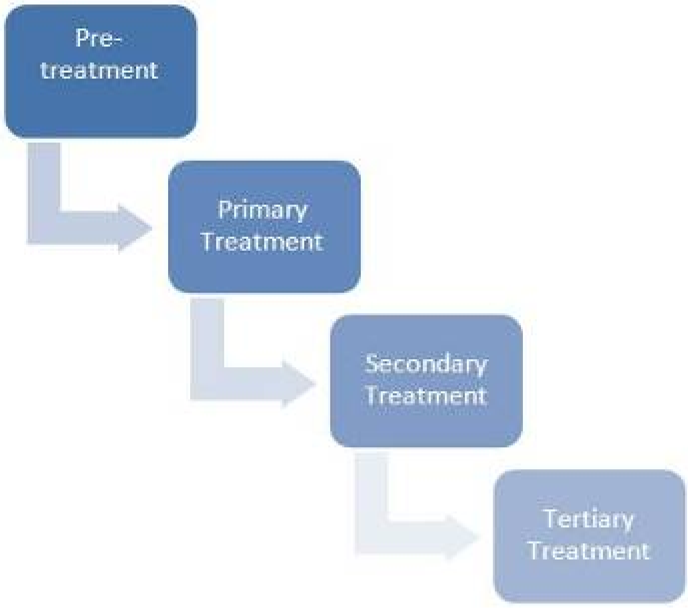

Figure 2.1 Wastewater Treatment Process

2.1 Preliminary treatment

Preliminary treatment is required to remove the coarse solids and other large materials from raw wastewater. Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units. A number of unit operations are engaged in the preliminary treatment of wastewater to eliminate undesirable characteristics of wastewater. The operations include use of screens and grates for removal of large materials, comminutors for grinding of coarse solids, pre-aeration for odour control. Sometimes pH correction and removal of oil & grease is also done. At times, member industries do preliminary treatment in their premises, before sending the effluent to CETP for further treatment. If preliminary treatment or pre-treatment is taken up by individual member industry, it improves the performance of CETP.

2.2 Primary treatment

Primary wastewater treatment, at times, is the first step in the wastewater treatment process or it may be the second step after the preliminary treatment. It involves physical separation of suspended solids from the wastewater using primary clarifiers. This process is helpful in reduction of total suspended solids (TSS) and associated biochemical oxygen demand (BOD) levels and prepares the waste for the next step in the wastewater treatment process. The objective of primary treatment is to remove of settleable organic and inorganic solids by sedimentation and removal of materials that float (scum) by skimming. Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (TSS), and 65% of the oil and grease are removed during primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected. The effluent from primary sedimentation units is referred to as primary effluent. Primary treatment ensures satisfactory performance of subsequent treatment units.

Sedimentation chambers are the main units involved but various auxiliary processes such as fine screening, flocculation and floatation may also be used.

The second step may be chemical treatment (generally with lime and alum) which is sometimes preceded by flocculation. The purpose is to remove metals by precipitation but it also removes some associated colloidal BOD. The process generates chemical sludge.

The primary treatment involves various physical-chemical processes:

- Flocculation-It is a physico-chemical process that encourages the aggregation of coagulated colloidal and finely divided suspended matter by physical mixing or chemical coagulant aids. Flocculation process consists of a rapid mix tank and a flocculation tank. The process involves mixing of wastewater stream with coagulants in a rapid mix tank, which is then passed on to the flocculation basin where slow mixing of waste occurs which allows the particles to agglomerate into heavier more settleable solids. Either mechanical paddles or diffused air facilitates better mixing.

  The different types of chemicals used in coagulation include inorganic electrolytes, natural organic polymers and synthetic poly electrolytes. The selection of a specific chemical depends on the characteristics and chemical properties of the contaminants.

- Sedimentation- This process is aimed to remove easily settleable solids. Sedimentation chambers may also include baffles and oil skimmers to remove grease and floatable solids and may include mechanical scrapers for removal of sludge at the bottom of the chamber.

- Dissolved Air Floatation- Use of bubbles in this process is required to raise the suspended particles in wastewater up to surface level and hence make it easy for their collection and removal. Air-bubbles are introduced into the wastewater and attach themselves to the particles, thus causing them to float. This process of diffused air flotation can be used to remove suspended solids and dispersed oil and grease from oily wastewater. Wastewater is pressurised and contacted with air in a retention tank. The pressurised water that is super-saturated with air is passed through a pressure-reducing valve and introduced into at the bottom of floatation tank. As soon as pressure is released the super-saturated air begins to come out of solution in the form of fine bubbles. The bubbles get attached to suspended particles and become enmeshed in sludge flocs, floating them to surface. Float is continuously swept from the surface and sludge may be collected from the bottom. Addition of certain coagulants increases the oil removal efficiency of DAF units.

- Clarification- Clarification system uses gravity to provide continuous, low cost separation and removal of particulate, flocculated impurities and precipitates from water and generally follow the processes which generate suspended solids such as biological treatment. In a clarifier, wastewater is allowed to flow slowly and uniformly, permitting the solids to settle down. The clarified water flows from the top of the clarifier over the weir. Solids get collected at the bottom and sludge must be periodically removed, dewatered and safely disposed.

Chemical Treatment Processes

Chemical treatment may be used at any stage in the treatment process as and when required (preferably before biological treatment as it removes toxic chemicals which may kill the microbes). Mainly used methods are-

- Neutralization- Incoming untreated wastewater has a wide range of pH, and it is difficult to treat wastewater with such a high variability of pH. Neutralization is the process used for adjusting pH to optimize treatment efficiency. Acids such as sulphuric or hydrochloric may be added to reduce pH or alkalis such as dehydrated lime or sodium hydroxide may be added to raise pH values. Neutralization may take place in a holding, rapid mix or an equalization tank. It can be carried out at the end of the treatment also to control the pH of discharge in order to meet the standards.
- Precipitation- For removal of metal compounds from the stream of wastewater, precipitation is carried out in two steps. In the first step, precipitants are mixed with wastewater allowing the formation of insoluble metal precipitants. In the second step, precipitated metals are removed from wastewater through clarification and/or filtration and the resulting sludge must be properly treated, recycled or disposed. pH is an important parameter to consider in chemical precipitation. Metal hydroxides are amphoteric in nature and their solubility increases towards higher or lower pH. Thus, there is an optimum pH for hydroxide precipitation for each metal. Wastewater generally contains more than one metal. Therefore, selecting the optimum treatment chemical and pH becomes more difficult and involves a trade-off between optimum removal of two or more metals. Various chemicals used for this process are lime, sodium hydroxide, soda ash, sodium sulphide and ferrous sulphate. Normally, hydroxide precipitation which is effective in removing metals like antimony, arsenic, chromium, copper, lead, nickel and zinc. Sulphide precipitation is used in removing mercury, lead, copper, silver, cadmium etc.

2.3 Secondary treatment

This process involves decomposition of suspended and dissolved organic matter in waste water using microbes. The mainly used biological treatment processes are activated sludge process or the biological filtration methods.

Biological treatment processes mainly used for secondary treatment and are based on microbial action to decompose suspended and dissolved organic wastewater. Microbes use the organic compounds as both a source of carbon and as a source of energy.

Biological treatment can be either aerobic where microbes require oxygen to grow or anaerobic where microbes grow in absence of oxygen or facultative where microbes can grow with or without oxygen. Micro-organisms may be either attached to surface as in trickling filter or be unattached in a liquid suspension as in activated sludge process.

Activated sludge process- It is a continuous flow, aerobic biological treatment process that involves suspended growth of aerobic micro-organisms to biodegrade organic contaminants. Influent is introduced in the aeration basin and is allowed to mix with the contents. A suspension of aerobic microbes is maintained in the aeration tank. A series of biochemical reactions in the basin degrade the organics and generate new bio mass. Micro-organisms oxidize the matter into carbon dioxide and water using the supplied oxygen. These organisms agglomerate colloidal and particulate solids. The mixture is passed to a settling tank or a clarifier where micro-organisms are separated from the treated water. The settled solids are recycled back to the aeration tank to maintain a desired concentration of micro-organisms in the reactor and some of the excess solids are sent to sludge handling facilities. To ensure biological stabilization of organic compounds, adequate nutrient levels of nitrogen and phosphorous must be available to the bio mass. The key variables to the effectiveness of the system include:

a) Organic loading which is described as food to micro-organism ratio (F/M) ratio or Kg of BOD applied daily to the system per Kg of biological solids in aeration tank. F/M ratio determines BOD removal, oxygen requirements and bio mass production. Systems designed and operated at lower F/M provide higher treatment efficiency.

b) Sludge retention time (SRT) or sludge age is the measure of the average retention time of solids in the system and the SRT, similar to F/M ratio, affects the degree of treatment, oxygen requirements and the production of waste sludge. Systems designed and operated at higher SRT provide higher treatment efficiency.

c) Oxygen requirements are based on the amount required for biodegradation of organic matter and the amount required for endogenous respiration of micro-organisms.

Various modifications in activated sludge process are possible by changing one or more of the key parameters. Sequential batch reactor is a form of the activated sludge process where aeration, sedimentation and decantation processes are performed in a single reactor.

Biological filters - These filters are biological reactors filled with media which provide a surface that is repeatedly exposed to wastewater and air and on which a microbial layer can grow. The two most common types of biological filters are;

a) Trickling Filters: In trickling filters treatment is provide by a fixed film of microbes that forms on the surface which adsorbs organic particles and degrades them aerobically. Wastewater is distributed over a bed made of rock or plastic and flows over the media by gravity.

b) Rotating Biological Contractor: A rotating biological contactor (RBC) consists of a series of discs about 40% of the area is immersed in waste water and the remainder of the surface is exposed to atmosphere, provide a surface for microbial slime layer. The alternating immersion and aeration of a given portion of the disc enhances growth of the attached micro-organisms and facilitates oxidation of organic matter in a relatively short time and provides a high degree of treatment.

Anaerobic Treatment Systems- These processes are slower than aerobic degradation and when sulphur is present, obnoxious hydrogen sulphide gas is generated. Though the capital cost is high, part of it can be compensated by recovery of bio gas. They are not so commonly used in wastewater treatment systems for CETPs except as a means for sludge stabilization.

2.4 Tertiary treatment

Tertiary treatment may include a number of physical and chemical treatment processes that can be used after the biological treatment to meet the treatment objectives.

It is the next wastewater treatment process after secondary treatment. This step removes persistent contaminants that secondary treatment is not able to remove. Tertiary treatment is the final cleaning process that improves wastewater quality before it is reused, recycled or discharged to the environment. Tertiary treatment is used for effluent polishing (BOD, TSS), nutrient removal (N, P), toxin removal (pesticides, VOCs, metals) etc.

Tertiary treatment can also be extensions of conventional secondary biological treatment to further stabilize oxygen-demanding substances in the wastewater, or to remove nitrogen and phosphorus.

Tertiary treatment can also involve physical-chemical separation techniques such as activated carbon adsorption, flocculation/precipitation, membranes filtration, ion exchange, de-chlorination and reverse osmosis.

Advanced treatment processes which generally constitute of or are part of the tertiary treatment may also sometimes be used in primary or secondary treatment or used in place of secondary treatment.

Some of the common tertiary treatment processes are described below:

- Granular Media Filtration- Many processes fall under this category and the common element being the use of mineral particles as the filtration medium. It removes suspended solids mainly by physical filtration. Two common types of these granular media filers are

  a) Sand filters are the most common type which consists of either a fixed or moving bed of media that traps and removes suspended solids from water passing through media.

  b) Dual or multimedia filtration consists of two or more media and it operates with the finer, denser media at the bottom and coarser, less dense media at the top. Common arrangement is granite base at the bottom, sand in the middle and anthracite coal at the top. Flow pattern of multimedia filters is usually from top to bottom with gravity flow. These filters require periodic back washing to maintain their efficiency.

These processes are most commonly used for supplemental removal of residual suspended solids from the effluents of chemical treatment processes.

- Membrane Filtration– This technique is used to separate particles from a liquid for the purpose of purifying it. In membrane filtration, a solvent is passed through a semi-permeable membrane. The membrane's permeability is determined by the size of the pores in the membrane. The size of the pores has to be carefully calculated to exclude undesirable particles, and the size of the membrane has to be designed for optimal operating efficiency. The result is a cleaned and filtered fluid on one side of the membrane, with the removed solute on the other side. Microfiltration, ultrafiltration and nano-filtration are examples of membrane filtration techniques.

- Reverse Osmosis Systems– This is also a membrane separation method that is used to remove several types of large molecules and ions from solutions through application of pressure to the wastewater on one side of a selective membrane. The result is that the contaminant is retained on the pressurized side of the membrane and the treated waste water is allowed to pass to the other side.

- Ion Exchange – Ion exchange is a process of exchange of ions between two electrolytes or between an electrolyte solution and a complex. Ion Exchange can be used in wastewater treatment plants to swap one ion for another for the purpose of demineralization. There are basically two types of ion exchange systems, the anion exchange resins and the cation exchange resins. It can be used for softening, purification, decontamination, recycling, removal of heavy metals from electroplating wastewaters and other industrial processes, polish wastewater before discharging , removal of ammonium ion from wastewaters, salt removal, purify acids and bases for reuse, removal of radioactive contaminants in the nuclear industry, etc.
- Activated carbon– Activated carbon is used in a large range of applications in tertiary waste water treatment. Powdered as well as granular activated carbons are used for the purpose of de-chlorination of organic compounds. Organic compounds in waste water are adsorbed on to the surface of the activated carbon. A number of factors affect the effectiveness of the activated carbon. These include pore size, composition and concentration of the contaminant, temperature and pH of the water and the flow rate or contact time of exposure. Activated carbon can be applied on a broad spectrum of organic pollutants and is typically used to remove contaminants from water such as pesticides, aromatic compounds such as phenol, adsorbable organic halogens, non-biodegradable organic compounds, colour compounds and dyes, chlorinated/ halogenated organic compounds, toxic compounds, compounds that normally inhibits biological treatments, oil removal in process condensates, halogens, especially chlorine that oxidises downstream processes and organics that have the potential to foul ion exchange resins or reverse osmosis membranes.
- Ultraviolet (UV) Disinfection – This technique is primarily employed as a disinfection process that inactivates waterborne pathogens without use of chemicals. Additionally, UV is also effective for residual TOC removal, destruction of chloramines and ozone.

Design of the actual treatment system for a CETP involves selection of alternative processes based on the ability of individual treatment processes to remove specific waste constituents.

2.5 Best Available Techniques (BAT) for waste water treatment

BAT refers to 'best' in relation to techniques, means the most effective in achieving a high general level of protection of the environment as a whole; 'available techniques' means those techniques developed on a scale which allows implementation in the relevant class of activity under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced within the state, as long as they are reasonably accessible. 'Techniques' includes both the technology used and the way in which the installation is designed, built , managed, maintained, operated and decommissioned. The scope of BAT reference document of European Commission on wastewater and waste gas treatment and management in the chemical sector comprises:

- Application of environmental management systems and tools
- Application of the treatment technology for wastewater and waste gas as it is commonly used or applicable in the chemical sector, including the treatment technology for wastewater sludge, as long as it is operated on the industry site

- Identification of or conclusion on best available techniques based on the two preceding items, resulting in a strategy of optimum pollution reduction and, under appropriate conditions, in BAT-associated emission levels at the discharge point to the environment.

And the definition of best available techniques is - "best available techniques" shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.

One of the BAT measures is Waste Minimization proves. Waste Minimization can be subdivided in the following major ways:

- Process Modification (PM)
- Equipment Modification (EM)
- Material Substitution (MS)
- Reuse / Recovery / Recycle (RRR)
- Housekeeping (H)

Table below present potential of waste minimization is some of the important selected industrial sectors.

Table 2.1 Waste Minimization Potential in various selected Industries

Industry Type	**PM**	**EM**	**MS**	**RRR**	**H**
Agrochemicals	#	*	**	*	*
Bulk drugs Pharmaceuticals	#	*	**	**	*
Chemical	#	*	***	**	*
Metal finishing	*	*	*	***	**
Paper Manufacturing	**	*	*	**	**
Petrochemical	#	*	**		*
Tannery	*	*	**	*	**

Source: Bastock et al (1994) and Gardener et al (1987)

*low, **medium, ***high

Process modification does not mean for the complete process line, normally individual activities in processes are modified to alter the inputs or outputs. Industries such as tannery and metal where processes are uncomplicated it might be relatively easy to modify the process, but the same might not be feasible for large industries.

3. Methodology

This chapter of the report presents the approach adopted for carrying out this study.

3.1 Scope of the study

- Documentation of the global best practices in industrial waste water technologies for primary, secondary as well as tertiary treatment and best treated effluent disposal/reuse practices, with special reference to the technologies/practices adopted in common effluent treatment plants (CETP) technologies.
- Analysis of costing and economic viability of those technologies in India.

3.2 Methodology & Approach

For the study, effluent treatment processes for few selected industries like

- Textile,
- Tannery,
- Electroplating,
- Pharmaceuticals

Based on the industry type selected, extensive literature review and few site visits were carried out. During the site visits, CETP & ETP operators and members of industrial estates were interviewed using a structured questionnaire (Annexure 1).

Literature on wastewater treatment technologies specific to Effluent Treatment Plants (ETPs) and CETPs of these selected industries was reviewed for both Global and Indian context.

The documented case studies are presented in subsequent chapters which define the BAT adoption process, capacity, influent characteristic, treatment technology used, effluent characteristics, sludge management, regulatory norms and cost issues of the selected ETPs and CETPs.

Some of the selected case studies have been economically analysed to understand the economic feasibility of a particular technology.

The report does not only restrict to the technical issues but also has taken an attempt to look at managerial and regulatory issues attached to performance of CETPs.

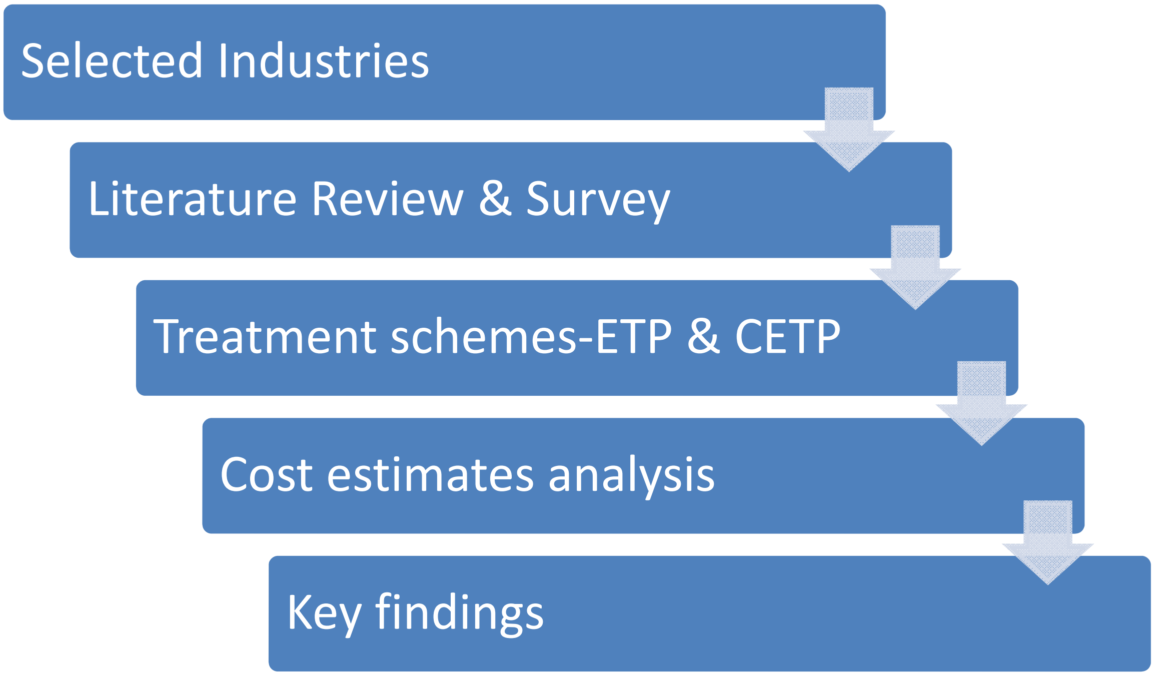

Figure 3.1 Approach of the study

4. Textile Industry

4.1 Introduction

The textile industry is one of the oldest industrial sectors in the world. Textile industries consume large volume of water and chemicals for wet processing of textiles. The effluents from textile units have various types and qualities of wastewater. The wastewater from printing and dying units in a textile plant are often rich in colour, containing residues of colouring agents and chemicals, and needs appropriate treatment.

