Common Effluent Treatment Plant

State-of-the-Art

Sponsor :

Ministry of Environment and Forests

Government of India

National Environmental Engineering R[illegible]

Nehru Marg, Nagpur-440 020, India

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FOREWORD

Ministry of Environment and Forests (MEF), New Delhi retained National Environmental Engineering Research Institute (NEERI), Nagpur in December 1990 for evaluation of feasibility reports submitted by State Governments on Common Effluent Treatment Plants (CETPs) for industrial complexes and to provide assistance in implementation of schemes including training of O&M staff.

During evaluation of pre-feasibility and feasibility reports on CETPs submitted by various State Governments, it was felt that there is an urgent need to write a State-of-the-Art on CETPs drawing experiences from India and abroad. In view of this, a State-of-the-Art document has been written covering various salient facets of CETPs. This information package will be immensely useful as a 'Reference Guide' to field engineers, scientists and operating staff dealing with CETPs.

The trust reposed in the Institute by MEF through this assignment is gratefully acknowledged.

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ABSTRACT

Small Scale Industries (SSI), even if they strongly desire to install an effluent treatment plant to protect the water environment and meet the social obligation, they are unable to do so because of various constraints, viz. availability of land, funds and manpower.

If the protection of water environment is considered as a collective responsibility instead of an individual responsibility, then Common Effluent Treatment Plant (CETP) is the obvious solution to tackle the problem of wastewater treatment in an industrial estate. Besides, CETP offers the major advantage of economy of scale in terms of money, land and manpower.

This document highlights various aspects of the common effluent treatment including joint treatment of industrial waste alongwith sewage, literature review on work done in this field, financial apportionment, designing, implementation and operation of CETPs, ownership and management etc. Cleaner technologies, waste minimisation and environmentally balanced industrial complexes are also discussed to elaborate how to reduce End-of-the-Pipe (EOP) treatment to be given to combined wastewater in CETP. Experience of CETP in India as well as in abroad is also presented as case studies in the document.

1
Introduction

1.1 INDUSTRIAL DEVELOPMENT IN INDIA

Generally, the industry in India has developed within the last 50 years, apart from the pulp and paper industry which is more than a century old.

The chemical industry in India started with a few industries immediately after the Second World War, comprising two petroleum refineries, a fertilizer factory, as well as a few units for pharmaceuticals and caustic soda. After introduction of the first Five Year Plan started in 1951, the organised industrialisation began.

In the next decades, a number of petrochemical complexes were established, starting with one in Bombay and one in Gujarat. Indigenous production of pesticides (DDT and BHC) was started in 1954, and in 1958 the total annual production of these and three other pesticides was 5000 MT. This figure increased rapidly to about 61000 MT in 1986-87, which were produced by about 55 units. In addition, around 350 small scale units undertake formulation of 80000 MT per year.

The dyestuff industry started with one plant in 1946. By 1956 eight plants produced 16 MT annually, whereas in 1986 the large scale industry produced 28000 MT and the small scale industry 8500 MT. Most of this production takes place in Maharashtra and Gujarat.

Paints are produced at 24 large units with a total installed annual capacity of 20 million MT. In addition, certain products are reserved for production in the small scale units.

As mentioned above, the pulp and paper industry has traditions in India. However, upto 1970 there were only 17 pulp, paper and board mills with a total installed annual capacity of 137000 MT. Now around 300 mills with a total installed annual capacity of 3 million MT produce about 1.8 million MT annually. In addition, there are 5 units manufacturing newsprints with a total installed annual capacity of 300000 MT and 5 units manufacturing rayon grade pulp with total installed annual capacity of 196000 MT. The total annual consumption of paper in India is about 3 million MT.

The fertilizer industry started as mentioned above shortly after the War. Today, 44 large nitrogenous fertilizer plants have an installed total annual capacity of about 7 million MT, whereas 14 complex fertilizer manufacturing units have an installed annual capacity of about 1.6 million MT, calculated as P_2O_5. In addition, 46 units with a total capacity of around 57000 MT, calculated as P_2O_5, produce superphospate only. The total production of nitrogenous and phosphatic fertilizers was about 8 million MT in 1986-87.

The drugs and pharmaceuticals industry is characterised by the large number of small industries. By the end of 1989, only about 250 of the total number of units were large scale units, while almost 9000 were small scale units. The total value of the production in 1988-89 was Rs.5.3 billion and the value of formulated products was about Rs.27 billion.

The main productions within the inorganic chemical industry are the chlor-alkali and soda ash production. The chlor-alkali production takes place at 38 plants with a total annual production of 734000 MT in 1986-87. The soda ash manufacturing takes place in 7 units producing 942000 MT in 1986-87.

The very large increase in chemical manufacturing capacity is also reflected in the value of export of basic chemicals from India. From a modest Rs.140 million in 1964, exports in 1989-90 reached Rs.21 billion. In other words, export of chemicals from India has increased 150 fold in the past 25 years (1,2).

1.1.1 Industrial Estates

With the purpose of promoting rapid and orderly establishment of industrial areas and industrial estates, several States enacted Acts of Industrial Development in the early sixties in order to establish such areas and estates. These Acts instituted Industrial Development Corporations, the functions of which were to achieve the following objectives of the Government in the field of industrialisation :

1. To create appropriate essentials such as developed land/factory sheds for setting up industrial units. The developed plots and industrial sheds are provided with power connection, approach roads connecting them with highways, water supply, drainage and other facilities such as street lighting, banking, tele-communications, schools, shopping complexes and canteens.

2. To stimulate industrialisation in backward and tribal areas by setting up industrial estates.

3. To develop housing zones within the industrial estates with the view of attracting skilled and semiskilled labourers to take up jobs in industrial estates.

The Industries Association in the States cooperate with the State Industrial Development Corporation in the overall development of an industrial estate.

To encourage the growth of small scale industries, more than 800 items are reserved for this sector. The small scale industries are also entitled to financial assistance in the form of risk capital, long term and medium term loans and short term working capital, provided by State Financial Institutions and Small Industries Development Corporations, as well as tax benefits when located in backward areas. Benefits such as reduced charges for electricity and water, exemption on sales taxes etc. are also available to small scale industries.

Due to this policy, the industrial estates are dominated by small and medium scale industries which in turn create a number of environmental problems, some of which are listed below :

- Inadequate understanding of the technology of waste generation and treatment
- Lack of required space for pollution control facilities
- Ineffective supervision and management of even simple installations
- Lack of technical assistance from consultants within the industrial estates
- Non-availability of common effluent treatment systems
- Lack of effective regulatory approach and laxity of enforcing agencies.

1.2 PROTECTION OF WATER ENVIRONMENT IN INDUSTRIAL ESTATES

Protection of water environment calls for wastewater treatment before its disposal into inland water bodies or as onland irrigation. Secondly, water is a precious commodity and therefore must be conserved. In view of this, it is necessary to treat the wastewaters for reusing/recycling it. Both types of wastewater, viz. municipal sewage and industrial wastewater need to be treated so as to confirm the discharge conditions as stipulated in 'consent' given by State Pollution Control Boards.

The industrial wastewater contains many pollutants making it objectionable. Some of the established mal-effects are given in Table 1.1. The domestic effluent also contains pathogens. These pathogens create and spread water borne diseases and disorders.

Under the Water (Prevention and Control of Pollution) Act 1974, every industry has to provide adequate treatment for it's effluents before disposal whether it is in stream, land, sewerage system or in sea. The effluent can be treated jointly by the industries themselves or under some other higher organisation. This is akin to muncipal corporation treating the sewage of all the individual houses.

Table : 1.1

Ill Effects of Industrial Wastewaters

Parameter	Ill Effects
Acids	- Damages metal/concrete structures, pumps etc. - Produce hydrogen sulfide gas - Destroy microorganism
Alkalies	- Break natural buffer systems - Destroy microorganism - Produce asphyxiation by coagulation of gill secretion in fish
Suspended Matter	- Reduce photosynthetic activity - Chock gills of fish - Interfere fish breeding - Formation of floating mass of evil odour
Toxic Metals	- Cause chromosome damage and interfere heredity - Arrest movements of gill filaments - Destroy microorganism
Pesticides	- Changes metabolic activity of body - Depresses photoplankton in plankton
Dyes	- Imparts colour even when present in micro quantities
Oils	- Affects reaeration of water - Coats gills of fish - Spoils beaches

The BOD/COD and suspended solid loads contributed by industrial wastes is much more as compared to that of municipal sewage. The large scale industries generally have their own treatment plant. If not, they atleast do not have financial, manpower and land availability constraints for installation and maintenance of the treatment plants. Medium and small scale industrial units do have some limitations on available finance, land and manpower for having individual treatment plant. As far as small scale industries (SSI) are concerned the problems faced by these units are manifold in nature. The technologies adopted by the SSI units are mostly outdated. They generally suffer from manpower shortage. SSI are always regarded as 'one man show'. Lack of finance is the greatest bottleneck. These units due to ignorance and lack of finance fail to adopt pollution control measures, though they alone contribute about 40% of the total industrial pollution load in the country. In such small units, which operate 'one shift a day', maintenance of ETP is difficult and may not be financially viable also.

To overcome these difficulties, the industrial wastes can be treated jointly alongwith municipal sewage in sewage treatment plants. If this option is not viable, wastes from various industrial units in an estate can be economically treated combinedly in a Common Effluent Treatment Plant (CETP).

This report reviews various aspects of the joint treatment as well as CETP specifically in detail. This report is expected to prove as an useful guide to the designers, operating personnel and management people dealing with CETP.

1.3 OBJECTIVES OF THE CETP

Although the real measurable cost of industrial environmental pollution control remains relatively small when compared to total production or value added costs, it can be considered a significant amount when considered by itself. The main objective of the CETP is, therefore, to reduce the treatment cost to be borne by an individual member unit to a minimum while protecting the water environment to a maximum.

Wastewater treatment is a prime objective of the CETP. The wastewater can be treated economically in CETP to produce process grade water. This water can be reused and recycled in the industry. Water conservation thus can be one of the objectives of the CETP.

The burden of various Government authorities working for controlling and monitoring of water pollution control can be reduced to a great extent if CETPs are implemented. The long procedures of granting the consent, cess collection and regular monitoring will no more be necessary for State

Pollution Control Boards as the company or cooperative society formed for running the CETP will be responsible for ensuring the discharge conforming to laid-down standards.

1.4 ADVANTAGES OF THE COMBINED TREATMENT

1.4.1 Joint Treatment of Municipal and Industrial Waste

- The most important single advantage is the savings in both capital and operating costs for both industry and the municipality. In general, a large single sewage treatment plant is cheaper than a multitude of scattered smaller units.

- A second factor favourable to combined treatment is the intangible advantage of specialization. A municipal sewage treatment plant is operated by trained experts. Such a waste treatment plant, however, is alien to the normal experience of most industries and would be a side line to the main effort of production. It is likely that an overall effluent of better quality will result when all treatable industrial wastes are processed in the central waste treatment plant.

- Another important factor is availability of land on the industrial site, which is becoming scarce day by day and for many industries, it may be simply impossible to spare or to acquire land for the individual treatment plant.

- Domestic sewage contributes nutrients and a diluting potential making an industrial waste more amenable to degradation and destruction in biological processes of sewage treatment plants. The beneficial effects of domestic sewage towards increasing the susceptibility of the various wastes to biological decomposition of the sewage in treatment plants are worth exploiting (3,4).

  The decomposition of industrial wastes mixed with domestic sewage will proceed at a maximum rate if there exist the following ratio :

  BOD : N = 17:1
  BOD : P = 90:1

  On an average domestic sewage contains the following quantities of nutrients:

nitrogen (N)	:	12.8	g/capita/day
phosphorous (P_2O_5)	:	5.3	g/capita/day
potassium (K_2O)	:	7.0	g/capita/day

Considering 54 g of BOD/capita/day as a waste generation rate, one arrives at the ratios of :

BOD : N = 4.2 : 1 (Required 17:1)
BOD : P = 23.0 : 1 (Required 90:1)

which are much more than required ratios. From this it can be concluded that domestic sewage supplies excessive quantities of nutrients to the biological treatment which may advantageously be used for combined treatment together with oligotrophic industrial wastes (5).

- The domestic waste provides a continual seed source to the biological units. It also serves to cool and buffer the industrial waste, as well as to dilute any shock-loadings. More efficient nutrient utilization is achievable in combined treatment as the biooxidation of the industrial organics served to scavange the excess nitrogen and phosphorous from the domestic waste (6).

1.4.2 Combined Treatment of Heterogenous/Similar Industrial Wastewaters

- Wastewaters of individual industries contain very high concentration of pollutants occasionally and to reduce them by individual treatment to the desired concentration many times become technologically difficult and uneconomical also. Combined treatment provides a better and economical solution because of the equalisation and neutralisation taking place in CETP.

- Individual industries find themselves unable to arrange for the required finance for construction of the individual treatment facilities.

- Many industries being of small and medium size and running in single shift do not attend, operate and maintain the treatment plant. They do not have necessary expertise for doing so. Such industrial units can be relieved off from their responsibility of treating the wastewaters being generated from the respective units if they join CETP.

- A high degree of security of operation is achieved in CETP minimising risks of health hazard and water bodies pollution.

- SSI units in an estate, if considered for individual treatment plant, require large number of equipments like mixers, aerators, pumps and standby equipments etc. The overall blocking of funds and installed HP becomes more than what would have been required in a single large sized plant treating the same collective quantity of effluents.

- Due to combining of various effluents, it attributes to dilution effect, equalisation, mutual neutralisation and therefore treatment of the combined wastewaters become comparatively much easier and cost involved is lesser.

- Because of economy of scales, CETP is much less expensive in respect of both capital and operating cost of treatment plants of the individual industries. The same can be said regarding total area requirement and length of pipe lines.

- Professional and trained staff can be made available for operating a CETP which cannot be ensured in case of small scale treatment plants of individual industries. A laboratory support and good documentation can be easily provided.

- Disposal of treated wastewater generated by CETP becomes more organised and streamlined.

- Collection of cess from individual units become much simplified.

- Sludge disposal becomes extremely simple as it is to be collected from a single point of CETP.

- Individual problems would be common problem in CETP and, therefore, can be attended faster.

- It shall reduce the burden of various Government authorities for controlling and inspection.

1.5 DISADVANTAGES OF THE COMBINED TREATMENT

1.5.1 Joint Treatment of Municipal and Industrial Waste

- Expansion of the industry might be delayed or affected by municipality problems in raising funds or for other reasons which might lead to disapproval of waste treatment expansion.

- The political situation of the municipal corporation may change which can affect service charges or change the agreements made by a former administration.

- Where secrecy of industry's process and operations is important, it could increase the chance of revealing knowledge to competitors (7).

1.5.2 Combined Treatment of Heterogenous/Similar Industrial Wastewaters

- Expansion of an existing industrial unit may have to be with-hold due to to non-availability of spare capacity of CETP to treat the extra additional load resulted from expansion.

- The sharing of financial burden cannot be done accurately and this leads to many inequalities amongst the financial burden to be shared by member industries. For example, an industry generating acidic or alkaline waste need not neutralise the waste at source and thus saves the partial cost of pH adjustment. But the industrial unit generating waste with pH 7.0 will have to contribute to the cost of neutralisation at CETP though its waste needs no neutralisation. Similarly, the plants generating waste with low biodegradability contribute the cost in terms of KgBOD load (same as for other industrial wastes with high biodegradability) though that waste require more oxygen and in turn more operating cost. Thus, the industries generating wastes with low biodegradability may have higher economical benefits as compared to industries generating highly biodegradable waste.

2

Status of CETPs in India

Government of India has appreciated the fact that the provision of effluent treatment plant (ETP) by each individual industry in various industrial estates in India to produce effluent of desired quality would not only be immensely expensive (as regards to both the capital and operating costs), but would also ensure no guarantee of performance by the individual industries. Furthermore, the disposal of treated effluent is also problematic as every individual industry can neither reach the water body by its own pipeline (even though effluent is assumed as fit for such disposal) nor can use its industrial land purchased at a premium for onland irrigation of effluents. Government of India realised the necessity of CETP to overcome these problems. CETP not only help the industries in easier control of the pollution but also it is a step towards clean environment and service to society. Accordingly, Ministry of Environment, Government of India had instructed various State Pollution Control Boards to examine the possibilities of establishing CETPs in various industrial estates in the respective States.

2.1 POTENTIAL LOCATIONS FOR ESTABLISHING CETPs AS IDENTIFIED BY VARIOUS STATE GOVERNMENTS

In response to instructions of Central Government, various State Governments have started identifying the potential locations for establishing CETPs in their states. Table 2.1 shows a partial list of the CETP schemes proposed by various State Government. This list is not exhaustive and is incomplete as State Governments are still in the process of identifying locations for CETP and preparation of feasibility reports to be submitted to Central Government for its consideration. Other details of the proposed schemes such as project cost, flow, financial grants/loans and technical aspects etc. are also given in Table 2.1.

2.2 EXISTING CETPs IN INDIA

Idea of CETP for a cluster of industries to control water pollution is a recent one and not much attention was paid to this field in the past. Work carried out in this direction till 1990 was very limited. Till this date, India has only one CETP under operation at Jeedimetla near Hyderabad in A.P. However, this scheme is still under the process of development and two phases of the scheme are completed. Phase III and Phase IV are still to be implemented. Presently the effluents are being collected with the help of tankers. The details of the plant and its performance evaluation are discussed separately in Chapter 12.

Table : 2.1

CETP Schemes Under Consideration of Government of India

S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total Units	Total Qty of Efflu. m³/day	Organi-sation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machi-nery	Conti-ngency	Bldg	Convey-ance				Cent-ral Govt.	State Govt.	Fina-ncial Instt	Memb-bers of the Scheme	
1.	CETP for Mallapur, A.P.	272.4	18	100	54.4	50	50	Not known	2050	APIIC	25%	25%	50%	-	Suitable conveyance system is existing.
2.	CETP for Nacharam, A.P.	497	24	250	91	50	82	Not known	7300	APIIC	25%	25%	50%	-	-do-
3.	CETP for cluster of tanneries in T.N.	670													
	(i) Pammal & Pallavaram							59	3000-4000	Yet to be constituted	25%	25%	40%	10%	
	(ii) Erode							56	3000-4000	-do-	25%	25%	40%	10%	
4.	CETP for Dyeing units in T.N.	1132						854 total	26240 total		25%	25%	40%	10%	

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs) Land	Machinery	Contingency	Bldg	Conveyance	Total Units	Total Qty of Efflu. m^3/day	Organisation	Sharing of Costs Central Govt.	State Govt.	Financial Instt	Members of the Scheme	Technical Aspects of the Scheme
	(i) Karur							128	7680	-do-					
	(ii) Tiruppur							261	15000	-do-					
	(iii) Periasemur							212	1300	-do-					
	(iv) Erode							191	800	-do-					
	(v) Bhavani							30	180	-do-					
	(vi) Ammapettai							32	1280	-do-					
5.	CETP for Pyara Nagar, Medak, A.P.	82 + 26	25.9	31	25	26		28 (12 are major & medium indust-	1000 m^3/d from only 12 major & medium industries	M/s Bonthapally Envirotech Pvt. Ltd.					The CETP will receive effluents from medium scale industries
6.	CETP for Bollaram, A.P.	113	1.85	67 4	32.0	11.6	-	16 (to be covered by CETP out of total 40 units in indl. area	435 m^3/d	M/s Progressive Effluent Treament Ltd.	25%	25%	50%		Mode of disposal after treatment is land application or recycling

contd.

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total. Units	Total Qty of Efflu. m^3/day	Organisation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machinery	Contingency	Bldg	Conveyance				Central Govt.	State Govt.	Financial Instt	Members of the Scheme	
7.	CETP for Ankaleshwar Estate, Gujarat	600	0.7	137	-	380	80	1179 m^3/d	25000 Surat	GIDC					Industries with 50 KLD discharge to pro-pre-treatment; The estate is devided into 4 zones based on category of industries.
8.	Common ETP for Vapi Indl. estate, Gujarat	680	-	570	23.6	101	-	1440	50000 m^3/d	GIDC Vapi	20%	20%	50%	10%	Proposed capacity of CETP is about 45 MLD.
9.	CETP scheme for leather complex at Unnao, U.P.	27.4 includes						8 (tanning) & 1 (leather board manufactu-	1000 m^3/d						The scheme includes treatment as well as coveyance. Pre-treat

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total. Units	Total Qty of Efflu. m^3/day	Organisation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machinery	Contingency	Bldg	Conveyance				Central Govt.	State Govt.	Financial Instt	Members of the Scheme	
7.	CETP for Ankaleshwar Estate, Gujarat	600	0.7	137	-	380	80	1179 m^3/d	25000 Surat	GIDC					Industries with 50 KLD discharge to pro-pre-treatment; The estate is devided into 4 zones based on category of industries.
8.	Common ETP for Vapi Indl. estate, Gujarat	680	-	570	23.6	101	-	1440	50000 m^3/d	GIDC Vapi	20%	20%	50%	10%	Proposed capacity of CETP is about 45 MLD.
9.	CETP scheme for leather complex at Unnao,U.P.	27.4 includes						8 (tanning) & 1 (leather board manufactu-	1000 m^3/d						The scheme includes treatment as well as coveyance. Pre-treat

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total Units	Total Qty of Efflu. m^3/day	Organisation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machinery	Contingency	Bldg	Conveyance				Central Govt.	State Govt.	Financial Instt	Members of the Scheme	
12.	Collection, treatment & disposal of industrial wastewaters at Pattancheru, A.P.	507	20	250	105	50	82	about 200 SSIs and medium scale industries	9518 m^3/d; scheme can accomodate expansion upto 2000 A.D.	Pattancheru Envirotech Ltd. will implement scheme. APIIC is the nodal agency	25%	25%	50%	-	Pretreatment by indl. units; CETP designed to treat BOD load of 11250 kg/D so as to reduce BOD & SS standards to 20/30 mg/L.
13.	CETP for Pashamylaran, A.P.	562	-	300	107	50	105	Not known	10700 m^3/d	APIIC	25%	25%	-	50%	Effluents will be collected through a drainage system
14.	CETP for 5 textile mills at Indore, M.P.	133						Not known	3571 m^3/d						Conveyance effluents by channels.

