SECTION 8

CASE STUDIES

This section presents three cases of centralized effluent treatment and three cases of industrial waste minimization.

8.1 CASE STUDY 1: CENTRALIZED TREATMENT OF HAZARDOUS WASTE IN THAILAND

This case study was prepared from information in the report *Commissioning and Operating an Inorganic Waste Treatment Facility*, written by Teerapon Soponkanaporn and Aioporn Sophonsridsuk, of the Siam Control Company Limited, Bangkok, Thailand, in 1989.

8.1.1 History of the Facility

In Thailand, hazardous waste is becoming a problem of great concern, especially toxic chemicals and heavy metal pollutants discharged from factories. In fact, heavy-metal-contaminated wastewater is one of the major hazardous wastes in Thailand. The main source of these heavy metals is electroplating factories. Presently, approximately 200 medium- and small-scale registered electroplating factories are scattered around the Bangkok area.

Treatment of the wastewater at these electroplating factories has not been successful because of a lack of space, trained personnel, financial support, and satisfactory sludge disposal sites. For these reasons, the Ministry of Industry (MOI) has had difficulty monitoring and controlling hazardous wastes from these electroplating factories.

Recognizing the above problems, the MOI established Thailand's first industrial hazardous waste treatment center in 1988. The center is located in the district of Bangkhuntien, approximately 20 km west of Bangkok. The Bangkhuntien center is the first of four such industrial hazardous waste treatment centers that are planned for the western, northern, and eastern suburbs of Bangkok and Rayong. Each center will provide both physical-chemical treatment facilities and distillation and incineration for handling industrial liquid, sludge, and solid hazardous wastes.

8.1.2 Collection

Wastes are collected by tankers (for wastewaters) and trucks (for solid wastes) for treatment at the Bangkhuntien Industrial Hazardous Waste Treatment Center (BIHWTC). Upon arrival at the BIHWTC, vehicles are weighed and samples of the wastes are taken for a screening analysis. This analysis determines the nature of the wastes and their compatibility with other wastes to be treated. Following analysis, the wastes are discharged into the appropriate sumps for treatment.

The BIHWTC is designed to treat inorganic wastes such as electroplating wastewaters from electroplating factories, spent chemicals such as pickling waste from hot-dip galvanizing and electronic factories, hydroxide sludges from electronic and automobile assembly factories, and mercury wastes from fluorescent lamp manufacturing factories. For more information on the total number of factories using BIHWTC services and the total quantities of waste, see Figures 8-1 and 8-2.

Currently, Siam Control Company, Ltd. (SCC), which operates and manages the facility, is working with the MOI to reduce traffic congestion associated with waste transportation by adjusting the transportation schedule to transport the waste earlier or later in the day, thus avoiding peak travel hours. SCC is also considering waste minimization by factories (e.g., treating wastes with an ion exchange process prior to transport) as a way to reduce the amount of waste being transported, thereby minimizing problems associated with waste transportation.

8.1.3 Treatment Processes

The BIHWTC includes 1) a 200-cubic-meter-per-day (CMD) chemical treatment plant for treating electroplating wastewater on a batch basis (see Figure 8-3), 2) an 800-CMD continuous chemical flocculation and sedimentation treatment plant and polishing ponds for treating textile dyeing wastewater, and 3) chemical fixation plus cement mixing facilities for handling hazardous sludge or solid wastes (see Figure 8-4).

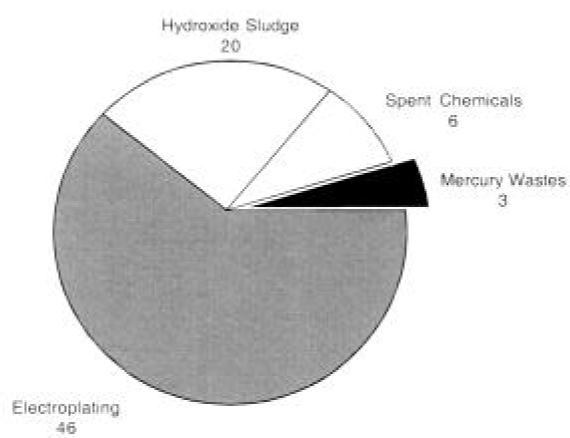

Figure 8-1. Total number of factories using BIHWTC services (Soponkanaporn and Sophonsridsuk, 1989)

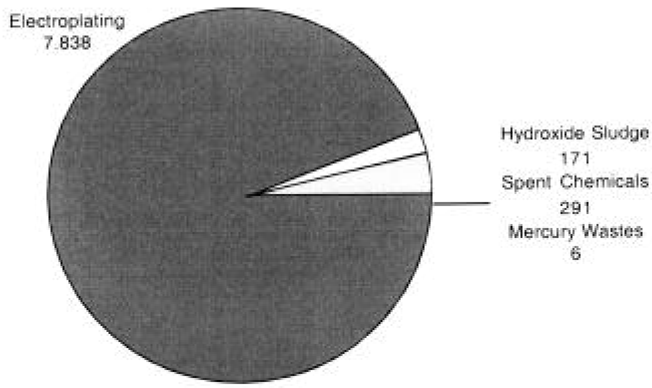

Figure 8-2. Total quantity of wastes (ton) (Soponkanaporn and Sophonsridsuk, 1989)

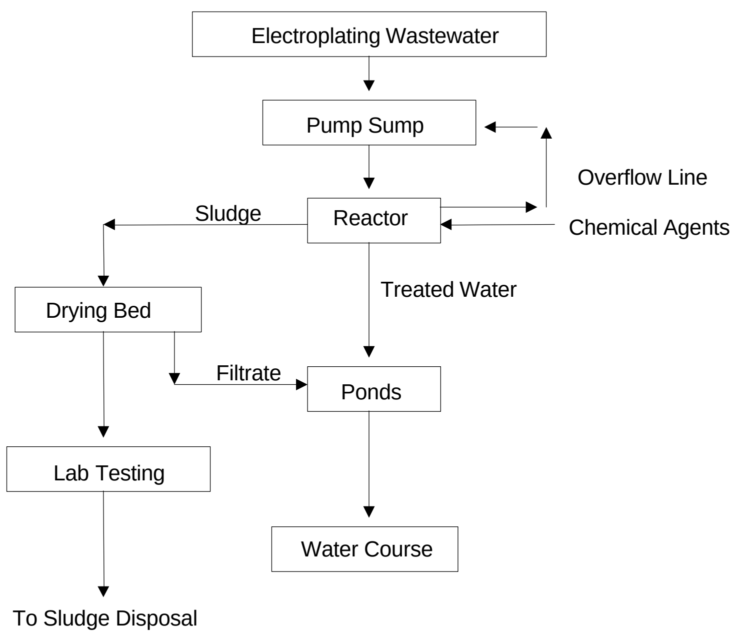

Figure 8-3. Flowchart of electroplating waste treatment (Soponkanaporn and Sophonsridsuk, 1989)

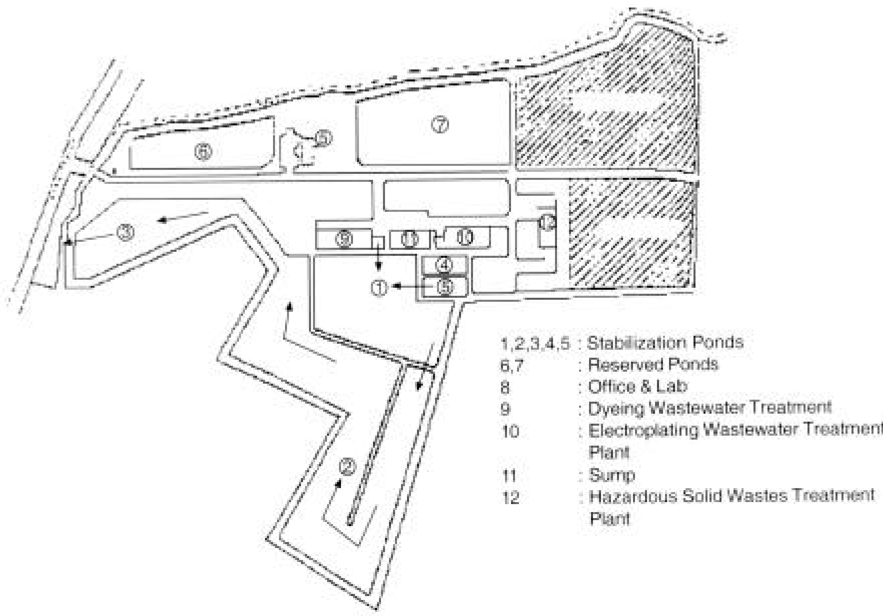

Figure 8-4. Plan layout: Bankhuntien Industrial Hazardous Waste Center (Soponkaraporn and Sophonsridsuk, 1989)

8.1.3.1 Electroplating Wastewater

Electroplating wastewaters accepted at the BIHWTC are treated separately according to their major contaminants (i.e., cyanide, chromium, or other heavy metals).