The integrated textile industry is engaged in production of yarn, fabric and finished goods from raw fibres. Initially, raw fibres are transformed into yarn, thread or webbing. Then the yarn is converted into fabric in looms. Fabric is then dyed or printed to convert into finished product. In short, process flow is fibre manufacturing, yarn manufacturing, fabric production and finishing processes. Textile manufacturing units use natural and synthetic fibres, different chemicals as raw materials and other utilities such as water, energy and labour.

4.1.1 Environmental issues of textile industries

The textile industry is water and labour intensive and produces pollutants of different forms. The manufacturing operation also generates vapours during dyeing, printing and curing of dye or colour pigments. Dust emission is associated with fibre processing. Other than these process operations, textile mills have wood, coal or oil fired boilers and thermic fluid heaters which are point emission sources.

Major environmental issues in textile industry result from wet processing. Wet processes may be carried out on yarn or fabric. The transformation of raw cotton to final usable form involves different stages. The various important wet processes involved in the textile industry are as follows:

- **Sizing / Slashing**: This process involves sizing of yarn with starch or polyvinyl alcohol (PVA) or carboxy methyl cellulose (CMC) to give necessary tensile strength and smoothness required for weaving. The water required for sizing varies from 0.5 to 8.2 litre / kg of yarn with an average of 4.35litre / kg.

- **Desizing**: The sizing components which are rendered water soluble during sizing are removed from the cloth to make it suitable for dyeing and further processing. This can be done either through acid (sulphuric acid) or with enzymes. The required water at this stage varies from 2.5 to 21 L /Kg. with an average of 11.75

- **Scouring / Kiering**: This process involves removal of natural impurities such as greases, waxes, fats and other impurities. The desized cloth is subjected to scouring. This can be done either through conventional method (kier boiling) or through modern techniques (continuous scour). Kiering liquor is an alkaline solution containing caustic soda, soda ash, sodium silicate and sodium peroxide with small amount of detergent. The water required for this process varies from 20 – 45 L/ Kg. with an average of 32.5

- **Bleaching**: Bleaching removes the natural colouring materials and renders the cloths white. More often the bleaching agent used is alkaline hydrochloride or chlorine. For bleaching the good quality fibre, normally peroxide is used. The chemicals used in peroxide bleaching are sodium peroxide, caustic soda, sulphuric acid and certain soluble oils. The water and chemical requirement and the effluent generation normally vary based on the type of operation and the material (yarn / cloth) to be processed. Bleaching the yarn both through hypo-chloride and hydrogen peroxide methods require same quantity of water and it varies between 24 to 32 L/kg. But in the cloth bleaching, the water requirement is much higher and it fluctuates between 40 - 48 L/kg.

- **Mercerising**: The process of Mercerisation provides lustre, strength, dye affinity and abrasion resistance to fabrics. It is generally carried out for cotton fabrics only for easy dyeing. Mercerisation can be carried out through cold caustic soda solution followed by washing with water several times. The water required for this process varies from 17 to 32 L / kg, with an average of 24.5
- **Dyeing:** Dyeing is the most complex step in wet processing which provides attractive colour for the product. Dyeing is carried out either at the fibre stage, or as yarn or as fabrics. For dyeing process, hundreds of dyes and auxiliary chemicals are used. In brief, the water requirement for dyeing purpose (include all types and shades) varies from 36 – 176 L/kg with an average of 106. The effluent generation during dyeing process fluctuates from 35 to 175 L/kg with an average of 105 L/kg.

Table below summarizes the above mentioned characteristics of the textile wastes after the various processes.

Table 4.1Typical Characteristics of Textile Wastes in the manufacturing processes

Processes	pH	Total Suspended solids mg/L	BOD mg/L
Sizing / Slashing	7.0 – 9.5	8500 – 22500	620 – 2500
Desizing	6 – 8	16000 – 32000	1700 – 5200
Scouring / Kiering	10 –13	2200 – 17400	100 – 2900
Bleaching	6	6500-22000	-
Mercerising	12 -13	430 – 2700	150 – 280
Dyeing	10.5	10200	-

Source: IPPC reference document on Best Available Techniques for Textile industries, February 2003

The four main sources of wastewater from the textile industry are wastewater from dyeing, chemical fibre production, wool scouring and dissolved fibre waste. Of these, dyeing is the main source of wastewater pollution, which discharges huge volume of wastewater every day.

4.1.2 Global Scenario in Textile Industries

The Integrated Pollution Prevention and Control (IPPC) Directive 2008/01/EC of the European Union (EU)[4] forms the basis within the European Union of the permit procedure for industrial installations. The IPPC Directive is based on the concept of Best Available Techniques (BAT). EU Member States are required to implement the IPPC Directive in national law and ensure the existence of rigorous approval requirements on the basis of best available techniques.

[4]Promotion of Best Available Techniques (BAT) in the Textile and Leather Industry in Developing Countries and Emerging Market Economies, February 2003

European companies increasingly import textile products from outside the EU, especially from developing countries and emerging market economies. China, Turkey and India are now the largest suppliers of textiles and clothing to the EU. These products are finished in the EU, or sold directly. Often requirements for environmental protection in industrial production existing in the countries outside the EU are not comparable.

4.1.2.1 Textile Industry Scenario in Turkey

Turkey is a rapidly developing country and the textile sector is the driving force for the export industry. Turkey is currently the second largest exporter of textiles to the European Union[5]. As of 2006, there were more than 35,000 textile and clothing companies in the country, 68 of which were among the 500 largest companies in Turkey. The Turkish textile and clothing industry needs to adapt to the rapidly changing and increasingly competitive international conditions. The Turkish clothing industry is the fourth largest supplier in the world, with a share of 4.3% of global market. It is also the second largest supplier to the EU.

There is a high level of awareness regarding Best Available Techniques (BAT) in Turkey and there are on-going efforts to raise awareness and promote the use of BAT.

4.1.2.2 Textile industry scenario in China

China has the world's largest textile and clothing industry. Its export volume rose by an annual average of 16.8% between 1970 and 1999[6]. Textile and clothing exports contributed approximately USD 36 billion to China's exports in 2006, the largest export markets being the USA and Europe.

The main environmental problems related to the textile industry are wastewater, emission to air and noise. Of these, wastewater is the biggest problem in terms of its impact on the environment. From the mid-1990s, the total amount of wastewater discharged by the textile industry annually has been over 1.1 billion m^3, which accounts for over 6% of all the wastewater from Chinese industries and makes textiles one of the top ten polluting industries. The chemical oxygen demand (COD) is around the 300,000 tonnes mark, which accounts for roughly 5% of the total COD contributed by Chinese industries.

4.1.2.3 Textile Industry Scenario in Germany

In the last few decades the German textile and clothing industry has undergone severe structural changes. The structural changes can be illustrated in figures: for instance, the output of the textile and clothing industry in Germany fell by nearly 70%, between 1991 and 2010. The clothing sector, which suffered an 85% decline, performed worse than the textile industry (down 50%)[7].

The sector still spans a broad range of fields, from traditional segments grappling with the pressures of stiff international competition right through to the newer and markedly expanding segments of technical textiles which are setting the pace of innovation.

In the course of these structural changes, the German textile and clothing industry has become more international and flexible and has oriented itself towards higher-quality and

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5 Clothing Industry in Turkey Republic of Turkey – Ministry of Economy, 2012
6Kahlenborn, W., Sawhney P., Zwagerman N., 2009, Internationalising BAT: Promotion of Best Available Techniques (BAT) in the Textile and Leather Industry in Developing Countries and Emerging Market Economies.
7Federal Environment Agency, Germany

innovative products. In particular, the sector has taken the international lead in the field of so-called technical textiles, which are linked with a high level of research activity.

In the textile finishing industries wastewater discharge is of hight environmental relevance. The textile finishing industry is ranking number eight concerning overall wastewater flow in Germany. About 94 per cent of industries discharge their wastewater to municipal wastewater treatment plants.

4.1.2.4 Textile Industry Scenario in India

The textile industry is one of the oldest and largest industrial sectors in India. The textile units are scattered all over India. The textile industry in India constitutes one of the country's major export sectors. India makes a major contribution to world trade in cotton yarn, accounting for some 25% of the total. The government plays a highly active role in promoting the increasing exports from the country. Between 2004 and 2005, exports from the textile sector went up 23% to almost USD 12 billion.

According to data from the Directorate General of Commercial Intelligence & Statistics, in 2005 and 2006 the EU and the USA accounted for about 62% of Indian textile exports. The EU is the largest market for Indian exports after the USA. India's position in the EU textiles and clothing markets was third after China and Turkey, with a share of approximately 8.1%

Table 4.2 Production statistics for India

Production of fibres	**kg million/year**
Raw cotton	4,122
Man-made fibre	1,023
Production of yarn	
Cotton yarn	2,272
Total spun yarn 3,223	3,223
Man-made filament yarn	1,109

Source: Compendium of Textile Statistics, 2006, Office of Textile Commissioner

In order to promote cleaner production and modernisation of the textile sector, Ministry of Textiles, Government of India introduced the Technology Up-gradation Fund Scheme (TUFS) in April 1999. The scheme is intended to facilitate the introduction of state-of-the-art technology in the industry. Existing units with or without expansion and new units are eligible under the TUF scheme.

There are 2324 textile industries in the country including composite and process houses[8]. State-wise distribution of these units is given in Table 4.3. It can be seen from these data that there are 83 composite mills in the country. Rest 2241 are semi composite and processing units. Tamil Nadu, Gujarat, Punjab and Maharashtra are among the states which have large number of textile industries amounting to 1895 i.e. about 81 per cent of total industries.

[8]Advanced Methods of Treatment of Textile Effluent Treatment, CPCB report 2007, India

Table 4.3 State-wise distribution of textile industries

State/UT	Composite mills	Semi composite/processing units	Total
Andhra Pradesh	-	54	54
Assam	1	1	2
Bihar	-	4	4
Delhi	-	61	61
Gujarat	17	506	523
Haryana	1	74	75
Himachal Pradesh	-	4	4
Jammu & Kashmir	1	2	3
Karnataka	8	33	41
Kerala	3	11	14
Madhya Pradesh	3	9	12
Maharashtra	27	222	249
Orissa	1	1	2
Punjab	4	378	382
Rajasthan	2	30	32
Tamil Nadu	2	739	741
Uttar Pradesh	4	76	80
West Bengal	8	32	40
Pondicherry	1	4	5
Total	83	2241	2324

Source: Advanced Methods of Treatment of Textile Effluent, CPCB report 2007, India

4.2 Effluent Treatment System

As in the case of other countries, textile industries in India are also highly water polluting, besides causing air pollution. Major air pollution sources are the boilers and thermic fluid heaters. The liquid effluent characteristic and effluent quantity vary according to the processes involved, chemicals used and the scale of operation. Therefore, very often the quality of effluent from one industry varies from the other similar industry.

As the textile manufacturing units use different type of raw materials, chemicals and processes, the wastewater treatment may require the use of unit operations specific to manufacturing processes in use. Techniques for treating industrial process waste water in this sector are - source segregation and pre-treatment of waste water streams.

Processes are as follows:

- Precipitation, coagulation and flocculation
- Biological oxidation
- Membrane filtration
- Reverse osmosis
- Adsorption by activated carbon
- Advanced chemical oxidation

The treatment processes are briefly discussed below:

Primary and Secondary Treatment

The conventional treatment systems like physico-chemical treatment or physico-chemical treatment followed by biological treatment system are installed in majority of textile industries. The first step in the wastewater treatment is to mix and equalize the waste water streams that are discharged at different time, and different intervals from different stages in the processes. Some industries also prefer screening, oil trap prior to equalization for removal of solids and oil and grease. Equalization ensures that the effluent have uniform characteristics in terms of pollution load, pH and temperature. The effluent is then subject to flash mixing for the addition of coagulants such as lime, alum, ferrous sulphate, ferric chloride, poly-electrolyte and processed through clari-flocculator or flocculator and settling tank. Selection of appropriate coagulants and doses of chemicals is determined on the basis of treatability study of effluent samples. The chemical treatment helps in reduction of colour and suspended solids. A significant reduction in BOD and COD values is also observed. This physico-chemical treatment is followed by biological treatment process which further reduces BOD and COD values. The textile process houses which undertake chemical processing do not have much organic load in their effluents. In such cases, the recent trend is to set up an activated adsorption system or an ozonation unit instead of biological treatment.

Tertiary Treatment

Textile effluents may require tertiary or advance treatment methods to remove particular contaminants, dissolved salts or to prepare the treated effluent for reuse. Some common tertiary operations are removal of residual organic colour compounds by adsorption and removal of dissolved solids by membrane filtration. Sometimes the wastewater is also treated with ozone or other oxidizing agent to destroy many contaminants. Evaporation and crystallization are other methods to minimize effluent disposal problems.

4.2.1 Advance methods for tertiary treatment

Adsorption

The adsorption process is used to remove colour and other soluble organic pollutants from effluent. The process also removes toxic chemicals such as pesticides, phenols, cyanides and organic dyes that cannot be treated by conventional treatment methods. Dissolved organics are adsorbed on surface as waste water containing these is made to pass through adsorbent. Most commonly used adsorbent for treatment is activated carbon.

The activated carbon once it is saturated needs replacement or regeneration. The chemical regeneration can be done within the column either with acid or other oxidizing chemicals.

Ion Exchange

Ion exchange process is normally used for the removal of inorganic salts and some specific organic anionic components such as phenol. In the ion exchange process the impurities from the effluent streams is transformed into another one of relatively more concentrated with increased quantity of impurities because of the addition of regeneration chemicals.

Reverse Osmosis

After primary, secondary and/or tertiary treatment, further purification by removal of organics and dissolved salts is possible by use of reverse osmosis. The process of reverse osmosis is based on the ability of certain specific polymeric membranes, usually cellulose acetate or nylon to pass pure water at fairly high rates and to reject salts. To achieve this, water or wastewater stream is passed at high pressures through the membrane. The applied pressure has to be high enough to overcome the osmotic pressure of the stream, and to provide a pressure driving force for water to flow from the reject compartment through the membrane into the clear water compartment.

RO membranes are susceptible to fouling due to organics, colloids and microorganism. In a typical reverse osmosis system, the feed water is pumped through a pre-treatment section which removes suspended solids and if necessary, ions such as iron and magnesium which may foul the system. The feed water is then passed through the reverse osmosis modules at high pressure.

Table 4.4 Performance of Treatment System for Wash Water

Parameter	**Influent**	**Primary Treatment**	**Ozonation**	**RO Stage I**		**RO Stage II**	
				Permeate	**Reject**	**Permeate**	**Reject**
pH	9.88	9.61	6.92	6.03	6.72	5.76	7.04
Total suspended solids, mg/L	167	56	19	6	70	6	124
Total dissolved solids, mg/L	3104	1946	3256	922	9830	196	17828
Chemical oxygen demand, mg/L	586	166	130	26	327	17	754
Biochemical oxygen demand, mg/L	190	41	41	1	16	02	208
Total Hardness, mg/L	96	-	-	-	60	Nil	1080
Chlorides, mg/L	334	636	692	314	108	34	4416
Colour, % purity	<10	<10	Colourless	Colourless	<10	Colourless	10-20

Ultrafiltration

Unlike reverse osmosis membranes which retain all solutes including salts, ultrafiltration membranes retain only macro molecules and suspended solids. Thus salts, solvents and low molecular weight organic solutes pass through ultrafiltration membrane with the permeate water. Since salts are not retained by the membrane, the pressure differences across ultrafiltration membrane are negligible. Flux rates through the membranes are fairly high, and hence lower pressures can be used.

Nanofiltration[9]

Nanofiltration can be positioned between reverse osmosis and ultrafiltration. Nanofiltration is essentially a lower pressure version membrane where the purity of permeate water is less important. The nanofiltration is capable of removing hardness elements such as calcium or

[9] P.Schoeberl, M. Brik, R. Braun, W. Fuchs, Treatment and recycling of textile waste water, *Desalination* 171 (2004) 173-183ation 171 (2004) 173-183

magnesium together with bacteria, viruses, and colour. Nanofiltration is operated on lower pressure than reverse osmosis and as such treatment cost is lower than reverse osmosis treatment.

Nanofiltration is preferred when permeate with some residual TDS but without colour, COD and hardness is acceptable. Feed water to nanofiltration should be of similar qualities as in case of reverse osmosis. Turbidity and colloids should be low. Disinfection of feed may also be necessary to remove micro-organism. The filtration spectrum indicating size and weight of molecules, operating pressure etc. in respect of reverse osmosis, ultrafiltration and nanofiltration, is shown in Table below.

Table 4.5 Filtration spectrum of different membranes

Process	**Pore size (micron)**	**Molecular weight**	**Examples/use for removal of**
Microfiltration		0.0007 – 2.00	> 100000 Bacteria, pigments, oil etc.
Ultrafiltration	0.002 – 0.10	1000 - 200000	Colloids, virus, protein, etc.
Nanofiltration	0.001 – 0.07	180 - 15000	Dyes, pesticides, divalent ions etc.
Reverse osmosis	< 0.001	< 200	Salts and ions

4.2.2 Effluent Reduction and Sludge Management

To increase the efficiency of treatment and reduction of effluent, the processes involved are:

- Separation of various stream of effluent and their individual pre-treatment before equalization.
- Wax recovery to be adopted where wool scouring is carried out.
- Caustic recovery plant needs to be installed after mercerising process. It will not only reduce the consumption of caustic but also reduce the water consumption and volume of water. Recovered caustic is reused and water (effluent) is recycled. It saves approximately 30% of the chemical (caustic soda) cost even after considering the operating cost of the caustic recovery unit.
- Ammonia mercerising is the latest technology. It is a cryogenic technology where no substantial quantity of effluent would be generated from this process. Mercerisation is carried out in an enclosed chamber with the help of liquid ammonia at the temperature of -32 degree centigrade. However, safety aspect for storage and handling of the ammonia should be given due importance in order to minimize chances of accidental release of ammonia in the atmosphere.

Salt is used in dyeing and bleaching operation as dye fixing agent and it serves as an electrolyte. Use of glauber salt in dye preparation would be effective in salt recovery from dye house effluent and the recovered salt may be recovered and might find a reuse in some other industry.

4.3 Best Available Technology (BAT)

There has been a great deal of stress on a wide spectrum of activities that promote cleaner production. These activities are demonstration and training for new technologies on:

- Effluent treatment
- Waste minimisation
- Replacement of chemical dyes with natural dyes

Textile industries in India are required to comply with the regulations of the Environment Protection Act 1986.Necessary environmental legislation is already in place. The legislation includes the Water (Prevention and Control of Pollution) Act 1974, the Water Cess Act 1978. The promotion of Common Effluent Treatment Plants (CETPs) has been a major effort of both Central and State Governments. The frameworks and laws in the country were conducive to the import of modern technologies. Besides, buyers' pressure appears to be another important potential driver in the spread and adoption of BAT and cleaner production options. In a few cases, pressure from NGOs and the public was perceived as being important. The industry would be willing to adopt environmental technologies in line with the BAT approach as long as they could see that this would not put them at a competitive disadvantage.