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total Units	Total Qty of Efflu. m^3/day	Organi-sation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machi-nery	Conti-ngency	Bldg	Convey-ance				Cent-ral Govt.	State Govt	Fina-ncial Instt	Memb-bers of the Scheme	
15.	CETP at Industrial Area Urla & Bhanpuri, Raipur, M P.	140	40	33.4	16.6	-	50	225 (of which 140 are polluting)	1050 m^3/d This includes 775 m^3/d of Indl. efflu-luents & 175 m^3/d sewage.						2 indl areas have been included Conveyance by open channels. Mode of disposal by re-use/land application.
16.	CETP at Indl. Area, Govindpura, M.P.	117						523	1000 m^3/d		25%	25%	50%	-	Treated effluents to be used for irrigation purposes.
17.	CETP at Pologround, Indor, M.P.	70						90	1000 m^3/d includes sewage						

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total Units	Total Qty of Efflu. m³/day	Organisation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machinery	Contingency	Bldg	Conveyance				Central Govt.	State Govt.	Financial Instt	Members of the Scheme	
18.	CETP at Indl. area, Maharajpura, Gwalior, M.P.	76						61 (of which only 14 are polluting units	155 m³/d						Effluents from 6 types (chemicals & oil) to be treated in CETP.
19.	CETP for cluster of dyeing industries in Textile Colony, Indl. Area 'A', Ludhiana, Punjab	62.6	22	13.62	4.29	15.2	7.5	10	645 m³/d	Punjab Water Supply Sewerage Board	25%	25%	40%	10%	Effl. is collected thru sewers & disposed into existing sewerage system.
20.	CETP for cluster of textile mills at Batala Road, Amritsar, Punjab	277.54	14	78.1	7.49	163	14.9	38	10000 m³/d	Punjab Water Supply & Sewerage Board	50%	-	40%	10%	-do-

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs. Lacs)					Total Units	Total Qty of Efflu. m³/day	Organisation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machinery	Contingency	Bldg	Conveyance				Central Govt.	State Govt.	Financial Instt	Members of the Scheme	
21.	CETP for cluster of dying industries along Rahon Road, Ludhiana, Punjab	101.85	48.4	13.4	15.1	21.5	3.5	9	950 m³/d	Punjab Water supply & Sewerage Board	25%	25%	40%	10%	-do-
22.	CETP for cluster of electro-plating industries along Gill Road, Ludhiana	31.17	11	4.60	4.63	2.81	8 12	19	Not known	Punjab Water Supply & Sewerage Board	25%	25%	40%	10%	Treated effluent will conform to standards (including chromium)
23.	CETP at Panoli, Dist. Bharuch, Gujarat	1285	-	440	85	760	-	Not known	36 MLD capacity of CETP	GIDC	25%	25%	40%	10%	
24.	CETP for Sarigam, Valsad, Gujarat	1615	-	550	115	950	-	Not known	45 MLD capacity of CETP	GIDC	25%	25%	40%	10%	

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S. No.	Name of CETP Scheme	Total Cost in Rs. Lacs	Break-up of Costs (Rs Lacs)					Total Units	Total Qty of Efflu. m^3/day	Organi-sation	Sharing of Costs				Technical Aspects of the Scheme
			Land	Machi-nery	Conti-ngency	Bldg	Convey-ance				Cent-ral Govt.	State Govt.	Fina-ncial - Instt	Memb-bers of the Scheme	
25.	CETP for Sachin, Gujarat	969	-	330	69	570	-	Not known	27 MLD capacity of CETP	GIDC	25%	25%	40%	10%	
26.	CETP for Tarapur, M.S.	431	-	237	-	34.1	160	Not known	Not known	MIDC					
27.	CETP at Trans-Thane,M.S.	100	76.5	5	-	18.45	-	Not known	Not known	MIDC					
28.	CETP at Jayasingpur Indl. Coop. Estate Ltd. ,Kolhapur, M.S.	33.65	-	22.5	4.5	3.25	3.75	57 (all SSI)	599 m^3/d	25%	25%	40%	10%		

Source : Appraisal of CETP proposals, Ministry of Environment & Forest, Government of India, New Delhi, 1990.

2.3 CETPs UNDER IMPLEMENTATION IN INDIA

In India, many CETP schemes are under various stages of implementation. A brief description regarding some of these schemes is given below :

2.3.1 Patancheru, A.P.

The industrial area has 276 industries with about 46 major units consisting of chemicals, drugs and pharmaceuticals, paint, tannery, pesticides, cellulose products, etc. A sewerage system and a CETP has been designed to treat upto 10 MLD flow. The plant is under construction. The treatment process starts with equalisation followed by anaerobic (UASB) and aerobic treatment units. Gas is expected to be collected for local industrial use (without conversion to electricity).

As institutional arrangements, under the initiative of the Andhra Pradesh industrial infrastructure Corporation (APIIC), the industries have themselves floated a separate Limited Company (Patancheru Envirotech Ltd.) for the sole purpose of owning and operating the CETP. The total cost of the project was firmed up at Rs. 5.07 crores and finance arranged as follows:

Source	Rs. Lacs
Equity from end users	100
Equity from IFCI and IDBI	36
Term loan from IFCI and IDBI	310
Term loan from A.P. Govt.	11
Subsidy from DOEn	25
Subsidy from DNES (expected)	25
Total Rs.	507 lacs

Operating costs (and debt servicing charges) will be recovered from users based on wastewater volume and BOD.

A few industries will have to provide pre-treatment in their own premises before releasing the wastewater to the CETP. For the first two years the wastewaters will be collected and conveyed to the CETP by tankers. This may continue longer if considered desirable. Those industrial wastes not meeting standards will not be allowed to discharge into the CETP. Patancheru Envirotech Ltd. will, no doubt, be responsible for meeting the final discharge standards of the Pollution Control Board while the individual industrial units will be responsible for meeting the standards set for them and non-compliars will be reported to the State Pollution Control Board for action. Under no circumstances will non-compliars be allowed to benefit unfairly from the CETP.

As the end users themselves will own the treatment facility and be responsible for their final effluent, it is hoped that necessary control will be exercised on any non-compliar among them to ensure the desired performance of the CETP.

2.3.2 *Bollaram, A.P.*

Here, there are about 20 industries, all manufacturing bulk drugs. The institutional arrangements are similar to those of the Patancheru case described above, and are likely to prove successful in practice especially since the quality of effluent brought in by the tankers will be closely monitored to ensure that pre-treatment is carried out.

2.3.3 *Nacharam, A.P.*

Here, a different institutional arrangement has been envisaged. About 35 industries with about 6 to 7 major units (distillery, starch, chemicals, etc.) will discharge into an industrial sewer and CETP (yet to be constructed) which will be owned by the APIIC. All the capital costs will be met by APIIC though some recovery may be made atleast partially from the user industries who will meet operating costs as may be levied by the APIIC. This way, the industry will pay but the whole responsibility will rest with the public authority. There is a danger that the expenditure contemplated on this scheme may prove infructuous if all parties do not cooperate with APIIC.

2.3.4 *Pali, Rajasthan*

Over 70 small and medium scale textile cloth and yarn dyeing units are located here. The Rajasthan Industrial Investment Corporation (RIICO) provided a CETP at Government cost but it fell into disuse owing to the huge cost of neutralisation (Rs. 78 lacs/year) for the highly alkaline wastewater received at the plant.

Consultants are now working to study changes required in the various manufacturing processes to facilitate subsequent treatment and land disposal. Several changes have been recommended to reduce caustic alkalinity and sodium content. Again an institutional problem has been created in which the State Pollution Control Board cannot come down heavily on another governmental agency (RIICO) to implement the measures promptly. Thus, pollution continues and the public money spent on treatment plant construction remains infructuous.

2.3.5 Vapi, Gujarat

Preparation of basic engineering package for a CETP at Vapi has been assigned to NEERI by Ministry of Environment & Forest (MEF). This industrial estate, the biggest one in Asia, accomodates 1440 industrial units. Types of industries include Textile, Paper, Dyes, Chemical, Paints, Pharmaceutical etc. 587 units out of existing 1440 industrial units in the Vapi estate do not contribute any wastewater leaving 853 units as polluting units. The total wastewater generation is estimated as 51.3 MLD. Inventory of industries and treatability studies are in progress.

2.3.6 Parvanoo, Kala Amb, Barotiwala & Mehatpur, H.P.

Here also, NEERI has been retained by MEF for preparation of basic engineering package and assistance in commissioning and trouble shooting of CETP.

The four industrial estates accommodate mostly Fruit Processing industries, Electroplating units and Paper mills. Parvanoo estate has nearly 100 industries out of which 32 are polluting units generating about 6 MLD of wastewater. There are total 30 industrial units in Kala Amb estate and 14 of them are polluting units discharging about 11.5 MLD of wastewater. Barotiwala estate houses 20 industries and nearly all are polluting units and they generate nearly 20 MLD wastewater flow. Mehatpur estate has got nearly 150 industrial units and 10 of them are polluting units discharging about 4 MLD of wastewater.

2.4 ROLE OF GOVERNMENT OF INDIA IN ENCOURAGING CETP SCHEMES

Under the World Bank aided "Industrial Pollution Control" project there is a provision of loan and grant assistance to proposals on construction of Common Effluent Treatment Plants for treatment of effluents from clusters of industries, particularly of the small size, in a combined manner. A total of $ 24 million loan assistance and $ 12 million grant assistance is available under this component.

Proponents are eligible to avail grant and loan assistance under the project, on the following financing pattern :

GRANTS GOI	STATE GOVT.	IBRD LOAN FROM IDBI	MINIMUM PROMOTOR'S	TOTAL CONTRIBUTION
20%*	20%*	40%	20%	100%

* 20% Subject to a ceiling of Rs. 50 lacs each

If as a result of application of the ceiling there appears a gap in the means of financing of a sub-project, the gap may be financed by higher promotors' contribution and/or normal rupee loans outside IBRD line. The grant from Central and State Governments are limited to SSIs but the IBRD loan includes SSIs and the medium-scale units in a cluster.

The processing sequence for CETP sub-project approval under the project is given in Annexure I. All proposals for loan-grant assistance would have to fulfill certain eligibility criteria. These are given in Annexure II. The form on which the application is to be submitted is given in Annexure III. The project proponent needs to submit 4 copies of the application; one each to the following : (i) MEF (ii) IDBI (iii) NEERI and (iv) Pollution Control Board of the concerned State; simultaneously. The proposal will be processed as given in the processing sequence given in Annexure I. The proposals (one each) are to be forwarded to the following officials in these organisations :

(i) Shri K.N.Desiraju
Deputy Secretary
World Bank Implementation Cell
Ministry of Environment and Forests
Paryavaran Bhavan, CGO Complex
New Delhi - 110 003

(ii) General Manager
IFD-ICCS
Industrial Development Bank of India
IDBI Towers, Cuffe Parade
Bombay - 400 005

OR

(iii) Shri K.V.Mahadevan
Manager
Industrial Development Bank of India
IDBI Towers, Cuffe Parade
Bombay - 400 004

(iv) Dr. S.N.Kaul
Head
Wastewater Engg. Division
National Environmental Engineering Research Institute
Nehru Road, Nagpur - 440 020

(v) Chairman
State Pollution Control Board
of the State of ....
....

The loans will bear interest at a concessional rate of 15.5% per annum inclusive of interest tax unless otherwise reversed by the Government of India in consultation with the World Bank. The loans will be repayable by the proponents in a period not exceeding 15 years with 4 years of grace. These loans will not be subject to conversion option as the loans will be for pollution control.

The grants from the GOI and the State Governments will also be channelled through the State Pollution Control Board concerned. The State PCBs will monitor and report on the progress of schemes to the Government.

Government of India has decided certain policy framework which must be strictly observed for implementation of CETPs in India. These documents are given in Annexures I to V.

2.5 GOVERNMENT RESOLUTIONS

Government of India has also established regular standards for various parameters of the incoming wastewater to be handled as well as outgoing treated wastewater of CETP. These standards for the inlet effluent quality for CETP and treated effluent quality of CETP are reproduced respectively in Table 2.2 and Table 2.3.

Government of India has classified the hazardous wastes in 18 different categories and has specified regulatory quantities for each category of these hazardous waste. This classification of hazardous waste as per notification no.465 dated 28th July, 1989 published in The Gazette of India,Part II-Section 3 Sub- section (ii) is as follows :

Waste Categories	Types of Wastes	Regulatory Quantities
No.1	Cyanide wastes	1kg/year calculated as cyanide
No.2	Metal finishing wastes	10kg/year, the sum of the specified substance calculated as pure metal
No.3	Waste containing water soluble chemical compounds of Pb, Cu, Zn, Cr, Ni, Se, Ba and Sb	10kg/year, the sum of the specified substance calculated as pure metal
No.4	Hg, As, Tl and Cd bearing wastes	5kg/year, the sum of the specified substance calculated as pure metal
No.5	Non-halogenated hydro-carbons including solvents	200kg/year calculated as non-halogenated hydrocarbons
No.6	Halogenated hydro-carbon including solvents	50kg/year calculated as halogenated hydrocarbons
No.7	Wastes from paints, pigments, glue, varnish and printing ink	250kg/year calculated as oil or oil emulsions
No.8	Wastes from dyes & dye intermediate containing inorganic chemical compounds	200kg/year calculated as inorganic chemicals
No.9	Wastes from dyes and dye intermediate containing organic chemical compounds	50kg/year calculated as organic chemicals
No.10	Waste oil and oil emulsions	1000kg/year calculated as oil emulsions

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Waste Categories	Types of Wastes	Regulatory Quantities
No.11	Tarry waste from refining and tar residues from distillation or pyroletic treatment	200kg/year calculated as tar
No.12	Sludges arising from treatment of waste-waters containing heavy metals, toxic organics, oils, emulsion, spent chemicals and incineration ash	Irrespective of any quality
No.13	Phenols	5kg/year calculated as phenol
No.14	Asbestos	200kg/year calculated as asbestos
No.15	Wastes from manufacturing of pesticides and herbicides and residues from pesticides and herbicides formulation units	5kg/year calculated as pesticides and their intermediate products
No.16	Acid, alkaline, slurry wastes	200kg/year calculated as acid, alkalies
No.17	Oil-Specification and discarded products	Irrespective of any quantity
No.18	Discarded containers and container's liners of hazardous and toxic chemicals and wastes	Irrespective of any quantity

Table : 2.2

Inlet Effluent Quality Standards for CETP*

Parameter	Concentration
pH	5.5 - 9.0
Temperature, °C	45
Oil & Grease	20
Phenolic compounds (as C_6H_5OH)	5.0
Ammonical nitrogen (as N)	50
Cyanide (as CN)	2.0
Hexavalent chromium (as Cr^{+6})	2.0
Total chromium (as Cr)	2.0
Copper (as Cu)	3.0
Lead (as Pb)	1.0
Nickel (as Ni)	3.0
Zinc (as Zn)	15.0
Arsenic (as As)	0.2
Mercury (as Hg)	0.01
Cadmium (as Cd)	1.0
Selenium (as Se)	0.05
Fluoride (as F)	15.0
Boron (as B)	2.0
Radioactive materials	
Alpha emitters, Hc/ml	10^{-7}
Beta emitters, Hc/ml	10^{-8}

Concentration in mg/l except pH, Temperature and Radioactive materials.

Note : 1. These standards apply to the small scale industries, i.e. total discharge upto 25 KL/day.

2. For each CETP and its constituent units, the State Board will prescribe standards as per the local needs and conditions; these can be more stringent than those prescribed above However, in case of clusters of units, the State Boards with the concurrence of CPCB in writing, may prescribe suitable limits.

*Source : The Gazette of India : Extraordinary - Part II - Sec.3(i) pp 10, dated 27th Feb.1991.

Table : 2.3

Treated Effluent Quality Standards for CETP*

Parameter	Concentration in mg/L except pH & Temperature		
	Into inland surface waters	On land for irrigation	Into marine coastal areas
pH	5.5 - 9.0	5.5 - 9.0	5.5 - 9.0
BOD_5 20°C	30	100	100
Oil & Grease	10	10	20
Temperature	Shall not exceed 40°C in any section of the stream within 15 m downstream from the effluent outlet	-	45°C at the point of discharge
Suspended solids	100	200	a For process wastewater - 100 b. For cooling water effluents 10% above total sus. matter of influent cooling water
Dissolved solids (inorganic)	2100	2100	-
Total residual chlorine	1 0	-	1.0
Ammonia nitrogen (as N)	50	-	50
Total Kjeldahl nitrogen (as N)	100	-	100
COD	250	-	250
Arsenic (as As)	0.2	0 2	0.2
Mercury (as Hg)	0.01	-	0.01
Lead (as Pb)	0 1	-	1.0
Cadmium (as Cd)	1.0	-	2.0
Total chromium (as Cr)	2.0	-	2.0
Copper (as Cu)	3.0	-	3.0
Zinc (as Zn)	5.0	-	15
Selenium (as Se)	0.05	-	0.05
Nickel (as Ni)	3.0	-	5.0
Boron (as B)	2.0	2.0	-
Percent sodium	-	60.0	-
Cyanide (as CN)	0 2	0 2	0.2
Chloride (as Cl)	1000	600	-
Fluoride (as F)	2 0	-	15
Sulphate (as SO_4)	1000	1000	-
Sulphide (as S)	2.8	-	5.0
Pesticides	Absent	Absent	Absent
Phenolic compounds (as C_6H_5OH)	1.0	-	5.0

All efforts should be made to remove colour and unpleasant odour as far as possible

* Source : The Gazette of India : Extraordinary - Part II - Sec.3(i) pp 11 dated 27.2.91

3

Traditional Joint Disposal of Wastes

Two main types of wastewaters, viz. municipal sewage and industrial wastes if jointly treated and disposed provide many advantages. Number of research workers have carried out experiments on laboratory, pilot as well as on full scale to assess feasibility of joint treatment of sewage and various industrial wastes. This chapter aims at highlighting the R&D work done as well as experience gained in this area.

3.1 SEWER DISPOSAL OF INDUSTRIAL WASTES

In India, sewer disposal of industrial waste was a very common practice till few years back. Indian standards also laid down norms for the allowable limits of various parameters of wastewater for sewer disposal as shown in Table 3.1. Industries have to pay a certain cess if they want to dispose of their wastes in sewers.

In USA, sewer disposal of industrial wastes is an approved and established method subjected to some conditions. A survey (9) carried out by Ohio River Valley Water Sanitation Commission (ORSANCO) in 1956 of 100 sewage treatment plants over the entire U.S. which included the largest cities as well as moderate and smaller sized municipalities indicated that median treatment plant handled industrial waste loadings as follows :

Industrial Flow	-	25.5 percent of total Flow
Industrial BOD	-	36.5 percent of total BOD
Industrial SS	-	32.5 percent of total SS

Overwheming majority of the plants showed a spirit of cooperation and mutual confidence in between municipality and industry in solving the industrial waste treatment problem. Most of the municapilities surveyed accepted industrial wastes either without reservation, or with only general prohibitions against materials harmful to the system or its function. The two, municipality and industry, approached waste treatment as a common problem which they must both work to solve. The operating problems created by industrial wastes did not appear to affect appreciably the treatment plant performance in removal of BOD and suspended solids

Table : 3.1

Indian Standards for Industrial and Sewage Effluents Discharge into Public Sewers IS:2490-1982

Parameter	Concentration in mg/L except pH & Temperature
pH	5.5 - 9.0
BOD_5, 20°C	350
Oil & Grease	20
Temperature	45°C at the point of discharge
Suspended solids	600
Dissolved solids (inorganic)	2100
Total residual chlorine	-
Ammonia. nitrogen (as N)	50
Total Kjeldahl nitrogen (as N)	100
COD	-
Arsenic (as As)	0.2
Mercury (as Hg)	0.01
Lead (as Pb)	1.0
Cadmium (as Cd)	1.0
Hexavalent chromium (as Cr^{6+})	2.0
Total chromium (as Cr)	2.0
Copper (as Cu)	3.0
Zinc (as Zn)	15
Selenium (as Se)	0.05
Nickel (as Ni)	3.0
Boron (as B)	2.0
Percent sodium	-
Cyanide (as CN)	0.2
Chloride (as Cl)	1000
Fluoride (as F)	15
Sulphate (as SO_4)	1000
Sulphide (as S)	-
Pesticides	Absent
Phenolic compounds (as C_6H_5OH)	6.0
Radioactive materials	
Alpha emitters, µc/ml	10^{-7}
Beta emitters, µc/ml	10^{-6}

All efforts should be made to remove colour and unpleasant odour as far as possible.

The reimbursement in terms of sewer charge (or treatment cost) was to be made by the industry to the authority running the sewage treatment plant (10).

In Great Britain, if industrial effluents are discharged to a municipal wastewater treatment plant, then limits to BOD, suspended solids and the concentration of potentially harmful substances usually are set by the municipality. These limits (particularly BOD) depend on the capacity of the treatment plant, and normally a charge based on the volume and BOD of the waste is levied by the municipality on the producer of the effluent. Thus, industry has to decide in each case whether it is cheaper to treat its own wastes fully or whether significant economics can be made by pretreating to a given level before discharge to a sewer (11). But if a later option is selected, then municipalities are required by law to treat industrial wastes which are compatible to treatment in a sewage treatment plant. Sewer taxes are a matter to be worked out on a local level between the municipal authorities and the industries. In case of disagreement on the sewer tax rate, the industry in England may appeal to the Central Government in London (3).