Cyanide-Contaminated Wastewater

The conventional alkali chlorination process is used to destroy cyanide in the electroplating wastewater. This process involves using lime to adjust the pH of the wastewater to between 11.0 and 11.5, then adding sodium hypochlorite (as a chlorine source) and allowing it to react with the wastewater for the desired time. This converts the cyanide to gaseous nitrogen and carbon dioxide. During this process, pH and ORP levels are automatically controlled.

Chromium-Contaminated Wastewater

The toxic hexavalent chromium in the electroplating wastewater is first reduced to trivalent chromium by adding sodium metabisulfite to the wastewater and adjusting the pH to between 2.0 and 2.5 using sulfuric acid. Then, lime can be used to precipitate the trivalent chromium at a pH of approximately 10.

Wastewater Contaminated With Other Heavy Metals

Wastewater contaminated with other heavy metals (e.g., nickel, copper, zinc) is treated using conventional precipitation with lime at an alkali pH of approximately 10. Polyelectrolyte may be added to improve the setting of hydroxide sludges.

8.1.3.2 Spent Chemicals

Treatment methods for spent chemicals vary depending on the contaminants present in the wastes. Currently, the only spent chemical that the BIHWTC treats is pickling wastewater, which contains high concentrations of heavy metals. Heavy metals in the pickling wastewater are precipitated in the same way as those in non-chromium-contaminated electroplating wastewater. The only difference is that the amount of lime used to treat the pickling wastewaters is considerably higher because of higher concentrations of acid and metal.

Sludge resulting from the chemical treatments is discharged onto drying beds that contain a layer of sand. Next, the dried solid wastes are treated using a stabilization process before landfilling.

8.1.3.3 Solid Wastes

The hazardous wastes that the BIHWTC currently treats are classified as hydroxide sludges and mercury wastes.

Hydroxide Sludges

Hydroxide sludges contain heavy metals (e.g., lead, manganese, chromium, nickel) other than mercury from various inorganic wastewater treatments. These sludges are mixed with a high amount of lime to increase the pH to approximately 12 before landfilling.

Mercury Wastes

The mercury in contaminated wastes is stabilized by adding sodium sulphide to convert the toxic mercury to a more stable mercury sulphide. It is then fixed with cement to form hard blocks before landfilling. Mercury wastes from fluorescent lamp factories are ground before initiating treatment.

8.1.4 Disposal

After treatment, the effluent is tested for pH, dissolved solids, cyanide, and heavy metals in the center's laboratory to ensure that the effluent meets MOI standards. The effluent then is discharged to a nearby waterway. Treated sludge is hauled to a disposal site in Ratchaburi province approximately 100 km from the center. Extraction tests are performed on the treated sludge before landfilling to ensure that it will not contaminate ground water with heavy metals.

Development of the landfill site has been costly, exceeding the original MOI budget. As a result, SCC also is looking into recycling heavy metals from electroplating wastewater and sludges using the "ferrite" process. This process incorporates heavy metals into a ferromagnetic precipitate in the presence of an adequate concentration of iron. Part of the iron required for the process can be obtained from the pickling wastewater. Because the ferrite process (see Figure 8-5) is similar to the present treatment process for inorganic wastes at the BIHWTC, incorporating this new process would require only slight modifications. The ferrite process would convert solid wastes into safe and commercially valuable products and would therefore reduce the amount of waste sent to the landfill.

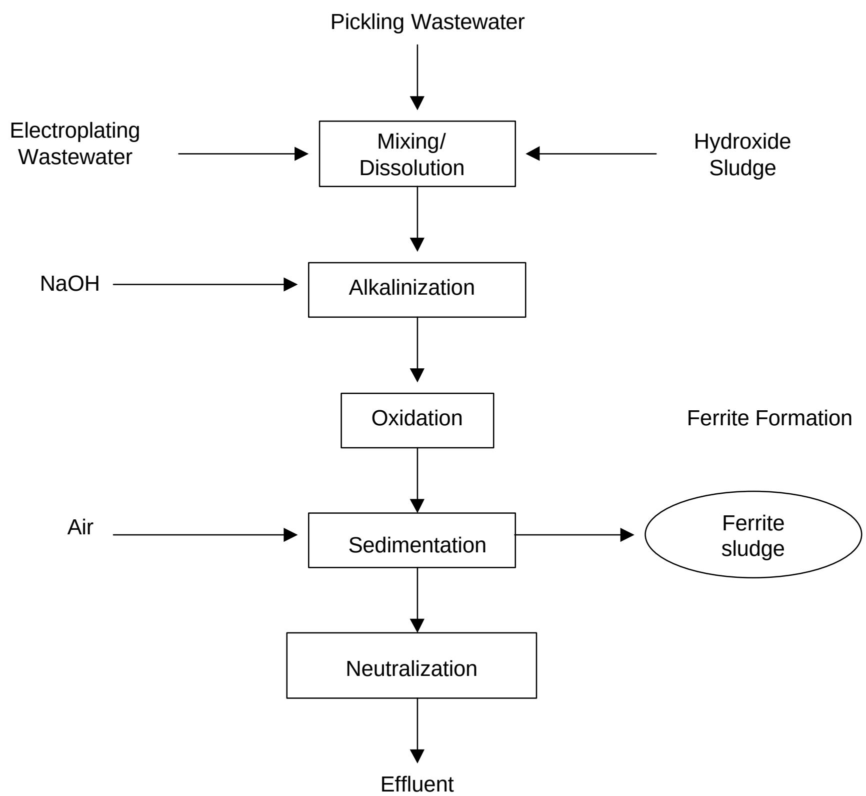

Figure 8-5. Flow chart of heavy metal recovery by ferrite process (Soponkanaporn and Sophonsridsuk, 1989)

8.1.5 Operation and Management

To reduce its burden and continue implementation of its privatization policy, the government awarded the operation and management of the BIHWTC to SCC, a private firm, with a leasing contract for 5 years. SCC has sole responsibility for conducting waste collection, transportation, treatment, and disposal.

Users pay fees for the following services directly to SCC:

- Transportation from the factories to the BIHWTC
- Waste treatment
- Transportation from the BIHWTC to the disposal site
- Disposal

These service fees vary depending on the type and volume of waste treated as well as the distance from the factories to the BIHWTC.

SCC pays rental and royalty fees to the government based on the quantity of wastes treated to offset construction costs for the facility. The government plays only a supervisory role. At last count, the government had spent a total of $1.2 million to cover the initial cost of the facility, including land acquisition; construction of the center's detoxification facilities for liquid, sludge, and solid hazardous wastes; and installation of necessary equipment and utilities.

8.2 CASE STUDY 2: CENTRALIZED WASTE TREATMENT IN A COMMON EFFLUENT TREATMENT PLANT IN INDIA

This case study was prepared from information contained in a report funded by the World Bank entitled *India Industrial Pollution Control Project: Feasibility Assessment of Common Treatment Facilities, Volume 2.2, Vapi Industrial Estate*, prepared by Chemcontrol, Copenhagen, Denmark, 1991.

8.2.1 Case History

In 1960, the Gujarat Industrial Development Corporation (GIDC) established individual industrial estates throughout Gujarat. Potentially heavy polluting industries (e.g., chemicals, pharmaceuticals) were located within special estates near the coast to prevent inland water pollution and to provide easy access to national highways and the interstate railway system. Vapi is located in Pardi Taluka in the Bulsar District, about 230 km south of Baroda. This industrial estate currently contains about 1,030 functioning industrial facilities of small and medium size and more than 3,000 housing units. At present, the main effluent discharge point is via the Bhi Khadi stream to the Kolak River. Figure 8-6 shows an aerial view of the Vapi industrial estate.

The present conditions at Vapi constitute a considerable health hazard for people who live or work inside the estate. As a result, GIDC has proposed a common effluent treatment plant (CETP) for industrial effluent and domestic wastewater at a site near the Damanganga River. In 1995, the World Bank approved funding for the construction of this facility.

8.2.2 Collection

At present, effluent from various industries flows through open drains to three different discharge points at the Vapi estate. GIDC has proposed a common sewer system to carry wastes to the CETP and estimates that the collection and conveyance system and pumping stations will cost approximately 42.4 million Rs, including the costs of laying sewer pipes and constructing manholes, etc.