The important drivers of BAT are:

- Generating awareness of the existence of new technologies
- Improving accessibility to these technologies
- Creating potential sources of financing
- Demonstrating how the new technologies work in practice

In general, environmental awareness has been on the rise in India over recent years and many of the Indian industries are willing to upgrade and adapt the technology to the Indian context. The larger companies have sufficient funds and have already access to BAT; the challenge is to make BAT accessible to small and medium enterprises (SMEs) may be on sharing basis at cluster level. The application of technologies in SMEs also requires close technical support to ensure that they are implemented in the correct manner.

4.4 Textile Case studies

4.4.1 Common Effluent Treatment Plants (CETP), Tirupur

Coimbatore district of Tamil Nadu is well known for cotton fabric production. Tirupur, one of the towns in Coimbatore District is located at the bank of river Noyyal, a tributary to river Cauvery. The quality of Noyyal river water and climatic condition of Tirupur has been ideal for dyeing operation of yarn and fabric. There are 748 dyeing and bleaching industries in Tirupur that generate over 90,000 m^3/day of wastewater. Out of this a total of 502 industries are attached with 20 common effluent treatment plants (CETPs) and others are having their individual effluent treatment plants. The adopted technology was able to remove the color and other organic impurities to the stipulated standards but failed to arrest the inorganic contaminants. Untreated effluent discharged to the receiving water body caused gross damages.

The water of Orathupalayam dam located downstream of river Noyyal became unfit for irrigation. In view of the deteriorating water quality in the Noyyal river, Madras High court has made it mandatory for the polluting industries to have zero liquid discharge (ZLD) system. Ninety units were closed for not providing zero liquid discharge system.

Installing ZLD technology is beneficial for the CETP and it helps close monitoring of water usage, minimum wastage and promotes recycling by conventional and less expensive solutions.

Though the operating cost is high, it makes up for the high recovery of water (>90-95%), besides recovering of the salt. Moreover, ZLD promotes more sustainable growth of the industry while meeting most stringent regulatory norms. There is also possibility of reuse of treated wastewater for industrial and municipal use.

Case study of Sivasakthi textile processors, Tirupur

Sivasakthi Textile Processors has six flow reactors (batch process) with different capacities are used for dyeing including wetting, bleaching, neutralizing, washing, colouring, washing, etc. In the reactors, 1 ton of cotton yarn requires 10 m^3 of water whereas 1 ton of polyester yarn consumes only 4 m^3 in each steps. Dye bath solution requires dyes, alkali and sodium salt in the process. Quantity of salt (Sodium Chloride) used usually depends on the requirement of colour shade. The total quantity of yarn/fabric processed in the unit is 1500–2000 kg/day and the volume of effluent generated is of the order of 100–200m^3/day. Effluents are segregated into dye bath wastewater and wash water and treated accordingly.

Wash water is collected in holding tanks and pumped to primary treatment unit. Lime and ferrous sulphate slurries are flash-mixed with effluent and allowed for settling. Following primary treatment the effluent is carried to pressure sand filter, iron removal filter, ion exchange filter and reverse osmosis (RO) system. Double stage RO system (each with six membranes) with spiral wound membrane is in operation. Pump pressure is maintained in the range of 21.2–28.2 kg/cm^2. Rejects of first RO is sent to second RO and the final reject (20%) is sent to multi effect evaporator (MEE). Condensate water of MEE is recycled in the cleaning operations. MEE outlet with 100 g/L solid content is allowed for solar evaporation and the combined permeate is used in the process.

Dye bath water is collected in a separate tank and after following pre-filtration is subject to nanofiltration. Pre-filtration is essential for longevity of the membrane. Total reject about 30% is sent for multi effect evaporation (MEE) and solar evaporation systems (SES). Permeate is used for preparation of dye bath solution.

The characteristics of the raw effluents, intermediate effluents and permeate are presented in the table below. The low hardness of permeate is an added advantage in the process. Reject of NF filtration contains 4.8% salts that is mixed with more salts and used in the process. Salt recovery from the dye bath alone has 50% returns.

Performance of RO in the studied textile dyeing units

The characteristics such as high concentration of TDS, Chloride, Sodium and Sodium Absorption Ratio (SAR) show that the untreated and primarily treated wastewaters are unfit for irrigation and their discharge into river may further worsen the water quality. Therefore, the advanced treatments such as Reverse Osmosis and/or Nanofiltration separation technologies are essentially used to remove mainly the inorganic and to some extent, the organic constituents from aqueous solution and non-aqueous solution by Polyamide membrane.

Table 4.6 Characteristics of effluents of Shivasakthi Textile Processors, Tirupur[10]

Parameter	Wash water			Dye bath water		
	Inlet to ETP	**Outlet of chemical treatment**	**RO permeate**	**RO reject**	**Dye bath wastewater**	**NF reject**
pH	9.76	9.78	7.52	8.21	10.42	8.21
Electrical conductivity (mS/cm)	6.80	6.63	0.77	32.1	53.9	63.55
Total suspended solids (mg/L)	47	26	BDL	46	76	60
Total dissolved solids (mg/L)	4280	3620	474	21670	39179	48294
BOD (mg/L)	80	63	10	450	180	100
COD (mg/L)	317	204	24	1143	909	402
Total hardness (mg/L0 as CaCO3	320	141	3	728	88	45
Ca-hardness (mg/L0 as CaCO3	272	104	3	687	68	22
Sulphate (mg/L)	75	116	8	328	174	362
Chloride (mg/L)	1912	1771	184	10756	19179	26432
Sodium (mg/L)	1600	-	-	9280	-	20480
Potassium (mg/L)	38	-	-	208	-	62
% sodium	90	-	-	95	-	100
Sodium absorption ratio (SAR)	39	-	-	146	-	1329

Note: BDL, below detection limit; -, not analysed

The average removal % of important parameters is as shown in the table below:

Table 4.7 Average reduction of BOD, COD, TDS, Na, Cl of CETPs in Tirupur

Parameters	Percentage removal
BOD	88–98
COD	91–97
TDS	80–97
Sodium	96
Chloride	76–97

The principle followed in all the units are same whereas different module such as disc type module and spiral wound module membrane are housed in the RO system. Before charging into RO membrane, the impurities such as suspended and colloidal impurities of organic and inorganic compounds and dissolved polyvalent ions need to be removed.

The life of the membrane would be reduced due to the absence of preliminary treatment. The water regenerated using the advanced technology is found good quality and could be directly used in the dyeing process. A typical schematic diagram of the effluent treatment

[10]Ranganathan, K et al; Recycling of wastewaters of textile dying industries using advanced treatment technology and cost analysis-Case studies, K.; Resources, Conservation & Recycling vol. 50 issue 3 May, 2007. p. 306-318

plant provided with primary, secondary and advanced treatment technologies for recycling of wastewater is presented in the Fig. 4.1

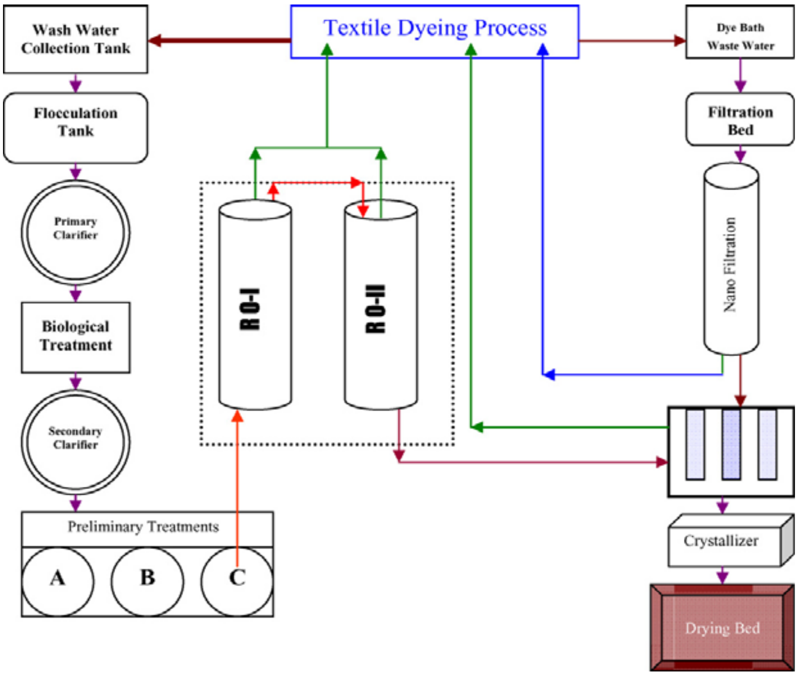


Figure 4.1 Typical schematic diagram of advanced wastewater treatment technology for recycling of textile dyeing wastewaters.

To extend the life of RO membranes, flushing the membrane periodically with clean water and occasional chemical cleaning is required. The pH around 5–6 is desirable to prevent both hydrolysis of membrane and precipitation of Calcium Carbonate ($CaCO_3$). A model flow chart of zero discharge scheme for the textile dyeing units is shown in the Fig. 4.2

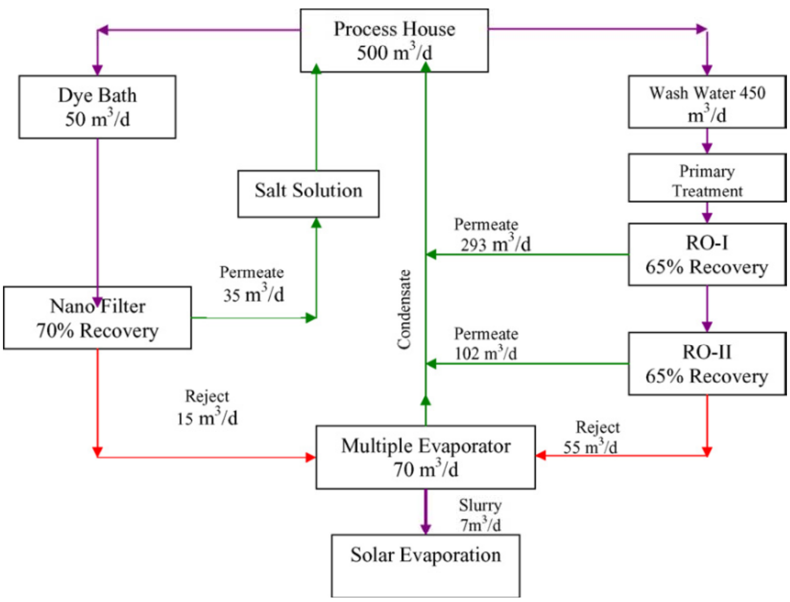


Figure 4.2 Flow diagram of conceptual zero discharge in textile dyeing unit using advanced wastewater treatment

Solar evaporation pond is lined with a concrete layer and arrangements are made to avoid ground water infiltration. An area of about 1000 m^2 is required per 4 m^3 of wastes for solar evaporation. The final dried salts are packed in polythene bags for final safe disposal.

Cost analysis and viability of the water recycling process

Wastewater treatment plant installation and commissioning cost is in the range of INR 40–100 lacs, INR 100–200 lacs and INR 200–300 lacs for small (below 300m^3/day), medium (300–600m^3/day) and large (above 600m^3/day) scale textile dying industries. The maintenance and operation cost is as below:

Table 4.8 O & M cost of the wastewater treatment plant

Cost	Currency (INR)
Chemical cost	7–8m^{-3}
Power cost	2–3m^{-3}
Sludge handling	0.75–1m^{-3}
Manpower	1–2m^{-3}
Filters/cartridges (spares)	5–10m^{-3}
RO/NF membrane maintenance	15–20m^{-3}
Interest and principal paid on the loan	40–50m^{-3}

Total expenses incurred for the water treatment and recovery is about INR 80/m^3 of the effluent. Due to non-availability of good quality water for dyeing processes in Tirupur, it is purchased from villages 15 km away from the towns and hence the cost of the water is approximately INR 100/m^3 including transportation. Hence, the technology is economically viable in the studied area.

The operation cost of multiple effect evaporator and maintenance of RO membrane module are high. Multi effect evaporation is a costly system for concentration of the effluents. It requires more maintenance and consumes more fuel and an average of INR 400 is required per m^3 of rejects. The recovered salt has poor purity and market value of salt is also very less (INR 4/kg). When the availability of land has become constraint, the MEE would be preferable. A common MEE set-up as joint ventures may be an economical option. Proper preliminary treatments should be followed to reduce the maintenance cost of RO membrane.

The most attracting part of water recovered from these membranes is its extremely low hardness, which is always demanded in textile sector for an improved finish and better quality dyeing. The treatment and maintenance cost INR 80/m^3 is cheaper than the water cost INR 100/m^3 in Tirupur. Common facility for Multistage Evaporator would be economical.

4.4.2 Case study of a Treatment Plant in Germany

This treatment plant is an activated sludge system with low food-to-microorganism ratio (F/M). It receives municipal wastewater and effluent from four large textile finishing mills. The textile wastewater is equalised and then mixed with primarily treated municipal waste water. The hydraulic percentage of textile wastewater is about 45% and referring to COD-load about 60%. Subsequent to primary treatment and equalisation, there is a biological treatment including nitrification/ denitrification and flocculation with $FeCl_3$ as final step.

Capacity of treatment plant

Total flow = 8377±1431 m^3 / day, Municipal = 4562±2018 m^3 /day and

Textile waste water = 3685±1431 m_3 /day with F/M ratio = 0.1

Influent, effluent characteristics & Regulatory standard

Table 4.9 Influent, effluent characteristics & Regulatory standard Germany Plant No 1

Parameter	Influent quality		Outlet effluent quality mg/l	Removal Efficiency mg/l	European & National standard mg/l	Meet standard
	Textile Mg/l	Municipal mg/l				
BOD 5day	157±57	114±50	3±2	97±2%	< 25 mg/l	√
COD	791±281	443±200	59±16	90±4%	< 125 mg/l	√
Ammonia	2.6±2.0	30±14	0.1±0.2			
pH	9.2±0.8	8± 0.4			6-9	√
PVA	28-138		0.6-7.8			
Nitrate, NO_3			2.9±1.9	88±6%		
N org	19.5±7	18±7	No	88±6%		
Total phosphorus	3.8±1.2	6±2	0.2±0.2	96±3	< 2.0 mg/l	√

Source: (Federal Environmental Agency, Germany, 2002)

The municipal sewage is treated in primary treatment unit before mixing with the textile wastewater. The textile effluent is passed through bar screen to remove large waste material and then passed through a grit chamber to remove the smaller material. The water is then pumped to an equalisation tank (one standby equalisation tank) and the wastewater is then mixed with the primarily treated municipal wastewater and passes to the neutralisation tank. The waste is then diluted and neutralized using H_2SO_4 or NaOH. Then the wastewater is treated using the activated sludge process and since it has a low F/M ratio longer retention time and aeration is required. The water is then passed to the secondary clarifiers after which $FeCl_3$is added to destabilize the colloidal materials and cause the small particles to agglomerate into larger settleable flocs, thus aiding the coagulation and flocculation process. The treated effluent is then directly discharged to the river.

The removable efficiencies are shown in Table 4.9. This system is able to meet European and Germany's National discharge regulatory standard.

Table 4.10 Percentage removal of BOD, N and P in German Plant No 1

Parameters	Percentage reduction
BOD_5	97±2%
COD	90±4 %
Nitrogen	88±6%
Phosphorus	96±3%

Sludge management

Sludge from clarifier and precipitation and flocculation chamber is treated with centrifuge before sludge storage tank. Sludge from primary sediment tank used in municipal wastewater treatment is also sent to the sludge storage tank. The sludge is then mixed and it is passed through chamber filter press to separate the liquid phase from the solid phase. The solid phase is then transported to a sludge drying bed.

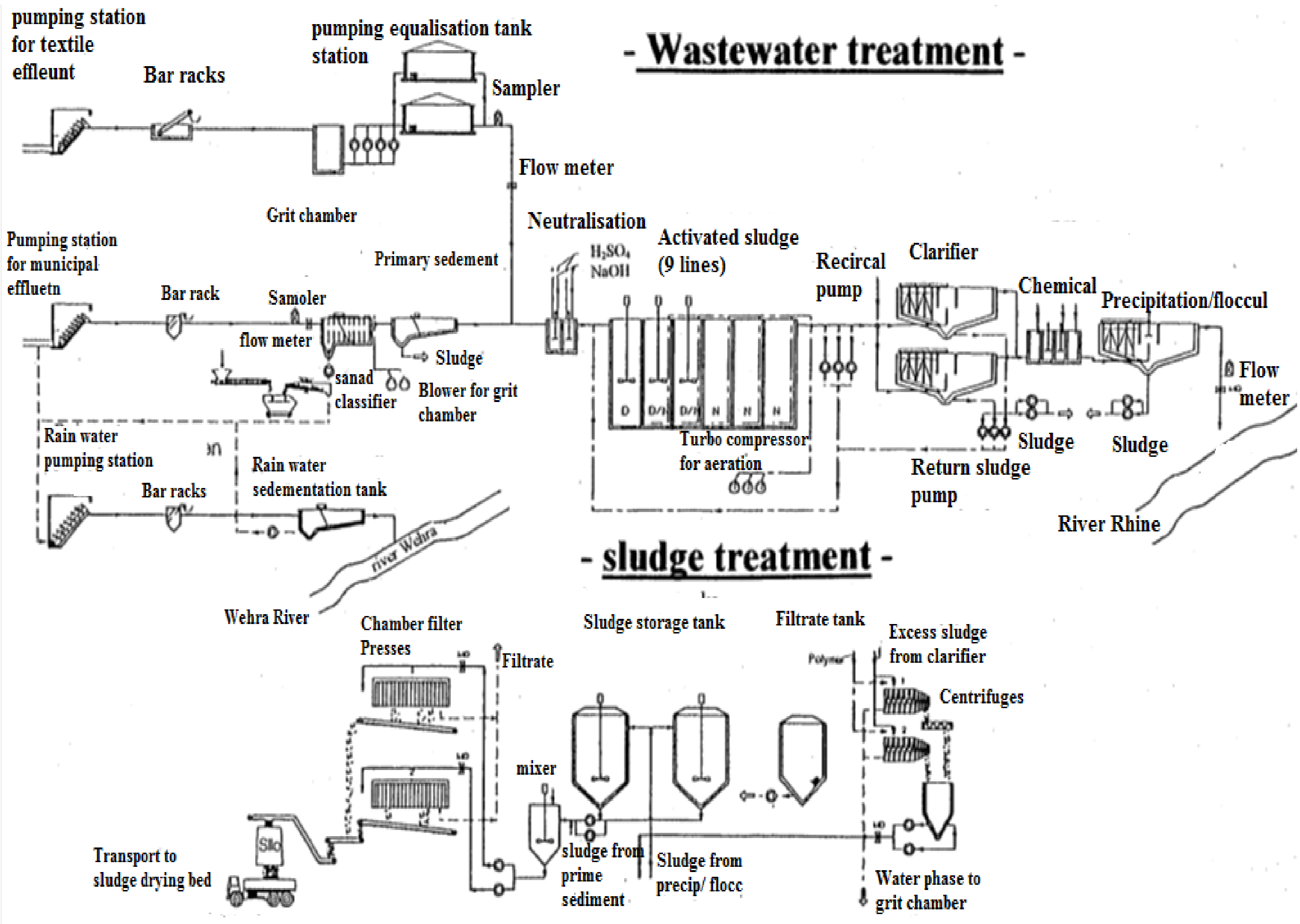


Figure 4.3 Wastewater treatment plant scheme Germany Plant No 1

Source: (Federal Environmental Agency Germany, 2002)

5. Tannery Industry

5.1 Tannery industry process

Tannery operations involve conversion of raw hides or skins into leather, a stable material, which can be used for manufacturing of large number of products. The tannery industry is a water and chemical intensive industry, wherein, a large number of complex chemical and mechanical processes are involved. These industries are one of the most polluting industries causing pollution in the environment.