In Japan, when any factory discharges its wastewater into a public sewer, the water quality must comply with the standards designated in the 'Sewage Law'. Table 3.2 shows the standards for industrial wastewater discharged to public sewer systems in Japan and the effluent standards for a typical wastewater treatment plant set by local Government. Factories must introduce pretreatment processes for wastewater if it does not meet the discharge standards. The 'approved wastewater quality' mentioned above meets the discharge standards when a wastewater treatment plant discharges its effluent into public sewers, the water quality, must comply with the standards designated in the Water Pollution Control Law (WPCL). Local Government sets effluent standards for the treatment plants which are more strict than those described by WPCL. It is also important to expose any violation of the discharge standards. The CETP authorities have the right to sample wastewater discharged from member factories without warning. When a violation of the standards is found, the treatment plant can impose a fine on the violating factory (12).

3.2 LITERATURE REVIEW OF WORK DONE ON JOINT TREATMENT

Extensive work has been done on joint treatment of sewage and various industrial wastes. An attempt is made to consolidate the information available in literature. Subsections 3.2.1 to 3.2.8 are devoted for joint treatment of sewage and any one industrial waste and subsection 3.2.9 covers the joint treatment of wastewater from a cluster of industries together with sewage.

Table : 3.2

Water Quality Standards for the Discharge of Industrial Wastewater to Sewerage Systems and for the Effluent of a Typical Treatment Plant

Parameter	Discharge Standards	Effluent Standards
Temperature, °C	45	-
pH	5 - 9	5.8 - 8.6
COD, mg/L	600	50
BOD, mg/L	600	-
Suspended solids, mg/L	600	50
N-Hexane extracts, mg/L	20	3
Phenols, mg/L	10	5
Cu, mg/L	3	3
Zn, mg/L	5	5
Fe (dissolved), mg/L	10	10
Mn (dissolved), mg/L	10	10
Total Cr, mg/L	2	2
Fluoride, mg/L	15	15
Cd, mg/L	0.1	0.1
Cyanide, mg/L	1	1
Organic phosphorous*, mg/L	1	1
Pb, mg/L	1	1
Chromium (hexavalent), mg/L	0.5	0.5
As, mg/L	0.5	0.5
Total Hg, mg/L	0.005	0.005
Alkyl Hg, mg/L	ND	ND
PCBs**, mg/L	0 003	0.003

* Includes phosphorous-based pesticides;
** Polychlorinated biphenyls;
ND - Not Detectable

3.2.1 Municipal Sewage and Textile Waste

In Dalton, Georgia, the textile wastewaters are mixed with domestic sewage. Approximately 80% of the water used in Dalton is textile process water. The wastewater generated is primarily soluble organic compounds with little organic strength associated with suspended solids. The first wastewater treatment plant in the Dalton area was a 0.5 MGD standard rate trickling filter plant built in 1952. Till that year, industrial contribution was less than the domestic waste. Another plant of 12 MGD capacity (28823 lb BOD/day) was built in 1963 because of rapid growth of industry and subsequent overloading of the treatment plant due to more wastewater generation. This plant included primary settling tanks, high rate trickling filters, activated sludge unit, final clarifier, DAF sludge thickners and anaerobic sludge digestion. By 1970, this plant had became sufficiently overloaded to justify an expanded plant or entirely new plant. In 1972, a 30 MGD plant (50400 lb BOD/day) was erected and commissioned. This plant included extended aeration activated sludge centrifuges. The initial two years of operational results showed good removal of organic strength as shown in Table 3.3 (13).

Table : 3.3

Results of Composite Samples

Parameter	Influent	Effluent
BOD, mg/L	212	8.2
COD, mg/L	546	111
TOC, mg/L	115	41
Suspended Solids, mg/L	95	21
Dissolved Solids, mg/L	518	390
Ammonia as N, mg/L	3.04	0.5
Kjeldahl as N, mg/L	6.73	1.5
Nitrite/Nitrate as N, mg/L	0.03	1.1
Oil and Grease, mg/L	36.7	21.2
Phenols, mg/L	0.15	0.04
Phosphorus Total as P, mg/L	14.9	13.7
pH	6.8	6.8
Color, APHA units	520	167
Plant Flow-Monthly Average	19.5 MGD	
Peak Three Day Average	26.0 MGD	
Aeration Basin Temperature	35°C (Summer)	
	18°C (Winter)	

Data from pilot plant studies at Rock Hill, and Greenville, South Carolina led to following conclusions (14) :

- A high degree of treatment of mixed textile finishing waste and sewage is possible at loadings similar to those usually provided for domestic sewage. Caustic recovery in the industrial waste is particularly desirable if a high degree of treatment is contemplated. For treatment by trickling filters, a loading of 4 MGAD, not including recirculation, seems safe for mixed textile finishing wastes and domestic sewage if a raw BOD loading of 3000 lbs/acre-ft is not exceeded. A 70 to 80 percent removal of BOD should be obtained at this loadings. Waste with as high a proportion of finishing waste as 5:1 by volume and 15:1 by strength have been treated at these loads without caustic recovery.

- Second stage treatment of textile finishing waste and sewage by trickling filters is possible. Loadings of 4 MGAD, not including recirculation, should give 50 to 60 percent removals. However, second stage filters did not seem promising as a final stage of treatment.

- Activated sludge treating wastes at Greenville on a pilot plant scale proved to be very satisfactory as a final stage of treatment and in 3 months of testing only on four days, effluent BOD of over 30 mg/L were noted.

The Guilford Industries - a textile processing mill in Guilford, Maine carried out pilot scale studies to evaluate the treatability of mill wastewater alone (Alternative I) as opposed to treatability of the mill wastewater alongwith the municipal wastewater from the same city (Alternative II). Complete mix units operated on an extended aeration mode were used for the studies. Table 3.4 shows the kinetic data for the two wastewater combinations. The values of the various kinetic constants are quite comparable. The BOD removal obtained by Alternative II was considerably higher than Alternative I, especially at low SRT. The settleability characteristics of the sludge were also better in the case of joint treatment. Table 3.5 summarizes the key design parameters.

The cost estimates included the cost of a pretreatment unit that would remove lint from the mill wastewater before biological treatment. The cost data presented in Table 3.6 illustrate the economic advantages for mill in joining with the local sewer districts (15).

Davis et al (16) reported laboratory scale results of combined treatment of cotton-polyester broad-woven fabrics textile mill dye house waste and domestic waste. The textile mill wastewater included dyehouse wastewater, boiler blowdown and air conditioning water.

Table : 3.4

Comparison of Kinetic Data from Extended Aeration Studies (22 + 1°C)

Parameter	Mill (Alternative I)	Mill & Town (Alternative II)
K, L/mg.day	0.002	0.004
K, day^{-1}	0.19	0.24
K_b (true cell yield coefficient)	0.52	0.53
K_t (decay coefficient), day^{-1}	0.013	0.024
a, mg/mg	-	1.41
b, day^{-1}	-	0.06
a'	0.47	0.52
b', day^{-1}	0.09	0.12

a - substrate used to form unit biomass, mg/mg
b - maintenance energy coefficient day^{-1}
a' - fraction of substrate used for oxidation
b' - volatile solids oxidation coefficient day^{-1}

Table : 3.5

Summary of Key Design Parameters

Parameter	Separate Treatment	Joint Treatment
Aeration Tank		
Volume, gal.	243000	543000
HRT, hours	23.3	29.2
MLSS, mg/L	2260	2240
F/M ratio, d^{-1}	0.09	0.11
lbO_2/lbBODa	1.7	1.22
Clarifier		
Overflow rate, gal/day/sq.ft.	600	600
Surface area, sq.ft.	417	745
Detention time, hours	3	3

Table : 3.6

Summary of Capital and Operating Costs of the Joint vis-a-vis Separate Treatment

Item (1)	Estimated Project Cost,$ (2)	EPA Grant 75% of 2,$ (3)	State Grant 15% of 2,$ (4)	District Cost,$ (5)	Mill Share % of 3+5 (6)	Mill Cost,$ (7)
Pretreatment	28500					28500
Interceptor	183200	137400	27480	18320	42	65400
Treatment facility	675600	506700	101340	67560	56	321600
	887300	644100	128820	85880		415500

Estimated Project Costs (Mill Alone)

Pretreatment	$ 28500
Treatment facility	$ 384180
	$ 412680

First Year Operating Costs to Mill

Mill alone = $ 25500

Mill & town $ 63500 X (56%) = $ 35560

First Year Average Annual Capital & Operating Costs

Mill alone ($ 412680 @ 10% for 20 yrs.)	$ 48473 + $ 25500 = $ 73973
Mill & town ($ 415500 @ 10% for 20 yrs.)	$ 20775 + $ 35560 = $ 56435

One of the alternative approach for improving treatment of the dye house wastewater was joint treatment in the combined municipal wastewater treatment plant. Bench-scale activated sludge treatability tests were conducted on a flow-blended domestic dye house wastewater samples. The treatability models and design parameters are summarised in Table 3.7. This table compares the individual treatment of dyehouse waste with combined wastewater (dyehouse + domestic waste). Chemical coagulation after biological treatment to remove the dyehouse wastewater colour was the most effective alternative. Alum coagulation was preferred, since it produced less sludge and was easier to handle than lime, it required a lower dosage than ferric chloride and due to availability and chemical cost, was more practicable than sodium aluminate treatment. The treatment scheme included equalization for the dye house wastewater, an activated sludge system, chemical addition facilities and a sludge handling system (16).

Table : 3.7

Biological Treatment Results Models* and Design Parameters

	Design Parameters	Dyehouse Waste-water	Combined Waste-water
Organic Removal[a]	K, day^{-1} (at 22°C)	6.00	9.55
Temperature Correction[b]	θ	1.086	1 087
Oxygen Requirements[c]	a', g O_2 used/gMLVSS b', g O_2 used/gMLVSS/d	1.05 0.042	0.82 0.07
Sludge Production[d]	a, gVSSgen /g MLVSS b, gVSSr/g MLVSS/d	0.62 0.03	0.66 0.05

[a]model used - So(Sr/Xv t) = K.Se
[b]model used - $K_1 = K_2\theta^{(T1-T2)}$
[c]model used - RrQ = a'SrQ + b'XvV
[d]model used - Xv = aSrQ - bXvV
*These models are fully discussed in references (17) and (18)

Cannon Mills Company, Kannapolis, North Carolina carried out pilot plant studies to assess treatability of a mixed textile waste and domestic sewage. The general plan of the treatment was as follows :

- Segregate the waste at the bleachery
- Store the caustic waste ahead of the plant in a lagoon in order to have 7 days detention and to provide means of pH control
- Treat the waste through a conventional two-stage high rate trickling filter plant
- Chlorinate the effluent during the summer months.

The treatment plant treats about 60% textile wastes and 40% domestic sewage. The plant consists of storage lagoon for the caustic waste, primary settling tanks, two-stage trickling filters (one roughing filter and another secondary filter), secondary settling tanks, chlorine contact tank and sludge digestors and vacuum filtration. The plant is achieving about 82.6% BOD removal (19).

In Georgia, most of the carpet industry's wastewaters are treated at 12 municipal wastewater treatment plants. Average BOD and COD from beck type dyeing wastewater (collected from 8 mills) was found as 232 mg/L and 943 mg/L respectively. The average BOD and COD from continuous dyeing wastewater (collected from 6 mills) is 930 mg/L and 2912 mg/L respectively. It was generally observed that the BOD of the mill's wastewater was higher than typical domestic sewage but TSS was found to be less. Wastewater treatment plant data from ten joint municipal industrial waste plants is given in Table 3.8. The treatment systems consist of coarse screening, activated sludge of extended aeration type and disinfection. Primary clarification is not necessary for plants receiving primarily carpet wastewater because of the low TSS concentration.

An EPA textile industry publication indicated that an overflow rate of 200 to 400 GPD/SFT was found desirable for an extended aeration system treating textile wastes (20). However, operating data of ten plants showed that municipal plants treating carpet wastes should be able to operate safely in the upper ranges of the EPA recommendation if the peak flows can be controlled and adequate depths are provided.

Current methods of sludge stabilization, dewatering and disposal employed in the plants are summarised in Table 3.9. It is interesting to note that five of the plants studied are not using the sludge handling system that was designed into the plant. The largest plant still using sand beds has a design capacity of 2.0 MGD.

Textile fibres (lint) and low weak end flows are posing problems in all the treatment plants. A good pretreatment programme to remove fibres at the industries and routine maintenance at the municipal treatment plants can reduce these problems. Water usage, wastewater discharges, chemical costs and energy costs can be greatly reduced in carpet manufacturing by dye bath reuse, gum recovery and rinse water reuse (21).

The sewage treatment plant (as existed in 1974) serving Borough of Glossop was designed for a DWF of 5230 m^3/day flow to include the textile mill effluents. This treatment plant consisted of inlet works, sedimentation tanks, biological filters, humus tanks, land irrigation equipments and sludge treatment units.

The textile factory although working 24 hours a day, was only open for 5 days of the week. Hence, one of the first design problems was to attempt to spread the load over a 7 day week. It was observed that if the total loading of 1021 kgBOD/day could be spread, it would offer a saving of some 28 percent on the capital costs of the biological filters. This was achieved by using small volumes of strong kier liquors. By arranging for

Table : 3.8

Wastewater Treatment Plant Data from 10 Joint Municipal Industrial Waste Treatment Plants

Plant	Preliminary & Primary Treatment	Ret. Time (Hrs.)	MLSS (mg/L)	F/M	lbBOD/d/ 1000 cft	Installed hp/ 1000 cft	Type of Aeration	Overflow Rate (gpd/sft)	Side Water Depth (ft)
Calhoen	Screening, Grit	20.45	5200	0.04	14.42	0.24	Brush	515	10.0
Cartersville	Screening, Grit	21.00	3300	0.08	15.50	0.24	Brush	523	10.0
Chatworth	Screening, Grit	18.75	4100	0.13	32.82	2.49	Diffused	512	8.5
Chickamauga	Screening	159.00	2500	0.03	4.36	0.53	Mech	178	6.5
Dalton RBD	Screening	33.05	6300	0.04	14.63	0.65	Mech.	590	13.0
Fort Oglethorpe	Screening, Grit	62.07	6000	0.01	3.18	0.60	Mech.	295	10.0
LaFayette	Screening	51.95	3800	0.02	5.59	0.90	Mech.	261	8.0
LaGrange	Screening	29.60	6600	0.05	20.67	1.12	Diffused	350	10.33
Ringgold	Screening, Grit	25.26	2800	0.08	14.22	0.50	Mech.	265	10.0
Summerville	Screening	29.30	5300	0.06	19.17	0.35	Mech.	542	8.0

Table : 3.9

Sludge Treatment and Disposal Method

Plant	Stabilization	Dewatering	Disposal
Calhoun	Aerobic digestor	None	Land Spreading
Cartersville	Aerobic digestor	None	Land Spreading
Chatworth	Aerobic digestor	Sand Beds	Landfill
Chickamaugao	None	Lagoons	Landfill
Dalton RBD	None	None	Lagoons
Dalton ABT	Anaerobic digestor	Sand Beds	Landfill
Fort Oglethorpe	Aerobic digestor	Sand Beds	Landfill
LaFayette	Aerobic digestor	None	Land Spreading
LaGrange	Aerobic digestor	Sand Beds	Landfill
Ringgold	Aerobic digestor	Sand Beds	Landfill
Rome	Anaerobic digestor	Belt Press	Landfill
Summerville	Aerobic digestor	Sand Beds	Landfill

storage of a portion of these liquors over the week and discharging them to the works at the weekend, it was possible to achieve the required degree of strength balancing. If the total weekday flow amounts to the 29860 m^3 expected, with a BOD of 123 mg/L, the amount of storage required for the weekend would be 818 m^3 at 1785 mg/L BOD to be discharged over the two weekend days. The sharing of financial burden for this sewage treatment plant is described in Chapter 5 (22).

3.2.2 Municipal Sewage and Tannery Waste

Very few locations are in the U.S.A. and Canada where tannery wastes (with secondary treatment) constitute a significant proportion of total flow. Six such cases are described in summary form in Table 3.10 (23).

Gloversville and Johnstown in Fulton County, New York are the home of a large tanning industry. Within the two cities are located 22 tanneries, 8 other major wet industries including textile dyeing facilities, and a large glue manufacturer. Approximately 50 percent of the flow and 60 percent of the BOD are attributed to the tanneries. The glue manufacturer contributes an estimated 10 percent of the flow and 14 percent of the BOD. The D.W.F. to be treated in Gloversville-Johnstown joint treatment plant, USA was on an average 6.9 MGD. The combined waste imposed BOD load of 26000 lbs/day and 22000 lbs of suspended solids/ day. The plant consisted of a bar screen, grit chamber, two primary settling basins, fixed nozzles, two final settling basins and sludge drying beds. The plant was built in the early 1900's and was incapable of handling more than one-half of the wastewater of the flow rates then encountered. In order to form definite conclusions on the proper treatment units to be included to upgrade the then existing waste treatment plant, pilot scale studies were carried out. These studies demonstrated that the conventional activated sludge treatment process was capable of reducing the BOD of the combined waste from 65 to 85 percent (depending primarily upon the organic loading) at loadings ranging from 60 to 115 lbs of BOD per 1000 cft of aerator capacity. A digestion batch experiment yielded about 9 cft of gas per lb of volatile matter destroyed and effected 71% reduction in organic matter. Because of the unique nature of the volume and characteristics of the tannery sewage waste mixture as well as the size and cost of the project, it was recommended to conduct field prototype studies prior to full scale treatment plant construction (23).

Accordingly, a prototype plant was constructed at the existing Gloversville wastewater treatment plant to confirm earlier laboratory studies on the treatability of the combined wastewater. Raw waste to treatment plant was tapped for the studies. Two-stage system of biological treatment employing a roughing filter preceeding the activated

Table : 3.10

Survey of Tannery Wastes Treatment in United States and Canada

Location	Municipal Treatment Plant	Separate Treatment By Tannery	Flow (Total) (Tannery) (% Tannery)	Results or Remarks
Aurora, Ontario, Canada	Secondary activated sludge. Separate sludge digestion	Pre-treats (settling)	1.2 MGD 0.17 MGD 14%	First known activated sludge treatment with major tannery wastes. Removal: BOD 95%, SS 90%, Digester liquid sludge to land irrigation.
Barrie, Ontario, Canada	Secondary activated sludge. Separate sludge digestion.	Expected to pre-treat (Settling). Now screens only.	1.56 MGD 0.57 MGD 37%	New plant completed 1965. Design capacity 3.6 MGD. Influent: BOD 360, Suspended Solids 600-1,000. Digester liquid sludge to land irrigation.
Fond du Lac, Wisconsin	Secondary trickling filters. Digestion Sludge to lagoons. (Vacuum filtration and incineration discontinued.)	Grease removal	6.4 MGD 3.0 MGD 47%	For tannery wastes only, coarse and fine screening to remove hair. Hair previously accumulated in trickling filters, creating anaerobic conditions and sludge build up. Hair also collected in piping, meters, and digesters. New fine screen subject to binding from grease. Old plant BOD removal 63%, SS removal 79%. Tannery characteristics : BOD 340, SS 1068, Settleable solids 33. New larger digesters placed in operation (vacuum filtration discontinued).
Napa, California	Secondary, 2-stage biofiltration, oxidation ponds. Separate sludge digestion, sludge to the lagoons.		4.25 MGD 0.25 MGD 6.0%	From two tanneries - Influent: BOD - 242, SS - 325, Total chromium - 6.1. Effluent BOD - 9, SS - 31, Total chromium 0.8, 9.5 cft gas/lb volatile matter added.
Sheboygan, Wisconsin	Secondary trickling filters. Separate digestion. Sludge to vacuum filters followed by flash drying to landfill.	Coarse & fine screening	9.5 MGD 1.3 MGD 14%	Original problems in digesters with hair and leather scrap overcome by coarse and fine screening at tannery. Sludge drying beds could not be used. Removal : BOD 87%, SS 86%
Coloumbus, Indiana	Activated sludge. Separate sludge digestion.	Lagooning	3.8 MGD 0.15 MGD 4%	BOD : tannery - 1180 to 3000, treatment plant - 175 Cow hair problems in digester. Leather scraps clogged communitor. Plant effluent coloured at all times by 1200 GPD of dye. Plugged diffusers. 90% BOD removal in plant. 1000 cft air per lb BOD removed.

sludge process was evaluated as a combined system. BOD reductions in the range of 80 to 90 percent were obtained. No problems of odour were encountered and the varying pH did not appear to affect. Colour removal was obtained, although not 100 percent, for 100 percent of the time. Results obtained indicated that treatability of tannery wastewater by a two-staged biological plant had been established.

Results obtained from this programme were used in the design of the joint wastewater treatment plant for the two cities. Design loadings for the same plant serving these areas are shown in Table 3.11 (24).

Table : 3.11

Design Loadings of the Joint Wastewater Treatment Plant

Source	Flow (MGD)		BOD(lbs/day)		Sus.Solids
	24 hr	8 hr peak	24 hr	8 yr peak	(lbs/day)
City of Gloversville	4.0	5.5	15145	25687	13778
City of Johnstown	3.4	4.4	12985	20558	11997
Glue Factory	1.0	1.0	5054	3436	7581
Future	1.1	2.2	1835	3670	2294
Total	9.5	13.1	35019	53351	35650

The Williamsport tannery of the Armour Leather Company produces about 400000 GPD of wastes. The tannery utilizes the vegetable tanning process and maintains multiple effect evaporators where 30 to 60 percent of the daily discharge of tan liquors is concentrated daily for sale as a water conditioning agent. A joint treatment plant was designed and constructed in 1954 to handle a maximum of 500000 GPD of industrial wastes plus the sanitary sewage from an ultimate population of 10000 people. The plant was designed to handle average and maximum flows of 1.1 and 2.1 MGD respectively. It incorporated primary treatment and chlorination with vacuum filtration and incineration of the resulting undigested sludge. The plant showed average BOD reduction of 54 percent and suspended solids removal of only 13.7 percent. The unusually low SS reductions might be the result of one or more chemical reactions between sewage, tannery wastes and the filtrate from vacuum filters. Coagulation of matter originally present in the dissolved state materially increases the suspended solids load on the plant.