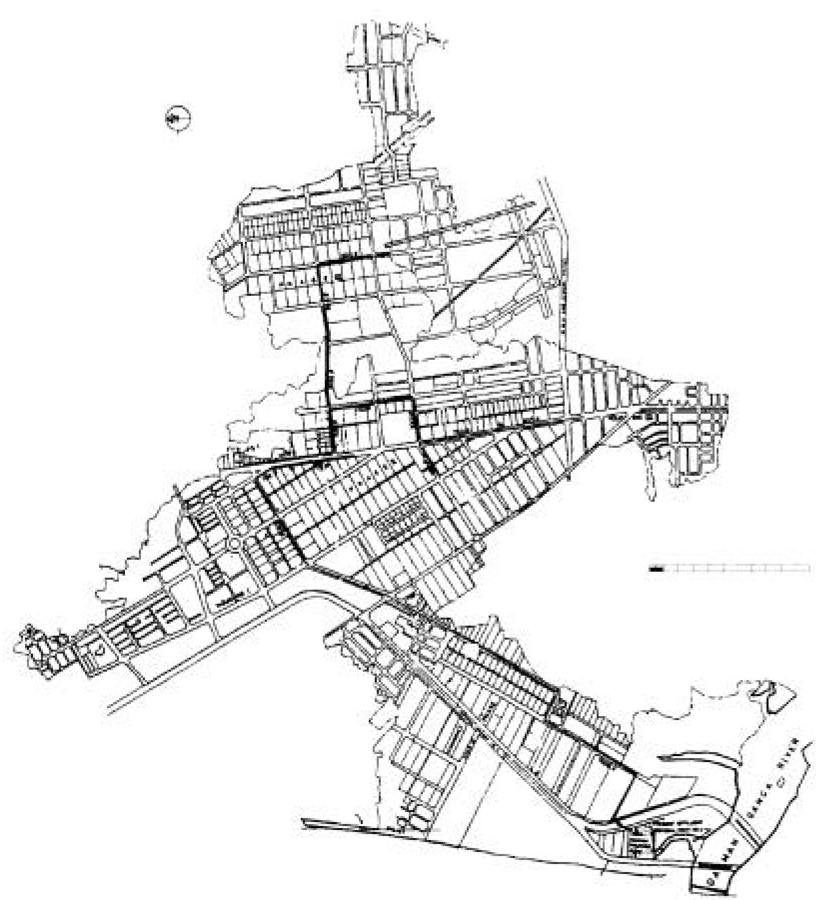

Figure 8-6. Aerial view of the Vapi Industrial Estate (Chemcontrol, 1991)

8.2.3 Treatment Processes

All industries are required by law to treat their wastewater at least according to pretreatment standards, but at present most industries discharge their effluent untreated into surface drains that ultimately carry the flow away from the estate through three outlets: the major creek flowing into the Kolak River and the two lesser ones flowing into the Damanganga River. To ensure trouble-free operation of the proposed CETP, however, all industries will be required to comply with pretreatment standards.

The design of the CETP assumes that industries will comply with the pretreatment standards but also acknowledges that full compliance may be unlikely at first. Provisions have been built into the design to accommodate minor shockloads of toxic materials, which will inevitably be discharged accidentally with so many industries assembled on one estate.

Incorporating special features to absorb minor shockloads will increase installation costs, however.

Figure 8-7 illustrates the proposed design of the CETP. This design accounts for space limitations and the expected nature of the wastewater influent, and emphasizes cost-effectiveness without compromising the plant's operational safety and reliability. The treatment train for the proposed CETP incorporates the following main processes:

- Pretreatment
- Primary precipitation/primary sedimentation
- Equalization
- Activated sludge process
- Secondary sedimentation
- Sludge concentration
- Lime dosing for stabilization
- Sludge dewatering
- Sludge disposal

Each of these elements of the design are discussed below.

8.2.3.1 Pretreatment

Although most wastewater will have been pretreated at the industrial source prior to discharge, the inflow of wastewater to the CETP will contain large fragments (e.g., pieces of wood, empty bags) that mechanically raked screens will withhold as screenings. In addition, suspended materials in the wastewater influent will include sand and grit which can cause excessive wear on fast-moving machinery such as pumps and dewatering centrifuges. A grit chamber will be used during pretreatment to separate this sand and grit from the wastewater.

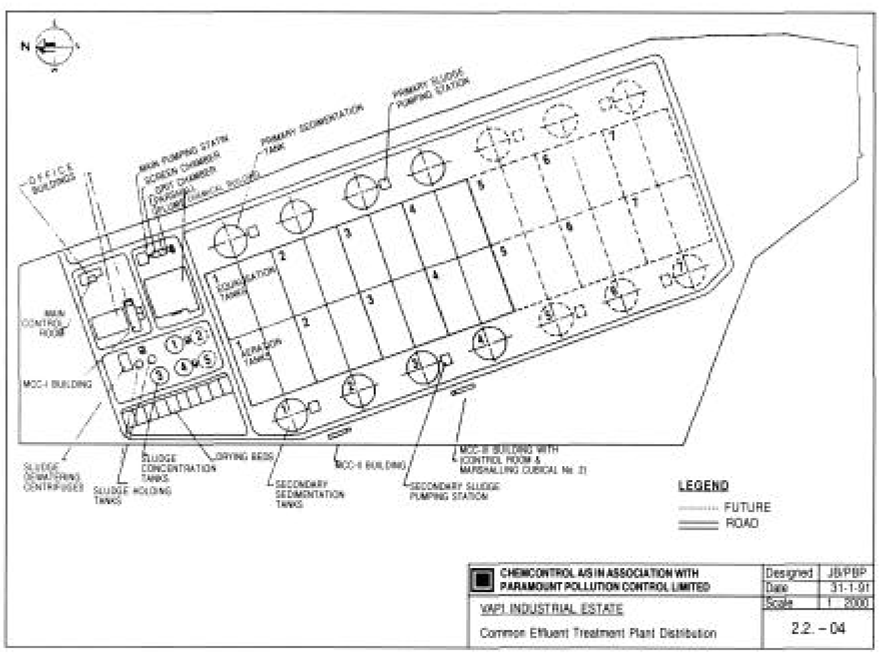

Figure 8-7. Layout of the Vapi Common Effluent Treatment Plant (Chemcontrol, 1991)

Provision also is made during pretreatment to adjust for low pH in the influent. All industries discharging wastewater to the CETP will be required to control the pH of their effluent to within the range of 5.5 to 9.5. The pH of the influent, however, will probably be on the lower end of what is tolerable for the CETP's biological processes. In addition, ferrosulphate will be added to the water during preliminary precipitation, thus increasing the risk of low pHs. Incorporating lime dosing into the design at the pretreatment stage, however, provides the necessary alkalinity or buffer capacity to withstand any pH drop resulting from the ferrosulphate dosage.

8.3.2.2 Primary Precipitation

Although industries discharging to a CETP are required to withhold or remove all toxic materials from their effluent, experience indicates that high concentrations of heavy metals will occur in the wastewater inflow to the CETP, at least during the first 5 to 10 years of operation. Excessively high concentrations of heavy metals could hamper the biological processes (i.e., aeration tanks) of the facility; therefore, the CETP design must provide for efficient removal of heavy metals from the wastewater before it enters the aeration tanks.

Ferrosulphate is dosed as a precipitation agent during primary precipitation to enhance the efficiency of primary sedimentation which is the next stage of the treatment train. Adding a precipitation agent such as ferrosulphate, optimizes the withholding of heavy metals in the primary sedimentation tanks. For this particular facility, ferrosulphate will be dosed as a 25-

percent solution prepared in the chemical storage building. Dosing will be done in the effluents from the main distribution chamber.

Primary Sedimentation

The main objective of primary sedimentation is to withhold raw sludge from the incoming wastewater in order to reduce the aeration tank volume. Figure 8-8 illustrates a primary sedimentation tank. If the primary sedimentation tanks are equipped with a flocculation step to enhance primary precipitation (using ferrosulphate), many heavy metals in the wastewater will be precipitated and withheld in the primary sludge.

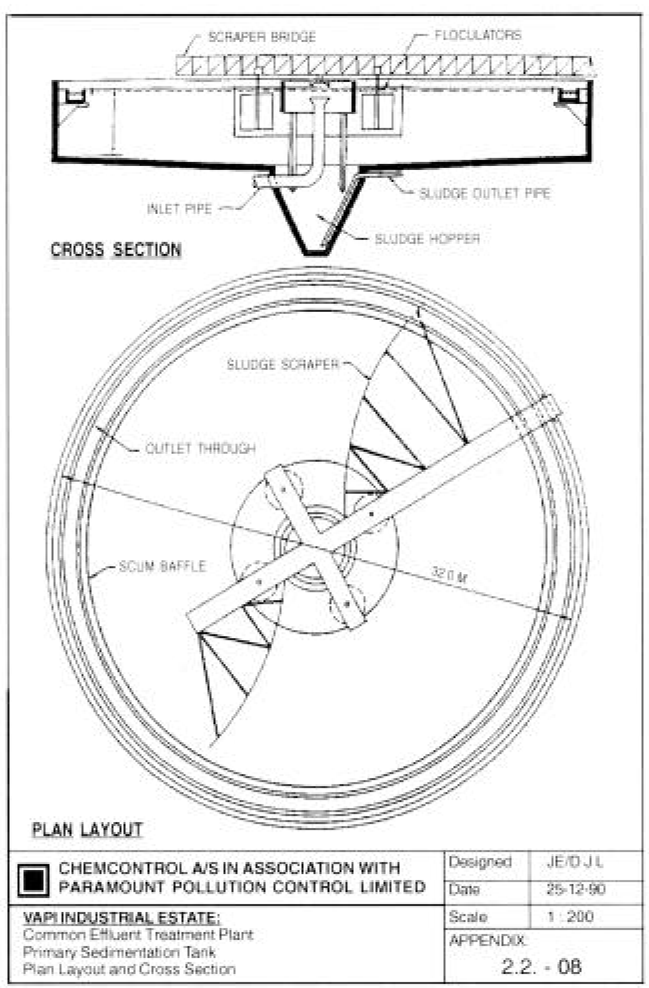

Figure 8-8. Primary and secondary sedimentation tank (Chemcontrol, 1991)

8.2.3.3 Equalization

The purpose of equalization tanks is to not to equalize the flow of influent wastewater, which will have little variation because most industries work continuously, but to equalize possible pH variations and to dilute unavoidable small shockloads of toxic or inhibitive materials in wastewater influent. This gives plant operators sufficient time to initiate countermeasures. Equalization tanks are operated with a constant water level and are kept completely mixed by mechanical agitators. The layout for the proposed equalization tanks for the Vapi facility, are outlined in Figure 8-9.