The Tannery Industry Operation is as follows:

Process in tanning industry can be broadly classified as pre-tanning, tanning and post tanning process.

Pre tanning is employed mainly for the removal of impurities from the raw materials. The impurities consist of mainly blood, hairs, etc., which has composition of protein. This process involves salt, lime and sulphides as process chemicals.

Tanning process is used for altering the characteristics of skin. The effluents of tannery process contains chromium and vegetable or synthetic tanning.

Post tanning processes include colouration and produce effluents containing residues of dyestuffs, and auxiliary chemicals.

The final effluent coming out of a tannery unit is amalgam of raw materials and variety of process chemicals. As the main raw material of the tanning industry is a natural product, its soluble impurities are generally readily biodegradable and represent a large part of the BOD load in the effluent. The process chemicals employed are a variety of organic and inorganic materials affecting concentration of total solids, pH, COD. Of particular importance is the presence of significant quantities of sulphide and chromium (III).

Table 5.1 Tannery Wastes – Typical Characteristics

Source	pH	Total solids mg/L	Suspended solids mg/L	BOD mg/L	Sulphide (as S) mg/L
Pre-tanning	10 – 12	5000-20000	200-2000	1000-5000	500-2000
Vegetable tanning	3-5	5000-20000	200-1000	500-5000	-
Chrome tanning	3-6	2000-10000	50-5000	250-2000	-
Mixed : vegetable tannery	8-12	5000-20000	100-1000	500-5000	200-1000
Mixed : chrome tannery	7-11	2000-10000	50-500	250-2500	100-500

Source: Integrated Pollution Prevention and Control, reference Document on Best Available Techniques for the Tanning of Hides and Skins, February 2003

5.2 Best Available Technology (BAT) in Tannery sector

This section clearly brings out the status of countries in respect to adoption of cleaner treatment technology options in the tannery sector. Most of the BAT techniques are based on the principle of environment friendly technology use.

The European Union (EU) is the world's largest supplier of leather in international market. Italy is the major contributor to the supply of leather in Europe in terms of production, employment, establishments, and turnover. Worldwide around 80-90% of the tanneries use Cr (III) salts in their tanning processes.

While in India there are about 2500 tanneries and most of them (nearly 80%) are engaged in chrome tanning process (Shukla et al., 2009). In India, Tamil Nadu, Uttar Pradesh, West Bengal and Punjab are the dominant states for tanning business.

5.2.1 Global Scenario

Turkey is one of the leading countries in terms of leather business. In Turkey, awareness regarding BAT is high but still they are not fully implementing BAT in their industrial processes. But Turkey has prepared BAT guidelines according to the EU directives and has started adopting it. Turkey favours application of cleaner production, which is an integral part of BAT techniques. Pressure from buyers is the main driver for the spread of BAT in Turkey. Financial support is an important factor that can enhance the promotion and adoption of BAT.

China is the biggest leather producing country in the world. China has taken significant consideration of green and clean technologies in the production process. Even it has approved many stringent environmental regulations to ensure environment protection. Stakeholders in China also believe that the financial incentives can help in wide spread adoption of cleaner production processes. In recent years, the leather industry has become increasingly aware of environmental protection. They have adopted many cleaner and greener leather production technologies in the recent past.

5.2.2 Indian Scenario

In India there have been some initiatives from government and international institutions to promote clean techniques. Most of the CETP operators in India are aware of some of the technologies mentioned as BAT, since they were also being applied in India. A wide spectrum of activities is found that promote cleaner production. The activities include:

- Helping to import less environmentally damaging tanning material such as wattle extract, benefiting a large number of smaller tanners
- Adopting "zero liquid discharge" technology in tanneries regulated by the state of Tamil Nadu
- Guidance from the Central Leather Research Institutes CLRI), Chennai and other technical bodies on the management of hazardous solid waste in secured landfills

A few organizations are involved in demonstration and training for adoption of new technologies in:

- Effluent treatment
- Waste minimization
- Replacement of chemical dyes with natural dyes

- Cleaner tanning techniques for raw skin as well as for the whole leather production process
- Chrome recovery technology; use of less chrome or chrome less technologies; chrome recycling and reuse methods should be prioritized
- Chilling preservation instead of salt treatment of hides

A few of the institutions have been involved in the development of ideas and e modification of new technology to the requirements of the leather industry.

Demonstration projects carried out by the UNIDO Regional Program Office in several tanneries, combined with dissemination of information, have proven to be very successful in propagating cleaner production.

Tannery waste treatment plants in the Netherlands, have been useful in the transfer of advanced technologies to the Common Effluent Treatment Plants (CETPs) in Tamil Nadu.

5.3 Tannery Sector Case Studies

5.3.1 CETP in Italy

Italy is the major contributor of the leather (raw hides or processed leather) supply in the EU. As a leader in this sector Italy has taken many steps for the enhancement of the process which not only include improvement in production but also inclusion of environment friendly processes. The case of a CETP in Italy has been referred as one of the 'Best Available Techniques' (BAT) under IPPC Directives of European Union.

Description of the CETP in Italy

The CETP's described in this section is operated in the municipality of San Miniato in Italy. The CETP receives the wastewaters of about 155 factories (120 tanneries and 35 allied industries) of the industrial area of Ponte-a-Egola in the municipality of San Miniato and two municipalities, San Miniato and Montopoli (15,000 and 5,000 persons respectively). Most of the tanneries are connected to the CETP by the industrial sewer, only few (5-6 factories) transfer the wastes by tank-trucks.

The sole leather and different vegetable tanned light leathers are the typical manufactures of the area: Ponte-a-Egola produces about 95% of the total Italian sole leather.

Plant design capacity: 7,500 m^3/day of industrial and 3,500 m^3/day of domestic effluents in dry period from two municipalities (San Miniato 2500 m^3/day and Montopoli 1,000 m^3/day). The plant receives also desultory wastewaters and sludge (industrial and urban) delivered by tank-trucks. Presently the volume of treated industrial effluent varies between 6,000 and 8,000 m^3/day.

The CETP construction started in the year 1980 and had been improvised. At present the CETP covers an area of about 13 hectares and employs 38 persons. The total "historical cost" of the CETP including the sludge thermal drying unit is around 91 billion Liras (Euro 47 million).

Table 5.2 Influent characteristics

Parameters	Units	Mean values
Industrial flow rate in the working days	m^3/day	5000 – 6000
PH	Units	8.2
Suspended solids	mg/L	5709
COD (raw)	mg/L	12857
COD (settled)	mg/L	6631
BOD5	mg/L	35
Ammonia nitrogen	mg/L	251
Chloride	mg/L	7091
Sulphide	mg/L	127
Sulphate	mg/L	185
Chromium	mg/L	18.6

Remarks: *12 individual pre-treatment plants have been implemented by tanneries of the industrial district of Ponte-a-Egola. The aim was to reduce the treatment cost and also to comply with the sewer discharge limits. Basic pre-treatments consist of fine screening, sulphide oxidation and primary sedimentation. The general efficiency of these interventions is not very high, but being the pre-treatments adopted by the bigger tanneries they cover about 20-30% of the total industrial effluent. This fact associated with more strict controls of the characteristics of the discharged effluent caused a sensible reduction of the pollution entering the CETP.*

Treatment technology

Pre-treatment: The coarse screening and first pumping of the industrial effluent are installed in an area outside the plant adjacent to the industrial district of Ponte-a-Egola where the industrial effluents flow by gravity.

From here the effluents are pumped to the fine screening and the grease and grit removal process and stored in the sulphide oxidation tanks. The sulphide oxidation process is carried out in batch in two alternating tanks: when one tank is under treatment the other in filling phase, and vice versa. At the end of the treatment the effluent is discharged by pumping.

The sulphide oxidation utilizes pure oxygen gas provided by a pressure swing adsorption (PSA) generator system using zeolites as absorber media molecular screen. The pure oxygen dissolution system is named down-flow bubble contact aerator (DBCA) and incorporates prolonged contact time and high rate of oxygen transfer in a cone-shaped chamber (see Note). This system offers high rate of oxygen transfer without the risk of bad smell emission (no H_2S stripping).

The oxidised effluent enters in to the primary sedimentation tanks for solids settling.

The domestic effluents join the primary treated industrial effluents at the inlet of the biological treatment.

Note.

Effluent enters the chamber at the apex with a velocity of approximately 3 m/sec. This inlet velocity provides the energy to maintain a two-phase bubble swarm in the cone, ensuring a very high bubble-water interface and resulting in a proportionately high gas-transfer rate. The expanding horizontal cross section of the cone reduces the downward flow velocity of the wastewater to less than 0.3 m/sec. Because the bubbles have a nominal buoyant velocity of about 0.3 m/sec, if the down flow velocity of the wastewater is reduced below the buoyant velocity of the bubbles, they will remain indefinitely in the cone, thus satisfying the required bubble residence time. The wastewater, however, has a residence time of about 10 seconds, reflecting the relatively small volume of reactor cone.

Primary treatment

Industrial wastewater, after the primary sedimentation tanks, sometime (when the organic load – COD – is very high) is introduced in the intermediate chemical treatment compartment where aluminium sulphate and poly-electrolyte solutions are dosed for flocculation and coagulation.

The flocculated effluent enters into the circular tank for solids removal and then into biological treatment.

Secondary treatment

The biological process includes de-nitrification (first step) and biological oxidation and nitrification (second step). The Nitrate removal (de-nitrification) is performed into an anoxic tank in which primary treated industrial effluent and urban waste waters are blended with the mixed aeration liquor and sludge of the biological phase continuously re-circulated. The mixing is provided by a series of submersible mixers.

The oxygen for the biological oxidation (BOD/COD removal and Ammonia nitrification) is provided by air injection (blowers and membrane diffusers). For enhancing COD removal, Activated Carbon is dosed in the oxidation tank.

The mixed liquor (effluent and biological sludge) enters the biological sedimentation tanks where settled sludge is continuously re-circulated to the de-nitrification tanks. The excess of sludge is periodically discharged and by-passed to the sludge treatment.

The supernatant liquid of the biological clarifiers flows by gravity to the tertiary chemical treatment. The dosed chemicals are Fe-salts, Lime and Polyelectrolyte. The quantity of chemicals varies according with the characteristics (SS and COD) of the effluent from the biological treatment (see Note).

Note: The typical COD and SS of the effluent from the biological sedimentation are 250-300 mg/L and SS 200-220 mg/L respectively. The tertiary treatment is therefore required for complying with the discharge standards.

Tertiary treatment

After settling the treated effluent flows to the final neutralisation, where pH is adjusted by dosing carbon dioxide (CO_2) gas. The use of this chemical is preferred because it does not increase the effluent salinity (chloride or sulphate).

The sludge generated by the tertiary treatment is pumped to the sludge thickener.

The discharge into Arno River is usually by gravity. Pumping is required only when the river level floods the plant discharge point.

Effluent characteristics

Table 5.3 Effluent characteristics

Parameters	Units	Value	Standard law
pH	Units	6.0 – 7.5	5.5 – 9.5
Suspended solids	mg/L	0 – 200	80
COD	mg/L	120 - 150	160
BOD5	mg/L	0-20	40
Ammonia nitrogen	mg/L	10 – 50	112
Nitrate nitrogen	mg/L	100-200	200
Sulphide	mg/L	0	1
Total chrome	Mg/L	0	2
Chloride	mg/L	30-45	50

Sludge management

Presently the sludge generated at various steps of the treatment is mixed in thickener. After mechanical thickening, the sludge is conditioned (cationic polyelectrolyte) and mechanically dewatered. The dewatering is performed by filter-presses. The sludge dewatering unit has 4 filter presses: two recessed plate filter presses 1500 x 1500 mm with 140 plates in HD Polypropylene, fed by piston-membrane pumps (work pressure 9 - 10 bars), and two membrane chamber filter presses 1500 x 2000 mm, with 100 plates in HD Polypropylene, fed by eccentric-screw pumps (work pressure 7 bars), and final membrane pressurisation at 10 - 11 bars with water. The dewatered sludge can be disposed at 30-35% DS or further thermally dried to reach 80% (See Note). Four (4) parallel drying units are installed.

Note: *80% DS is not only an acceptable goal from a cost-effective point of view, but also imposed by the Italian legislation that allows maximum 20% moisture in the industrial sludge to be used for brick production. The other limits for tannery sludge are maximum 2.5 g of trivalent Chrome per kg of residue as DS. It is important to note that all the sludge produced by CUOIODEPUR in the year 2000 has been given to composting plants for fertilisers (92% ca.) and brick furnaces (8% ca.): no sludge has been disposed into landfills.*

Performance

For performance evaluation, important criteria that have been considered are meeting effluent discharge regulatory norms, sludge management, and cost.

As seen from table for effluent characteristics, all the parameters are in the limit. Hence the technologies used are adhering to regulation in terms of discharge standards of the country.

Sludge produced is dewatered and then used as fertilizer and brick making.

Total treatment cost: € 11.3 million or INR 61,90,33,947 (* Taking exchange rate of € at 55 INR during 2005) Total amount of wastewater treated: 1,528,082 m^3 from industrial zone and 1,470,361 m^3 from sewage network, TOTAL 2,798,443 m^3

5.3.2 Netherland ETP

European Union (EU) had selected Netherland's ETP study as one of the best of best projects of LIFE-Environment Projects funded by EU. The case demonstrates an effective and efficient TANnery EFfluent TREATment (TANEFTREAT) using an innovative integrated and compact biological and physical treatment plant.

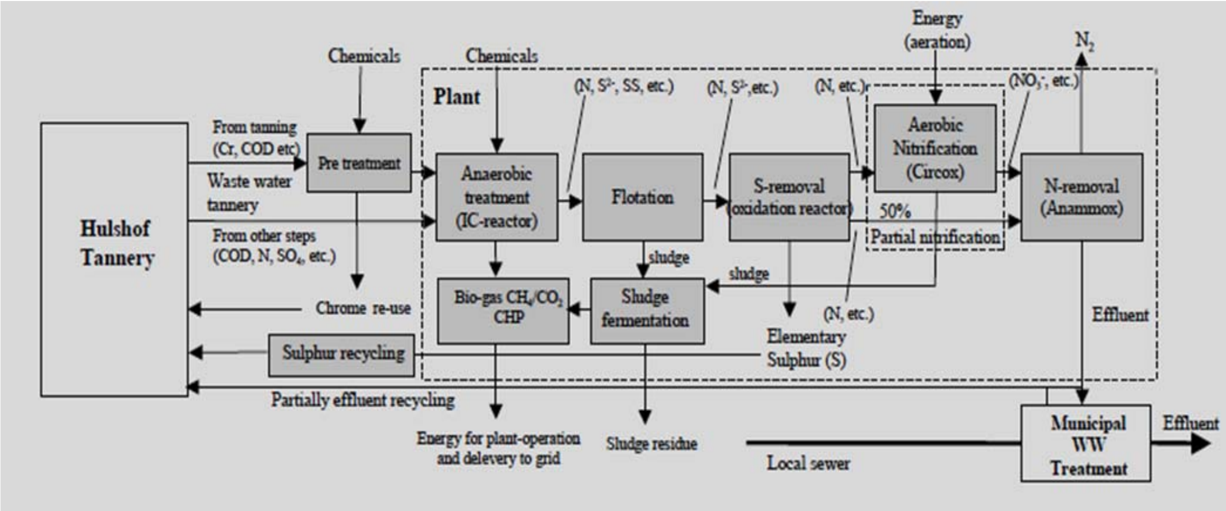


Figure 5.1 Simplified process flow diagram of the tannery effluent treatment plant in Netherland

Waterstromen and Hulshof Tannery together with Paques (engineer and developer of biological wastewater treatment plants) had put in place a waste water treatment facility in Netherlands. Waterstromen the operator of the plant is a private affiliate of Waterschap Rijn & IJssel, the water quality management authority for the eastern part of Gelderland and the southern part of Overijssel, Netherlands. The Hulshof Royal Dutch Tanneries dresses raw bovine hides to finished leather. Hulshof is the only Dutch tannery that comprises of all the four operations i.e. beam house operations, tan yard operations, post-tanning operations and finishing operations.

The plant showcases a smart combination of treatment technologies to treat the complex tannery effluent realizing high reduction rates (surface water discharge levels).The waste water treatment process comprises of the following steps:

- Removal of COD/organic matter (IC reactor and floatation);

- Removal of sulphur (Oxidation reactor);

- Removal of nitrogen (Cirox and Anammox reactor);

- Re-use of effluent as process water.

IC Reactor and Floatation

The waste water is chemically pre-treated and then the effluent entering the treatment plant is subjected to anaerobic treatment in the first chamber i.e. IC reactor which helps in removing COD/organic matter from the waste water stream. Micro-organisms are used to reduce the organic matter producing methane (biogas) in the process. A major part of the chromium is attached to the biological sludge in the IC reactor. In the next step, sludge floatation helps in the separation of sludge from the waste water stream. Also, biogas is used for flotation to prevent oxidation of sulphide to elementary sulphur in the flotation unit.

Sulphur-Oxidation reactor

Tannery waste water contains significant amounts of sulphur being present in the form of sulphate and sulphide. In the IC-reactor the sulphate is being reduced (under anaerobic conditions) to sulphide resulting only sulphide form in the waste water stream for further processes. In the oxidation reactor the sulphide is being oxidised to elementary sulphur that is removed using flocculation and settlement. Since most of the organic matter is removed in the previous step (IC-reactor with flotation), the elementary sulphur sludge contains a relatively low concentration of organic matter.

Cirox and Anammox reactor

The wastewater flows from oxidation reactor to the Cirox reactor in which partial aerobic nitrification of the waste water takes place. The de-nitrification within the treatment plant is performed using the anammox bacteria (*brocadia anammoxidans*). These bacteria make only partial (50 %) up-front nitrification of the wastewater because in the Anammox reactor a fifty/fifty mixture of ammonium and nitrate is converted into nitrogen.

Further the effluent is mixed with municipal wastewater for treatment.

Performance

COD removal was better than expected - the project achieved a 95% removal rate, whereas the BAT had a COD removal rate of <90%. Sulphur removal showed considerable improvement. Here, the project achieved a 70% removal rate, compared with a BAT removal rate of 40%. Chromium removal rate is 99%, while nitrogen removal is 79%. Chemical use was better than expected. The project achieved an 80% reduction on the amount of chemicals used with the BAT.

5.3.3 SWEDEN ETP

The tannery Elmo Leather AB in Sweden has the wastewater treatment plan with a system of nitrogen removal. The plant has two additional steps of nitrification and de-nitrification for the tannery waste water treatment system. The wastewater treatment process is as follows:

The tannery waste-water is screened through a 2mm screen before entering the inlet pumping station for biological treatment. Biological treatment is spread across 2 steps.

The step 1 of the biological treatment helps in equalization and removal of COD and toxic matter. The wastewater is pumped into the aeration tank (volume of 2000 m^3) where micro-organisms are grown to oxidize a great part of the organic matter and sulphide in the wastewater. Oxygen is supplied through robust aerator mixers to secure stable operation of the first biological step. Phosphoric acid is dosed to Support the growth of micro-organisms. From the aeration tank the wastewater flows to a de-aeration tank where iron salts and polymer can be added to improve performance of the first settling tank. In the first settling/sedimentation tank most of the suspended solids in pre-treated wastewater are removed. Excess sludge collected at the bottom of the settling tank is pumped to sludge dewatering in the existing sludge dewatering building.

Intermediate pumping station: Pre-treated wastewater is collected in an intermediate pumping station from where it is then pumped to the second aeration tank. The pumping of the wastewater into aeration tank is dependent on the operation mode in the aeration tank.