The cost of the sewage treatment plant was estimated as $ 588000 if only sewage was to be treated, or $ 1,040,000 if the tannery wastes were included.

The regular rate schedule finally adopted by the Authority was based on water usage or volume of wastes discharged and applies to all wastes that do not contain suspended solids in excess of 300 mg/L. It provided for a surcharge for wastes containing suspended solids in excess of that amount, the surcharge so imposed varied according to the amount of the excess. The schedule of rates also provided for a 30 percent discount on the volume charge to any industry which delivered its wastes directly to the sewage treatment plant as compared with those using the public sewage collection system (25).

The City of Grand Haven and the village of Spring Lake, USA jointly installed a combined treatment plant for the domestic/industrial wastes generated within their territories. A chrome tannery processing about 2000 cattle hides/day contributed about 20% of the total flow, while its BOD and suspended solids share was approximately 90-95%. Laboratory and pilot scale studies carried out on the combined waste warranted adequate dilution or primary treatment of tannery wastewater prior to its discharge to municipal sewers. Activated sludge process was found to be the most appropriate option for the combined wastewater. However, equalisation, removal of chrome and sulphide and pH adjustment to prevent H_2S release were considered as mandatory. Sludge treatment involved dewatering of sludge to 65-70% followed by auto combustion in the incinerator. Heat treatment was observed to enhance dewaterability to a great extent. Accordingly, a pretreatment plant was erected in the tannery and consisted of screening, equalization, chemical dosing and pH adjustment. Joint treatment plant designed on the basis of laboratory and pilot scale data handles degritted municipal flow blended with pretreated tannery wastewaters. The mixed wastewater is subjected to chemical treatment and settling for chromium and phosphorous removal. The wastewater then biologically treated through activated sludge process and chlorinated before final discharge into the Grand river (26).

The joint treatment plant at Fond Du Lac, Wis., USA is also reported treating tannery wastes and domestic sewage. The plant comprised of grit removal equipments, flocculators, primary clarifiers, rock trickling filters and final clarifiers, sludge digesters, vacuum filters and flash drying equipments for sludge conditioning. The plant is designed for an ultimate DWF of 8 MGD and a BOD load of 12900 lbs/day equivalent to population of 77000. The plant while operating at sewage : tannery waste ratio of 4:0.66 achieved overall BOD and suspended solids removals of 90.4 and 92% respectively (27).

3.2.3 Municipal Sewage and Cannery Waste

Fort Fairfield combined treatment facility treats domestic waste and potato processing plant waste. The industrial waste is given separate primary treatment and then mixed with domestic waste. Secondary treatment involving use of rotating biological surfaces (RBS) is given to the combined waste. The biologically treated wastewater then subjected to disinfection using hypochlorite generation. The operating results were not available (28).

Norgard et al (29) investigated three processes applicable to the treatment of a large volume of combined sewage and fruit canning waste at San Jose, California on pilot plant scale during two canning seasons. The three basic processes considered were :

1. Anaerobic primary treatment followed by either activated sludge or high-rate filter second-stage

2. Primary sedimentation plus secondary treatment by both single and two-stage high rate filters, and

3. Activated sludge both with and without primary sedimentation.

Anaerobic fermentation process failed to remove sufficient BOD to warrant further consideration although it showed promise in bench-scale operation. As high-rate filters would not be physically suitable for the large treatment works that eventually would have been required for the San Jose metropolitan area, they were not studied beyond the first season of the investigation. The activated sludge process incorporating primary sedimentation, sludge reaeration and supplemental ammonia feed during the peak months of the peach-pear season, gave a high degree of treatment with relatively low aeration detention times. From the standpoint of flexibility and areal requirements, it was best suited to the conditions encountered at San Jose (29).

The Wulkatal combined treatment plant was designed for sewage generated from 25000 inhabitants, wastewater generated from a canning operation with a yearly production of 24000 tonnes and beet sugar mill processing 300000 tonnes of sugar beats per season. In actual operation, extended aeration with simultaneous precipitation (Fe^{++}) when applied in the plant for a combination of sewage and fruit & vegetables canning effluents provided following advantages :

Evening out of variations in carbonaceous load of 1:15 without marked variations in the effluent quality

- Excellent treatment efficiency and full nitrification all over the year

- High removal of total phosphorous (79%) at a low input of iron (0.8 kgFe^{++}/kgP) with very good settling properties of the mixed liquor (35 ml/g; effluent SS 6 mg/L)

- Small requirements on personnel due to a very simple operational scheme (Only one shift during week days on work)

- Small amount of excess sludge

- If aimed for, controlled denitrification seems to be possible.

The disadvantages in comparison to other solutions are:

- High energy requirements (1.6 KWHr/kgBOD removed)

- Higher construction cost than more highly loaded plants (30).

3.2.4 Municipal Sewage and Chemical Industry Waste

A joint waste treatment plant built in 1959 was under operation to treat municipal waste from the City of South Charleston and South Charleston plant of Union Carbide Chemicals company manufacturing nearly 400 chemicals (31). The City owned the treatment plant and accepted to treat Union Carbide's wastewater. Carbide delivered its waste to the joint treatment plant and assured not to build a competitive treatment plant. Union Carbide provided the pilot plant data for the design basis and took the responsibility for the design of the works.

Union Carbide's wastes originate from four different areas. It was collected and transported individually to the treatment works site. Design domestic waste flow was 4050 GPM or 5.8 MGD which included 1000 GPM flow from Carbide Technical Centre. The industrial waste flow, averaging 7000 GPM contained an average of 130000 lb 10-day BOD per day. Peak daily BOD was double the average.

The joint treatment plant consists of the following units :

The domestic sewage passes through comminutors, a Parshall flume, a grit removal basin, parallel primary clarifiers and a chlorine contact basin. Upon leaving the chlorine contact basin, one-third of the flow passed directly to the activated sludge system. The industrial waste passes through a Parshall flume, grit removal basins and parallel primary clarifiers. Upon leaving the primary clarifiers, the flow splits and one-third passes through pH-adjustment facilities, nutrients are added and the flow continues to the secondary process. Sludge from the domestic primary basins is thickened with waste activated sludge prior to vacuum filtration. Two circular aeration units are provided for the activated sludge process. The BOD load on the activated sludge unit was 169 lb/1000 cft/day. The aeration detention time was 7.67 hr and the detention time in the settling zone was 2.50 hr. The estimated costs for the plant was $ 8,623,000 of which Union Carbide's contribution was $ 6,327,000 and the City of South Charleston's was $ 2,295,000. Similarly, total annual operation cost was estimated as $ 172400 of which Union Carbide shared $ 157800 and City contributed $ 14600.

The high ratio of first cost to volume of wastes to be treated was attributable to the necessity for use of special alloy metals and expensive protective coatings to withstand corrosiveness of industrial wastes before pH adjustment (32,33).

In actual operation, the joint municipal-industrial wastewater treatment plant in South Charleston, W.Va., USA was reported to give primary treatment to 12 MGD flow of Union Carbide plant (petrochemical plant) and 2 MGD flow of city sewage. This initial facility was completed in 1963 at a cost of $ 5,800,000 and the investment by Union Carbide and City of South Charleston was in 5.45:1 ratio. As stated earlier, the municipality financed and built the combined treatment plant and Union Carbide operated the plant and the operating costs are distributed appropriately to the City and to Union Carbide. The petrochemical waste stream undergoes aerated grit removal, primary clarification and pH adjustment prior to the biological treatment step. The municipal waste stream separately undergoes comminution, grit removal, primary clarification and chlorination; sludge is thickened and subsequently deaerated by vacuum filtration. Peripheral-feed circular clarifiers were selected to keep floating material, which may be flammable, away from the drive motors in the centre of the tank. The mixed pretreated wastes are then fed to the aerator clarifier unit where it is properly aerated for biological oxidation. BOD:N:P ratio was maintained at 100:5:1 by addition of ammonia and phosphoric acid. This plant was evaluated for a period of four years. The performance data for this type of activated sludge process indicate that the removal capacity of BOD from the mainly petrochemical waste at 80 percent efficiency reaches 180 lb/day/1000 cft aeration volume. An average removal of 130 lb BOD/day/1000 cft was obtained. A concentration of 5000 mg/L of highly active and biological solids could be maintained to accommodate wide variation in wastewater strength and constituents. The effect of detention time, organic loading and sludge age on performance were delineated (6).

Farbenfabriken Bayer Co. carried out pilot plant studies to determine whether its industrial (chemical) waste was to be treated separately or in conjunction with sewage of the city of Wuppertal, West Germany. The average BOD of the city sewage at Napperstal (containing high portions of other industrial wastes) was found as 400 mg/L while the average BOD of the industrial wastewater from Farbenfabriken Bayer was observed as 1500 mg/L. Quantitywise contribution of Farbenfabriken Bayer waste was about 20 percent of the combined wastewater flow. It was decided based on the pilot plant studies, that the industrial waste was to be treated in a combined treatment facility employing a 2-staged activated sludge process. To obtain 50 mg/L effluent BOD, the space BOD loadings of 2.5 kg/m^3/day and 0.5 kg/m^3/day were recommended for the first and second stage of activated sludge process respectively. To achieve 90 to 95 % BOD removal, the sludge load has recommended not to exceed 0.5 kg of BOD in the first stage and 0.1 kg of BOD per kg of dry solids in the second stage, with MLSS concentration of about 5000 mg/L in the first stage and SVI of 70 ml/g. Oxygen requirement was observed as 1.25 and 2.2 kgO_2/kgBOD for the first stage and second stage respectively. The quantity of surplus sludge averaged 0.45 kg of dry solids per kg of BOD in the influent (5).

3.2.5 *Municipal Sewage and Paper Mill Waste*

Physico-chemical treatment of combined municipal-industrial wastewater containing approximately 80% paper industry (deinking and paper making) effluents were carried out on a pilot plant at Neenah-Menasha wastewater treatment plant located in Menasha, Wis., U.S.A. The pilot treatment facility treating 6000 gal/day, included chemical coagulation (using ferric chloride), sedimentation, high-rate filtration and carbon adsorption. The combined raw wastewater contained an average of 1240 mg/L of suspended solids and 483 mg/L of BOD. The removal of both BOD and COD depended upon the periodicity of carbon replacement and normally varied between 90 and 99%. Thermal regeneration of the spent carbon was determined to be feasible with an average attrition loss of 5% or less. The adsorptive properties of the regenerated carbon, for each of the two regeneration cycles, were comparable to the virgin carbon (34).

A pilot plant study carried out to investigate the feasibility of the joint treatment of the wastewaters from 4 paper mills and domestic waste from the city of Green Bay, Wis., U.S.A. revealed the following conclusions :

- Contact stabilization is the best configuration of the activated sludge process as compared to other types such as conventional, step aeration and Kraus process for this application. The waste was observed as deficient in nutrients and, hence addition of nitrogen and phosphate to influent wastewater was recommended.

It is economically advantageous to bypass the primary treatment for pulp mill waste with high BOD and low suspended solids.

The full scale design parameters for the contact stabilization-type activated sludge process to treat these wastes are shown in Table 3.12. The additional solids-handling studies concluded that heat treatment of the sludge followed by vacuum filtration and incineration was the preferred method (35).

Table : 3.12

Full-Scale Design Parameters for Contact Stabilization Treatment Plant

Parameter	Value
Primary clarification (GBMSD* only) :	
Average flow	113550 m^3/day
Peak flow	454200 m^3/day
Detention time	2.7 hr
BOD removal	33.0%
TSS removal	60.0%
Primary sludge	228.2 m^3/day
	5.5% TSS, 83.7% volatile
Secondary treatment (GBMSD plus mills) :	
Average forward flow	204012 m^3/day
Peak forward flow	355790 m^3/day
BOD (470 mg/L)	95.2 MT/day
TSS (100 mg/L)	23.0 MT/day
MLVSS (86% volatile)	3500 mg/L
kg BOD applied/kgMLVSS under aeration	0.3
Detention time :	
Reaeration (R)	4.1 hr
Contact (R + Q)	2.9 hr
R/Q	0.7
kgO_2required/kgBOD removed at 26.6°C	1.6
Waste activated sludge :	
kgTSSproduced/kgBOD removed	0.65
Volume	6056 m^3/day
TSS concentration	1.0%
Final clarification :	
Solids loading	112.2 kg/m^2/day

*Green Bay Metropolitan Sewerage Districts

The wastewater treatment plant of Kalamazon in Michigan provides secondary treatment to effluents from seven primary plants operated by various paper mills in addition to the primary plant operated by the city for its municipal waste and the waste from a large pharmaceutical company. In 1971, the plant was serving three cities, five townships, six paper companies and a pharmaceutical company with a combined BOD load equivalent to about 500000 population.

Each paper company disposes the primary sludge of its own and the primary effluent from the industrial plants is conveyed to the city's secondary plant by a separate system.

Anaerobic digestion of the sludge was practiced successfully in the plant for many years but the addition of pharmaceutical waste made this operation difficult may be because of the substances discharged from the antibiotics plants which proved to be toxic to anaerobic bacteria. Lagooning of the waste activated sludge was also found unsatisfactory. After long-term studies, a system was selected for sludge treatment comprising of wet-air oxidation process for sludge conditioning, vacuum filters for sludge dewatering and multiple hearth furnace for incineration. The system was designed to handle 97.5 tons of dry solids per day. About 77% of the load was from waste activated sludge generated in the city's 45 MGD secondary treatment plant. The remaining 23% was from raw primary sludge (36).

A 22 MGD capacity joint wastewater treatment plant to include municipal waste from Lynchburg city and effluent from a paperboard mill was in operation at Lynchburg, Va., U.S.A. Prior to construction, to determine applicable design parameters for joint treatment, treatability studies were carried out which yielded following results :

- Combined wastes were compatible with activated sludge process and F/M ratio to be maintained was found as 0.15 to 0.20 day^{-1}. The activated sludge production rate was 0.57 lbs of volatile solids produced per pound of BOD removed and the endogenous destruction rate was 0.038 per pound of MLSS under aeration

- Energy oxygen coefficient averaged 1.08 lbs of oxygen per lb of BOD removed while endogenous respiration constant was 0.08 lbs per lb of MLSS under aeration

- Approximately 30% of the raw domestic and paper mill BOD was removed by primary treatment

- The ratio of the oxygen transfer coefficient of the combined wastes to that of tap water (α) averaged as 0.83.

The full scale joint treatment plant was designed on the basis of these treatability studies results. Domestic and paper board mill wastes enter the plant through separate interceptors. The paper board mill waste receives primary treatment prior to being combined with domestic waste for joint secondary treatment. Paper board mill primary sludge is dewatered and disposed of in a landfill. The combined wastes pass through primary settling, aeration, secondary settling, disinfection and then are discharged into the river. The domestic primary and excess activated sludge are thickened, heat treated, dewatered and disposed of in a landfill (37).

In City of Brewer, Maine, the industrial (paper mill) contribution to total waste generated is about one-third the flow, slightly over half the BOD and about two-thirds TSS. In 1972, City and the mill formally agreed to joint treatment with an industrial capacity of approximately 1.1 MGD to handle 3100 lbsBOD/day. Design parameters for the plant were as follows :

Flow (MGD)	-	2.18
BOD (lbs/day)	-	5600
Suspended Solids (lbs/day)	-	8400

The operational data of the plant for first two years showed BOD removal of about 92.9% and suspended solids removal of more than 85%.

The capital cost of the wastewater treatment plant was $ 4.6 million. The mills share was $ 210000, that of City's was $250000 and the rest was Federal and State grants. Annual operation and maintenance costs were based on a pro rata basis based on BOD, TSS and flow. A portion of the total operation and maintenance cost for the treatment plant was allocated to BOD, TSS and flow in 1976 and the mill's share of each component was 55%, 76% and 40% respectively. The total O & M cost to the mill for 1976 was $116,300. The mills share for 1977 was estimated to be 43% of the total O&M cost (38).

A joint wastewater treatment plant at Westernport, Maryland treats kraft pulping wastes and the domestic sewage from Luke, Maryland. The plant consists of a primary clarifier, activated sludge process units and final clarifiers. The sludge handling involved sludge thickener, sludge blending tanks and vacuum filter. The plant was designed to treat an influent of 21 MGD (20 MGD of kraft waste and 1 MGD of municipal sewage), 51000 lbsSS/day and 46000 lbsBOD/day. The facilities were sized to ensure an 80 percent removal of both suspended solids and BOD. Limited operating data is available for the plant performance. During sixties, the plant was handling only 12 MGD of flow (39).

3.2.6 Municipal Sewage and Meat Packing Waste

Hill has reported performance of a treatment plant built in 1938-39 at Austin, Minnesota, USA handling municipal sewage and packinghouse wastes together. The plant consisted of primary sedimentation tanks, primary filters and intermediate settling, final filters and final settling. Though designed to handle 4 MGD combined flow and 15880 lbsBOD/day, the plant was handling 4.95 MGD flow and 26150 lbsBOD/day. BOD and suspended solids in the treatment effluent were 48-408 mg/L and 30 mg/L respectively as against designed effluent BOD and suspended solids of 30 and 25 mg/L respectively. The sludge digesters were handling 5.2 lbs/cft/month as against designed loading rate of 2.5 lbs/cft/month. Under excessive loadings, the operation of the plant had been difficult and hence enlargement of the existing plant was felt necessary. Based on the research work carried out by various agencies, it was confirmed that packinghouse wastes when sufficiently concentrated can be treated successfully by anaerobic digestions at temperatures ranging from 90 to 95°F. Accordingly, in 1958, another combined treatment plant was built and commissioned to treat domestic sewage from packinghouse and city and also industrial waste from packinghouse The treatment plant was designed so as to utilize the capacity of the existing sewage treatment plant to treat domestic sewage of city origin, packinghouse sewage and a portion of the packinghouse waste Separate anaerobic digestion plant was designed to treat the remainder of the packinghouse waste. Anaerobically treated packinghouse waste, after solids separation, was treated alongwith partially treated sewage in final trickling filters (40).

The village of Hebron accomodates the only major industry in the village i.e. a beef slaughtering plant in terms of wastewater loadings. Initially, the village owned and operated two treatment plants. All municipal sewage was treated at a trickling filter plant. Pretreated packinghouse wastes were pumped to another lagoon system for secondary treatment. Effluent from both plants failed to comply with the State Pollution Control Board's water quality and effluent standards. To tackle this problem, engineering studies were initiated in 1976. The most cost-effective alternative was determined to be joint treatment of both waste streams, utilizing the existing lagoon system, supplemented by AWT facilities. The trickling filter plant was then to be retired.

High strength meat packing waste loads were reduced in anaerobic lagoons and then combined with municipal wastes for further treatment in an aerated pond. Following stabilization ponds to polish the effluent and entrance nitrification, AWT facilities were utilized to meet effluent standards for BOD, TSS and phosphorous. However, ammonical nitrogen reduction required longer detention times in the stabilization ponds or by break point chlorination.

Start-up data indicated that :

An alum dosage of 35 mg/L as Al was adequate for effective phosphorous removal

A chlorine dosage of 63 lbs/MG at a detention times of about 30 minutes achieved a nearly complete kill of fecal coliforms (41).

Hill has reported detailed performance evaluation of two combined treatment plants treating packinghouse waste and municipal sewage at Sioux Falls, South Dakota and at Austin, Minnesota (described in previous paragraphs). Both the plants handle equal volumes of packinghouse wastes and domestic sewage and are owned and operated by the municipality.

The sewage treatment plant as Sioux Falls comprises certain facilities allocated to the treatment of the packinghouse wastes. These include an equalisation tank, a flocculating tank, a primary sedimentation tank, four primary filters of the backwash type and an intermediate sedimentation tank. These facilities are provided exclusively for the treatment of the packinghouse wastes. The domestic sewage is screened, detrited and settled in separate facilities. The settled sewage may be combined with the packinghouse waste which has been flocculated, settled, filtered and the whole applied to a second stage conventional filter, the effluent of which is pumped to the activated sludge plant and then settled, or the settled domestic sewage may go directly to the activated sludge plant and only the packinghouse waste may be applied to the second stage filter.

The combined packinghouse waste and domestic sewage at Austin has quite different characteristics from those of the combined wastes at Sioux Falls, due to the different pretreatment given the packinghouse waste at Austin. At Sioux Falls, 60 per cent of the total organic load of the domestic sewage and packinghouse waste is removed by preliminary sedimentation. At Austin, only about 15 percent of the total organic load is removed by flocculation and sedimentation tanks. The pretreated effluent is biologically treated through trickling filters. The preliminary filters have consistently removed from 30 to 40 percent of the BOD at loadings from 11000 to 15000 lbs/acre-ft/d. At neither plant has the problem of ultimate disposal of sludge been solved (42).

Gohary reported that the meat packing waste when treated aerobically (complete mix A.S.P.) with a ratio of industrial waste : sewage as 1:5, BOD reduction of upto 94 percent was achieved at a loading of 13.8 kgBOD/m^3/day and HRT of 2 hours. When the industrial waste/sewage ratio was changed to 1:1, BOD reduction dropped to 75% (43).

3.2.7 Municipal Sewage and Dairy Waste

According to Watson et al, no pretreatment of dairy and food processing wastes, even though they contain edible fats, oils and greases, is necessary in combined treatment. Except possibly for equalisation for pH control at some locations, no conditioning of such wastes is required (44).