When a shockload of toxic or inhibitive materials is recognized in the equalization tanks, activated carbon is immediately dosed into the inlet end of the aeration tanks. Dosing continues as long as any toxic materials remain in the tanks.

Activated carbon dosing only takes place in emergency situations. To determine when this dosing is necessary, bench-scale activated sludge plants are operated continuously in the laboratory, fed by effluent from the primary sedimentation tanks. If the respiration rates for these small plants decrease, then activated carbon is added to the aeration tanks.

8.2.3.4 Activated Sludge Process

The activated sludge process biologically degrades organic matter in wastewater. The oxygen necessary to sustain the biological processes, such as substrate respiration and nitrification, will be provided by surface aerators that mix air into the mixture of wastewater and activated sludge in the aeration tanks (see Figure 8-10). To reduce the power demand for aeration, a dissolved oxygen control system regulates the operation of the surface aerators, maintaining a relatively constant concentration of oxygen in the aeration tanks. Dosing of activated carbon occurs in the aeration tanks when necessary. Designers selected the activated sludge process for the CETP because, in combination with activated carbon dosing, it is the most robust biological process for treating industrial wastewater.

An analysis performed on current effluent from the Vapi industrial estate indicates a very low phosphorus content, which could adversely affect the biological growth of activated sludge in the aeration tanks. This necessitates constant dosing of phosphate to the aeration tanks in the form of a fertilizer with trace substances such as manganese. The fertilizer should have as little nitrogen content as possible because the wastewater already contains a surplus of nitrogen to sustain the growth of activated sludge.

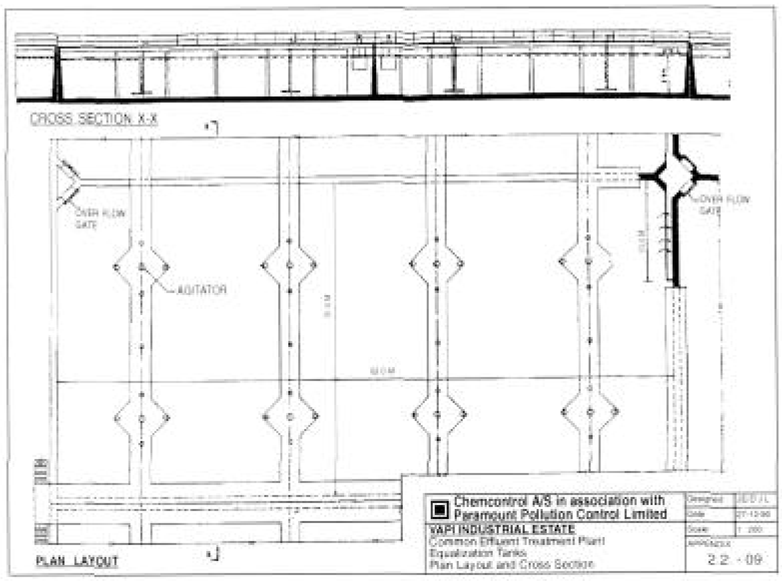

Figure 8-9. Equalization tanks (Chemcontrol, 1991)

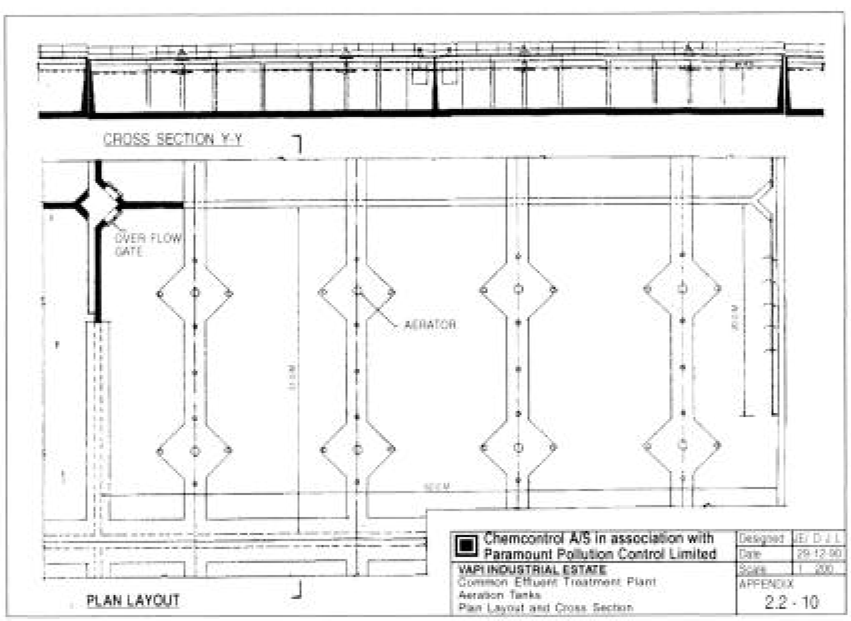

Figure 8-10. Aeration Tanks (Chemcontrol, 1991)

8.2.3.5 Secondary Sedimentation

The secondary sedimentation tank is designed to withhold, settle, and concentrate the activated sludge to such a degree that the effluent from the CETP should be able to meet tolerance limits for inland surface waters (biological oxygen demand less than 30 mg/L and suspended solids less than 100 mg/L) (see Figure 8-8). This only occurs, however, when the operation of the activated sludge process is trouble free and with only very minor inhibition of the biological processes.

Gravity withdraws the sludge settled in the secondary sedimentation tanks into return sludge pumping stations. Then, screw pumps continuously lift most of the sludge and send it back to the aeration tank inlet as return sludge. Centrifugal pumps will pump excess sludge from the wet well to the sludge concentration tanks. The amount of excess sludge the pumps withdraw each day will be based on maintaining a constant sludge concentration in the aeration tanks.

8.2.3.6 Sludge Concentration

Primary and secondary sludge is concentrated before dewatering to reduce the costs of electricity and polymers associated with dewatering. The two sludge types are treated differently because they will probably be disposed of in different ways.

Primary sludge is pumped directly from the primary sludge pumping stations to the sludge concentration tank designated for this sludge type. Secondary sludge is pumped from the return sludge pumping stations by the excess sludge pumps to the two sludge concentration tanks designated for this sludge type. An automatic valve arrangement ahead of the two concentration tanks ensures that only one tank receives sludge at a time.

All three sludge concentration tanks are equipped with a continuously operating sludge scraper (see Figure 8-11). Concentrated sludge is withdrawn intermittently during day and night to secure as high a sludge concentration as possible. Concentrated sludge is discharged into sludge sumps, one for each sludge type, then it is pumped to sludge holding tanks.

8.2.3.7 Lime Dosing for Stabilization

Primary sludge is stabilized to prevent the unpleasant odors that emanate from the anaerobic decomposition of sludge. Secondary sludge is fully stabilized because of the long sludge age in the aeration tanks (extended aeration). Lime dosing is used for stabilizing primary sludge. Lime slurry used for dosing is prepared by mixing lime and water. This is performed in a chemical storage building, then the slurry is pumped to the sludge well. Once dosed, the mixture of primary sludge and lime is pumped to the sludge holding tank.

Sludge will be taken out of the sludge concentration tanks around the clock to make operation of these tanks as stable and efficient as possible. The mechanical dewatering of the two sludge types takes place in two shifts. This necessitates having a buffer capacity between these two processes, provided in the two sludge holding tanks. One tank is provided for each of the two sludge types.