The final purification of the wastewater takes place in the second aeration tank. The tank is designed with a big volume (5100 m^3), so that biological nitrogen removal could take place. Nitrogen is present in the wastewater mainly as ammonia and its removal is by nitrification and de-nitrification.

In the biological process the ammonia nitrogen is oxidized into nitrate. This process takes place under aerobic conditions, i.e. in the presence of oxygen. In the second process (de-nitrification), the nitrate is reduced to gaseous nitrogen, which escapes into the surrounding atmosphere. The de-nitrification takes place under anoxic conditions. The combination of aerobic and anoxic conditions (which is necessary for the nitrogen removal) is created by turning off the aeration when de-nitrification taking place.

The wastewater is then pumped into de-aeration tank from aeration tank where polymer can be added to improve performance of the final settling tank. In the final settling tank, the suspended solids settles and the treated wastewater (almost free from suspended solids) is transported to a disc filter, which has a maximum size of 10 Fm to ensure that levels of remaining suspended substances are low. The treated water is discharged into river.

The major part of the sludge is pumped back into the aeration tank in both biological steps and while a minor part of the sludge is pumped to sludge watering in the existing sludge dewatering building. It is important for the stability of the nitrification/denitrification that micro-organisms from the sludge are transferred back to the aeration tank.

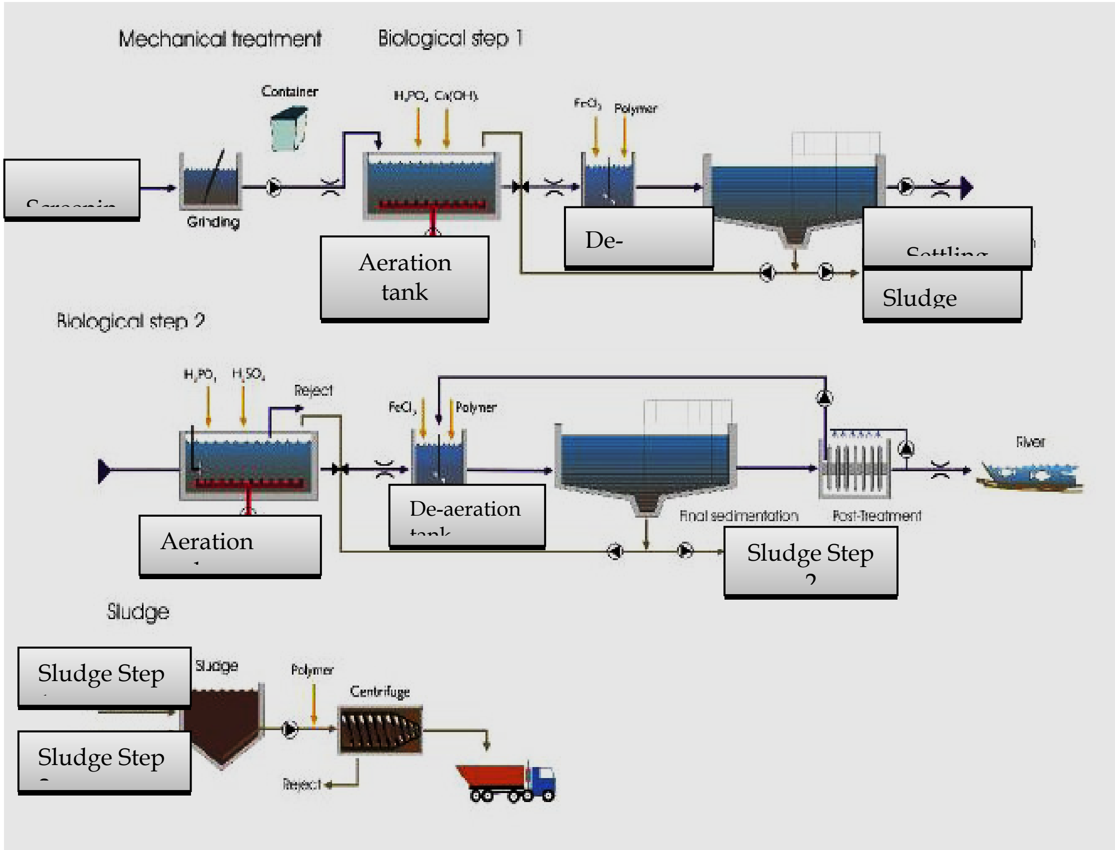


Figure 5.2 Treatment Scheme of the tannery effluent treatment plant in Sweden

Performance

The plant showed an average reduction of some key parameters like BOD-removal 98%, COD-removal 92%, Nitrogen-removal 89% and Chromium removal 89%.

5.4 Indian Tannery case-study

Tanning is one of the oldest industries in India and ranks amongst the five top-most export oriented industries of the country. The total value of leather and leather products covering both export and domestic markets is estimated around US $ 8 billion for the year 2008. The main centres of tanning industry are located in the states of Tamil Nadu, Uttar Pradesh, West Bengal, and Punjab.

Tamil Nadu has demonstrated best practices in CETP. Tanning is the predominant industrial activity carried out in clusters in Tamil Nadu over several decades. However, it is only since 2002 that the Tamil Nadu Pollution Control Board has been exhorting all tanneries to install membrane technologies with suitable reject management system for the recovery and reuse of permeate water and salt in the process and hence to facilitate zero discharge of effluents.

5.4.1 CETP at Vaniambadi, Tamil Nadu

The state of Tamil Nadu in India is having maximum number of CETPs and has large number of tanneries. Hence, the selected CETP for comparison is from the state of Tamil Nadu and catering to tanning industries. This case shows that India is using better and cleaner technologies as compared to best available techniques. The techniques used are able to meet the regulatory norms easily and are cost effective. Section below, will provide the detail about the techniques and functioning of the selected CETP.

Details of CETP

CETP at Vaniambadi caters to about 130 tanneries which process rawhide to finished leather. The capacity of the CETP is 4 MLD. The length of the effluent transportation network is about 8 kms. Zero Discharge System of effluent disposal is presently run on a trial basis in the CETP. The individual member tanners are carrying out pre-treatment comprising settling tank for non-chrome bearing effluent. The chrome bearing effluent is separately treated in the chrome recovery unit in individual tanneries.

Table 5.4 Influent characteristics

S. No.	Parameters	Value
1.	pH	7.5 – 9.0
2.	Temperature	25 – 35
3.	Alkalinity as $CaCO_3$	700 – 1100
4.	COD	2500 – 3500
5.	BOD 5 days @ 20˚C	1200 – 1600
6.	Total Solids	13000 – 17500
7.	Total dissolved solids	12000 – 16000
8.	Total suspended solids	500 – 1500
9.	Chloride as Cl	5000 – 8000
10.	Sulfate as SO_4^{2-}	1000 – 1500
11.	Total chromium as Cr	<2.0

Primary treatment

The first step of the process is mechanical screening, which removes all the big sized waste products like polythene packets, leaves, etc. Screened influent is then contained in an equalization tank, which has submersible mixers. This effluent is then transferred to primary clarifier where in chemical dosing of the wastewater is done with the help of alum and polyelectrolytes. From this, clarifier liquid is sent to intermediate storage tank, which is then filtered through fine screen and transferred to anoxic tank.

Secondary treatment

After this it is conveyed to aeration tank and then to Membrane Bio-reactor (MBR). After MBR treatment, effluent is subjected to Reverse Osmosis System. To achieve zero discharge, the CETP has installed RO system with reject management system (RMS). The RO system is needed because in CETP only organic pollutant and chromium are removed but not TDS and hence treated tannery waste water from CETP is not suitable for reuse in the tannery for wet finishing operation due to high TDS. RO system addresses the above issues. This RO filter treats water and the TDS is reduced to less than 500 mg/L and this permeate can be reused further. Rest of the water is subjected to evaporation to remove excess salts from it.

Table 5.5 Treated effluent quality from membrane bioreactor

Parameters	Value
BOD	<2mg/L
TSS	<2mg/L
Ammonia	<1 mg/L
TN	<10mg/L
TP	<0.1mg/L
Turbidity	0.1 NTU
SDI	3

Effluent characteristics

Table 5.6 Quality requirement for water recovered from RO system for reuse

S. No.	Parameters	Value
1.	pH	6.5 – 7
2.	Total Dissolved Solids	<500mg/L
3.	Suspended Solids	Nil
4.	Chloride	<175mg/L
5.	Sodium	<275mg/L
6.	Water recovery rate	75%

Performance

Under EPA rules 1986, the prescribed standards for treated effluent, this CETP is able to meet the regulatory norms.

Table 5.7 Performance evaluation in terms of wastewater treatment

Parameters	Global case-reduction %	Indian case-reduction %
pH	8.5%	22.2%
Suspended solids	96.5%	100%
Chloride	36.5%	97.8%

Table 5.8 O&M cost of treatment processes

O & M Costs	Rs. Per Cubic Metre
Primary Treatment	5.5
Biological Treatment	11
Reverse Osmosis	16
Evaporation	25
Water Distribution	1
Others	3.5
Total	62

The CETP management is charging Rs 5,000 as fixed charge to tanners having tanning capacity1000 kg/day and 5paise/ L as variable cost.

Sludge from primary clarifier is taken out and then processed in chamber filter press, where it is dewatered and then disposed to a secure landfill.

5.5 Combined Wastewater Treatment Plants

The new and innovative technology of recovering the metals before the effluents enter the municipal waste water treatment plants is being practiced in many countries including India. Examples from Thailand is mentioned briefly.

CETP Thailand:

The tanneries in Thailand are located in clusters such as Km-30 group and Km-34 group in Samutprakarn province. Both clusters of tanneries use a central wastewater treatment system. In general, tanneries discharge wastewater from the various production treatments into a single collection drain, leading to the wastewater treatment system. The majority of tanneries in Thailand consider pre-treatment before the waste water enters the collection drain. Owing to the type and amount of chemicals applied in the different production steps, as well as because of the different reactions taking place in the various productions steps, the composition/characteristics of wastewater generated in each production step shows big variances. Therefore, separate treatment (or pre-treatment) of wastewater generated at the different production steps is considered.

Wastewater discharged from the beam house contains toxic sulphide, which besides creating odour problems is also highly toxic and, hence, is treated (oxidized) separately at its origin in the beam house. For the chromium wastewater from tanning of each tannery, if there is no preliminary chromium treatment, there will be the problem of chromium accumulation in the common wastewater treatment system both in the form of effluent and sludge or sediment. Wastewater from other parts contains mostly organic substances, which can be purified directly in the central treatment system.

5.6 Conclusion

India is using an advance technology of Zero Liquid Waste Discharge (ZLD) by using Reverse Osmosis System. It has also been observed that the chrome recovery (in case of chrome tanning industry) and nitrogen recovery is not that efficient in comparison to the global cases like the example shown from Netherland and Sweden. Also issues related to operation and maintenance, paucity of funds, inadequately trained staff are quite evident which lead to further under-performance of the available technologies.

6. Pharmaceuticals

6.1 Pharmaceutical Industry

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.

6.2 Effluent characteristics

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.

In general, wastewater from this 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.

6.3 Treatment process

Segregation of waste in most cases is required for some waste streams to be treated independently. It is often used as a cost saving method since it is usually more economical to treat a small concentrated flow than a large diluted effluent stream.

Intermittent effluent discharge often dictated that there is a balancing facility (equalisation tank). If there are suspended solids, mixing is necessary or alternatively the sludge should be removed. The equalization tank can be used for self-neutralization of mixed acid and alkali effluents.

If further neutralization is required, depending on the nature of the effluent neutralizing chemicals such as sodium hydroxide, lime or calcium carbonate (for acidic) and sulphuric and hydrochloric acids (for alkali) are used.

If chemical pre-treatment is required to remove emulsions, colloidal material and intractable organics a separate reaction tank is required. Usually a coagulant along with lime is used, the more effective coagulants being ferric chloride, ferric sulphate and alum. A primary sedimentation tank should be installed when lime dosing for discharge pre-treatment is used. To remove large amounts of sulphate precipitation can be done as the calcium salt by addition of lime. However if oily effluents are in greater quantity it may be economical to specifically treat them using and oil skimmer, or dissolved air flotation, or electro-flotation which can also break emulsions.

Pre-aeration can remove volatile material present in effluent and it also increases the dissolved oxygen which in turn will aid biological treatment process.

If the effluent consists of simple organic materials biological treatment is preferred. In most cases activated sludge process is used as a completely mixed system. Majority of the organic chemicals present in pharmaceutical waste is biodegradable; this in turn allows an acclimatized microbial population to develop. For effective treatment a favourable physical and chemical environment for biological activity must be ensured.

6.4 Case of wastewater treatment in United Kingdom

AstraZeneca is a global, integrated biopharmaceutical company. It discovers, develops, and manufactures prescription medicines for six important areas of healthcare, which include some of the world’s most serious illnesses: cancer, cardiovascular, gastrointestinal, infection, neuroscience, and respiratory and inflammation.

AstraZeneca’s manufacturing processes are regulated under the IPPC regime. The site has a number of discharge consents from the Environment Agency. However, the company decided to achieve better treatment of its effluent and to position itself as a plant capable of taking on a wider range of projects.

The AstraZeneca effluent plant at Avlon Works, Avonmouth, United Kingdom has been designed to meet the current and likely future expansion of the effluent load from the plant and to enable it to treat on site the effluent that was previously being sent for treatment elsewhere. The advanced control system incorporated at the site allows to undertake remote administration of the SCADA (supervisory control and data acquisition) system, allowing to retain historical data so it can be checked how efficiently the plant has been running.

6.4.1 Effluent Characteristics

The plant produces four effluent streams:

Stream 1 and 2- Strong effluent and Weak effluent – are blended together to form a waste stream containing COD concentrations of up to 3,000 mg/L with a varying flow rate from 500 - 3,000 m^3/day.

Stream 3 – High Strength effluent - containing COD concentrations up to 90,000 mg/L, was normally loaded into road tankers for off-site disposal by incineration or treatment, but is now fed into the treatment plant.

Stream 4 - Foul effluent - is a combination of sanitary effluent, effluent from the site restaurant and laboratories.

The Weak Effluent and foul flows make up the majority of the treatment volume, while the strong and particularly the High Strength effluent contribute the bulk of the COD load.

6.4.2 Selection and Introduction of Treatment Technology

A Best Practicable Environmental Option (BPEO) study was undertaken to assess the present and longer term requirements for treatment of liquid waste at the works. The report indicated an aerobic oxidation process as the preferred treatment technology.

AstraZeneca moved towards the Anox moving bed bioreactor process which provides a more robust treatment route, followed by chemical phosphate removal and a Dissolved Air Flotation (DAF) plant.

In the MBBR biofilm technology, the biofilm grows within engineered plastic carriers, which are designed with high internal surface area. These biofilm carriers are suspended and thoroughly mixed throughout the water phase. With this technology, it is possible to handle extremely high loading conditions without problems of clogging, and treat industrial and municipal wastewater within a relatively small footprint.

The MBBR biofilm technology is efficient, compact and easy to operate. It can be an excellent solution as a stand-alone process, or it can be used to specifically enhance or upgrade treatment potential of activated sludge processes.

The MBBR can be used as sole biological treatment or in combination with other technologies. The MBBR could be designed as a single step, or a multi-step process. It works well together with chemical treatment. When operated at low organic loading and as a multi-step process, a unique microflora is developed in each step and this will significantly increase the possibility for removal of both easily degradable organic matter and more hard-to-degrade organic matter in the different steps.

The MBBR biofilm technology can be used as a preliminary treatment stage or as a combined hybrid stage or treat reject water from anaerobic digestion and also as a final polishing step.

System description

The MBBR biofilm technology is based on specially designed plastic biofilm carriers or biocarriers that are suspended and in continuous movement within a tank or reactor of specified volume. The design of associated aerators, grids, sieves, spray nozzles and other integral parts to the reactor is also of great importance in making up the system as a whole.

The wastewater is led to the MBBR treatment reactor where biofilm, growing within the internal structures of the biocarriers, degrade the pollutants. The biocarrier design is critical due to requirements for good mass transfer of substrate and oxygen to the microorganisms. Excess biofilm sloughs off the biocarrier in a natural way.

An aeration grid located at the bottom of the reactor supplies oxygen to the biofilm along with the mixing energy required to keep the biocarriers suspended and completely mix within the reactor. Treated water flows from reactor through a grid or a sieve, which retains the biocarriers in the reactor. Depending on the wastewater, the reactors may be equipped with special spray nozzles that prevent excessive foam formation.

6.4.3 Treatment scheme for AstraZeneca effluent plant

A front-end engineering design producing a robust, flexible and fully automated plant has been developed which is capable of handling a wide range of effluent flows and loads, whilst maintaining performance.

The effluent treatment plant is designed to receive all four streams. With a total flow rate ranging from 500 – 2500 m^3/day with a COD of approx. 3000 mg/L. The designed ETP has 4200 Kg/d COD capacity.

In addition, a new Weak Effluent collection and pumping pit discharges to an existing interception facility upstream of the effluent treatment plant.

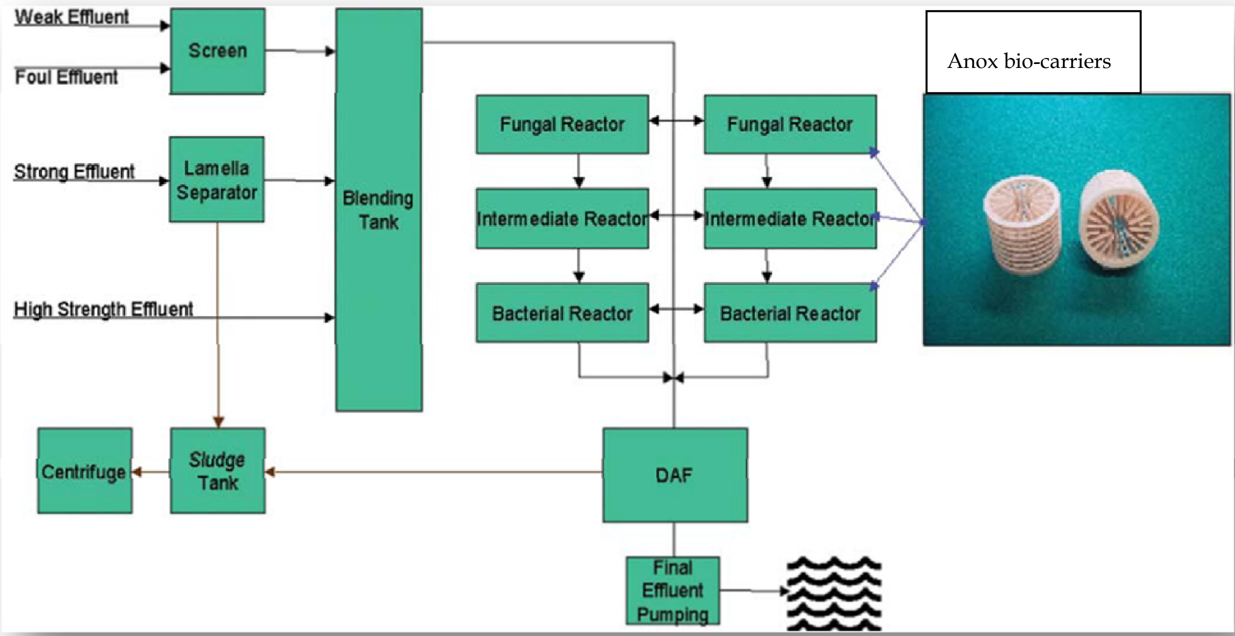


Figure 6.1 Treatment scheme for AstraZeneca effluent plant at Avlon Works, Avonmouth, United Kingdom

Preliminary treatment

Equipment used:

- Inlet screens
- Weak Effluent Balancing Tank 2513 m^3
- Strong Effluent Balancing Tank 90 m^3
- High Strength Balancing Tank 90 m^3
- Strong Effluent Lamella Separator
- Weak Effluent Heat Exchanger

- Mixed Effluent Blending Tank 90 m^3
- Nutrient and pH balancing equipment

Secondary Treatment

Equipment used:

- 2 No. fungal reactor tanks at pH 4.0, 550m^3 each
- 4 No. bacterial reactors at pH 7.0, 550m^3 each
- pH balancing equipment

(The fungi reactor remove approximately 60% of the COD load while the bacteria reactor further improve the water quality offering up to in excess of 80% overall removal efficiency.)