The Torrington sewage disposal works are designed to deal with a DWF of 168000 GPD made up of domestic sewage, infiltration and dairy waste as 15000, 3000 and 150000 GPD respectively. The works comprised of the following units: Combined screening and detritus tank, storm water overflow, upflow settling tank, two percolating filter beds, humus tanks and sludge drying beds. The plant was put into operation in 1952 (45).

The two-stage RBC system processing combined domestic and cheese-manufacturing wastewater at Newman Grove, Nebraska provided excellent treatment when hydraulic and organic loads were approximately 93 and 25% of the design loads respectively. The influent design average wastewater BOD and suspended solids were 1820 mg/L and 460 mg/L. The effluent BOD was less than 11 mg/L and suspended solids concentration was less than 20 mg/L for 90% of the time. It was further inferred that the allowable BOD load on the rotating biological contactor system could be increased by about 50% for an effluent quality of 30 mg/L BOD by providing 75% of the disk area in the first stage and only 25% in the second stage (46).

In the case of Kagerod township and Milkfood Inc., Sweden, a joint effort to solve municipal and industrial environmental protection problems has resulted in a solution that has obvious technical and economic advantages for both parties and provides a cleaner environment for the communities inhabitants. The township's population considered was 2000 producing about 120 kg BOD/day. The industrial wastewater, most of which is from the Milkfood plant was expected to amount to approximately 450 kgBOD/day corresponding to 7500 person equivalent. The new wastewater treatment plant was therefore designed to accomodate a wastewater quantity corresponding to 9500 population equivalent. Average daily flow was 140 m^3/hr out of which 30 m^3/hr was from the Milkfood plant. The wastewater treatment plant designed for this waste involved conventional activated sludge process and chemical post-precipitation with aluminium sulfate. The treatment plant was put into operation in the beginning of 1972 and its performance since then is excellent. The treated wastewater has BOD 5 mg/L, 6 mg/L nitrogen and 0.2 mg/L phosphorous which corresponds to a reduction of 99, 89 and 99 percent respectively (47).

Kraft Foods decided in 1967 to build a new cheddar cream cheese plant in Lowville, N.Y. The Kraft proposed that Lowville domestic wastes and

Kraft plant waste be treated in a single biological treatment facility operated by the Village. Kraft agreed that it would pay its proportional part of the costs in the use of the joint approach.

The records showed that about 50% of the total hydraulic load and about 70% of the total BOD load handled in the joint system was contributed by the industrial plant. Thus, by mutual agreement, the Kraft plant was normally charged for 60 percent of village's total annual capital and operating cost. It was observed that the agreed limit of 7-day average BOD load of 726 kg/day was occasionally exceeded on a daily basis. Because of this, and to provide a reserve for future growth of the Kraft plant, it was decided to provide some additional perforated piping operating continuously to achieve the required additional aeration capacity Kraft agreed to reimburse the village for its share of the piping and to pay for the cost of an additional blower and associated electrification and housing. It was determined that the additional aeration would add about 363 kg of BOD capacity to the system. The village then allocated this increased capacity for the use of Kraft. Good performance of this joint system was borne out by the fact that the BOD in the finished effluent is always less than 10 mg/L.

Kraft Foods has had a margrine and salad dressings production plant in operation in Champaign which was to be expanded. The company proposed to the Champaign-Urbana Sanitary District that it provide sewerage service for the expanded plant at Kraft's expense. The municipality, however, took a stand that it could accept the hydraulic load but the plant would have to provide pretreatment facilities to meet the following limits specified in a proposed ordinance : 200 mg/L of BOD, 200 mg/L of SS and 100 mg/L of Fats, oils and greases. Kraft plant's hydraulic load is less than 3% and daily untreated BOD load was less than 25% of the total load handled by the municipal system.

The experience at Lowville indicates that the joint approach is a mutually beneficial one for the community system. In contrast, the Champaign situation offers the example of an approach that is not beneficial to the welfare of the community, her citizens and the contributing industrial plant with compatible wastes. Because at the time that Kraft was planning a plant expansion, Champaign-Urbana was planning to expand its treatment plant, this facility could readily have been designed to accept Kraft wastes after these had been passed through a gravity oil separators to remove so-called insoluble fats, oils and greases.

Because of the economy of scale, it appears certain that Kraft Foods and the citizens of Champaign-Urbana would each have invested less capital in treatment facilities and had to pay less annual treatment costs if the joint treatment approach had been used. The conclusion of the Kraftco was that where a completely equitable formula has been mutually established, it would be better for all concerned if the plant invested in the community system, funds almost equal to those required for pretreatment facilities, rather than build and operate pretreatment facilities (44).

3.2.8 Municipal Sewage and Miscellaneous Waste

The complex industrial wastes generated at the Naval Rework Factory (NARF) facilities at Jacksonville, Fla., U.S.A. which repairs damaged aircrafts and helicopters was earlier considered as non-amenable to secondary biological treatment as it contain cyanides, chromates, heavy metals and other chemicals of toxic nature. Laboratory and pilot plant studies showed that the industrial wastes were indeed biodegradable and could be subjected to secondary biological treatment under proper design and operating conditions. Based on the pilot plant results, a combined treatment plant involving completely mixed activated sludge system and special oil collection and disposal facilities was designed and constructed This plant initially treating 2.15 MGD combined flow (1.5 MGD industrial wastes and 0.65 MGD domestic waste) consists of the following unit processes :

- Pump station and control (pretreatment of cyanide and chrome waste)
- Primary clarification to remove oil & grease, grit and paint strippings
- Biological aeration in a completely mixed basin
- Secondary clarification
- Aerobic sludge digestion
- Oxidation ponds for effluent polishing, and
- Chlorination.

The unique design tailored to this particular waste has resulted in an average 97 percent BOD removal in the initial periods of operation (48).

Coal pile leachate produced from a fire in the heating plant coal pile in Cornell University, Ithaca, N.Y. was polluting the nearby creek. Pickard and Anderson (49) designed a system to treat the coal pile leachate and municipal wastewater combinedly on a regular basis Use of existing sanitary sewer networks to transport the coal pile leachate after neutralization to the City Wastewater Treatment Plant was also unique.

An equalization/retention tank collects the leachate from the coal pile. From the tank the leachate is pumped by precision chemical feed pumps to a 'mixing tank through which boiler blowdown wastewater flows by gravity. Automatic controls based on pH match the leachate feed rate to the available alkalinity in the boiler blowdown to produce a neutralized effect.' Equipment to feed additional alkalinity was also provided as a backup neutralization system.

Although coal pile leachate is similar to acid mine drainage which has been extensively studied, they are not comparable because of the differences in the way each are generated. Operating results of the system were not reported (49).

The City of Basel, Switzerland manufactured an ultra-modern sewage treatment plant. For both domestic and industrial effluents within the City limits of Basel itself. Although financed and administered locally, this computer-controlled installation had minimal effect on the residents of Basel; the real beneficiaries were those living in France, Germany and Netherlands (countries located on downstream of River Rhine). The overall plant consists of three separate facilities :

One for domestic wastewater treatment

One for treatment of effluent from the chemical firms, and

A sludge-treatment plant to serve both the domestic and industrial facilities.

The facility for the treatment of domestic wastewater, known as ARA-Basel, has been designed as a mechanical-biological treatment plant incorporating a third stage of chemical purification by means of precipitation with ferrosulphate during the biological treatment stage.

The plant for treatment of industrial wastewater, known as ARA Ciba-Geigy/Roche (ARA CGR) was based on chemical-biological method of purification. The mechanical screening by rake installations takes place at the pumping station of the wastewater suppliers.

The first stage includes a mixing chamber to partially homogenise the input. The industrial wastewater then goes to a two-stage neutralization stage, using lime wash produced at the plant, and caustic soda and sulphuric acid as needed. Preclarification then takes place, by means of screens and return sludge to optimise removal of solids and use of chemicals. This is followed by a buffer step in which five days' input can be levelled out in seven days' output. Three-stage flocculation and precipitation then removes inhibitions for the subsequent biological purification stage. Floatation tanks are fitted with earing devices on floor and liquid surface. From this point onwards, the wastewater is fed to biological system. Aeration takes place using oxygen instead of air mainly because it produces less sludge and waste air. It comes by pipeline in compressed form. On completion of the biological treatment stage and final sedimentation, the clarified water is piped to the river Rhine.

Primary, excess and floating sludge from both the domestic and industrial wastewater plants enter a common sludge thickening installation. Thickened sludge passes to the incinerator. It is concentrated at approximately 800°C. Heavy ash settles out and flue ash is settled in washers. The final residue, which looks like grey sand, is used mainly for landfill.

To eliminate inconvenience to the people living in the area - and ecological harm to humans, animals and plants - all basins have been covered and all exhaust air is collected, distributed to scrubber systems, and finally treated to eliminate all smoke dust and even condensation.

To achieve the required efficiency and safety with minimum staff requirements the two wastewater treatment plants and the sludge treatment plant are all controlled by a decentralised, computer supported system (50).

In 1906, a joint treatment plant was built at Tadcaster to treat the combined domestic and breweries wastewaters. In 1968, the Council extended new work in order to treat domestic sewage from the villages of Clotton, Appleton Roebuck, Ulleskelf and Bolton Percy. The population in 1983 was almost 8000 and the DWF was 1.37 m^3/d. During 1970-72, Tadcaster RDC built new sewers specifically to convey industrial effluents from the three breweries by gravity to a new industrial pumping station. The mixed brewery effluents were pumped to the head of the 'new' sewage treatment-works for distribution, part of the flow receiving treatment in about one-third of the domestic works and the balance going forward to limited sedimentation in the 'old' works.

Although domestic sewage is fully treated and the works used to provide treatment to as large a part of the brewery load as possible, the BOD load entering the river remains unacceptably high (51).

3.2.9 Municipal Sewage and Mixed Industrial Wastes

In case of highly industrialised cities or towns, various industries discharge their effluents into the municipal sewers which ultimately carries this combined waste to sewage treatment plant. The sewage treatment plants serving these area have to handle many industrial wastes simultaneously. A brief review of literature on the joint treatment of sewage and mixed (heterogenous) industrial wastes is presented in this subsection.

The City of Niagara Falls is a highly industrialised city and accomodates various industries like electrochemical, electrometallurgical, paper, food products, organic chemicals and abrasives. In the middle 1930's, the city constructed a sewage disposal plant giving only primary treatment consisting of coarse screening, grit removal, fine screening and chlorination. In 1969, an industrial waste survey was carried out to collect necessary data for designing a secondary treatment plant. This survey revealed that a biological system would not successfully treat these wastes. Therefore, pilot plant studies incorporating chemical precipitation of phosphates, flocculation and clarification and carbon adsorption was envisaged. Provision was also made for dissolved air floatation followed by activated carbon units. Removal of COD and suspended solids was 70% and 90% respectively throughout the test period. Phosphorous and phenol removal was excellent and the effluent was essentially colourless. Sludge generated could be easily dewatered and disposed of by conventional means.

Based on the pilot plant data, a full scale plant was designed for average 48 MGD flow and 86 MGD peakflow. The pilot plant data showed the need for flexibility in the final treatment process in order to treat adequately a constantly changing waste. The major industries had all entered into agreements with the City for sewerage services by March 1971. Each industry agreed to repay the City its share of the City's capital cost of the treatment plant and its share of the yearly operation and maintenance costs. The terms of the agreements were for 10 years with renewable 10 year increments for a total of 30 years, which is the life of the City's bond issue. Each industry's share of the capital cost of the plant was based on its commitment for capacity for flow, suspended solids and COD, and its share of the maintenance and operating expenses was determined by its average yearly flow and loadings.

The wastewater treatment plant consisted of bar rack, rapid mixer, flocculation basin, clarifiers, carbon contact beds and chlorine contact chamber. Operating results were not available (52).

Duck Creek wastewater treatment plant is a combined municipal industrial waste treatment plant serving the City of Garland, Texas. The municipal effluents are from a population of 145000 and the industrial discharges are from 265 various light industries ranging from paint manufacturing and metal plating to food and dairy processing. These industries with little or no pretreatment, discharge their effluents into the municipal drains. The influent to combined treatment plant is composed of approximately 60-70% municipal and 30-40% industrial waste.

With an expansion of the existing wastewater treatment facility at the Duck Creek wastewater treatment plant from its previous 10 MGD biological treatment configuration, the City of Garland elected to expand the facility with the addition of a 22.5 MGD physico-chemical treatment process.

The major processes of the physico-chemical configuration are equalisation, chemical coagulation, flocculation, precipitation, recarbonation, filtration, activated carbon adsorption and disinfection.

The biological treatment process at the Duck Creek wastewater treatment plant consists of bar screens, grit channels, primary clarification, trickling filters and final clarification. Sludge is removed from the bottom of the clarifier and treated later alongwith the sludges from the physico-chemical process. Maximum daily flow rate through this biological process is 7.5 MGD.

The sludges removed from the biological and physico-chemical process are combined in two sludge equalisation and holding tanks which provide upto 18 hours detention time. The combined sludges are pumped into filter presses to obtain sludge cakes of 40% solids by weight. The sludge cakes alongwith the recovered grit and screening are hauled by truck to a sanitary landfill (53).

Quirk (54) has presented the results of a laboratory scale study conducted to determine the feasibility of employing the activated sludge process to a mixture of domestic sewage and several industrial effluents. The principal waste streams considered for biological treatment consisted of a mixture of domestic sewage and the effluents from two large cereal factories and separate discharges from two board mills. The wastes discharged from the cereal industries were composed of highly carbonaceous material and contained maltose and related sugars from spent flavour solutions, grain losses, cereal nutrients, vitamin additives and general process dragout. The waste discharged from the board mills contained dissolved and suspended material from the pulping operations as well as various chemicals from the bleaching, brightening and colouring of the raw pulp and spent waters from the board machines. A mixture of primary effluent (sewage and cereal wastes) and presettled board mill effluent was used in the studies.

Keeping an aeration period of 4 hour constant, loading rates were varied from 0.5 to 2.1 lbBOD/lbsludge/day and included a sludge loading range of from 0.08 to 0.4 lbBOD applied/lb of sludge/day. The average efficiency of BOD removal remained substantially constant at 88 percent. These results revealed that the combined waste possessed a treatment potential substantially higher than the operational characteristics associated with the domestic sewage fraction indicated (55). The sludge volume index averaged below 75 for all the loadings investigated. For the wastes studied, the overall oxygen requirement was calculated at 53 percent of the BOD removed.

Paisley sewage treatment works (56) handles domestic waste as well as wastes from various industries such as pigment manufacturing, textile and thread mills, corn-oil processing, laundering, tanning, food and soft drinks, plating and metal work, drum cleaning and whale oil processing. Pigment manufacturing industry contributes the largest volume of industrial effluent. It is imperative for all industries that the waste discharged should be pretreated,if required, to achieve the standards laid down by Paisley Corporation, viz.

pH	-	6 - 9
Suspended Solids	-	500 mg/L
Sulphate^{-}	-	1500 mg/L
Copper	-	10 mg/L
Ammo. Nitrogen	-	450 mg/L

Wastewater from pigment manufacturing industry is subjected to pretreatment primarily to remove residual isopropyl alcohol, nitrobenzene and ammonical nitrogen in the effluent. Tannery wastewater is also pretreated prior to discharge into municipal sewers, for sulphide removal using catalytic oxidation and pH is adjusted using waste acid from a nearby factory (56).

The water pollution control facility at South Paris, Maine serves a tannery (chromeside upper leather manufacturing); a cannery processing beans, apple sauce, shelled beans, blueberries and potatoes; and raw and partially treated wastewaters of the town. This unique secondary treatment facility receives raw domestic sewage (0.45 MGD), storm water (5.80 MGD), cannery wastewater (0.15 MGD) and tannery wastewater (1.25 MGD). In general, the BOD loading was 12600 lb/day and the suspended solids loading was 22400 lb/day.

The basic treatment units included headworks building (screening, hair removal, grit chamber and flow measurement), tanhouse waste holding tanks (tannery), equalization tanks (tannery), primary clarifiers, carbonation tank, pump building (primary and carbonation sludge pumps and nutrient feed equipment), upflow clarifiers, aeration tanks, secondary clarifiers, post-chlorination detention tank, sludge holding tanks, control building (control room, laboratory, sludge dewatering facilities and a flue gas compressor building) (57).

The Adolph Coors Co. waste treatment plant is reported treating simultaneously all of the wastewaters generated by a brewery, aluminium can manufacturing plant, two porcelain plants producing a variety of products and domestic waste from the city of Golden, Colorado where these industries are located. The said waste treatment plant is a high rate activated sludge plant using a modification of the Hatfield process. The batch processes used in producing beer made flow equalization and pH neutralization necessary. 3.7 MGD flow of industrial waste and 1.5 MGD flow of domestic waste combinedly enters barscreen, grit chamber and surge basin and is pumped out at a constant rate. The flow from the surge basin is again adjusted for pH to accomodate the chemical wastes from the associated industries which enter the mass waste stream after flow equalization. The flow then enters the primary clarifier. Also, directed to the primary clarifier are various in-plant waste streams.

The primary effluent then enters the secondary or activated sludge portion of the plant. The practice of splitting the return sludge flow, total 30%, and pre-aerating 40% of the total return with small amounts of highly digested anaerobic sludge had been effective in controlling filamentous organisms and allowing more desirable organisms, i.e. protozoa, to predominate in the system. After employing recovery of useful byproducts from the wastewater, BOD loadings were greatly reduced and F/M ratio was brought approximately from 0.70 to 0.35 resulting in greater removal efficiencies and a more controllable activated sludge SVI of 150 or less were consistently attainable. Percent BOD, COD and SS removals were observed as 95% (700 mg/L to 34 mg/L), 90% (1105 mg/L to 105 mg/L) and 90% (295 mg/L to 30 mg/L) respectively. The final effluent from the plant was chlorinated and returned to a tributary of a river.

The waste treatment plant produces 13 to 15 tons of dry sludge/day. The waste activated sludge is concentrated in dissolved air floatation cells to 4% solids by weight, mixed with primary sludge and dewatered by vacuum filters. Lime and ferric chloride were used in the filtering process. The sludge cake is being disposed off on land (58).

A pilot plant studies were performed to evaluate a low loading, completely mixed biological process for treatment of combined domestic and industrial wastes produced in the town of Veldese, North Carolina. Results indicate that BOD reductions of 90 percent can be obtained upto BOD loadings of atleast 2.0 lbBODa/lb sludge/day. Approximately 38 percent of removed BOD is oxidized and 62 percent is converted to new growth. The sludge endogenous respiration rate is about eight percent per day. These factors result in oxygen requirements of about 0.55 lb per lb of removed BOD and net sludge production of 0.35 lb solids/lb BOD removed. Required settling tank loading for sludge removal is about 35 lb sludge solids (dry basis) per day per sq.ft. of surface area and excess sludge disposal is recommended by centrifugation and landfill. Chlorine feed machines should be sized for a dosage rate of 10 mg/L (59).

The design study for upgrading the existing joint wastewater treatment plant in the city of Tampere, Finland was carried out in 1975-78. Almost half of the wastewater flow originated from industries : textile, metal and paper board mill. A simultaneous precipitation process proved to be the most economical process for upgrading the existing plant. Primary sedimentation was recommended as an addition to the existing plant. At a sludge load of approximately 0.3 kgBOD_7/kgMLSS and $FeSO_4$ feed rate of 120-150 g/m^3, the process was expected to reach the required level of 25 mg/L BOD_7 and a total phosphorous level of 1.0 mg/L. Laboratory scale studies showed that paper board mill effluent can easily be treated together with the municipal wastewater in this case (60).

The city of Jerome, Idaho, had a conventional wastewater treatment plant consisting of primary and final clarification and a rock trickling filter in between. The plant was designed to handle the projected population of the city, about 6000. Subsequently, the influx of industries contributed to the load on the treatment plant. The load on the treatment plant including domestic, dairy, and potato processing wastes was at 33000 population equivalents. In order to cope with the additional quantity of BOD load, a plastic media tower and a 5-acre aerated lagoon was added. The plant then consisted of primary clarification, a plastic media filter, a humus settling tank, a conventional media trickling filter and an aerated pond. Results obtained from the plant indicated achievement of design performance and over 94% efficiency was obtained. As an interesting sidelight to this project, provision had been built to recirculate sludge from the humus tank over the plastic media tower to enable the maintenance of a high mixed liquor suspended solids content in the filter (61).

A 6 MGD capacity plant based on powered activated carbon treatment (PACT) process was reported treating a domestic waste from a town of Vernon serving a residential population of 30000 people and wastes generated from textile dyehouse operations, metal plating and manufacturing industries. The plant was reported to perform excellently and high removals were obtained viz. BOD from 200 mg/L to 4 mg/L, COD from 840 mg/L to 73 mg/L, suspended solids from 450 mg/L to 8 mg/L. The effluent was almost colourless (62).

Orth et al (63) recommended use of aquatic plant treatment system using water hyacinth for treatment of combined industrial-municipal waste. The authors proposed that such systems can be used in the early phase of development of an industrial estate. The same system can be employed for advanced treatment (tertiary or polishing treatment) once the full-scale centralised treatment plant is installed.

In China, a large number of ponds have been used to receive not only human and animal manure but also silkworm dung, sugarcane leaves and other residues, which can be used either for feeding fish directly or as nutrient resources to promote the growth of algae and plankton for fish farming. On the basis of this practice and experience, various field-pond systems, such as mulberry fields fish ponds, sugarcane fields fish ponds and paddy fields fish ponds have been developed; the sludge removed from the bottom of these ponds has been applied to the subsoil of the fields as organic fertilizer, thus forming various small ecological circulation systems.