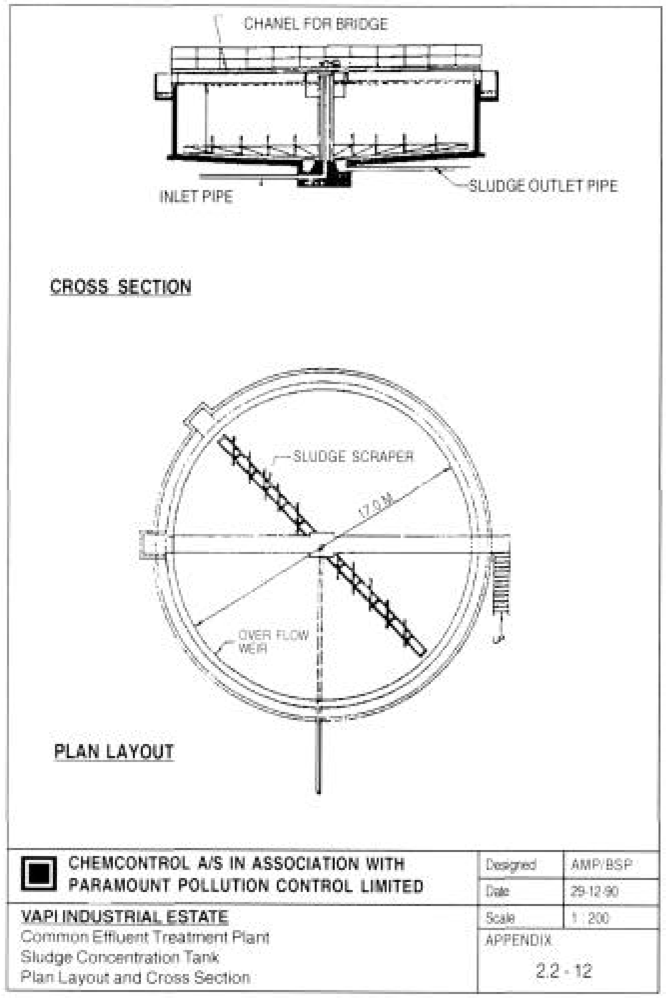

Figure 8-11 Sludge concentration tank (Chemcontrol, 1991)

8.2.3.8 Sludge Dewatering

Centrifuges are proposed for dewatering primary sludge in the Vapi CETP. If the primary sludge must be incinerated due to high heavy metal content, it will be dewatered using centrifuges and then placed on drying beds on a concrete floor where solar heat will further dry the sludge.

Secondary sludge is unsuitable for dewatering on sludge drying beds because the sludge has such a fine flock structure that water in the middle of the sludge layer is unable to escape and evaporate. Thus, mechanical dewatering is the only way to reduce the volume of secondary sludge before its ultimate disposal.

8.2.3.9 Sludge Disposal

The proposed disposal method for sludge produced at the CETP is for use on agricultural land. This is the least expensive and most environmentally attractive method provided the sludge does not contain hazardous components in excessively high quantities or concentrations. If the primary sludge has an excessively high heavy metal content, it will need to be incinerated. Both primary and secondary sludge will be dewatered to reduce the amount or volume of sludge before disposal. Any sludge suspected of still containing hazardous material will be disposed of in a local controlled landfill.

8.2.4 Operation and Management

The GIDC manages the Vapi industrial estate. Officers of GIDC have suggested that GIDC also own and manage the CETP. The total project cost for the CETP at Vapi is estimated at 444 million Rs. Annual operating costs are estimated to amount to 54.5 million Rs.

8.3 CASE STUDY 3: CENTRALIZED TREATMENT IN CETREL S.A. ENVIRONMENTAL PROTECTION COMPANY, PETROCHEMICAL COMPLEX OF CAMAÇARI, BAHÍA, BRAZIL

8.3.1 Case History

The Petrochemical Complex of Camaçari is located in the municipality of Camaçari, state of Bahía, Brazil, and includes several petrochemical industries and other transformation industries.

Between 1975 and 1976, the project of this industrial area defined centralized treatment and disposal as the option for all its solid and liquid waste, and this method was implemented in the following years.

CETREL S.A. - Environmental Protection Company deals with hazardous effluents and wastes and provides environmental advisory services to local industries. It has recently assumed the control of atmospheric emissions. The public urban cleaning entity is in charge of the collection and disposal of non-hazardous solid waste in sanitary landfills.

CETREL was created by the municipal and state governments with a small participation of the private sector. As its technical competence grew, it began to attract the interest of industries, which contributed the capital required for the physical and technological expansion of the plant. This reduced State participation in the project. Since 1991, public/private participation has increased to 34.43% and 65.57%, respectively.

At the beginning, there was only one effluent treatment plant responsible for the area's hazardous solid waste, but at present the company operates eight large treatment, disposal, and environmental monitoring systems:

- Collection, transportation, treatment, and disposal of effluents
- Processing and disposal of non-inert solid waste (class II)
- Temporary storage of hazardous solid waste (class I)
- Incineration of organochlorine liquid waste
- Incineration of hazardous solid waste
- Atmospheric monitoring network
- Groundwater management
- Ocean disposal system (terrestrial and submarine outfalls).

8.3.2 Operational Units

CETREL has six operational units:

- Effluent treatment station, formed by three aeration tanks, a volatile removal chamber, an equalization tank, twelve secondary basins, three sludge thickeners, two aerobic digesters, 16 “sludge bed” cells and an effluent accumulation tank.
- Incineration area, formed by two incinerators: one for hazardous effluents and the other for hazardous solid waste.
- Solid waste disposal system, formed by various industrial landfill cells, in addition to silos, patios and sheds.
- Groundwater monitoring network, formed by 508 monitoring and production wells and a hydraulic barrier with 26 wells.
- Ocean disposal system, formed by a “stand-pipe”, a terrestrial outfall (11 km in length), two balance towers and one submarine outfall (4.8 km).
- Air monitoring network, formed by eight fixed stations that continuously evaluate air quality, an air pollutant remote sensor (FTIR), a telemetry system, an acoustic radar and “summa canisters” equipment.

8.3.2 Treatment Processes

8.3.3.1 Effluent Treatment

The industries of the Petrochemical Complex of Camaçari must respect the state resolution that establishes effluent disposal standards. Furthermore, CETREL complies with another resolution that establishes standards for sea disposal (through outfalls) of effluents treated by the company.

The installed capacity of the central effluent treatment plant (ETP) is 144,000 m^3/day with a removal efficiency of 98% of BOD (biochemical oxygen demand) and 86% of COD (chemical oxygen demand).

Effluents are conducted to the ETP through a network of collectors and pumping stations. With an installed capacity for 120 daily tons of BOD, 360 daily tons of COD, and 54 tons of SS (suspended solids), the ETP treats a volume equivalent to the sewerage of a city of 3 million inhabitants.

The treatment starts in the VRU (volatile and semivolatile removal unit); then, effluents are homogenized in the equalization tank, to prevent organic load and flow peaks which affect the process. Upon passing to the aeration tanks, the liquid mass passes through the activated sludge, that has an average efficiency of 98% in terms of BOD removal. Once the organic matter has been degraded, the liquid mass passes to the secondary basins for liquid (effluent treated) and solid (sludge activated) separation. Part of that sludge continually recycles toward the aeration tanks; the other part is discarded from the process and passes to the thickeners.

Then, the biological sludge is stored over a long period, with aeration and without organic matter, in aerobic digesters, where the microorganisms are significantly reduced because of self-cannibalism.

8.3.3.2 Hazardous Industrial Waste Treatments

Industrial wastes are classified as hazardous (class I), non-inert (class II), and inert (class III), according to the Brazilian Standard (NBR) 10,004 – Solid Waste Classification, that specifies parameters for waste leaching and solubilizing tests. This Brazilian standard is based on U.S. EPA recommendations.

Processing and final disposal of class II waste is carried out in industrial landfills with capacity for 80,000 tons/year.

The temporary storage area for hazardous waste consists of silos, patios and sheds. After this area, the waste goes to incineration.

- **Industrial Landfill**

The mass disposed of in an industrial landfill constitutes a dynamic system, whereby the contents undergo chemical, physical, and biological alterations. The substances prepared in the landfill can migrate by liquid or gaseous routes outside the system, provided that there are no waterproof barriers (natural or synthetic). In CETREL, barriers are formed by a well-compacted clay layer overlapped by a high-density polyethylene membrane (HDPE).

This landfill is made up of an isolated chamber (cell) dug in the soil, protected by a highly waterproof clay layer (coefficient: $K < 10^{-7}$cm/s) and a HDPE membrane to ensure that the leachate does not contaminate the ground water table.

Since 1994, CETREL has been using the new landfill construction technology for class II wastes in overlapping layers. This technology makes it possible to form a "vertical landfill" of up to 17 m, in order to maximize land use and reduce the potential soil pollution area.

The new vertical landfill has the capacity to receive 300,000 m^3 of waste of up to 17 m high with a shelf-life of 60 months. It is subdivided into two sub-cells: the first one, reserved for waste disposal in drought periods, allows the entry of trucks to the landfill and disposal of wastes in the work fronts, where they are scattered and compacted by a tractor until reaching the specified degree of compaction; and the second one, reserved for waste disposal in rainy periods, allows waste discharge directly from the hoppers to the cell through a launching platform.

- **Hazardous Solid Waste Incinerator**

The primary function of the incinerator installed in the **COPEC** is hazardous solid waste incineration, mainly organochlorine, including PCB. This unit operates 24 hours a day in three 8-hour shifts. The waste is burned at high temperatures (1,250 ^{o}C), with a rough cooling in the post-combustion chamber that inhibits the formation of dioxins and dibenzofurans.

The gas washing system reduces stack emissions to levels lower than those specified by the legislation.

This solid incinerator, with a capacity for 4,500 tons/year, provides two important services:

- it meets the demands of hazardous solid waste generators of the state of Bahía, thus facilitating compliance with the legislation that prohibits the disposal of that type of waste in landfills;
- it serves other state companies, thus making up for the lack of hazardous waste incinerators at the national level.

- **Biological Washing Unit for Contaminated Soil**

CETREL developed a washing treatment technique (bio-washing) to reduce soil contamination from hazardous waste (class I) to non-inert waste (class II), and further dispose of it in an industrial landfill.