- Polymer, ferric sulphate and dosing equipment to flocculate biomass and precipitate phosphate salts
- 2 No. DAF units 75 m^3 each
- Tidal Tank for Final Effluent storage 250 m^3

First stage of the plant provides coarse solids separation for the Weak Effluent and foul arisings, and balancing for all streams to provide a sufficient hold up volume for toxic shock control. Strong Effluent is pumped via a Lamella separator to the blending tank to reduce activated carbon particulates. Weak effluent is pumped via a heat exchanger to the blending tank to raise the mixed fluid temperature following process upsets, while the high strength stream is pumped via a balance tank into the blending tank which provides residence time for thorough mixing, nutrient addition and pH control prior to pumped discharge to the biological second stage. High Strength Effluent has to be maintained at 25°C by a shell and tube heat exchanger to prevent crystallisation at lower temperatures.

The biological process is driven by gravity flow and consists of two reactor streams. Each of three reactors is fabricated from high Molybdenum 316L stainless steel, arranged in parallel with cross connections providing operational flexibility.

The first reactors operate at pH 4 to promote fungal growth and are adjusted to pH 7.0 in the second and third reactors to enable bacteria to proliferate. In all reactor cases the biology is sustained by means of aeration and mixing. An aeration grid located at the bottom of the reactor supplies oxygen to the biofilm along with the mixing energy required to keep the biocarriers suspended. Biofilm grows protected within these engineered plastic carriers, which are designed with a high internal surface area. The organic substrate adheres to suspended Anox bio-carriers that have extended surface area to maximise the efficiency of aeration and mixing. Foaming is suppressed by spray nozzles mounted in the tank roof and is controlled by means of foam level probes. Reactor tank headspaces and all other internal vessels are forcefully extracted to atmosphere via the vent stack to control. The Anox bio-carriers are retained within each reactor by means of screens.

The fluid then gravitates into a final stage of treatment where polymer, ferric sulphate dosed to flocculate the dislodged/sloughed biomass and precipitated phosphate salts. The sludge is then separated via dissolved air flotation (DAF). Final effluent is pumped via the existing effluent discharge pipeline to the River Severn. Sludge removed from the primary lamella and DAF units is stored and dewatered using centrifuges. Sludge is transported from site as sludge cake for final disposal.

COD to the treatment plant has been extremely variable during the first three months of operation with peaks of 2600kg COD/day down to almost zero load. However, the final effluent quality has consistently achieved consent levels, which are set at 1000kg COD/wk with a daily maximum of 500kg COD/day. Phosphate load has also been variable, but the plant has coped well to mitigate it.

6.5 Case of wastewater treatment in India, Patancheru CETP

The Common Effluent Treatment Plant emerged as a necessity following the industrial development in Pattancheru Industrial belt. The various incentives offered by Government of Andhra Pradesh created a hub of activity in this area during 1970-80. The establishment of Chemical, Pharmaceutical industries brought a distinction to this area and it has become an address for bulk-drug manufacturers. With this development the pollution generated has become an issue.

To overcome the pollution problem, and maintain the ecological balance in Patancheru, the industrial units, in particular, pharmaceutical and bulk drug units with the encouragement from Andhra Pradesh Industrial Infrastructure Corporation Limited (APIIC) formed a company in 1989 – M/s Pattancheru Enviro Tech Limited. The objective was to establish of a common effluent treatment plant for treating the industrial effluents emanating from this industrial belt for Pollution Control. A common Effluent Treatment Plant (CETP) was established with a capacity of 7500 m^3 per day. The cost of the project was Rs. 5.70 Crores. The Plant started its operations in 1994 and the management of the plant was taken over by the directors representing industry. An amount of Rs. 3.00 Crores was spent subsequently for upgrading the treatment facilities in the CETP. Liquid Oxygen injection technology was adopted for the first time in the country for biological treatment in a CETP. However, the Common Effluent Treatment Plant (CETP) could not achieve the desired results initially due to high TDS.

Various measures have been taken to tackle this problem and the CETP is meeting the outlet standards consistently. The standards fixed for accepting effluent tankers at CETP, Patancheru with time frames are as under:

1	Earlier to taking over in 1996 by PETL from APIIC	Inlet TDS	>40000 mg/L
2	After taking over the management by industries in 1997	Inlet TDS	<20000 mg/L
3	Subsequently reduced	Inlet TDS	<15000 mg/L
4	Subsequently, as per the Hon'ble Supreme Court directions during 1999	Inlet TDS Inlet COD pH Suspended Solids	<15000 mg/L <15000 mg/L 6.5-8.5 1000 mg/L
5	Subsequently, as per the Hon'ble Supreme Court directions during 1999	Inlet TDS Inlet COD	<5000 mg/L <15000 mg/L

This CETP has 106 No. of member industries. All the member industries are sending only their low TDS effluents (TDS less than 5000 mg/L from 01.02.2009) to the CETP for treatment and disposal. The present utilization in 2500 m^3 and the capacity of the dedicated pipeline to carry the treated effluent to STP at Amberpet is 5000 m^3. The pollution load has also significantly reduced on account of various measures taken by the industry and CETP.

Table 6.1 Inlet parameters

Inlet Parameters	Actual
pH	6.50 to 7.50
Total Dissolved inorganic solids mg / L	3000
Chemical oxygen demand mg /L	3500
Ammonical Nitrogen mg / L	35
Oil & Grease mg / L	10

Table 6.2 Outlet parameters

Outlet Parameters	Actual
pH	6.50 to 7.50
Total Dissolved inorganic solids mg /L	1700
Total Suspended inorganic solids mg /L	50
Chemical oxygen demand mg /L	200
Biological oxygen demand mg / L	16
Ammonical Nitrogen mg /L	1 to 5
Oil & Grease mg /L	1 to 5

The reduction in the Pollution load over time can be evaluated from the following table.

S. No.	Results of CETP	No. of 10 KL tankers received	Pollution Load			
			Inlet		Outlet	
			COD MT	TDS MT	COD MT	TDS MT
1	Before taking over from APIIC, 1996	28383.68	11353	11353	2838	7096
2	After taking over by industries, 1997	49040	7356	9808	2452	5885
3	During the calendar years:					
	2001	57817	5782	8673	1214	5782
	2002	62142	5593	8700	932	5593
	2003	59832	5086	7180	1017	5385
	2004	58541	4683	5854	1054	4683
	2005	58637	4105	5277	1055	4368
	2006	52335	2955	3435	803	2798
	2007	57342	3727	3683	1081	3668
	2008	60513	3783	3314	1273	2850
	2009	40859	1323	1173	198	811
	2010	43906	1411	1018	95	742
	2011	46489	1498	1079	91.6	723

Source PETL

It may be seen that organic pollution released by the CETP in 1996 was 2838 MT and by 2011 it was reduced to 91.6 MT.

Installation of zero liquid discharge systems viz., Stripper, MEE, ATFD and RO in the 25 major bulk drug industries, with result the quantity of effluent received at M/s. PETL was reduced from 1750 KL/Day to 1100 KL/Day.

6.5.1 Wastewater Treatment

The CETP receives effluents mainly from pharmaceutical and other chemical industries and sewage of BHEL Township through about 100 – 130 no. of pre-treated effluent tankers (1000 – 1300 cum. of effluents) from member industries and about 1000 – 1300 cum sewage water from adjacent Iskavagu. The tankers received at CETP for treatment are checked for various parameters like pH, TDS before un-loading.

Unit Operations

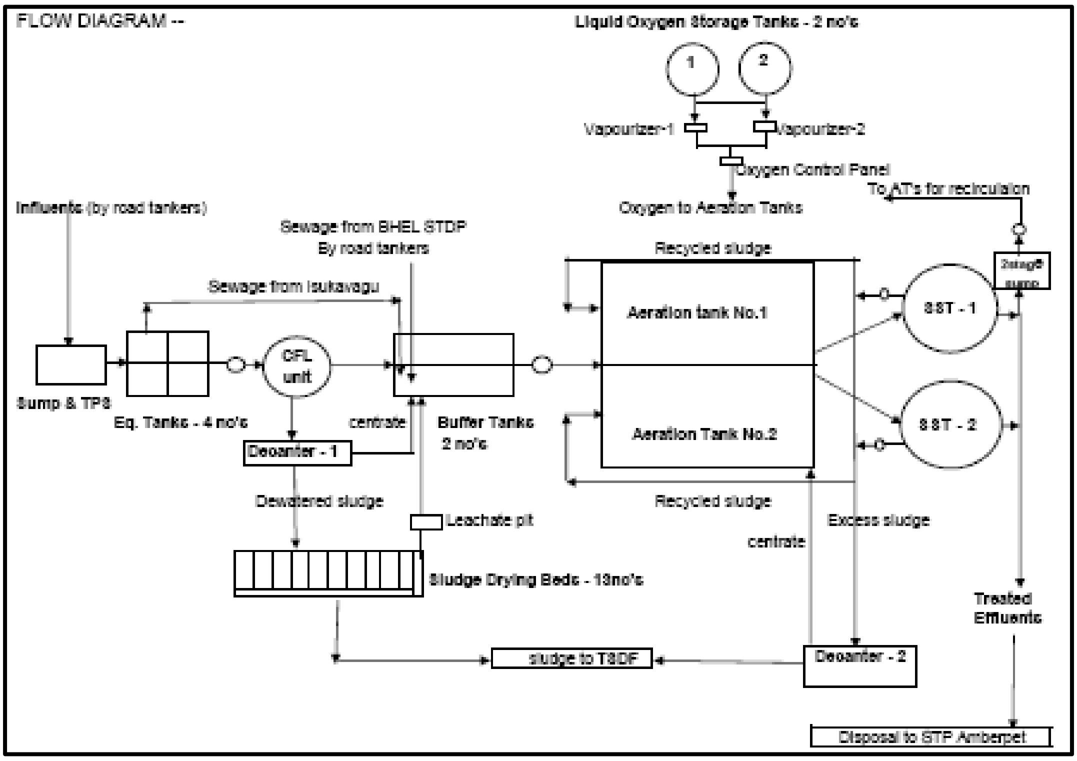
1. Receiving Sump & Terminal Pumping Station: Pre-treated effluents received by road tankers are tested / analysed for inlet standards and unloaded in the sump. The influents are pumped to Equalization Tanks, to equalize the effluents.
2. Equalization Tanks: There are 4 Equalization Tanks to store the effluents for about 2-3 days. Equalization Tanks are provided with aeration grid and air blower to equalize the influents and to strip of any organic volatile matter. The effluents from equalization tanks are being pumped to Clariflocculator through Flash Mixer after addition of alum and poly electrolyte.
3. Clariflocculator & Flash Mixer Unit: This unit is used to remove suspended solids from the wastewater. Alum is use for coagulating the suspended solids and these solids are separated. The suspended solids removed are collected in a sludge storage tank. The separated sludge is sent to Decanter – 1 (centrifuge) for further separation of liquids and solids in the form of cake. The clarified effluents from Clariflocculator flow to Buffer Tanks by gravity.
4. Decanter No. 1 (Centrifuge): The suspended solids removed in Clariflocculator with 1- 2% concentration are pumped to Primary Decanter. Polyelectrolyte solution is added to improve separation efficiency. In this unit sludge is separated into clear liquid and solid cake. The clarified water (Centrate) goes to Buffer Tanks, for further treatment. The sludge cake is collected in TSDF containers / and disposed to TSDF, Dundigal. Filter Press is provided as a standby unit to Decanter during maintenance of Decanter.
5. Sludge Drying Beds (13 numbers): The sludge cake from Decanter – 1 (Primary decanter) is disposed to TSDF, Dundigal.
6. Buffer Tanks: The clarified effluents from Clariflocculator unit are collected in these tanks. The raw sewage from adjacent Iskavagu is mixed with clarified effluents in these tanks. Diffused aeration is provided to maintain homogeneous conditions for further treatment (for better mixing and to increase pre aeration). The sewage is added to improve the biological treatment efficiency in the next units, as a constant seed in Aeration Tanks.
7. Aeration Tanks: There are 2 numbers of Aeration Tanks, with a capacity of 4,300 cum each. There are 4 floating aerators of 50 HP capacity and 6 floating aerators of capacity 30 H.P each. Surface Aerators are provided to supply oxygen from air and to maintain required dissolved oxygen in aeration tanks. Oxygen is controlled by checking the D.O. levels in Aeration Tanks at regular intervals.
8. The influents of Aeration Tank are degraded by microorganisms (MLSS / MLVSS) present in the Aeration Tank, thereby reducing the pollution loads, BOD & COD. As a result, the micro-organisms multiply and MLSS levels are maintained in the Aeration Tank by recirculation of sludge from Secondary Settling Tanks.

9. Secondary Settling Tanks: The outlet of the Aeration Tank is connected to Secondary Settling Tanks, which receives the treated effluents from Aeration Tank along with the Biological sludge in the form of Suspended Solids. The MLSS settles at the bottom in the form of sludge. Settled sludge is re-circulated back to Aeration Tanks to maintain MLSS levels in the Aeration Tanks. The excess sludge is waste through Decanter – 2. The clarified water from Secondary Settling Tanks is pumped to tertiary treatment i.e., MBR Technology / storage tank.
10. Decanter – 2 (Centrifuge): The excess sludge produced in Aeration Tanks is collected in Secondary Settling Tanks at the bottom, which is sent to Sludge pit of Decanter. The sludge is separated as sludge cake and clarified water in the Decanter. The clarified water goes back to Aeration Tank and the sludge cake is transferred to Secured Land Fill Unit. Filter Press is provided as a standby unit to Decanter during maintenance of Decanter.

Tertiary Treatment

MBR Technology: Designed capacity 2500 m^3 / day

The clarified water from secondary settling tanks is pumped to MBR Plant. UF Membranes provide a physical barrier that prevents passage of bacterial organisms and solids in to the water supply. As a result high quality water can be produce with nominal chemical addition and treatment. The treated water from MBR Plant collected in Storage Tank for pumping to STP, Amberpet for further treatment.



Other Steps taken to control the pollution

A ban notification prohibiting establishment / expansion of certain polluting industries in and around IDAs / IEs including industrial areas located in "Patancheru-Bollaram" areas has been issued since 1999.

All the member industries were directed to segregate the effluents into High Total Dissolved Solids (High TDS) and Low Total Dissolved Solids (Low TDS) streams. The High TDS effluents are force evaporated individually within the premises of industries and salts are sent to Treatment Storage and Disposal Facility (TSDF), Dundigal.

The low TDS pre-treated effluents are transported to CETP by the industries in dedicated tankers duly following the manifest system.

All the industries have been directed to close the outlets, which may otherwise join the water bodies. Industries were directed to construct separate drains for storm water /rain water and effluents.

Order issued since 1999 to transport the effluents to CETPs between 6 AM to 6 PM and also to confiscate and penalize the tanker and transport companies indulging in illegal movement of effluent tankers operating without proper manifest forms and plying in between 6:00 PM to 6:00 AM i.e. during night times, to control illegal dumping of effluents. Night surveillance teams had been informed to check the illegal dumping of effluents and hazardous waste and to check the illegal movement of effluent tankers.

The following have been implemented since 1.02.2009:

- Deputed AEEs/Analysts from 6.00 A.M to 6.00 P.M who check the inlet standards of effluent tankers received from member industries.
- Returned 769 tankers (7690 KL) which did not meet the standards.
- Monitored PETL on regular basis for inlet and outlet standards
- PETL improved the aeration process at primary treatment
- Dissolved Air Floatation (DAF) unit was upgraded
- Improved seeding of effluent with microbes to improve the biological treatment
- Replaced the ½ inch liquid oxygen pipeline with 1 inch pipeline at secondary treatment unit to increase the quantity of oxygen for aeration
- Installed online VOC, TDS, TOC and flow meters at the outlet of M/s. PETL.

For further polishing of the effluent an 18 Km pipeline was laid for transportation of treated effluents from the outlet of PETL to K&S main sewer which is connected to the newly constructed Sewage Treatment Plant (STP), Amberpet and finally discharging the treated wastewater into river Musi.

6.5.2 Improving the process control through new technologies

While taking measures for improving the performance through process control, PETL explored new technologies for further improving the outlet parameters. These efforts resulted in identifying MBR Technology for further reduction of Organic load (COD). Action has been taken to order the equipment for ultra-filtration through Membrane Bio-reactor technology. Further, M/s. PETL made an additional investment of Rs 5.0 Crores for installation of Membrane Bio reactor to further reduce the COD to about 140 mg/L, and it was commissioned on December, 2010.

The various steps taken and efforts made usher in bringing new technologies and acted for rejuvenation and significant improvement in the treatment of effluents and help the pollution control and ecological balance of this industrial hub.

6.5.3 Results

Due to implementation of the measures, M/s. PETL has made substantial progress in achieving the outlet standards and is meeting the outlet standards consistently.

Table 6.3 Performance of M/s. PETL during 1994 to October 2010.

YEAR	INLET (TOTAL DISOLVED SOLIDS in mg/lt)	OUTLET (TOTAL DISOLVED SOLIDS in mg/lt) (Standard-2100 mg/lt)
1994 – 1997	20,000 – 40,000	About 18,000
From 12.05.1998	< 15,000	About 8,000
From 26.12.2005	< 10,000	About 6,000
From 01.02.2009	< 5,000	About 2,700
May 2010	< 2,293	1,994
June 2010	**< 2073**	**1856**
July 2010	**< 2368**	**1846**
August 2010	**< 2350**	**1837**
September 2010	**< 2334**	**1856**
October 2010	**< 2319**	**1847**

At present all the treated effluent of M/s. PETL is joining the STP at Amberpet for further treatment and also M/s. PETL and STP at Amberpet are meeting the prescribed discharge standards.

7. Electroplating Industry

Electroplating industry in India is spread throughout the country. They are mainly in small scale sectors with over 3,00,000 small scale units. The pollutants from the electroplating industries are invariably hazardous, as the effluents contaminate air, water and soil. Some of the polluting agents have deleterious effect on human health, examples being cadmium, lead, nickel, etc. The environmental load in electroplating industry mainly consists of process waste water, hydroxide sludge and sulphuric acid. The untreated rinsing water has a lot of waste.

Electroplating involves the deposition of a thin protective layer (usually metallic) onto a prepared surface of metal, using electrochemical processes. Electroplating is used to impart various properties and attributes, such as protection from corrosion, improving surface hardness, aesthetical attributes, the shine or lustre, colour, value addition etc.

Electroplating operations can be found as individual plating units or form part of large scale manufacturing plants or as smaller units catering to specific needs. They are spread across the entire country with significant concentration in several states like Haryana, Uttar Pradesh, Maharashtra, Karnataka, Punjab, Andhra Pradesh, West Bengal and Tamil Nadu. Electroplating is considered a major polluting industry because it discharges toxic materials and heavy metals through wastewater (effluents), air emissions and solid wastes into the recipient environment.

Electroplating process, inputs and the outputs, by-products are shown in the figure below.