In comprehensive ecosystem ponds, the incoming wastewater is treated and utilised by ecological systems established artificially or semi-artificially. These consists of decomposers, (i.e. bacteria and fungi), producers, (i.e. algae and other aquatic plants), and consumers, (such as fish, ducks and geese), and the pond environment itself, thus resulting in various food chains. The ponds are comprehensively utilized as a recoverable resource to grow aquatic plants and raise fish, shrimps, ducks and geese. There are quite a few ecosystem ponds in China at various cities e.g. Qiqihar city (150 MLD flow pond system achieving COD, BOD and SS removal in the order of 83.5-89.5, 93.5-98.2, 91.6-94.3% respectively.

The city of Changsha, since 1957 is treating 250 MLD of municipal wastewater accounting for 75% of the city's total daily discharge, and organic industrial or agricultural wastewaters from slaughterhouses, breweries, cattle or pig pens and poultry farms with a total flow of some 50 MLD, through farming fish in the wastewater treatment ponds. Under conditions of hydraulic wastewater loadings of 400 to 500 m^3/ha/day, BOD loadings of 20- 30 kg/ha/day and pond water temperatures of 15 to 25°C, the ponds exhibit the following typical removal efficiencies : SS - 74 to 83%; BOD - 75 to 91%; total nitrogen - about 70%, phenol, cyanide and some trace metals such as mercury, cadmium, arsenic and lead- above 90%. In addition to significant reduction in pollution load, bumper fish harvests to the tune of 4500 to 6000 kg/ha/year have been achieved as against normal fish production in clean water ponds as only 750-1500 kg/ha/year.

It is calculated that on average each m^3 of wastewater with 50-60 mg/L BOD and 20-30 mg/L nitrogen can serve to produce 0.05 - 0.1 kg fish, equivalent to a net income of 0.03-0.05 yuan ($ 0.011-0.017). In contrast, each m^3 of municipal wastewater costs 0.15-0.20 yuan for treatment with conventional secondary treatment facilities.

Yarhu (Duck Lake) oxidation ponds system in Ehchang county, Hubei province is receiving and treating 80 MLD wastewater from the chemical industry region of Wuhan city, with a detention time of 56 days. The raw combined wastewater contains organic phosphorous pesticides, parathion, malathion rogor, HCCH and nitrophenol as its major pollution constituents of which the HCCH, parathion and nitrophenol are the most difficult to degrade. This system's capital cost is only one fifth to one sixth of that of the conventional secondary treatment facilities (400 to 500 yuan/m^3/day). The annual operating and maintenance cost of the system is only 300000 yuan, which is much cheaper in comparison with activated sludge process running at equal capacity (2.6 million yuan). Another pond system built in Shijiazhuang city is treating a mixture of sewage and industrial wastewaters from textile dye printing, pesticide production, chemical engineering and machine manufacturing plants (64).

4

Combined Treatment of Industrial Wastes

4.1 CETP SERVING CLUSTER OF SIMILAR INDUSTRIES

The tannery complex at Kanpur consists of 42 vegetable tanneries and 9 each of chrome and mixed tanneries producing 125 tons of leather and 5.2 million litres of wastewater per day with high suspended solids, high BOD, variable pH and high concentration of tannin and chromium.

Most of the tanneries in Kanpur are small and the availability of finances and open space for the provision of complete treatment system is limited. Accordingly, Cheda et al (65) envisaged CETP scheme with minimal pretreatment at individual tanneries (Fig. 4.1). The classification of tanneries has been done on the basis of daily hides processing capacity of the tannery.

Class A tannery - hides processing capacity per day	> 250
Class B tannery - hides processing capacity per day	50 to 250
Class C tannery - hides processing capacity per day	< 50

Pretreatment is an essential prerequisite in the joint management of tannery wastewaters to preclude conditions leading to the formation of lime mortar which clogs the wastewater conveyance system. The constraints on land and finances warranted provision of plain settling for class C tanneries, chemical precipitation and settling for class B tanneries, and chemical precipitation, settling and aerobic biological treatment for class A tanneries.

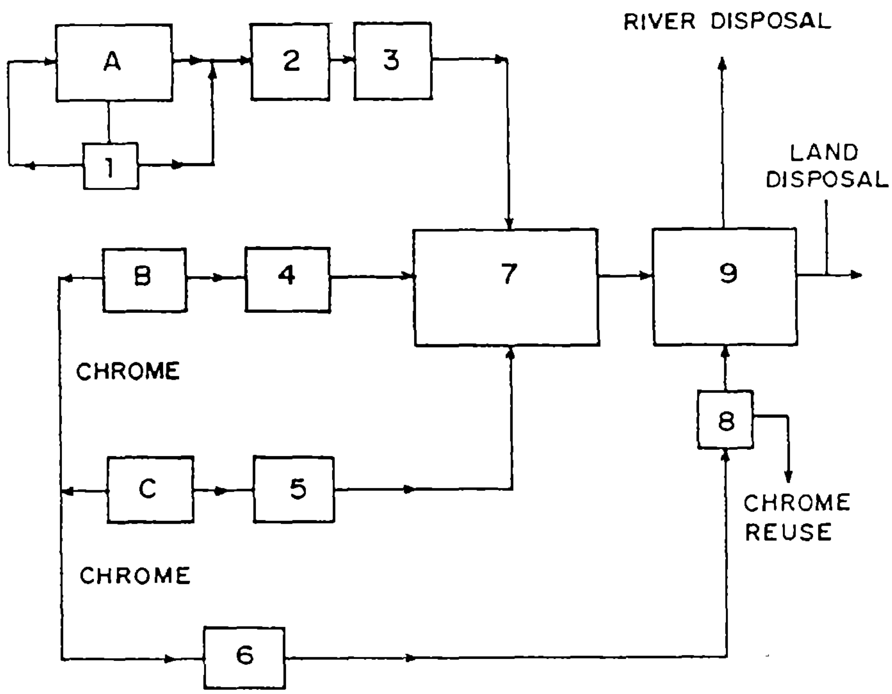
A detailed treatability study was carried out for class I settling (class C tanneries), class II settling (class B and class A tanneries) and aerobic biological treatment (class A tanneries). The overflow rate in the design of plain sedimentation tank based on class I clarification was express ed as:

$$OR = -0.0233\ (SS) + 254.22$$

where,

OR = overflow rate (m/d)

SS = concentration of suspended solids in influent (mg/L)



1 CHROME RECOVERY
2 CHEMICAL PRECIPITATION
3 BIOLOGICAL TREATMENT
4 CHEMICAL PRECIPITATION
5 PLAIN SETTLING
6 TANKER CONVEYANCE
7 COLLECTION AND CONVEYANCE SYSTEM
8 CHROME RECOVERY COMBINED
9 JOINT TREATMENT PLANT

FIG. 4.1 : JOINT WASTEWATER CONVEYANCE AND TREATMENT SYSTEM

Studies on chemical treatment using alum, ferrous sulphate and ferric chloride provided following relationships:

Alum :

$$S = \frac{D}{4.75 + 0.01356\ D}$$

Ferrous Sulphate :

$$S = \frac{D}{3.38 + 0.01438\ D}$$

Ferric Chloride :

$$S = \frac{D}{3.58 + 0.01366\ D}$$

where,

S = COD removal (percent)
D = coagulant dose (mg/L)

Equations 2 through 4 hold good for coagulant dose of 500 to 3000 mg/L.

A comparison of capital costs and annual operation costs for pretreatment systems in class B tanneries reveals that the annual operation cost of system employing ferrous sulphate is substantially lower (0.33 times) despite higher capital investment (1.4 times) as compared to the system employing alum for comparable COD and tannin reduction (55-65% and 52-68% respectively). Similar cost comparisons ruled out the use of ferric chloride.

The kinetic coefficients for the design of aerobic biological system in class A tanneries, viz. Y, K, K_s and K_d have been estimated as 0.4642 mg VSS/mgCOD, 0.3251 per day, 283.8 mg/L COD and 0.01365 per day, respectively, resulting in a COD reduction of 81% and tannin removal of 78.5% at a MCRT of 6.5 days and MLSS of 4000 mg/L. The settling characteristics of biological sludge at these design parameters have been observed to be good (SVI = 75 - 100).

Aerobic treatment of vegetable tan liquor facilitates the biodegradability of highly reduced pyrogallol and catechol in vegetable tannins as evidenced by the high tannin removal efficiency.

The composited characteristics of effluent from pretreatment systems discharged in the CETP and predicted characteristics of influent to the CETP are presented in Table 4.1. (The unit costs of pretreatment system amounts to Rs. 3.84, 2.23 and 1.41 per m^3 wastewater and Rs. 0.13, 0.08 and 0.05 per kg hide for class A, B and C respectively (66).

Pretreated wastewater is discharged in a joint conveyance system designed as a covered composite open channel comprising of a salt glazed stoneware section for conveying the industrial wastewater and a brick trapezoidal section for the excess surface runoff during the monsoon.

Table : 4.1

Wastewater Characteristics in Conveyance System and at Joint Wastewater Treatment System

Class of Tannery	pH	SS mg/L	COD mg/L	Tannins mg/L
A	7 5	30	250	30
B	7-9	100	1500	140
C	8-9	350	570	200
Predicted charact-ristics at joint treatment system	7.5	110	745	100

The chromium recovery scheme, comprising of precipitation of basic chrome sulphate as chromium hydroxide, segregation of chrome sludge, and dissolution of concentrated sludge in sulphuric acid, results in reusable chromium sulphate. Detailed design and costing of recovery scheme for a tannery processing 5000 kg hides/day and spent chrome flow of 25 m^3/d brings out saving of Rs.3000/d for the industry at a capital expenditure of Rs.1.3×10^5 and operation cost of Rs.2775/d (net savings of Rs.225/d).

The wastewater from the tanneries after pretreatment would be conveyed through the covered open channel collection system to the joint treatment system comprising of a carrousel oxidation ditch and secondary settling tank. Evaluation of experimental results on percent COD reduction, hydraulic retention time θ and mean cell residence time, θ_c, yield θ_{min} of 1.8 days and $\theta_{c(min)}$ of 4.33 days. Further, incorporating experimental results, mass balance in aeration tank and graphical cost optimization identifies θ_c optimal as 6.5 days and corresponding recirculation ratio, r of 0.44.

Flow sheet for joint treatment system is shown in Fig. 4.2 alongwith the characteristics of effluent from the treatment system.

Since the combined treatment is biological in nature, wastewater dilution factor, V, to ensure survival of fish (48 hours exposure) is expressed as,

$$V = \frac{A}{A_0} + \frac{1}{2}\left(\frac{B}{B_0} + \frac{C}{C_0}\right) + F - 1$$

where,

A = settleable matter in wastewater (mg/L)
B = BOD of settled wastewater (mg/L)
C = COD of settled wastewater (mg/L)
F = Fish toxicity factor

A_0, B_0, C_0 are effluent stadards set by U.P. Pollution Control Board for settleable matter, BOD and COD (mg/L) respectively.

Noxiousness degree, S is then estimated from dilution factor, V expressed in approriate slabs rather than in discrete numbers to account for deviation in sampling and analysis is of wastewater.

V	1-4	5-8	9-12	13-16	17-20	21-28	29-36
S	1	2	3	4	5	6	7

Annualized cost apportioned to each polluter is calculated as,

Annual apportionment = S x annual flow x total annualized cost of joint wastewater collection and treatment system per unit flow.

The average annualized cost to be shared by various class of tanneries at Kanpur is listed in Table 4.2.

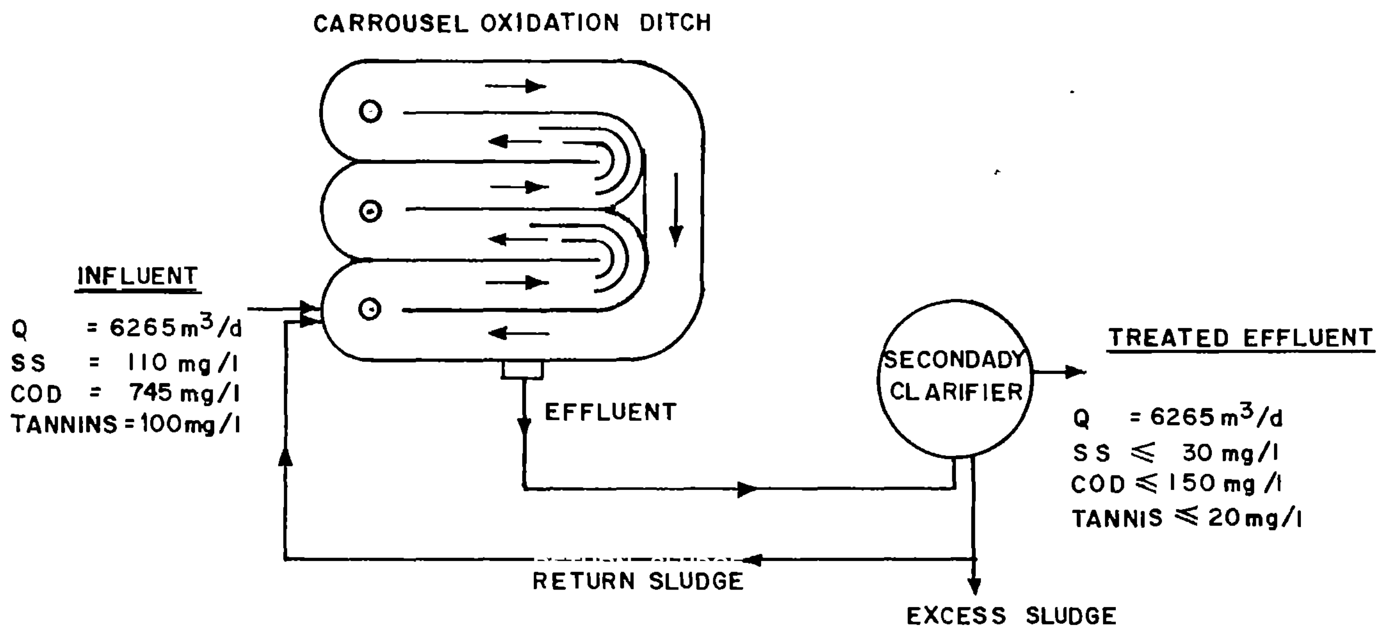


FIG. 4.2 : FLOW SHEET FOR JOINT WASTEWATER TREATMENT SYSTEM

Table : 4.2

Average Annual Financial Burdens

Class of Tannery	Average Flow per Tannery (m^3/d)	Annualized Financial Burden (Rs.)
A	354.00	43395.37
B	107.74	52829.56
C	25.01	6131.74

In Japan also, joint pretreatment facilities are existing. Group of tanneries, the wastewater of which is to be treated at the combined wastewater treatment plant at Tobu, are located in the Takagi and Shigo districts, there being 234 tanneries in Takagi and 99 in Shigo. All of these tanneries are either small size or privately run. Almost all turn raw hide into tanned leather by the chrome tanning process. Joint pretreatment facilities included grit chambers, screens, wastewater pumps, rectangular sedimentation tanks (10 hour detention time), sludge thickeners, sludge heat treatment devices (heated to about 90°C), vacuum filters and deodourising devices. The dewatered cake is presently landfilled but will eventually be incinerated.

The effluent from the joint pretreatment plant is discharged into municipal sewer system and treated ultimately by a biological process with municipal wastewater at the Tobu wastewater treatment plant. The plant treats 28000 m^3 of the tannery wastewater,together with 28000 m^3/day of the municipal wastewater (67).

4.2 CETP SERVING HETEROGENOUS INDUSTRIES

For the combined treatment of industrial wastes, it is generally required that the wastes be pretreated to reduce the concentrations of BOD and suspended solids to values similar to those of municipal sewage, typically 300-800 mg/L BOD and 200-550 mg/L suspended solids. The removal of trace organics that have passed through the preceeding stages may require tertiary treatment such as granular activated carbon treatment (68).

Longhurst and Turner (68) reviewed the treatment processes most suitable for various industries such as leather tanning, textile, electroplating, lead acid battery industry and paint industry and found out following areas of commonality :

- Primary settlement
- DAF (with chemical addition)
- Biological oxidation
- Final sedimentation and pH correction

Therefore, the wastes from such industries should be mixed together and be given above mentioned treatment jointly. However, there is atleast one basic incompatability present here.

The mineral acid and alkali and heavy metal effluents would have to be kept separate as they (i) are a toxic hazard to the biological treatment processes and (ii) seriously contaminate the organic sludges produced in biological treatment making ultimate disposal more difficult.

A possible philosophy for a combined treatment system as suggested by the authors is shown in Fig. 4.3. This also includes some municipal waste which if available would assist in providing adequate nutrient and oxygen demand ratios. When discharge standards require removal of colour to very low concentrations, tertiary treatment may be necessary. The granular activated carbon process will remove, by adsorption, dyes and many organics present in industrial effluents including those from textile and paint industries (68).

Fukashiba industrial wastewater treatment plant in Japan is reported to cater the Kashima petrochemical complex consisting of 19 core factories (petroleum, petro-chemicals and thermal power generation) and 39 other factories (including organic chemicals, foods, metals, machinery etc.). The total amount of industrial wastewater produced is 59800 m^3/day. The treatment plant also accepts municipal wastewater from the surrounding area, totalling 1100 m^3/day. Since 1970, when the plant was put into operation, the sewerage system and the treatment plant have been operated directly by Ibaraki Prefecture Government - the local Government body.

The performance data of the Fukashiba treatment plant shows that the solids retention time (SRT) was 5 to 7 times longer than that of the conventional plant. It was also necessary to keep the air/water volume ratio higher about 6.8 Nm^3 air/m^3 influent probably because of the decreased solubility of oxygen due to the high concentration of total dissolved solids in the influent.

F/M ratio was maintained around 0.13 kgBOD/kgMLSS/day. High concentration of ammonical nitrogen was tackled by maintaining high DO (DO $>$ 2 mg/L) and long SRT (SRT $>$ 20 days) to accelerate nitrification.

The processing of the Fukashiba treatment plant are shown in Fig. 4.4. The key process of the plant is activated sludge treatment. Table 4.3

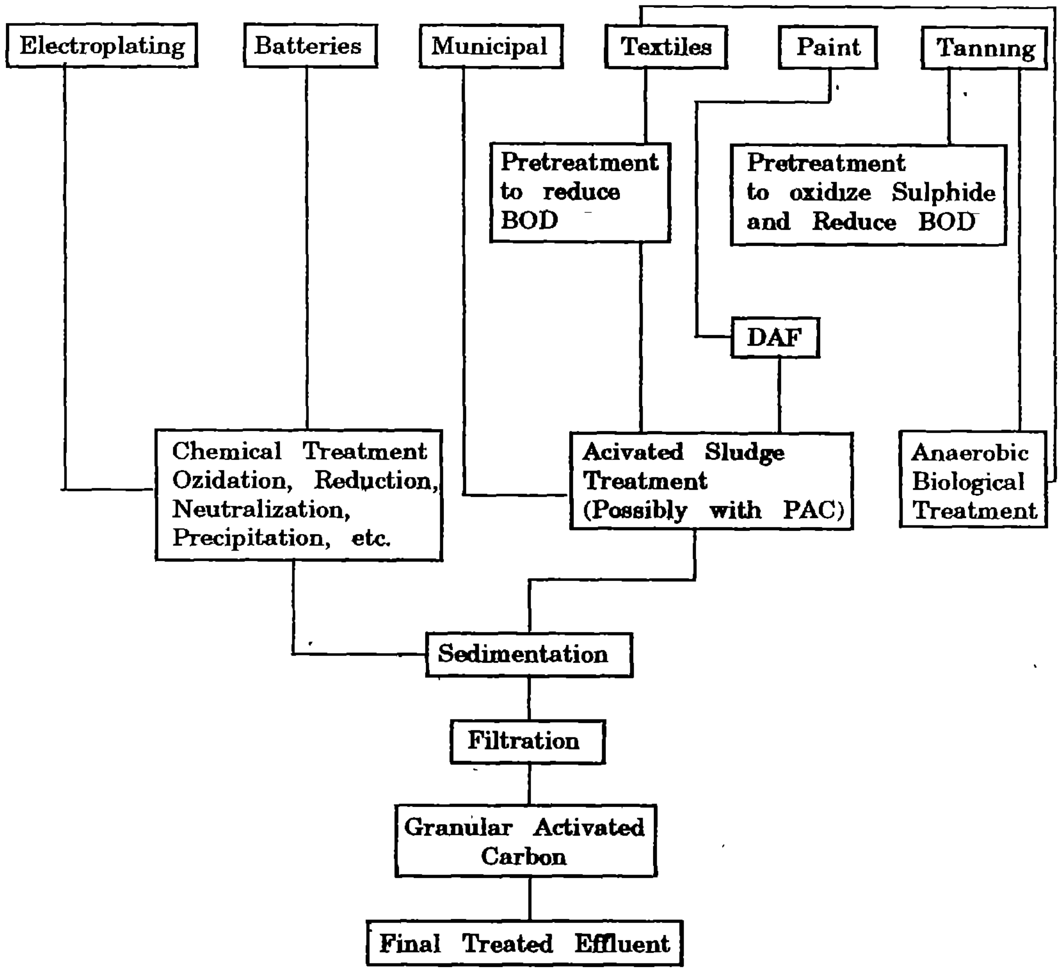
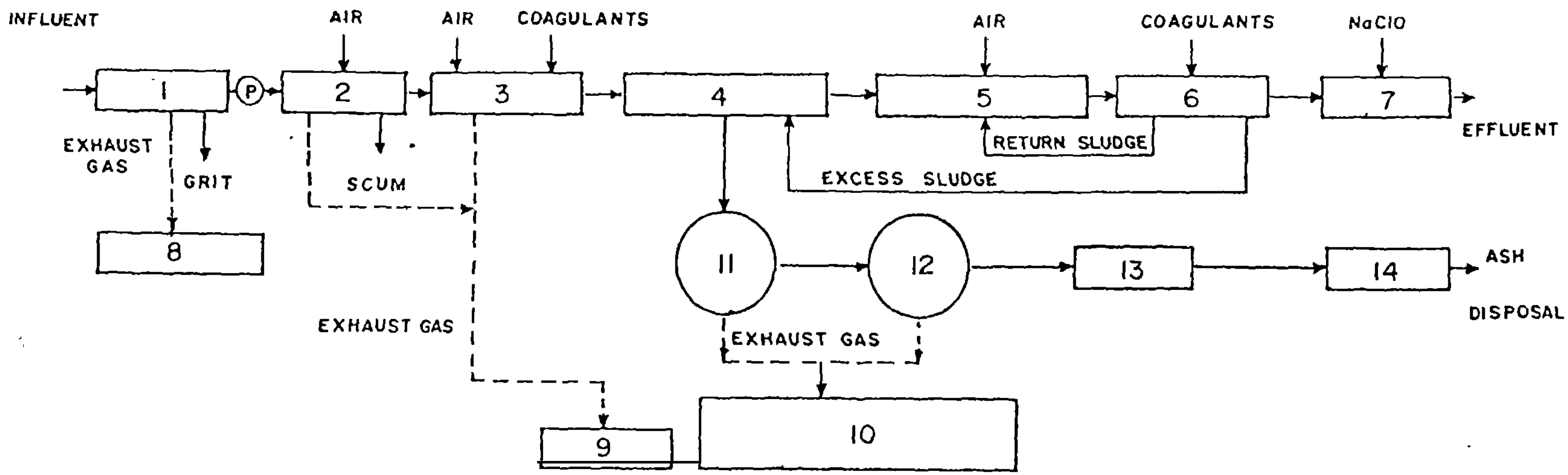


FIG. 4.3 : SCHEME FOR THE TREATMENT OF MIXED INDUSTRIAL EFFLUENTS



1. GRIT CHAMBER
2. OIL FLOTATION TANK
3. CONDITIONING TANK
4. PRIMARY SETTLING TANK
5. AERATION TANK
6. FINAL SETTLING TANK
7 CHLORINATION
8. ACTIVATED CARBON ADSORPTION TOWER
9. SOIL ADSORPTION BED
10. CHEMICAL SOLUTION (NaClO) WASHING TOWER & ACTIVATED CARBON TOWER
11 SLUDGE THICKENER
12. SLUDGE STORAGE TANK
13 SLUDGE DEHYDRATOR
14. MULTIPLE HEARTH FURNACE

FIG. 4.4 : FLOW CHART OF THE FUKASHIBA INDUSTRIAL WASTEWATER TREATMENT PLANT

shows the average water qualities of the treatment plant influent and effluent in 1985. Total dissolved solids concentration was very high in the influent so also nitrogen in the form of NH_4. Industrial wastewaters accounted for 98% of the flow in 1985 and almost the same amount in 1986 (12).