The objective of the processing technologies, in liquid phase, for contaminated soils and hazardous wastes is to obtain aqueous solutions that transport pollutants and degrade them as much as possible or that absorb pollutants in the form of fine particles suspended in biological sludge or generated solutions.

It should be emphasized that the great advantage of liquid-phase processing of contaminated soils, sediments, and wastes is the speed of the physical processes of biological reactions comparable to those verified in the activated sludge process.

The processes are based on the following properties and mechanisms:

- Volatile organic compounds are easily dissolved in liquid mass and absorbed in the atmosphere.
- Semivolatile compounds present a high carbon/water absorption coefficient, which favors the incorporation of organic substances in the clayey fine particles or activated sludge. During the washing process, solutions present high concentrations of organic loads (COD and SS)
- Pollutants are absorbed in fine particles (sediments and clays) and organic carbon, instead of coarse particles (sand and gravel).

8.3.3.3 Air Monitoring

The air quality analysis of the Petrochemical Complex of Camaçari is carried out based on a methodology similar to that adopted in the most advanced industrial complexes worldwide, such as that of Bayer in Germany and Lis, in Canada, corresponding to CETREL standards.

The network's eight fixed stations perform continuous air evaluations (24 hours) in the area and in neighboring communities. The stations are interconnected through a telemetry system, which allows access to fixed stations of the pole. The on-line monitoring of organic pollutant concentrations is carried out through the FTIR–Fourier Transform Infra Red and the Summa Canisters equipment.

8.3.3.4 Groundwater Management

Groundwater monitoring in the area of influence is carried out through a network of 508 wells that allow water sample collection for laboratory analysis. A hydraulic barrier was constructed to confine the pollutant plume and treat it in the ETP.

The areas that require attention are identified in maps and lithostratigraphs and confined by a hydraulic barrier that impedes migration of pollutant plumes to other regions.

8.3.4 Disposal of Treated Effluents and Wastes

In effluent treatment, the biological activated sludge treatment eliminates the polluting organic load, but generates biosolids as by-products (biological sludge), used as fertilizer and soil amendment.

The effluents treated in the ETP, with a purification index of approximately 98%, are disposed of at the bottom of the sea 4.8 kms from the coast, at a depth of 25 m, reaching a dilution of 1:400.

The ashes generated in liquid and solid waste incineration, as well as other non-inert wastes, are disposed of in the sanitary landfill.

8.3.5 Client Service

CETREL classifies its clients in two groups, according to the contractual relationship: permanent or for a specific length of time.

Criteria for client classification

G1	Companies interconnected to the CETREL integrated systems or which use those systems on an ongoing basis.
G2	Companies that contract CETREL services for a specific length of time.

Present or potential needs of the clients are classified in two main categories:

- environmental requirements: effective delivery of effluent and industrial waste treatment and disposal services, and environmental monitoring services (enforcement authorities);
- expectations with regard to services: attributes that the client expects from its relationship with CETREL, such as punctuality, good attention, promptness, market prices and speed, among others.

To identify specific needs of each client, mechanisms that can vary according to their characteristics:

- Contractual control: all environmental protection services offered have specific procedures. For G1 companies, mainly COPEC industries, an attendance process is followed to assess and guarantee compliance with environmental requirements. In case of G2 clients, CETREL prepares a specific specification for each contract.
- Attendance meetings: technical meetings are held to exchange opinions between G1 and G2 clients regarding their expectations of the service quality level.
- Opinion polls: starting in 1997 a specific and periodic research methodology was implemented for G1 and G2 clients, where the degree of satisfaction was measured.
- Visit to potential clients: the Client Service Group establishes an action plan for potential client visits, based on consultations with publications of state industrial federations and state environmental control entities, as well as their respective legislation.
- Legislation study: the main requirement of G1 clients is to treat their industrial effluents and wastes according to legal standards to prevent a significant environmental impact.