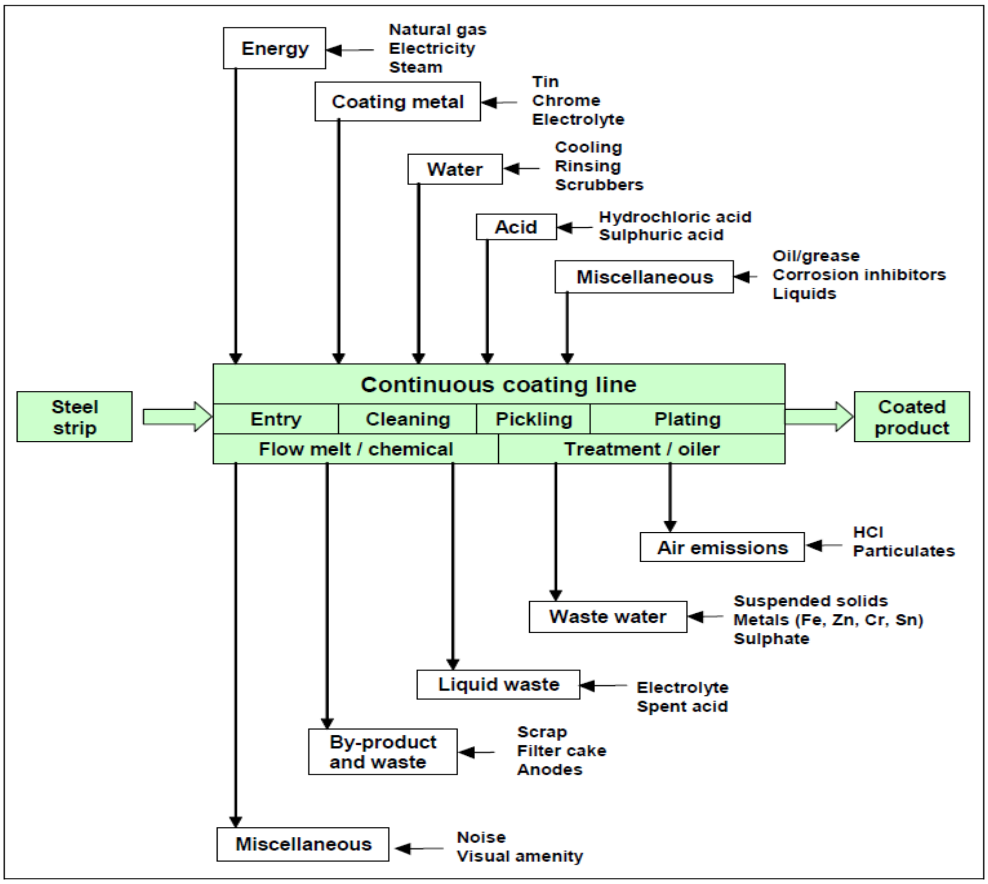


Figure 7.1 Schematic diagram representing input and output in an electroplating processing unit

7.1 Effluent characteristics

The process of electroplating involves pre-treatment (cleaning, degreasing, and other preparation steps), plating, rinsing, passivating, and drying. The cleaning and pre-treatment stages may involve a variety of solvents (often chlorinated hydrocarbons, whose use is discouraged) and surface tripping agents including caustic soda and a range of strong acids, depending on the metal surface to be plated. In the plating process, the object to be plated is usually used as the cathode in an electrolytic bath. The three main types of electroplating solutions used: are acid or alkaline solutions and may contain agents such as cyanides, toxic metals, etc. Any or all of the substances used in electroplating (such as acidic solutions, toxic metals, solvents, and cyanides) can be found in the wastewater, either via rinsing of the product or due to spillage and dumping of process baths. The solvents and vapours from hot plating baths result in elevated levels of volatile organic compounds (VOCs) and in some cases, volatile metal compounds (which may contain chromates). Approximately 30 % of the solvents and degreasing agents used can be released as VOCs if baths are not regenerated. The overall wastewater stream is typically extremely variable but usually high in heavy metals (including cadmium, chrome, lead, copper, zinc, and nickel, cyanides, fluorides), and oil and grease, all of which are process dependent. Cleaning or changing of process tanks and the treatment of wastewaters can generate substantial quantities of wet sludge containing high levels of toxic organics and/or metals.

Table 7.1 Characteristics of waste water

S. No	Parameter	Concentration	Prescribed limits for discharge into water bodies)
1	pH	2.1-3.5	5.5-9.0
2	TSS	60-525	100
3	Oil & Grease	7.48-49.2	10
4	Nickel	111-151	3
5	Hexavalent Chrome	340-371	0.1
6	Total Chrome	451-688	2.0

Source: Cleaner Production in Electroplating Industries, Information Bulletin, APPCB, 2004

7.2 Effluent Treatment Process

The minimum processes that are required for treating effluent of electroplating industry are:

- Cyanide reduction / destruction
- Chromium reduction
- Flow equalization
- Neutralization, and
- Metals removal

Individual design is necessary to address the characteristics of any specific plant but there are a number of common treatment steps. Cyanide destruction must be carried out upstream of the other treatment processes. If hexavalent chrome (Cr^{+6}) occurs in the wastewater, then this is also usually pre-treated to reduce it to a trivalent form using a reducing agent (such as sodium metabisulfide) followed by precipitation and sedimentation/filtration. The main treatment processes are equalization, pH adjustment for precipitation, flocculation, and sedimentation/filtration. The optimum pH for metal precipitation is usually in the range of 8.5-11 but this depends on the mixture of metals present. The presence of significant levels of oil and grease may affect the effectiveness of the metal precipitation process. Hence, the level of oil and grease affects the choice of treatment options and the treatment sequence. It is preferred that the degreasing baths be treated separately. Flocculating agents are sometimes used to facilitate the filtration of suspended solids. Final adjustment of pH and further polishing of the effluent may also be required. Modern wastewater treatment systems use ion exchange, membrane filtration, and evaporation to reduce the quantity of effluent that needs to be discharged and prevent release of toxics.

7.3 Best Available Techniques (BAT)

BAT includes prevention, separation of the waste water flow types, maximising internal recycling (by treating according to the use requirements) and applying adequate treatment for each final flow. This includes techniques such as chemical treatment, oil separation, sedimentation and/or filtration. Some of the key issues to be considered in the whole process of electroplating which forms part of BAT are:

- effective management systems
- efficient raw material, energy and water usage
- optimised use of chemicals in processes and directly related activities
- the substitution by less harmful substances
- minimisation, recovery and recycling of waste
- the prevention of environmental accidents and minimisation of their consequences

Recovery system forms part of BAT. Recovery systems focus on the reuse of raw materials utilized in electroplating. They are based on the concentration of the rinse waters and subsequent return of the concentrate to the plating bath, or on the electrolytic recovery of the metal. These technologies are attractive not only because of the savings resulting from a more thorough use of raw materials, but also because of the reduction in amount of hazardous wastes generated and associated liabilities. Some of these recovery systems are described below.

1. Evaporative Concentration

Evaporation is the oldest and most flexible of the recovery technologies and can be successfully applied to most electroplating processes. There are basically two types of evaporative systems; atmospheric and vacuum. In atmospheric evaporators, the rinse water is heated and passed through a packed column in counter current with dry air. In the vacuum evaporator, the rinse water is concentrated by boiling at low pressure. In both cases, the vaporized water can be condensed and reused for rinsing and the concentrated solution returned to the plating bath

The economics of an evaporative system depend upon the concentration of materials in the rinse water and the volume of drag-out. The vacuum units are 30 to 50% more expensive than the atmospheric ones, but the operating costs are about the same for both types. The fact that they are very energy intensive is their major drawback.

2. Reverse Osmosis

Reverse osmosis is a rather new technology that has been used for about ten years in water purification. It is based on the removal or separation of solutes from solutions by forcing water through a semi-permeable membrane. Because this separation is accomplished without a phase change, the energy requirements are low, which makes this technology extremely attractive.

The major difficulties in the use of these systems are associated with the fragility of the membranes. However, the development of improved polymers and membrane systems are overcoming this problem very rapidly. The useful life of membranes is about two years, and can be extended by using soft water and filters, and operating at the appropriate pressure and pH ranges. Reverse osmosis can be used effectively in heated plating operations or complementing other systems.

3. Electrodialysis

Electrodialysis systems are based on cells built like stacks of alternately placed cationic and anionic selective membranes across which an electric potential is applied. Cations and anions migrate in different directions and become "trapped" between the membranes forming alternate cells of ion depleted and ion concentrated solutions. Like reverse osmosis, it is a rather new technology that uses membranes and has similar limitations. However, it is more energy efficient and produces a more concentrated solution. The membranes last longer because they do not work under pressure

4. Ion Exchange

Ion exchange is the most energy efficient of all the recovery technologies. These systems are also the only ones that can be effectively used for treating a very dilute solution on a once-through basis. They are typically synthetic organic resins arranged in fixed bed columns. They are used in the recovery of chromic acid to return it to the plating bath and in the recovery of gold. The major drawback is the large volume of acid needed to regenerate the cationic resins, which makes the resulting "concentrated" solutions rather dilute. This problem can be minimized by complementing the system with another one, such as electrodialysis.

5. Electrolytic Technique

The major application of electrolytic techniques is the selective removal of metals from rinse waters, although it is used to reduce hexavalent chrome and to oxidize cyanides also. The recovery of metals from rinse waters by electrolytic methods has certain problems due to the low ionic concentrations, which result in cathode polarization. These problems, which include poor quality deposits, treeing, and water decomposition, can be greatly reduced by heating or agitating the solution. The use of large cathodic areas can help with these problems also. Solutions of this sort can be economically implemented only in closed loop systems.

7.4 Specific case studies using BAT

7.4.1 Case Study of CETP in Ludhiana

Electroplating is one of the predominant industrial sectors in Ludhiana. Around 500 electroplating units are operating in Ludhiana. These industries generate effluent which contains heavy metals such as zinc, nickel, chrome, copper, iron etc. in different concentrations. CETP for these electroplating units has been established and is being run under PPP mode by SPV of industries. The CETP has been installed in Phase-VIII, Focal Point, Ludhiana. All the small scale electroplating industries have been persuaded to join CETP. The CETP is working on the zero liquid discharge technology and no effluent is discharged into Budha Nallah. The treated effluent from the electroplating CETP is reused by dyeing industries adjoining to the CETP. Treatment process used by CETP comprised of Physico-chemical treatment as a primary treatment, followed by biological treatment. After this activated sand filters are used and there after anion-cation exchange, Reverse Osmosis, and finally Multi effect evaporator is used to get final treated effluent, which is then reused by dyeing industry, thus making this CETP a Zero Liquid Discharge setup. The table below provides a comparison of influent and effluent quality

Table 7.2 Comparison of influent and effluent quality

Inlet/Outlet	pH	TSS (mg/L)
Inlet	<2	134
Outlet/ R.O. Permeate	7.8	
Primary Sett. Tank Outlet	7.11	65
Resin Outlet	7.27	44

7.4.2 Nevada Goldfields' Wastewater Treatment System

In the South Carolina’s wet climate, Nevada Goldfields’ Barite Hills gold mining company extracts gold from soil using a high pH cyanide leaching solution. The process generated large volumes of cyanide and metal laden wastewater, which they had been storing on-site initially. But with stringent standards Nevada Goldfields needed to reduce the levels of many heavy metals to the part per billion (ppb) range. Nevada Goldfields installed combination of reverse osmosis and ion exchange which reduced metal levels to meet the required limits for all parameters of concern. Installation included a full-scale, 25 gpm system with two multimedia filters to remove metals and solids to less than 1 mg/L, two carbon adsorption filters to remove organic contaminants and finally, reverse osmosis and ion exchange equipment to remove salts, metals and dissolved solids before the water is discharged into the environment. The reverse osmosis concentrate is rerouted to holding ponds at the site. The system has been operating since December 1994.

7.4.3 Innovative Case Study, Massachusetts

Advanced Plating Corporation is a medium-scale electroplating company in Worcester, Massachusetts. It faced a new set of stringent waste water discharge criteria from USEPA. To meet that it adopted advanced technology over a conventional lime treatment system due to the associated cost savings and the inherent simplicity of the proposed system.

Treatment Method: There are 2 distinct treatment modules at Advance Plating. The nickel system consists of pH adjustment predominantly using spent sodium hydroxide and a series of pelletized reagent-filled reactor. The chrome system consists of an equalization tank, a reduction tank and a series of pelletized reagent-filled reactor tanks. The reagents adjusts the water pH and pulls metals out of solution by sequestration. This process results in extremely well bound metals that cannot be released from the reagent by TCLP or other leaching methods typically required by the regulatory community.

The use of a pelletized technology using special reagents has proven to meet the required discharge standards. Advance Plating has reported significant savings in electricity, chemicals and operating time compared to conventional treatment system.

Treatment results are shown below in the table

Analyte	Raw effluent	Treated effluent	Discharge limits
Nickel (mg/L)	250	0.01-0.8	6-10
Chrome (mg/L)	350-400	0.0012-0.5	1.3

Samples of reagent used were evaluated by a Canadian hazardous waste disposal facility that has a patented waste stabilization technology. They reported that the residual material was stable, did not release metals and did not require any stabilization treatment before disposal.

7.5 Economic Cost Analysis

Economic cost analysis was done for different BAT techniques used for recovery and recycling of waste. Cost related figures were obtained from electroplating operating units in Moradabad district, Uttar Pradesh. Detailed analysis of one of the BAT technique (Ion exchange is presented below), along with a comparative analysis table.

7.5.1 Ion exchange case study

An electroplating unit, performing Nickel plating in Moradabad, was surveyed for undertaking economic analysis. This system comprises of 2 stage counter current rinsing, which generates wastewater with concentration of **1025 mg/l** with flow rate of**160 litres/day**. Ion exchange used for this wastewater for the recovery of chemicals had exchange capacity of **30 milli equivalents (meq)/kg** of resin and density of resin is **250 kg/m³**.

Determining the mass and volume of resin required to treat 160 litres/ day of wastewater containing 1025 mg/L of concentration:

meq wt = atomic wt (in mg)/ valency

meq wt of Ni^{2+} = 58.6934/ 2 = 29.34

1 mg/l of Ni^{2+} = 1/29.34 = 0.034 meq/L

Then, **1025 mg/l** = 34.93 meq/L

Hence, required exchange capacity is equal to = 34.93 x **160** = 5590 meq

The required mass of resin as R_{mass} in kg,

R_{mass} = 5590 / **30** = 186.34 kg of resin

The required volume of resin is given as R_{vol}

R_{vol} = 186.34 / **250** = 0.74 m^3

1 m^3 = 35.31 ft^3

0.74 m^3 = **26.14 ft^3**

7.5.2 Estimation of cost

The cost of ion exchange is as follows:

Cost of resin (@ **Rs 8870 per ft^3**)

Cost of resin = **26.14** x **8870** = Rs 231720

Usually, a little fraction is lost during each regeneration (due to breakage). After every year, top up of columns with 10% is required.

Hence, replenishment every year = (10 x 26.14)/100 = 2.614 ft^3

Thus, cost of replenishment every year = 2.613 x Rs 8870 = Rs 23177

For a Copper or Nickel system, about 1 gallon of 93% sulfuric acid is used per cubic foot of resin. This is diluted to a 15% solution.

Requirement of acid = 15 x .45 x 26.14 = 176.45 kg

The ion exchange requires regeneration after every 100 days. Hence, regeneration will be required 3 times a year.

Requirement of sulfuric acid per year = 176.45 x 3 = 529 kg

Cost of regenerant (@Rs 6 per kg) = Rs 3174

Components	Cost (in Rupees)
Installation cost	231720
Maintenance cost	23177
Chemical cost	3174
Total Investment	258071

7.5.3 Savings in ion exchange

Mass of Nickel sulphate lost in a year = 2.32 x 300 = 696 kg/year

Mass of nickel chloride lost in a year = 0.186 x 300 = 55.8 kg/ year

Mass of boric acid lost per year = 0.107 x 300 = 32.1 kg/ year

Recovery of Nickel and recycling to Nickel plating bath (recovery rate >97%) and the balance 3% requires treatment. Hence, a large amount of money can be saved.

Reduced mass of nickel sulphate lost in a year = 696 x 0.03 = 20.88 kg/year

Reduced mass of nickel chloride lost in a year = 55.8 x 0.03 = 1.674 kg/year

Reduced mass of Boric acid lost in a year = 32.1 x 0.03 = 0.963 kg/year

Hence, savings in cost of chemicals are as follows. Savings of chemical = Cost of chemical (in Rs) x amount of chemical recovered.

Savings of Nickel sulphate per year = Rs178 x 675.12 = Rs 120171

Savings of Nickel chloride per year = Rs 360 x 54.12 = Rs 19485

Savings of Boric Acid per year = Rs 70 x 31.13 = Rs 2179

Total savings = Rs 141835

7.5.4 Payback period of Ion exchange

Amount saved per day from savings (assuming 300 working days) = 141835/300 = Rs 473

Payback period for the equipment cost = 231720/473 = 489.8 days ~ 490 days

Thus, payback period is 20 months (assuming 300 working days).

After the payback period of approximately 1 year and 8 months, the plating unit will be able to save some amount at the end of 2 years as shown:

Savings at the end of 2nd year = 110 days x Rs 473 = Rs 52030

Also, the cost of chemicals and maintenance for 2 years = 2 x (3174 + 23177) = Rs 52702

Thus, at the end of 2nd year the cost of chemicals and maintenance is almost recovered.

At the end of 3rd year the savings will be = 141835 – (672 + 3174 + 23177) = Rs 114812

Thus, by installing Ion exchange system of recovery, the savings per year will be Rs 115484. Thus, this technique of ion exchange is feasible from both economic and environmental point of view.

Ion exchange method is economical for the recovery and recycling of wastewater. The advantage of this technique is that it can be applied to a variety of metals. Also, it helps in removal upto parts per million (ppm) levels.

Using similar process for cost estimation comparative analysis of various BAT techniques used for recovery & recycling was done. Table below presents the estimates.

Table 7.3 Overall comparison of chemical recovery techniques

Technique	**Cost of Equipment (in Rs)**	**Recovery efficiency (in %)**	**Payback period (in months)**	**Savings/year (in Rs)**
Evaporation	117391	90	11	-
Ion Exchange	231720	97	20	115484
Reverse Osmosis	133020	95	12	123126
Electro Dialysis	354720	50	58	62909

The table above shows that Ion Exchange process has the most efficient removal efficiency but has pay-back period more that evaporation and RO techniques. But, the drawbacks of RO system were its incapability to concentrate wastewater to high concentrated chemicals (needs evaporation).

Also, the use of RO system was restricted to pH range of 2-11 only. Therefore, it can be concluded that the ion exchange method is superior to other techniques of chemical recovery.

7.6 Conclusion

Appropriate treatment technology varies from case to case depending on many factors. For example for achieving the removal of metals from a waste stream, both ion exchange and chemical precipitation techniques can be employed. However, if it is intended to recover the metals and recycle them, Ion exchange might be a better option as compared to precipitation. If the sludge from precipitation is to be landfilled then ion exchange should not be used.

The table below suggests appropriate recovery method for different types of metal plating.

Table 7.4 Selected Metal recovery Techniques & Methods for Types of Plating

Methods Techniques	**Cyanide Silver Plating**	**Cyanide Copper Plating**	**Acid Plating**	**Copper**	**Nickel Plating**	**Chrome Plating (Decorative)**	**Thick Chromium Plating**	**Cyanide Zinc Plating**	**Acid Zinc Plating**	**Cadmium Plating (Cyanide)**	**Chromic Passivation**	**Copper Pickling**	**Acid Pickling**
Ion Exchange				yes	yes	yes	yes				yes	yes	yes
Electrolysis	yes			yes				yes	yes	yes		yes	
Electro-Dialysis						yes	yes		yes				yes
Evaporation	yes				yes	yes		yes		yes			
State Recovery Rinse		yes		yes	yes	yes	yes	yes		yes		yes	yes
Typical Recovery Efficiency	>99%	98%		80-98%	98%	98%	95%	70%	80%	70%	98%	98%	80%

Source: UNEP, "Environmental Aspects of the Metal Finishing Industry, A Technical Guide", Paris 1993

8. Sludge Management

This chapter of the report specifically deals with the issues of sludge management and disposal. Sludge management is one of the most important criteria to evaluate the performance level of any CETP or Effluent Treatment Plant (ETP). Improper sludge management is a serious threat to environment.