A company within the Sanitation Districts of Los Angales County which previously handled wastes from restaurant grease traps expanded its operation to be a centralized waste treatment facility for nonhazardous solids from the liquid thus allowing the solids to be placed in a landfill and the liquid to be discharged to the sewer. This facility essentially provides treatment and disposal services for two types of nonhazardous wastes : renderable fats, oil and greases (FOGs) and inert sand and grit. The animal vegetable FOGs are usually generated from the grease traps of restaurants and food processors while the sand and grit are typically removed from the interceptors at car washes.

Table : 4.3

Average Values of Water Quality Parameters of the Fukashiba Wastewater Treatment Plant

Parameter	Influent	Effluent
Temperature, °C	27	27
pH	7.2	6.4
COD, mg/L	122	27
BOD_5, mg/L	106	6
Suspended Solids, mg/L	135	13
Oil (N-Hexane extracts), mg/L	3	Nil
Total N, mg/L	154	127
Total P, mg/L	3.7	0.9
Total dissolved solids, mg/L	9800	9400

The FOGs are initially processed separately from the sand and grit materials in order to recover the grease which is sold as an animal feed additive. The wastewater from the grease recovery process is blended with the car wash wastewater and treated further to produce a sewerable effluent and a nonhazardous filter cake for landfill disposal. It was decided by the company to design and construct a treatment facility to treat not only the wastewater from the grease recovery process but also those wastes that are pumped from the clarifiers of car washers, hotel laundries and other sources that produce non hazardous wastes like food processing plants, restaurants, soft drink producers and truck wash wastes. The treatment system comprised of the following unit processes :

1. Oil and grease separation
2. Chemical flocculation
3. Clarification
4. Sludge dewatering.

It is emphasized that such facilities need to be properly designed and regulated to ensure :

- that nonsewerable wastes are properly treated to remove the prohibited material

- that residual products are recycled or properly disposed off

- that protection against acceptance of hazardous wastes is adequate, and

- that regulatory requirements and effluent discharge limits are met to prevent problems in the sewerage system (69).

In a major mid-western community, ten companies - two pulp and paper mills, six paper mills, one milk processing plant and one foundry contribute 65% of the wastewater flow, 75% of the BOD load and 82% of the total suspended solids load to the joint treatment facility. The existing waste treatment plant consists of a conventional wastewater flow scheme involving primary settling, conventional activated sludge process and final settling. Sludge handling and disposal consists of dissolved air floatation, thickening of waste activated sludge, vacuum filtration of primary and secondary sludges and incineration of dewatered sludge.

The treatability studies carried out on combined waste indicated that about 40-50% of the BOD could be removed by absorption and bioflocculation by just admixing the raw waste with the acclimated biological sludge. Based upon these results, a contact stabilization process appeared to be the most appropriate activated sludge system for use with these wastewaters. There was an additional advantage in utilizing this process since it would eliminate the need for primary clarifiers, because of the colloidal and suspended BOD and solids would be absorbed, bioflocculated and entrapped in the activated sludge and subsequently stabilized and/or removed with the waste sludge.

In order to confirm the preliminary results of the batch activated sludge tests, continuous flow pilot plant studies were undertaken. The pilot plant data clearly showed that the contact stabilization process not only achieved better BOD removals in a shorter residence time at higher loading rates, but also produced a better settling sludge with less bulking characteristics. The process showed more than 90% BOD removal at loading of 0.3 lb BOD/lbMLSS/day. At the design loading of 0.2 lbBOD/lbMLSS/day, the BOD removal was more than 95% (70).

The Wazirpur industrial area is one of the planned industrial areas developed by the Delhi Development Authority. It is situated in the North-West of Delhi, surrounded by the residential localities of Ashok Vihar, Shalimarbagh and Azadpur.

Even though, in the masterplan, this area was principally earmarked for the growth of hosiery and allied products, other categories like rolling and pickling, electroplating, textile and other miscellaneous products like chemicals, soap and engineering are also found. An inventory of industries in the area carried out in 1984 revealed that out of about 1000 registered units, only 348 industries are relevent to water pollution and these can be classified into five categories, viz.

1.	Rolling & pickling	152
2.	Textile	56
3.	Electroplating and anodising	40
4.	Soap	16
5.	Miscellaneous (rubber plastic, candle, engineering)	84
	Total	348

The average flow of the combined wastewater from the area was 10400 m^3/day. The wastewater was having variable pH from acidic to near neutral pH range and was low in organic content, as indicated by BOD. The waste was toxic in nature and was high in heavy metal concentrations and suspended solids. Hence, the treatability studies were restricted to physico-chemical treatment. The results showed that most of the heavy metals could be removed from the pre-settled waste, at pH around 9.0 provided there was a good mixing of lime with waste, sufficient velocity shear gradient to form flocs and efficient clarifier for clarification of wastewater.

Based on the treatability studies, following treatment scheme was developed :

The combined wastewaters will be treated by addition of lime to increase the pH to about 9.0. At this pH, all the heavy metals are expected to be precipitated out of wastewaters and the clarified effluent is expected to meet the quality requirements of the CPCB. The proposed treatment scheme consists of equalisation basin (8 hour detention time), chemical dosing, flash mixer and clariflocculator. The treated effluent will be discharged into stormwater drains while the sludge will be conveyed to sludge lagoons. The cost of the proposed treatment plant was estimated in 1985 as Rs.80 lacs approximately. The cost of the treatment was to be shared equally by the Directorate of Industries and the industries in the area depending on their quantity and quality of effluent discharged (71).

5

Financial Apportionment Available Methods

There is general support throughout the world for the "Polluter Pays Principle" i.e. the industry must pay the cost of disposing of waste in an environmentally acceptable manner.

It, therefore, follows that the cost of operating a CETP must be borne by the industry which the CETP serves. This is also generally accepted, with the word of caution from especially the industry itself, that increased production costs can adversely affect competitiveness, especially when a large proportion of the waste producing industry relies heavily on the export market.

Even though the "Polluter Pays Principle" is accepted as the desired model, there is a strong argument for outside support due to the competition from other industries not required to comply with these new demands, and the social and environmental benefits obtained by operating combined treatment systems.

A CETP does not produce products of saleable value. Even if sludges and possibly the final effluent could be utilized, it would only result in the reduction of total expenses. Therefore, for a CETP to operate with a profit, or just to obtain a 'no-profit - no-loss' situation, it must obtain revenue from either levying of fees upon the industries delivering waste to the plant, outside assistance in the form of grants, low interest loans, tax benefits, etc. or a combination of these.

Even though it is accepted that standards of environmental pollution control also improve in countries competing with Indian exports, there is a strong opinion that some form of subsidy to the industry or to the owner of the CETP should be considered in order to ensure viability of the CETP and the competitiveness of the industries utilizing its capacity. At least this should be the case for the pioneering units now being discussed in India.

It is obvious that no single yardstick can be fixed for controlling pollution from the industrial estates under consideration and a thought should be given to the various alternatives available in terms of many interdependent factors such as drainage system nature and composition of effluents, degree of treatment to which the effluent must be subjected to, mode of disposal of treated effluent and also cost of waste treatment. Based on these factors, the promoting agency may have to develope a suitable financial apportionment method with a view to realise the capital and recurring expenditure incurred in constructing waste collection, treatment and disposal systems (71).

5.1 EQUITABLE SHARING OF THE FINANCIAL BURDEN - A PRIME REQUIREMENT

Equitable sharing should be the main objective while developing a financial apportionment methods. The direct as well as indirect benefits derived by CETP should be proportionately distributed to the member industrial units. Though this is practically very difficult, attempts have to be made towards achieving this condition. No industry should be benefited at the cost of other industry as far as financial apportionment is considered.

Equitable sharing can successfully be carried out if there is sufficient competition in the market to prevent the charge from being posed on to the consumer and the level of charge is equivalent to the level of damage or atleast to the cost of treatment. In implementing these charges, it is necessary to ensure that they are not merely taken as a license to pollute. An important aspect of effluent charges is that these encourage the industry to look at pollution as basically an economic problem. Insignificant as it may seem, there is a vast psychological difference between introducing a charge on effluents and applying a standard (72).

Number of formulations are now available to device sharing of financial burden but probably none is the ideal method ensuring 100 percent equitable or proportionate sharing. The methods available for cost-sharing are described in subsequent sections.

It is to be kept in mind that generally the methods of arriving at a figure of cost-share range from the very simple to the highly complex. The simplest involves some inequities. The more complex method eliminate some of these inequities at the sacrifice of simplicity and ease of administration. Therefore, there is no ideal method. In practice, a compromise is reached where little sacrifice is made in both.

5.2 QUANTITY METHOD

This is the simplest method and applicable for joint treatment of sewage and low strength industrial wastes. The total cost for debt service and costs of operation of the sewage treatment plant is divided by the total cubic meter of wastes handled to obtain a service charge in terms of cost per 1000 m^3 based upon volume alone. In areas having no industries, the wastes are generally uniform in composition so this approach is acceptable. In highly industrialised areas, however, the user with dilute wastes ends up subsidizing the user with wastes of high BOD and suspended solids contents and this is certainly not a fair or equitable method of obtaining of revenues (9).

5.3 QUANTITY-QUALITY METHOD

In this method, both the quality or concentration of the wastes in terms of BOD and suspended solids as well as the volume is considered in computing the sewer tax. An attempt is made in this method to levy charges proportioned to the use of and benefits received from the sewage treatment plant. This is in contrast to an ad valorem tax on property to finance sewage treatment works wherein the tax is merely based upon the ability to pay.

Table 5.1 lists each components of the sewage treatment plant with the annual operating costs of the component. These total annual costs are then apportioned to the three design parameters of a sewage treatment plant. For example, note that the operating costs of the interceptor sewers and pumping stations are Rs. 5.0 lacs and 1.6 lacs per year respectively. Since sewers and pumping stations are designed on the basis of volume alone and essentially their maintenance is a function of volume, these two costs are apportioned to volume of flow handled. Therefore these two figures of Rs. 5.0 lacs and 1.6 lacs are charged to volume alone. On the other hand, a primary settling tank not only handles the total volume of flow but also collects the settleable solids and floating solids which are pumped to the digester. Therefore, Rs. 1.2 lacs per year operating cost is equally charged to suspended solids and volume. The same reasoning is carried through for the remaining components of the treatment plant as indicated by Table 5.1.

The fixed annual costs are shown on Table 5.2 for each component of the sewage treatment plant. Again the same reasoning is used to assign the costs to the three pollution parameters.

Table 5.3 summarizes and totals Tables 5.1 and 5.2. of the total annual costs of Rs. 32.3 lacs to operate the sewage treatment plant under consideration, Rs. 19.25 lacs can be charged to volume, Rs. 6.75 lacs to suspended solids, and Rs. 6.30 lacs to BOD. This particular plant handles, say, three MGD of wastes containing 300 mg/L suspended solids, and 350 mg/L BOD. Table 5.4 shows the final step in calculating the actual unit costs in terms of Rs. per 1000 m^3, per kg suspended solids and per kg of BOD.

Normally, the average domestic and commercial user is assumed to have so-called "normal" sewage and will be charged a flat rate based upon volume which in turn is merely derived from the water bill (See Table 5.5 for example). Table 5.6 indicates the derivation of flat rate volume method (quantity method) or quantity metered wherein the charges are based upon volume alone.

Basically, this "Quality-Quantity" (Q-Q) method of financing is the ideal way of calculating the charges. However, there are certain inequities involving perhaps a philosophical discussion rather than a technical or financial approach.

The sewage treatment plant in this sample problem is handling three MGD of wastes, and all the costs of the plant, both fixed and operating, are charged to treating this three MGD of wastes. However, the plant may be designed with excess capacity for future growth. Let's assume for a moment that the municipal sewage treatment plant is designed for six MGD of wastes at 300 and 350 mg/L of suspended solids and BOD respectively for future growth of the community. All the fixed costs of the sewage plant are dependent on the size of the plant alone and not upon the quantity of wastes which the sewage treatment plant is receiving. Therefore, the donors of three MGD of wastes are paying at least in part for six MGD of wastes, a future sum. This excess capacity benefits the entire community, particularly undeveloped property. In one sense, then, the present users are paying for the amortization of capacity designed for future users and undeveloped properties.

Table : 5.1

Apportioning of Operating Costs of a Sewage Treatment Plant to Volume, Suspended Solids and BOD

Components	Annual Operating Costs Rs. in lacs	Volume		Suspended Solids		BOD	
		Percent	Rs. in lacs	Percent	Rs. in lacs	Percent	Rs. in lacs
Interceptor Sewers	5.00	100	5.00	-	-	-	-
Pumping Stations	1.60	100	1.60	-	—	-	-
Sedimentation	1.20	50	0.60	50	0.60	-	-
Trickling Filters	2.00	10	0.20	-	-	90	1.80
Sludge Digestion	4.00	-		100	4.00	-	-
TOTAL Rs. lacs	13.80	53.6%	7.40	33.4%	4.60	13%	1.80

Table : 5.2

Apportioning Fixed Costs to Volume Suspended Solids and BOD,

Component	First Costs Rs. in lacs	Annual Fixed (5%) debt Retirement	Volume		Suspended Solids		BOD	
			Percent	Rs. in lacs	Percent	Rs. in lacs	Percent	Rs. in lacs
Interceptor Sewers	200.00	10.00	100	10.00	-	-	-	-
Pumping Stations	10.00	0.50	100	0.50	-	-	-	-
Sedimentation	20.00	1.00	85	0.85	15	0.15	-	-
Trickling Filters	100.00	5.00	10	0.50	-	-	90	4.50
Sludge Digestion	40 00	2.00	-	-	100	2 00	-	-
Total Fixed Costs	370.00	18.50	64.1%	11.85	11.6%	2.15	24.3%	4 50

Table : 5.3

Total Annual Costs - Operating Plus Fixed Costs for Volume, Suspended Solids and BOD

	Volume	Suspended Solids	BOD	Total
Operating Costs Rs. in lacs (from Table 5.1)	7.40	4.60	1.80	13.80
Fixed Costs Rs. in lacs (from Table 5.2)	11.85	2.15	4.50	18.50
TOTAL COST , Rs. in lacs	19 25	6.75	6.30	32.30

Table : 5.4

Unit Costs for Sewage Treatment Based on Volume, Suspended Solids and BOD

Design Parameter	Design Basis of Plant	Design Basis in Terms of Annual Quantities	Unit Costs Total Costs/ Total Quantities
Volume	3 MGD	1095 MG/yr	Rs. 1925000/1095 MG = Rs. 1758/MG = Rs. 465/1000 m^3
Suspended Solids	300 mg/L	1240000 kg/yr	Rs. 675000/yr / 1240000 kg/yr = Rs. 0.544/kgSS
BOD	350 mg/L	1453000 kg/yr	Rs. 630000/yr / 1453000 kg/yr = Rs. 0.434/kgBOD

Table : 5.5

Unit Charge for 'Normal' Sewage Based on Water Bill

For billing small users, charges can be made on the basis of cost per 1000 m^3 assuming "normal" sewage as discharged by the small user contains 200 mg/L BOD and 250 mg/L Suspended Solids

1000 m^3 x 0.2 kg/m^3BOD x Rs. 0.434/kgBOD	= Rs. 87
1000 m^3 x 0.25 kg/m^3SS x Rs. 0.544/kgSS	= Rs. 136
Volume Cost from Table 5.4, Rs./1000 m^3	= Rs. 465
Total Cost per 1000 m^3 "normal" sewage	= Rs. 688

Table : 5.6

Flat Rate Method - Charges Based upon Volume Alone

Total Cost to Operate Plant (Table 5.3)		= Rs. 32.3 lacs/yr
Total Volume Influent to Plant (Table 5.4)		= 1,095 MG/yr
$\frac{\text{Rs. } 32,30,000/\text{yr}}{1,095 \text{ MG/yr}}$	= Rs. 2950/MG	= Rs. 780/1000 m^3

This fact has led many authorities to favour the method of levying surcharges (discussed in section 5.10) in which users and other property owners alike pay charges proportional to the benefits received.

This method is in reality, an extension of the Quantity-Quality Method. Part of the revenues are obtained by charges based upon BOD, Suspended Solids, and Volume of wastes discharged to the sewer. The remaining money can be obtained by ad valorem tax on users, non-users, and undeveloped properties alike. All benefits from the existence of a sewage treatment plant. Access to sewers enhance the value of undeveloped property.

This method is certainly the most equitable method developed to date. It is also the most complex of the systems of sewer charges to administer (9).

5.4 MALZ FORMULATION

'Polluter Pays' principle provides an acceptable measure for pollution control if a rational and simple method could be established to estimate the cost of fulfilling the legal obligations of each member polluter industry in the CETP scheme. A procedure based on the volume and degree of noxiousness of wastewater contributed to the system for an equitable distribution of annualised financial burden has been developed by Malz (73) and is used in USA.

Since the combined treatment is mostly biological in nature, wastewater dilution factor, V to ensure survival of fish (48 hours exposure) is expressed as,

$$V = \frac{A}{A_o} + \frac{B}{B_o} + \frac{TDS}{TDS_o} + F - 1$$

where,

A	=	Sedimentable matter, mg/L
B	=	COD of settled sample, mg/L
TDS	=	Total dissolved solids, mg/L
F	=	Fish toxicity

A_o, B_o & TDS_o = Compared with effluent discharge standards set by local governing body

Noxiousness degree, S, is then estimated from dilution factor, V, expressed in appropriate slabs rather than in discrete numbers to account for deviation in sampling and analysis of wastewater.

Dilution Value (V) and Noxiousness Degree (S)

V	S
1 - 2	1
3 - 4	2
4 - 6	3
6 - 7	4

Annualised cost apportioned to each polluter is calculated as follows:

$$\text{Cost Share} = \frac{S.\ Q\ Z}{\Sigma\ (S.\ Q)}$$

where,

Q	=	Annual flow of an individual industry
Z	=	Total financial burden on collection & treatment

The formula for calculating dilution factor, V and slabs for determining degree of noxiousness, S can be changed appropriately to suit the specific case. Cheda et al (66) have modified the formula to use it for a cluster of tanneries in U.P. as follows:

$$V = \left[\frac{A}{A_0} + \frac{1}{2} \left[\frac{B}{B_o} + \frac{C}{C_o} \right] + F \right] - 1$$

where,

A = Settleable matter in wastewater, mg/L

B = BOD of settled wastewater, mg/L
C = COD of settled wastewater, mg/L
F = Fish toxicity factor

A_o, B_o, C_o = Effluent discharge standards set by U.P. Pollution Control Board for settleable matter, BOD and COD respectively, mg/L

Noxiousness degree, S was determined from the following slabs of dilution factor, V values :

V	1-4	5-8	9-12	13-16	17-20	21-28	29-36
S	1	2	3	4	5	6	7

Annualised cost apportioned was calculated as :

Annual apportionment = S x annual flow x total annualised cost of joint wastewater collection and treatment system per unit flow.