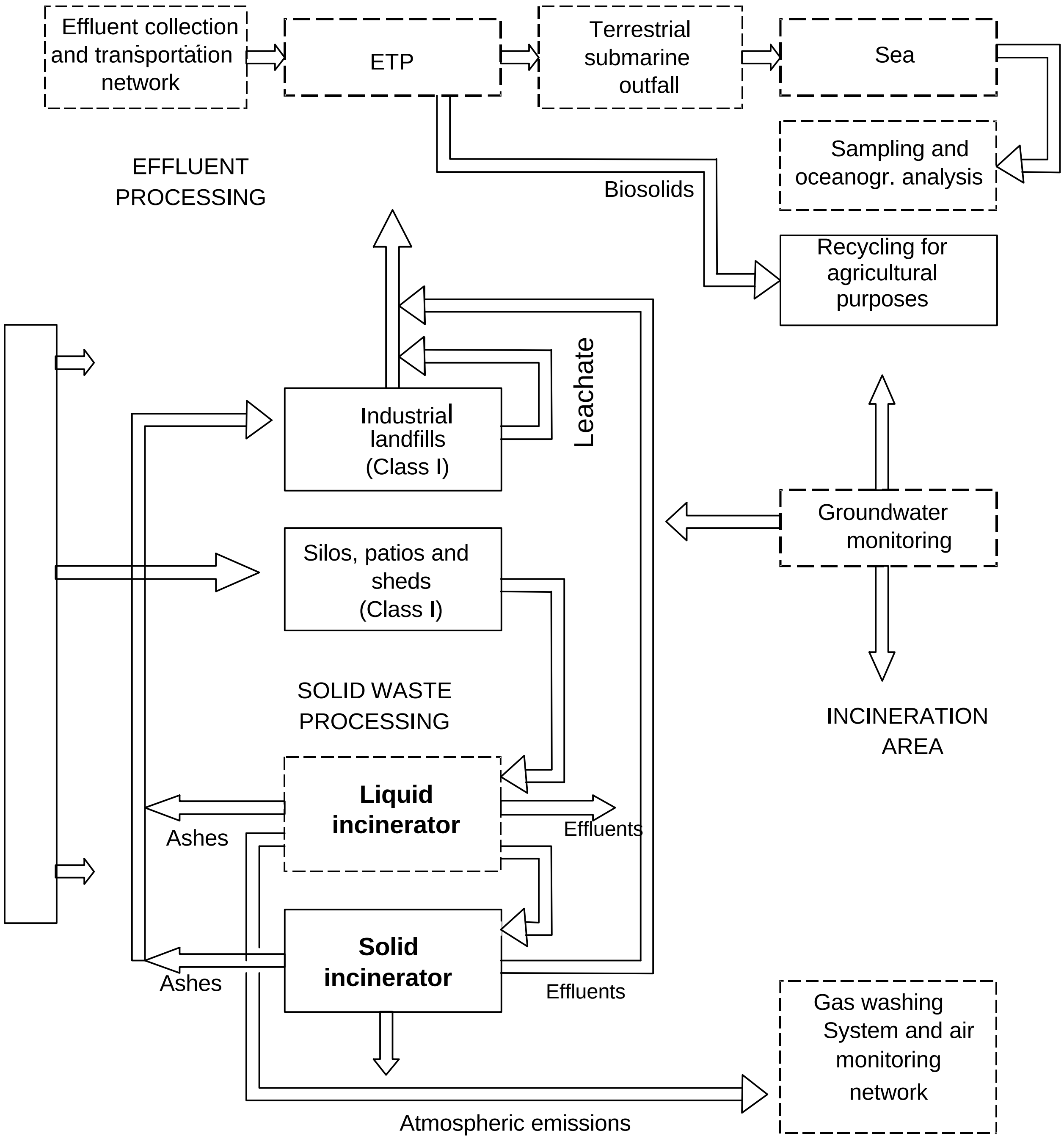

Figure 8-12. Integration of environmental protection systems of CETREL

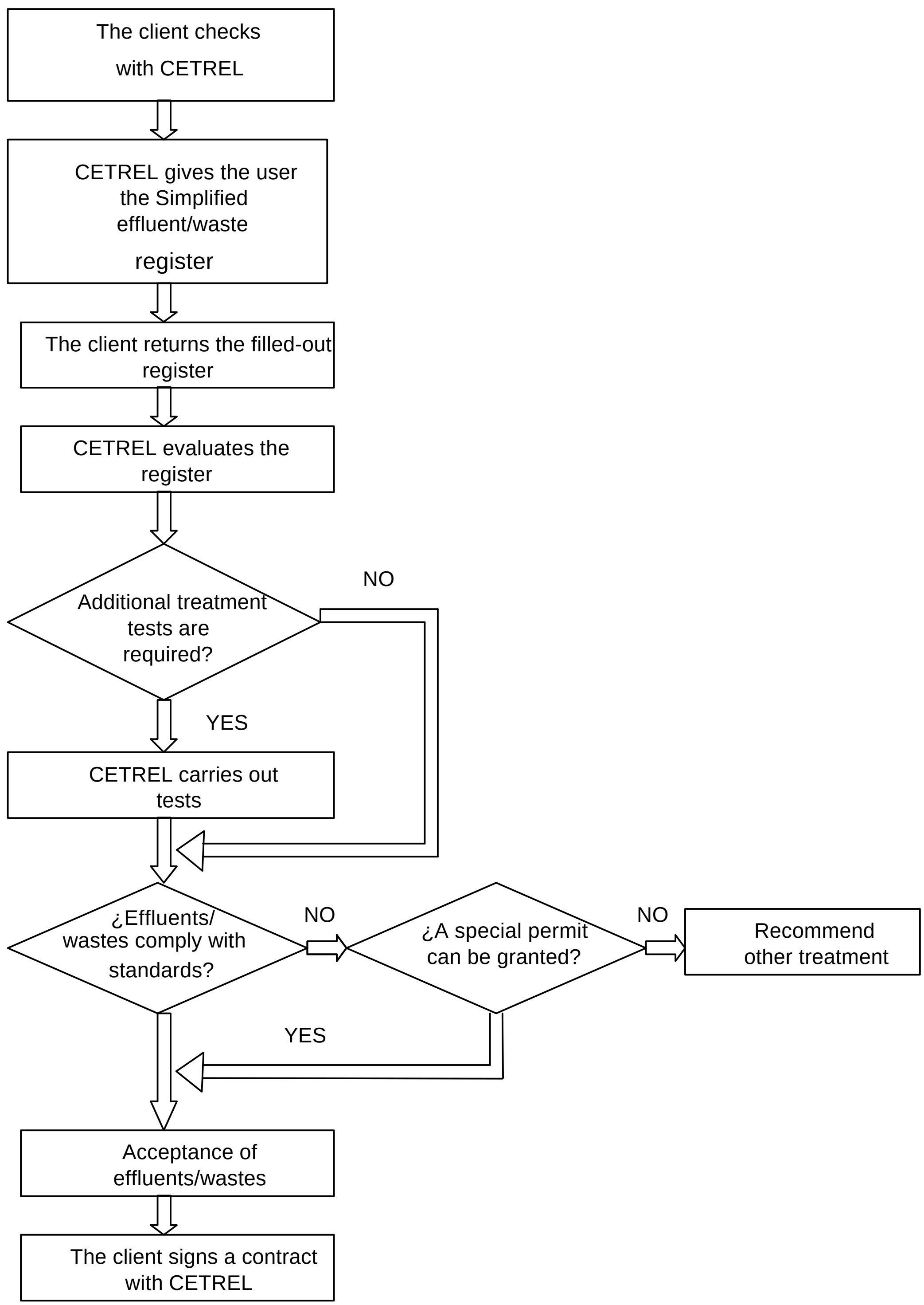

Figure 8-13. Client service flow diagram of CETREL

8.4 CASE STUDY 4: RATIONAL USE OF WATER IN INDUSTRIAL DRY CLEANING. CASE STUDY IN A SELECTED DRY-CLEANING PLANT IN BUENOS AIRES, ARGENTINA (1997 - 1998).

8.4.1 Case History

The textile industry is an activity that demands high water consumption and generates a correspondingly large volume of sewerage. It is classified within the ten most pollutant activities. The complex situation experienced by the sector, together with the strong legal pressure and the high cost of water in the metropolitan area (US$ 0.25/m3) makes improvements necessary in the different aspects of the process:

- rationalization of water use
- recycling of scouring and cooling liquids
- use of dry cleaning equipment
- optimization of dyeing techniques
- removal or substitution of polluting products.

8.4.2 Objective

To evaluate dry-cleaning processes and study the possibility of recovering the water used at different stages of the process.

8.4.3 Project Development

From the water-saving perspective, it is interesting to note that according to the survey conducted by the Centro de Investigación Tecnológica of Argentina (CIT), an average water consumption of 0.24 m3//kg of finished product was registered for the print shops and dry-cleaning category. As reference, an industrialized European country uses 0.14 m3/kg and utilizes equipment similar to that currently used in Argentina.

Most large-scale enterprises have implemented, or are in the process of implementing, purification systems for their discharges. Small and medium-scale industries cannot treat their effluents because of economic problems or lack of space. Although projects have been implemented for industrial discharge treatment in a common plant, they have not been successful.

Although most modern treatment technologies have been implemented in Argentina, SMSEs always consider associated costs to be very burdensome. Therefore, minimization is not only a logical and available tool, but a sound, essential and completely attainable element to face costs generated by industrial production.

If the purpose is exclusively to recover waters from dry-cleaning processes corresponding to:

- second rinse
- second rinse of the scouring
- softening of color tissues and washings (cationic basis) and
- softening of optic and melange white (silicone basis)

the total volume of water recovered annually will reach l38,200 m3.

The intention is not to carry out a detailed analysis at this stage, i.e. not to consider possible savings in raw materials dissolved in waters to be recovered (detergents, soda, acetic acid, softeners, etc.) nor those associated with not treating approximately 130 m3of sewerage per day. Nevertheless, it would be necessary to analyze the degree of saving in terms of exploitation and effluent of waters that can be recycled or, in other words, the tax paid to Aguas Argentinas for the use of water and sewerage.

8.4.4 Conclusions

According to present rates, Aguas Argentinas charges $Arg 0.5478/m3 for the “use of water and collector”, and therefore, the savings achieved by recycling the water used in dry-cleaning, would amount to approximately $ Arg 21,000/year, a significant figure if one considers that it usually simply "goes down the drain" -- literally -- with no comparative advantage.

This work, carried out in an SMSE, demonstrates that recovering waters from textile scouring and softening, saves approximately 22% of total water consumption.

Saving not only favors cost reduction, but also makes the sector's companies more competitive, which in turn, facilitates final disposal.

8.5 CASE STUDY 5: APPLICATION OF THE WASTE MINIMIZATION PRINCIPLE IN A TANNERY

8.5.1 Case History

The case study for applying the minimization principle in this industrial sector was performed by CEPIS in a tannery in Lima, Peru with GTZ support. The tannery has two main production lines: caprine and ovine hide. Of an average number of 28,000 hides processed monthly, 18,000 (65% of production) are caprine hides, and the remaining 10,000 are sheep hides. The production line of caprine hides was selected because of its low fat content, which facilitates reuse of hairing baths.

8.5.2 Objective

The case study was carried out (a) to evaluate recovery of effluents from the hairing and tanning processes; (b) to determine the optimal design parameters of the recovery systems in this sector and (c) to develop some proposals for the rational use of water and chemicals and plant cleaning.

8.5.3 Development of the Case Study

The characterization of hairing and tanning effluents showed high concentrations of sulfides and chromium. The values served as indicators to establish possible effluent reuse.

According to the literature, reuse of hairing baths is not very common because of the high fat content. In view of the fact that caprine hide is less fatty, reuse was considered a technically and economically feasible technique for this type of hide. Three evaluations were carried out on a semi-industrial scale to assess this hypothesis, as well as to determine the best reuse technique for the discharged effluent.

In addition to the routine analysis to determine sulfide concentration in the bath recovered, basic parameters were analyzed for variations due to reuse. It was concluded that the concentration of the polluting load increases considerably as well as the concentration of solids, which reduces the final effluent volume and hence, final treatment costs.

Reuse of the Tanning Bath

Although the volume of the tanning bath is small in comparison to that of the hairing bath, it is important to study techniques for its recovery and further reuse since the content of Cr^{+3} can reach toxic levels. Furthermore, the saving of this chemical implies a significant economic benefit for the industry.

On average, 25% was saved in all process chemicals, 55% of the bath volume was recovered for reuse, and the total required was completed with pickling bath. This means that 100% of the water volume was recovered through reuse.

8.5.3.1 Hairing and Tanning Bath Recovery System

A system was designed for the recovery, treatment, and storage of reuse baths (hairing and tanning baths). In addition, other measures were proposed regarding the rational use of water and chemicals, as well as industrial plant cleaning.

8.5.3.2 Economic Evaluation

The profitability of the hairing and tanning bath reuse proposals was evaluated. The indicators were internal rate of return (IRR), net present value of investments (NPV) and return period.

The evaluation shows that the project is economically profitable for the reuse of both hairing and tanning baths. The results were a net present value of US$ 34,581, an internal rate of return of 30% and a return period of three years and seven months.

Planned Income

With the case study results, comparisons were made to determine chemical and water savings that would be obtained when implementing the proposals for reuse of hairing and tanning solutions. The evaluation showed an annual saving of US$ 13,400 for a production of 18,000 caprine hides per month. An average weight of 1.15 kg was considered for a medium caprine hide to obtain the equivalent consumption.

In the case of reuse of the hairing baths of 500 medium caprine hides, a maximum of four reuses were obtained without altering the product quality; the total weight of the processed hides was 509.5 kg. In tanning, the processing of 1,770 medium hides (1,870 kg of hide) was tested with 15 reuses.

8.6 CASE STUDY 6: APPLICATION OF THE WASTE MINIMIZATION PRINCIPLE IN A TEXTILE INDUSTRY

8.6.1 Introduction

For the implementation of the CEPIS/GTZ case study (1993), the cotton sector was considered the most productive in the countries of Latin America.

The textile industry of the case study produces on average 260 tons per month: corduroy, drill, poplin, flannel, cretonne, plush, adhesive tape cloth, calico, polyester, and sandpaper.