8.1 Introduction

Sludge refers to the residual, semi-solid material left from industrial wastewater or sewage treatment processes. Due to the physical-chemical processes involved in the treatment, the chemical sludge tends to have concentrations of heavy metals. Nevertheless biological sludge is rich in nutrients such as nitrogen and phosphorous along with valuable organic matter that is beneficial to depleted soils or soils subject to erosion.

The treatment and disposal of sludge is an environmentally sensitive problem. It is a mounting global problem as sludge production will increase subsequently with the increase in number of waste water treatment plants and the evolution of more stringent environmental quality standards. Sludge is often regarded as the major problem of water pollution control in terms of their immediate offensive nature and potential for pollution.

With a few environmentally unfriendly disposal routes like land disposal and direct disposal to the sea having been phased out, the challenge facing sludge management is to find cost-effective and advanced solutions while responding to environmental, regulatory and public pressures. Recycling and use of wastes are the preferred options for sustainable development, rather than incineration or land filling, but sometimes it is not straight forward because of sensitivities such contaminants like heavy metals etc.

The disposal of sludge always requires careful management but the ease, or difficulty, with which disposal is actually achieved, and the associated costs depend very much on circumstances. Local and national geographical, agronomic, economic and stakeholder perception factors have considerable influence on sludge management.

8.2 Methods of sludge treatment

Before disposal, sludge is treated to change its chemical and/or physical properties to make it fit for environmentally safe disposal options.

The wastewater composition, chemicals used, and treatment units mainly determine the amount and properties of chemical sludge.

Stabilization treatments will decrease the volume, the amount of pathogenic organisms, concentrates contaminants and also diminishes odour. Hence, stabilization makes the transport of sludge safer and cheaper.

The sludge can then be treated by conditioning and thickening to improve the effects of dewatering. It also has a disinfection and odour reduction effect on the sludge.

Chemical or thermal conditionings are the most common conditioning techniques and there are four common thickening techniques: gravity thickeners, gravity belt thickeners, dissolved air floatation and drum thickeners. Chemical conditioning can also have a stabilising effect as well as deodorising but there is a cost component of chemicals. Thermal conditioning is suitable for all types of sludge. It requires energy and there are also chances of foul odour. These methods are used to reduce water content and increase dry solids content. They also improve the density and strength of sludge for further dewatering treatment.

Thickening is a step to reduce the water content in sludge and it can be done by a gravitation thickener, gravity belt thickener, centrifuge or dissolved-air flotation, etc. These methods basically separate the sludge into two phases; i.e. a clear water phase and the condensed sludge. Thickening increases the content of dry matter and decreases the volume of the sludge. Gravity thickening low in energy consumption requires lesser investment as compared to the other methods. However it is not as effective on secondary sludge. Gravity belt thickening and drum thickening often require a polymer to be incorporated for optimal functioning. These methods however are compact and don't require high amounts of energy. If the solid particles have a low rate of settlement the air flotation technique can be applied. Nonetheless, it incurs high energy costs.

The next step when there is a requirement to further reduce water content after thickening is often dewatering. There are many ways to dewater the sludge some of which are: the use of centrifuges, filter presses, recessed-plate filter presses, bed of reed or drying beds.

Sludge can also be dried instead of dewatered. The heat can be transferred either directly or indirectly to the sludge through direct contact with the sludge or through a heat transfer surface.

Table 8.1 Sludge management processes

	Methods	Purpose
Stabilization	1. Anaerobic digestion 2. Composting 3. Pasteurisation 4. Lime stabilization 5. Bed of reed	It reduces pathogenic micro organisms It concentrates contaminants Reduction of odour
Conditioning	1. Chemical 2. Thermal	Preparatory step for dewatering, thickening and drying. It improves the effect of the subsequent water reducing treatments
Thickening	1. Gravity thickening 2. Gravity belt thickening 3. Dissolved air floatation 4. Drum thickener	It reduces the water content in sludge It also increases the content of dry matter (DS) It decrease the volume of the sludge
Dewatering	1. Centrifuges 2. Belt filter press 3. Recessed-plate filter press 4. Drying bed	It reduces the water content in sludge It also increases the content of dry matter (DS) It decrease the volume of the sludge
Drying	1. Direct 2. Indirect	It reduces the water content in sludge It also increases the content of dry matter (DS) It decrease the volume of the sludge

8.2.1 Biological sludge treatment

The biological sludge treatment is essential to condense and to ameliorate sludge which is produced by wastewater/ effluent treatment.

Some of the treatment methods are:

Anaerobic digestion: It is the decomposition of sludge in an anaerobic environment. Mass reduction, methane production, and improved dewatering properties of the fermented sludge are important features of anaerobic digestion. However, it requires investment for a digestion chamber, etc. and it also has a slow degeneration rate. To improve the biodegradability of sludge pre-treatments such as thermal pre-treatment (Stuckey & McCarty, 1984; Li & Noike, 1992), addition of enzymes (Knapp & Howell, 1978), ozonation (Yasui & Shibata, 1994), chemical solubilisation by acidification (Gaudy et al., 1971; Woodard & Wukasch, 1994) or alkaline hydrolysis (Mukherjee & Levine, 1992), and mechanical sludge disintegration (Müller, 1996) and ultrasound pre-treatment (A. Tiehm, K. Nickel and U. Neis, 2001) can be done. The degeneration process can also be inhibited by the high concentration of inhibitors such as heavy metals, temperature, etc.

Aerobic digestion: This is the process of oxidizing and decomposing the organic matter in the sludge by micro-organisms in an aerobic environment. Aerobic sludge digestion is one process that may be used to reduce both the organic content and the volume of the sludge. Though this process is sensitive to temperature, heavy metals etc. and incur higher energy costs and there is no useful by-product such as methane.

Enzyme treatment: This method is usually used as a pre-treatment of sludge to improve the hydrolysis of organic matter in sludge which limits the rate of anaerobic digestion resulting in an improvement in both biogas production and also improves the dewatering properties of the digested sludge.

Thermal Hydrolysis: Thermal treatment is incorporated in the sludge treatment process to reduce sludge production, enhance biogas production in anaerobic digesters and inactivate pathogens, improve dewatering of sludge. This process hydrolyses organic solids and makes them soluble, thereby making sludge more readily biodegradable. It also reduces the hydraulic retention time in the anaerobic digester.

Chemical stabilization: In this process sludge is treated with chemicals in different ways to stabilize the sludge solids. The common methods of chemical stabilization are lime stabilization and chlorine stabilization. These methods stabilise all kinds of sludge, eliminates odour and destroys pathogenic micro-organisms (Andreadakis, 1999). Use of Polyelectrolytes as a conditioner for sludge dewatering operations is also gaining popularity due to their success of improving process yields.

Microbial consortium: Consortium of beneficial microbes that can degrade sludge. It can compose of aerobic and/ or anaerobic microorganisms. The application of microbial consortium modifies the microbial ecology of the sludge. This helps in achieving maximum biological growth and as a result, maximum organic matter will be consumed. Microbial consortium like EM (Effective Microorganism) reduces BOD, COD, TSS, Total and Faecal Coli form in all sewage and effluent generated in an industry; it also controls the pH value, so that the effluent, after being treated, carries a neutral pH of around 6.5 to 7.5. This consortium EM suppresses the putrefaction of sludge leading to odour reduction, the microbes also secretes some enzymes which digests their own cell and thereby reducing the biomass/ sludge. The need for use of extra chemical is also eliminated.

Table 8.2 Comparison of Indian and Global scenario in terms of sludge management

Method	Indian scenario	Global scenario	Benefits	Constraints
Anaerobic digestion	Using	Using	Biogas production	Requires digestion chamber Inhibited by high concentrations of heavy metals and temperature dependant
Aerobic digestion	Using	Using	Production of compost	Inhibited by high concentrations of heavy metals and temperature dependant High energy costs
Reed bed system	Rarely	More common in Denmark, Germany and Sweden	Stabilizes sludge as well as reduces water content	Variation in the success rate
Enzyme treatment	Moderately used	Used to improve digestion	Improves digestion Reduces sludge volume	Enzyme cost
Thermal Hydrolysis	Rarely	More common in Norway	Volatile Solids reduction, Increases biogas-production& DS concentration	Energy costs Odour
Constructed wetlands	Moderate Pilot scales	More common in Europe, North America	Low maintenance costs Low investment Low operation cost	Requires more land Dependant on plant species
Chlorine stabilization	Reasonable use	Used	Improved water reduction effects Stabilising effect and odour reducing effects	Cost of chemicals
Lime stabilization	Using	Used	Improved water reduction effects Stabilising effect and odour reducing effects	Cost of chemicals
Microbial consortium	Moderate use	Used	Specific targeting of waste e.g. oily sludge removal Environmentally safe	Inhibited by high concentrations of heavy metals Temperature dependant

8.2.2 Sludge disposal and use options

The sludge that results from wastewater treatment may have concentrated levels of contaminants that were originally contained in the wastewater. Hence a great deal of concern should be directed to the appropriate disposal of sludge to protect environmental considerations.

Failure to properly dispose sludge may result in simply shifting the original pollutants in the wastewater stream to the final sludge disposal site wherein they may become free to contaminate the environment. Most commonly the sludge may be disposed on landfills or special sludge deposits

Sludge and sludge components may also be used in different ways. The most obvious one is the direct use of treated biological sludge on land as a fertilizer and soil conditioner. Treated sludge may also be used on land indirectly after having utilized it as one of the ingredients in bio-fertilizers such as vermi compost. Finally sludge may be recycled to make products intended for sale in the market place. Such components/ products may be "bio-soils" (mixture of sludge with other materials), energy (biogas, electricity, oil, heat etc.), nutrients (phosphate, nitrogen), metals (coagulants) etc.

There are risks associated with the use of sludge as it may be contaminated with heavy metals, pathogens, toxic organic compounds, etc. However, careful management of sludge can minimize risks and objections to its reuse.

Table 8.3 Sludge disposal and use manners

Manner	Current situation in India	General situation in other countries	Benefits	Constraints
Landfill	Common practice	Common practice Illegal in Sweden	Simple Energy can be recovered from landfill gas	Potential air, water and soil pollution Noise from delivery vehicles , odour Possible attraction of birds and rats Transport charges
Simple compost	Used	Used especially in developing countries	Nutrient recycling Cheap fertilizer Replaces inorganic fertilizer Cheap disposal solution	Potential air, water and soil pollution Transport charges Requires storage facilities
Mechanized compost	Rare use	Moderate use	Reduces labour	Higher operation cost

Manner	Current situation in India	General situation in other countries	Benefits	Constraints
Incineration	Used	Used	No transport Green energy Stabilizes sludge Reduces volume	Stringent rules may result in higher cost Potential air, water and soil pollution Expensive technology
Vermicomposting of FIS (Food Industry Sludge)	Moderate use	Used	Simple technology Bio-fertilizer generation	Worms are sensitive to excess water, and toxic substances
Ocean dumping	Not practiced	Banned	Low cost	Water pollution Ecosystem destruction
Agricultural use	Common practice	Used but recently many countries have more stringent control standards	Nutrient recycling Cheap fertilizer Replaces inorganic fertilizer Cheap disposal solution	Potential air, water and soil pollution Transport charges if agricultural land is far from plant
Land restoration and Silviculture	Moderate use	Used	Increase biomass yields Nutrient recycling	Potential air, water and soil pollution Odour Transport charges
Supplementary fuel	Moderate use	Used	Green energy	Potential air, water and soil pollution
Gasification	Modest use	Used	Green energy Stabilizes sludge Reduces volume	Transport charges Fuel cost
Recovery	Rare	Used Sweden is a frontrunner	Separate nutrients Precipitation of chemicals and heavy metals Transportation reduced Reduced volume	High investment costs No established techniques
Building and construction materials	Moderate use	Used	Supplement building material Safe disposal	Load carrying capacities could be less

Sludge is a resource from which products as nutrients and energy can be retrieved. Hence direct disposal in landfill is not sustainable. This method has the potential to cause air, water and soil pollution and to an extent noise pollution from delivery vehicles which also adds towards transportation cost. Production of compost, bio-fertilisers, bio soils from stabilised sludge for agricultural use, land restoration and silviculture has great potential. However, there is a need to identify and remove sources of pollutants to improve the sludge quality. Only then should the sludge be used as fertilizer, cover material and construction soil.

Biogas produced in a biogas reactor where the sludge also is stabilized is a renewable fuel. Biogas can be used for production of electricity, heat and also fuel for buses and cars.

The inorganic materials from sludge can be used as building and construction materials. This will not only supplement building material but it also an opportunity for safe disposal of sludge. If the chloride concentration is low, chemical sludge can be utilised in cement kilns. Solidified chemical sludge can be supplemented with cement, fly ash and lime and used in construction related activities e.g. tiles and pavement blocks. The solidification/ stabilisation technology can be used to treat industrial solid waste containing toxic constituents to prevent their dissolution and release to the environment (Idachabaet al.2001).

When sludge is incinerated the product is energy and ashes which partly contain heavy metals and phosphorus. Processed sludge can also be used as supplementary fuel. The recovered energy may be used as heat or electricity. Ash can be used as building and construction material or as part of cover material. Ashes from sludge incineration can be used for brick making, manufacture of cement and use in pavement. There are several environmental impacts caused by incineration the major factor is emissions to air but there is also potential for noise, odour and visual pollution.

9. Key Findings

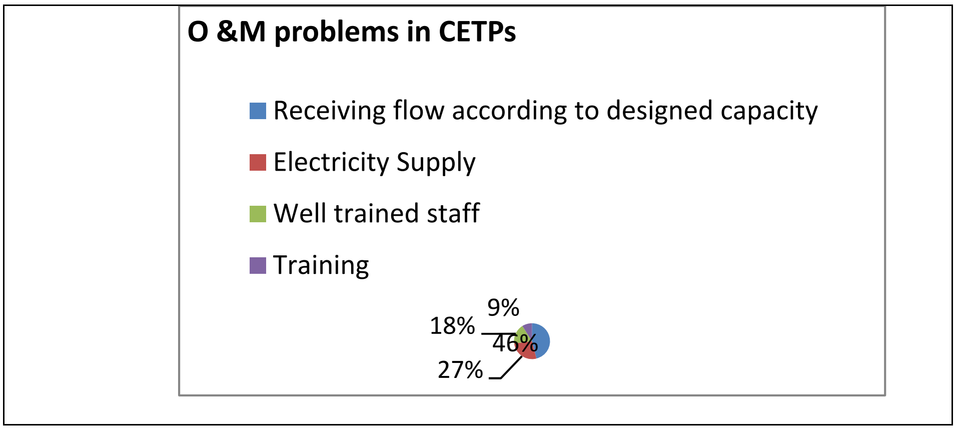
The study has assessed that technologically India is at par with other global counterparts. There are many CETPs in India which set the technological benchmark and use state-of-the-art technologies. These successful case studies need dissemination for the benefit of other existing and planned CETPs.

The study has attempted to assess other factors responsible for under performance of CETPs in India. The key factors that are responsible for under-performance of CETPs are listed below, but are not limited to these findings only:

- Institutional arrangements or the formal provisions that define and govern Roles and Responsibilities of all the stakeholders involved in the overall operation of the CETP. Formulation of the appropriate institutional arrangements for ownership and operation of a CETP is imperative for optimal functioning.
- Existence and enforcement of regulations is crucial, but generally enforcement is also not up to the mark. In absence of effective enforcement CETP owners tend to resort to cost cutting measures such as switching off electricity supply and cutting down on the quantity of chemicals.
- In most CETP's the amount of waste received for treatment is either much lesser or greater than its designed capacity. Performance in these types of cases gets affected.
- Some CETPs also face problem of receiving sewage along with industrial effluents, availability of sludge disposal options, and reuse options of treated water.

TERI team carried out a survey to assess the issues faced by CETP operators. Interviews were conducted with some of the important stakeholders like CETP operators, members of DPCC etc. and the issues in O & M have been categorized as:.

- Inflow of effluents not according to design capacity of the CETP
- Interrupted electricity supply
- Lack of well trained staff
- Lack of in-service training



But besides these lacunae in management and regulatory framework, India has made advancements in context of use and adoption of advanced treatment technologies.

Suggestions

Some suggestions are offered on the identified issues.

- Information and promotion of the principles of a cleaner environment in industrial estates are preferable means of obtaining compliance. If these principles are accepted by the industry, it will be possible to operate a CETP successfully.
- There are a number of possible options possible for institutional arrangements. Operation of CETP by special purpose vehicle (SPV) is a good option and helps in better operation and accountability. However there should be guidelines on formation of SPVs.
- The recycle/reuse of treated waste water from CETPs which comply with a certain standard should be encouraged with special attention to areas that are water scarce. In such cases discharge from the CETP should be preferably used by the participating industries. This will help in maintaining the water quality of effluent.
- In accordance with the "Polluter Pays Principles" i.e. the industry must pay the cost of disposing of waste in an environmentally acceptable manner. Therefore, cost of establishing and operating a CETP (capital and/or O&M) must be borne by industries that discharge their effluents into CETPs.
- No single yardstick can be fixed for the industrial estates under consideration and a thought should be given to the various inter dependent factors such as effluent collection system, nature and composition of effluent, degree of treatment to which the effluent must be subjected to, mode of disposal of treated effluent and cost of waste treatment. Based on these factors, the promoting agency has to develop a suitable financial apportionment method to realize the capital and recurring expenditure incurring in constructing waste collection, treatment and disposal systems.
- Equitable sharing should be the main objective while developing financial apportionment methods. The direct as well as indirect benefits derived by CETP should be proportionately distributed to the member industrial units.
- Industries have to operation charges to CETP operators. But in many cases the operators run CETP at loss due to non-recovery of operation charges from users. There should be proper and effective mechanism for collecting the operation charges.
- Revised guidelines for the centrally sponsored scheme of Common Effluent Treatment Plants states that the State Government/Union Territory Administration/PCC should ensure that forward and backward linkages are in place to cover proper conveyance system from the individual units to the CETP and the discharge of the CETP effluent. These could alternatively, be also provided by the State Government or it agencies.
- CETP caters to variety of industries and thus receive heterogeneous wastewater. In order for the CETP to function optimally the industries should pre-treat their effluent to meet inlet quality standards or design inlet quality parameters of CETP. Input parameters also need to be regularly monitored for ideal performance of CETP.
- There are various technologies in the market and they need to be evaluated with respect to the effluent of a particular industry with due consideration to peak loads. Treatability studies of effluent samples including both chemical and biological studies will give foresight to the effectiveness of the treatment schemes. Treatability studies of effluent samples often help selection of appropriate coagulants and doses of chemicals.

Annexure 1 Project Questionnaire

CETP__________________________ Date____________

Address_________________________

Interviewee______________________Designation_______________________________

1. Details about CETP

   Year of establishment_______

   Capacity__________________

   Number of Industries_________

   Inflow volume______________

2. Treatment technologies used in CETP

   Pre-treatment____

   Primary____

   Secondary____

   Tertiary____

3. Sludge Management & Disposal

   ____

4. Operation time____
5. Electricity availability____
6. Staff availability and competency____
7. Other issues/problems faced____
8. Cost

   Capital______________________________

   O&M cost____________________________

9. Recommendations for improvement, if any

   ____

10. Have you ever attended any training programme or have been given any technical support from authorities?

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