8.6.2 Objectives

The objectives of this project were:

- To identify and characterize wastes
- To evaluate chemical recovery methodologies in the laboratory
- To evaluate and verify input recovery and recycling techniques on a semi-industrial scale
- To plan and develop modifications on an industrial scale
- To carry out the economic evaluation at the industrial level.

8.6.3 Development of the Case Study

To initiate the study, the industrial productive process was reviewed. The processes are dry or wet according to generation of effluent. Both spinning and weaving are dry processes, while the others are wet.

8.6.3.1 Characteristics of Global Effluent

In general, the COD value was 120 to 2,000 mg/L, which is a value expected in this type of wa0ste (strong concentration). The COD and BOD_5 have a ratio of 7.5 to 15.0; in this case BOD_5 concentration ranged from 50 to 200 mg/L. The pH of 9.5 on average, considered high despite the sodium hydroxide recovery, indicated that the water was strongly alkaline. The temperature exceeded the permissible values for discharge in sewerage and receiving streams despite the fact that two heat exchangers had been installed, not for the purpose of lowering the effluent temperature but to pre-heat the water that feeds additional operations. It should be indicated that all wastes contained a large quantity of dyes, which are significantly pollutant from the aesthetic and probably toxic point of view.

8.6.3.2 Minimization Strategies

When initiating the case study, the industry confirmed to have some minimization alternatives implemented.

- **Minimization Strategies Developed by the Industry before the Case Study**

Reuse of the Mercerizing Bath

The sodium hydroxide bath is stored in two tanks of 11 m^3 capacity. After eliminating the impurities through a revolving filter, it is reused in another mercerizing process. The soda concentration is measured and is titrated with sulfuric acid (H_2SO_4) to complement the dosage.

Reuse of the Sizing Solution

After using the rubber in a process, it is stored in the pad tray and discarded once it gets dirty or when its concentration is reduced.

Reuse of Dyes in Thermosol

Only dyes used in Thermosol are recovered except reagents that are decomposed.

Reuse of Scouring and Bleaching Baths

The baths remaining from these processes are reused; the product concentration is determined and the concentration is completed when required. After a process, the scouring or bleaching bath is pumped to the tank which has a capacity of 1,500 L.

Recirculation of Industrial Wastewater, Plaid and Rotary Print Machine

The shower water that washes the rubber belt is reused using a closed circuit, previously filtered by strainers.

Recirculation of Cooling Waters in the Pre-shrunk and Tumbler Dryer

The cooling water of the rubber belt is recycled in closed circuit for the pre-shrunk machine, previously filtered before it goes to the tumbler dryer.

Effluent from the Mercerizing and Washing Machine

To recover heat, the effluent passes through an Alpha-laval heat exchanger, input flow is pre-heated and the effluent temperature is lowered, which requires less steam for heating. This represents a significant fuel saving for the enterprise. The Alpha-laval has been adapted with filters to eliminate impurities that might obstruct the equipment.

8.6.3.3 Minimization Proposals for the Case Study

Considering the processes developed in this company for cloth manufacturing and the measures applied, it is estimated that the company has already initiated the waste minimization strategy.

To determine the activities to be developed in the case study, CEPIS had to evaluate the following proposals:

a. Change of faucets in the areas of:
   - washing of tables and equipment in the calico section
   - washing of the Thermosol machine.

   The use of pressure faucets was recommended (regulating handgun type) which are used by the operator to handle the water flow easily and reduce water consumption.

b. Water recovery in the overflow of the plaid print machine, which required greater storage to facilitate its recovery.

c. Recovery of the cooling effluent in the singeing machine.

d. Reuse of scouring water from different cloths.

e. Use of potato starch in the sizing process. Purification of rubber used through filtration.

8.6.3.4 Alternative Implemented During the Case Study

Based on the list proposed, the industry implemented changes in the scouring process. The discharges from the washing of bleached and scorched-acidulated cloths were sampled to determine the characteristics and thus, select the cloth that could be further washed.

The results of the physicochemical analyses indicated that waters from the washing of bleached cloths could be reused to wash scorched-acidulated cloths. In addition, it made it possible to neutralize the acid effluent of the scorched-acidulated cloths, since the pH ranged between 8.6 and 8.9. An estimate was made of the discharges from the washing of the different cloths, so that a possible storage tank could be designed.

8.6.3.5 Economic Analysis of the Minimization Applied to the Case Study

Based on the fact that toxic discharges are generated especially in the stages of scouring and bleaching of semimanufactured cloths and that attempts have been made to develop clean technologies feasible for application in the textile production process, the economic viability of a method was carried out based on a system for recovering scouring and bleaching "baths" of the mercerizing train in the industry selected for the case study.

8.6.3.6 Comparison Between the Traditional Process and Waste Minimization

The process consisted in reusing chemical solutions applied in the removal of raw fiber impurities, as well eliminating colored matter before the final dyeing. In the example, a waste minimization method based on chemical reuse was tested through storage and pumping using elevated tanks. The use of the system generated an input saving with minimum increase in the operation time (3.5 and 7 minutes for the pumping and return, respectively) and slightly higher investment costs.

With this system the solution circulates from an impregnation tub with a 2.5-HP-pump through a suction and discharge line that consists of stainless steel pipes and PVC. Once the solution is extracted, it flows by gravity from the 1000-L storage tanks toward the tub, where the impregnation baths are prepared, doubling scouring and bleaching every 24 hours, with a recovery of 50% through reuse. The process is planned for 25 days a month.

Analysis of Investment Costs

The investment estimate considered a medium-size enterprise prototype designed to produce 3,120 tons of product annually; the preparation of corduroy, drill, poplin, linen cloth, plush, and polyester is emphasized. The cost per ton is estimated at US$ 83.00.

Analysis of the Operative Costs

Bearing in mind that the case study represents a medium size plant for Peruvian conditions, and working with average operation data, the analysts have estimated the costs involved in adopting the traditional technology, compared to the costs of introducing the textile effluent reuse method. Applying the traditional technology, the total operative costs during the first year would be US$ 1,356,403 and from the year 2 to 50, US$ 1,402,213.

Planned Income

If it is assumed that the company will have a production "mix" featuring, in particular, fiber cloths., the income projection will be as follows:

Income (year 1)	US$ 1,944,800
Income (years 2 to 5)	US$ 2,121,600

Structure of the Additional Investment

The investment required for the implementation of the waste minimization technology is US$ 11,800, including public works and equipment.

8.6.3.7 Results of the Clean Alternative Application

Impact on Profitability:

Considering an income tax (plus deductions) of 30% and a total recovery of working capital at the end of the project shelf life, the following profitability indicators are obtained for the traditional alternative:

NPV (12%)	US$ 1,657,162
NPV (15%)	US$ 1,476,002
NPV (20%)	US$ 1,220,297
IRR	84.2%

While the actual costs would be:

PCV (15%) = US$ 5,263,342

On the other hand, for the case of the waste minimization technology, an increase of 3% will be required in the fixed investment, while the costs of the "scouring" and "bleaching" stages are reduced by 50%. As a result the following will be obtained:

NPV (12%)	US$ 1,975,783
NPV (15%)	US$ 1,770,616
NPV (20%)	US$ 1,480,668
IRR	96.3%

Actual costs: PCV (15%) = 4,856,029

Since the waste minimization alternative represents a more intensive chemical use for a single planned level of production, this alternative will be chosen because it presents a minimum present cost value (PCV).

Considering the introduction of the waste minimization technology, the cash flow will be modified both by high investment costs and savings in operative costs. In any case, savings compensate investment requirements.

8.6.4 Conclusions

- The size of the industry in the context of waste minimization is of a secondary character. It is essential to show minimization profits through savings in water and energy consumption and the sale of by-products that were discarded. This technology generates additional advantages such as occupational health, environmental protection, and the training of industrial technicians and workers. The alternative should be evaluated by the industrial entrepreneur and the technician, taking into account the plant scheme and its production program, raw materials used, economic situation, and requirements of the control authority.

- Within the cotton industry, where the case study was conducted, the following minimization options showed excellent results:

    - Recycling of sodium hydroxide, previous filtration, and fulfillment of requirements for the mercerizing bath of the following batch of cloths.
    - Recycling of the remaining rubber solution, from previous batches.
    - Recovery of dyes used in Thermosol facilities.
    - Reuse of the scouring and bleaching baths in further batch operations.
    - Recirculation of rubber scouring waters, previous filtration of plaid and rotary print machines.
    - Recirculation of cooling waters from pre-shrunk machines and tumbler dryer.
    - Recovery of heat from the mercerizing and washing machine effluents to pre-heat the clean water at the entry of the washing machine.
    - Reuse of waters from the washing of bleached cloths in the washing of scorched-acidulated cloths.
    - Use of waters from the washing of bleached cloths to neutralize the effluent from the washing of scorched-acidulated cloths.

Thus, water consumption was reduced, chemicals were recovered, processes were optimized, energy consumption was reduced, and technicians and workers were motivated.

In this case, it was not profitable to use potato starch for sizing since a longer time and special enzymes are required to remove it from the cloth in the scouring process. This is complemented by the fact that enzymes would generate greater toxicity than the synthetic compounds used.