5.5 ROMAN FORMULATION

Participation in costs of a CETP should be conductive to the application of larger treatment plants in place of many small ones which in total, are always more expensive. Roman (74) proposed the following formula, which is widely used in Poland, to calculate the share of each industrial plant participating in the costs of a CETP :

$$I_u = \frac{Q_u}{Q} [I_o(1 + \left(\frac{S_u - S}{S}\right) . e) + I_d]$$

where,

I_u - Amount expressing share of the participating industrial plant

Q_u - Average daily effluent flow from the given industrial plant discharged to the CETP, in m^3/day

Q - Average daily effluent flow from all industrial plants discharged to the CETP, in m^3/day

I_o - Construction costs of the CETP

I_d - Construction costs of all additional facilities used for transport of effluents to the CETP, expressed as BOD_5 in kg O_2/m^3

Su - Average strength of an effluent of the given industrial plant, expressed as BOD_5, in kg O_2/m^3

S - Average strength of the mixture of all effluent discharged to the CETP, expressed as BOD_5, in kg O_2/m^3

e - Costs of treatment plant units depending on the pollution load to construction costs of the whole treatment plant

This formula is based on the following assumptions :

- The share in costs of building of a CETP should correspond to the amount and strength of discharged effluent

- The costs of facilities for transport of effluent to the CETP should be covered by all users of the plant proportionally to the amount of their effluents, but irrespective of distance of transport.

The second assumption creates a kind of reduced rate for participants situated at a greater distance from the common treatment plant and promotes enlargement of its territorial reach.

The amount of penalties for transgression of requirements for effluent discharge depends - according to the regulation being obligatory in Poland - on the pollution load contained in the discharged effluent above the admissible limit and on the type of polluting matter.

Some examples of the amount of fines to be paid by the 'guilty' industry in Poland are given below :

for 1 kg BOD_5	3	zloty
for 1 kg dissolved substances	3	"
for 1 kg suspended solids	3	"
for 1 kg fat	3	"
for 1 kg COD	2	"
for 1 kg heavy metals	50	"
for 1 kg phosphate (PO_4)	2	"
for 1 kg volatile phenols	10	"

The levels of the penalties were established in such a way that they are higher than the costs of removal of polluting matter in an effluent treatment plant (e.g. the cost of removal of 1 kg BOD^5 in a treatment plant ranges from 1.5 to 2.5 zloty whereas the penalty would be 3 zloty). Beside the fines for the amount of polluting matter paid by the industrial plant, Polish legislation provides also sentences of persons responsible for pollution of water. Penalties and imprisonment are applied depending on the size of damage caused by pollution.

Roman concluded that the economic aspects of water protection against pollution presented above should never be considered as the main factor influencing economic decisions in this field. They should always be regarded as one of many factors to be taken into account when making the decisions. Above all, the economic characteristic of solutions should only serve for determining that solutions which is most close to the optimum in relation to costs, because the necessity of water protection results mainly from conditions beyond economics, such as environmental protection and a healthy water supply for people.

While developing the above mentioned formulation, Roman deduced certain important conclusions as described below :

In general, it is convenient to apply unit investment costs defined as the quotient of the sum of investment costs of a treatment plant and of its capacity :

$$i = \frac{J}{Q} \text{ (cost } m^3\text{/day)}$$

where,

J - Investment costs of a given plant
Q - Average 24 hours amount of purified effluent, m^3/day

The sum of the unit investment costs is affected by various factors, the most important of which are :

- the size of the treatment plant expressed, for instance, as amount of effluent treated

- the concentration of polluting matter in effluent and other properties of effluent affecting the technological scheme of a treatment plant and admissible loading of its devices

- the required effect of the treatment plant.

In Fig. 5.1, an example of the relationship between unit investment costs and capacity of effluent treatment plants is presented. The relation reveals that large treatment plants are more economical than small ones, which is in conformity with the general rule of building: the economical effectiveness of investment projects increases with their size. From this fact, the following practical conclusions may be drawn :

- The use of a CETP working for several factories situated in the neighbourhood seems to be advantageous
- Discharge of effluents from individual producers to a main municipal treatment plant seems to be reasonable
- It is necessary to search for more economical solutions for small treatment plants, which cannot be, however, miniatures of the traditional systems in big treatment plants, but should be based on special solutions adjusted to the specific technical and economic character of purification of small amounts of effluent.

The influence of wastewater strength on the amount of investment costs is presented in Fig. 5.2. These data concern municipal effluent treatment plants. As may be seen, in such a case, the investment costs grow linearly with the increase of effluent strength. The growth of costs is marked, but relatively small, as a 5-fold increase effluent strength correspond only to a 1.7 - fold increase of investment costs. On this basis it can be concluded that from the economic point of view, it may be reasonable to strive at lowering the amount of effluent even in such a case, when it is accompanied by an increase of strength in reverse proportion to the amount of effluent. This statement, however, in case of specific industrial wastewater may sometimes not be true.

Fig. 5.3 shows the influence of the effluent purification degree on the amount of investment costs. A characteristic feature is the rapid change in growth of costs with the increase of purification effect. A particularly rapid increase of investment costs appears with the rise of the purification effect in the range above 90% (74).

5.6 MOGDEN FORMULATION

This formulation is derived on the principle of payment on the basis of cost incurred by the equivalent sized sewage treatment plant in comparison with the CETP. This formula is extensively used in Germany, U.K. and other countries. The formula is as follows (75) :

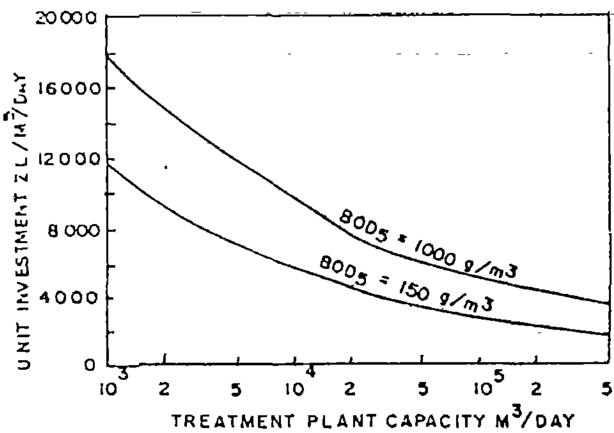


FIG. 5.1 :

DEPENDENCE OF UNIT INVESTMENT COSTS OF MECHANICAL - BIOLOGICAL EFFLUENT TREATMENT PLANTS ON THE CAPACITY OF THE PLANTS (TREATMENT EFFECT - DECREASE OF BOD_5 - 92.5%)

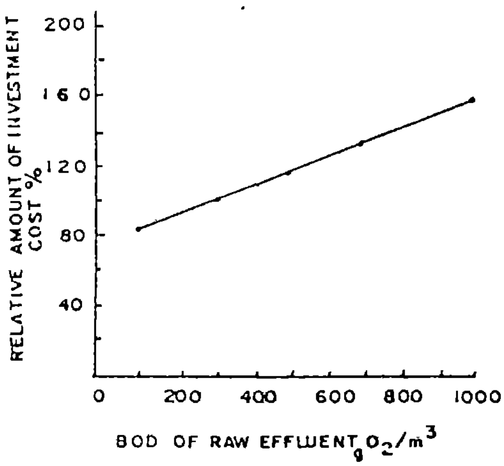


FIG. 5.2 :

EFFECT OF STRENGTH OF RAW EFFLUENT ON THE INVESTMENT COSTS OF EFFLUENT TREATMENT PANTS (TREATMENT EFFECT 92.5%)

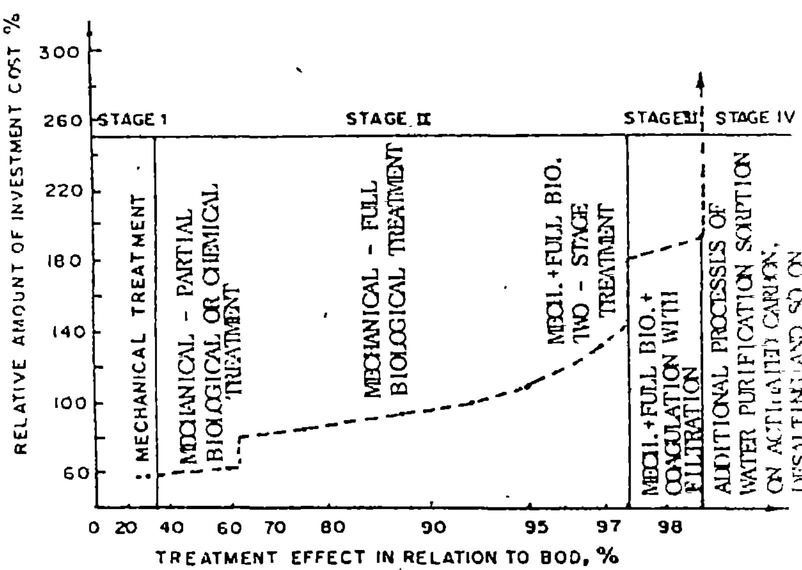


FIG. 5.3 :

DEPENDENCE OF INVESTMENT COSTS OF EFFLUENT TREATMENT PLANT ON THE TREATMENT EFFECT

$$C = V + \left(\frac{O_t}{O_s}\right) B + \left(\frac{S_t}{S_e}\right) S + \left(\frac{TDS_t}{TDS_s}\right) t$$

where,

C	=	total cost/m^3 of effluent
V	=	cost/m^3 which relate solely to volume
B	=	cost/m^3 which relate solely to bio-oxidation of settled sewage
S	=	cost/m^3 which relate to suspended solids removal
t	=	cost/m^3 which relate to total dissolved solids removal
O_t	=	oxygen demand of settled trade effluent
O_s	=	oxygen demand of settled sewage
S_t	=	suspended solids content of trade effluent
S_e	=	suspended solids content of raw sewage
TDS_t	=	total dissolved solid concentration of trade effluent
TDS_s	=	total dissolved solid concentration of raw sewage

5.7 MODIFIED MOGDEN FORMULA

$$C = R + V + \left(\frac{O_t}{O_s}\right) B + \left(\frac{S_t}{S_s}\right) S$$

where

C	=	total charge per m^3 of industrial effluent
R	=	reception and conveyance charge per m^3
V	=	volumetric and primary treatment cost per m^3
O_t	=	COD (in mg/L) of the industrial effluent after 1 hr quiscent settlement at a pH of 7.0
O_s	=	COD (in mg/L) of settled sewage
B	=	biological oxidation cost per m^3 of settled sewage
S_t	=	total SS in mg/L of the trade effluent at pH 7.0
S_s	=	total SS in mg/L of crude sewage
S	=	treatment and disposal of primary sludges per m^3 of sewage

R, V, O_s, B, S_s and S are assessed annually on a regional basis (75). It can be seen that no direct charge for the oxidation of ammonia is made although the unit charge B for biological oxidation does, of course, include an element for the cost of nitrification at those partially or fully nitrifying sewage works included in the regional average.

In contrast, the biological charge in the original Mogden formula was calculated on the basis of McGlowan Strength (76) which takes into account the nitrogen content of the industrial effluent and sewage. Problems may arise in using modified Mogden formula as a basis for equitable charging for the treatment employing activated sludge process for nitrification of wastes which are high in ammonical nitrogen concentration and low in carbonaceous BOD. In such cases, the biological treatment costs incurred may greatly exceed the charges levied (77).

5.8 FUKASHIBA CETP FORMULATION

At Fukashiba industrial wastewater treatment plant in Japan, catering Kashima Petrochemical Complex consisting of 19 core industries and 39 other factories, a specific methodology is adopted for sharing the cost burden. The quantity and quality of the wastewaters reported by the factories are called the 'approved wastewater quantity' and the 'approved wastewater quality'. Each factory has its own values for the approved wastewater quantity and quality but it may discharge less wastewater than the approved quantity and the quality may be better than the approved quality. Each factory has only one discharging outlet to the sewerage system where wastewater quantity and quality are monitored. The charges for industrial wastewater consist of a quantity rate and a quality rate (the quantity rate as reported in 1988 was 32 yen/m^3 of wastewater discharged). The quality rate is determined using the following expressions :

$$F = (B + C)/2 + S + 6N$$

where,

B = BOD_5 concentration, mg/L
C = COD concentration, mg/L
S = suspended solids concentration, mg/L
N = concentration of the N-hexane extracts, mg/L

When the F value is less than 120 mg/L, the quality rate is 10 yen/m^3 of wastewater discharged; when the F value exceeds 120 but is less than 240, the quality rate is 30 yen/m^3, when the F value exceeds 240 but is less than 360, the quality rate is 40 yen/m^3. Thus, the quality rate increases 10 yen/m^3 for the increase in F value of 120. F values are determined based on analysis of the samples taken manually by the chemists of the Fukashiba treatment plant. The number of sampling times is determined based upon the 'F load' which is the F value multiplied by the quantity of wastewater discharged daily. When the F load of a factory exceeds 500 kg/day, the factory is classified as 'A' and wastewater is sampled 5 times per month. When the F load exceeds 100 but is less than 500, the factory is classified as 'B' and the wastewater is sampled twice per month. When the F load exceeds 5 but is less than 100, the factory is classified as 'C' and the wastewater is sampled once a month. When the F load is less than 5, the factory is classified as 'D' and sampling is done once a year. Thus, the Kashima sewarage works and the Fukashiba wastewater treatment plant are independently operated based on the charging system (12).

5.9 BOROUGH OF GLOSSOP STP FORMULATION

The sewage treatment plant serving Borough of Glossop and Textile mill operating for 5 days in a week preferred to charge capital and running costs separately.

Running costs are charged on a modified 'Mogden' formula, whereas the charging formula for normal industrial effluents is based on the 'Mogden' formula.

The schedule of capital charges for weekday effluents is given in Table 5.7 (22).

Table : 5.7

Apportionment of Capital Costs

Description	Cost (£)	Textile Effluent Proportion	
		Percent	Cost (£)
Effluent pipeline	33,347	100	33,341
Pumping station	14,111	-	-
Inlet works	5,663	-	-
Sedimentation tanks	56,030	-	-
Filters	133,280	57	75,970
Humus tanks	55,053	38	20,920
Recirculation pumping station	24,092	2.4	579
Pressing plant	142,111	9	12,790
Miscellaneous	39,576	-	-
Sub-total	503,263	28.5	143,600
Contingencies, etc.	94,878	28.5	27,040
Administrative costs	41,900	28.5	11,940
Total	640,041		182,580

Two formulae are in operation for financial apportionment :

i) To recover running costs associated with the weekday effluent

$$C = V + P\left(\frac{BOD_t - 125}{125}\right) + O\left(\frac{BOD_t}{BOD_{ss}}\right) + S\left(\frac{C\%\ BOD_t}{SS_{ms}}\right) + AK$$

where,

C	=	cost of treatment per m^3
V	=	capital and running costs of the inlet works and sedimentation tanks (when used)
P	=	running costs of the recirculation pumping station (In the event of the V units above being used, the capital costs of this station are to be included in P)
O	=	running costs of biological filters and humus tanks
S	=	running costs of the sludge processing plant
A	=	administration and laboratory costs
K	=	a utilization factor, initially unity, to be reviewed by each party at regular intervals
BOD_t	=	average BOD of industrial effluent in mg/L
BOD_{ss}	=	average BOD of the mixed settled sewage and industrial effluent in mg/L
SS_{ms}	=	average SS of the mixed settled sewage and industrial effluent in mg/L
C%	=	a factor for the conversion ratio of BOD to secondary sludge. Initially 40 percent, but to be reviewed annually in the light of treatment records

ii) To recover capital and running costs associated with the weekend effluent (normal industrial effluent charging formula)

$$C = V + O\left(\frac{COD_{te}}{COD_{ss}}\right) + S\left(\frac{SS_{te}}{SS_{cs}}\right)$$

where,

C	=	cost of treatment per m^3
V	=	capital and operating costs of all volumetric units
O	=	capital and running costs of all oxidation units
S	=	capital and running costs of all sludge units
COD_{ie}	=	COD of industrial effluent in mg/L
COD_{ss}	=	COD of the settled sewage in mg/L
SS_{ie}	=	suspended solids in industrial effluent in mg/L
SS_{cs}	=	suspended solids in crude sewage in mg/L

5.10 SANITATION DISTRICTS SURCHARGE FORMULA

The Sanitation Districts in Los Angeles county, USA consist of 27 individual Districts. 15 of these Districts are joined together into the joint outfall system providing a common sewerage system for approximately 750 square miles of area and 8000 industrial companies. The Sanitation Districts provide and operate wastewater treatment facilities and trunk sewers. The largest treatment facility, the Joint Water Pollution Control Plant, provides primary treatment for about 350 MGD of wastewater and is planned for conversion to secondary treatment capabilities in the near future.

The Sanitation District's main source of revenue has been ad valorem (property) taxes on land, improvements and certain personal property within the District's boundaries. Each individual Sanitation District establishes an ad valorem tax rate sufficient to pay for capital improvements, and for operation and maintenance costs of sewerage facilities needed for wastewaters generated within the District.

Beginning in 1966, the Sanitation Districts began to investigate alternate sources of revenue. Federal and State grant funds for construction of sewerage facilities were first received by the Sanitation Districts at this time. The Districts investigated user charges requiring industrial companies to reimburse the Districts for the costs of industrial wastewater treatment and disposal.

It was observed that the Districts were not receiving payments from industrial wastewater discharges proportional to the costs of providing sewerage service.

In addition to obtaining supplementary revenue from industrial companies, the Districts at that time needed to obtain more information about industrial companies and to establish regulatory authority over industrial dischargers. Due to these needs, the Districts adopted an industrial waste ordinance in 1972 which provided for an industrial wastewater treatment user charge programme.

Accordingly, the Sanitation Districts established a quantity-quality surcharge structure making use of the charge parameters of total wastewater flow, COD, suspended solids and peak flow. The Sanitation Districts industrial wastewater surcharge formula is as follows :

Surcharge = a(V) + b (COD) + c (SS) + dM (P) - TAX

where,

Surcharge	=	net annual industrial wastewater treatment surcharge in dollars. No refund is made if a negative number results
V	=	total annual volume of flow, MG
COD	=	total annual discharge of COD in 1000 lbs
SS	=	total annual discharge of SS in 1000 lbs
P	=	peak discharge rate over a 30 min. period, occuring between the hours of 8.00 a.m. and 10.00 p.m.
A	=	average discharge rate, determined by dividing 'V' by the total annual hours of operation or working time for the industrial discharger, converted to GPM (see M)
a, b, c, d	=	unit charge rates adopted annually by the individual District based upon the projected annual total costs for wastewater collection, treatment and disposal, in dollars per unit
M	=	a multiplying factor accounting for increased District's costs due to high ratios of industrial discharge peak to average flow rates (P/A). Factor 'M' is obtained from the formula M = 2.50 log (P/A).
Tax	=	the annual ad valorem taxes paid to the Districts during the accrual year on the land or property utilized for the generation of industrial wastewater in dollars.

For the first three years of surcharge programme, the Districts endeavoured to recapture the full industrial share of capital (exclusive of Federal grant funds) and O&M costs. For these years, the total capital outlay for construction of sewerage facilities over the future five fiscal years was estimated and distributed to the three parameters of total wastewater flow, COD and SS. The distribution was in accordance with the percentage of the total existing capital facilities of the sewerage system predominently related to each parameter. For example, sludge digester costs are primarily related to the suspended solids parameter while activated sludge aeration tanks are primarily related to the COD parameter. The total O&M costs were estimated for the future five fiscal years and distributed among the three surcharge parameters.

The sum of the capital and O&M costs determined for the parameters of total flow, COD and suspended solids were divided by the projected five year total volume of wastewater and the total weight of COD and suspended solids to be treated by the sewerage system, in order to obtain the unit charge rates 'a', 'b' and 'c'. Table 5.8 gives the surcharge rates used for the two fiscal years 1972-73 and 1973-74.

Table : 5.8

Industrial Wastewater Treatment Surcharge Rates in USA

Unit Rate	Parameter	Surcharge Rates (in $)	
		1972-73	1973-74
a	Volume, MG/year	83.25	104.00
b	COD, 1000 lbs/year	4.75	6.25
c	SS, 1000 lbs/year	11.00	14.25
d	Peak Flow, GPM	22.00	18.75
Flat Rate Charge	Volume, MG/year	181.00	230.00

In the latest revisions to the Districts ordinance, the total annual capital costs are now calculated as 1/30 of the total capital investment in the sewerage system during the 30-year period prior to the accrual fiscal year. The O&M costs used are those estimated for the next future fiscal year. The sum of these capital and O&M costs is distributed to flow, COD and suspended solids parameters as indicated above.

A peak flow charge was established to develop revenue from companies who make periodic short term demands upon the sewerage system that are not reflected in the annual charges for flow, COD and SS and to encourage companies to discharge their wastewaters during the periods of low flow within the District's system. The companies are not charged for peak flow discharged between the hours of 10.00 p.m. and 8 00 a m. Industrial companies having yearly wastewater flows of 6 MG or less are permitted to file a surcharge statement using a flat rate charge equal to the charge for 'typical' industrial wastewater.

The companies with flow rates reaching a maximum of over 100 GPM or an average over 50000 GPD must provide a continuous measurement and recording of the wastewater flow. Palmer-Bowlus flumes are used for flow-measurements as they offer several advantages over weirs and Parshall flumes in open channel measurements (78,79).

5.11 CHEMTECH FORMULATION

The formulation developed by Chemtech Consultants (80) is based on the proportion of the CETP usage. A fair distribution of cost for a CETP would be that where industries pay according to the load which they impose on the CETP. This load comprises not only the volumetric flow but also include the influence that chemical, physical and biological conditions of the waste have on capital and operational cost of the CETP.

The formulation is as given below :

$$CC(i) = \frac{Q(i)}{Q(T)} \times CC(Q) + \left[0.5 \times \frac{B(i)}{B(T)} + 0.5 \times \frac{C(i)}{C(T)}\right] \times CC(B) = a \times CC(A)$$

where,

CC(i) = capital cost contribution by the ith industry in Rs
Q(i) = wastewater flow produced by the ith industry in m^3/d
Q(T) = total wastewater flow to the CETP in m^3/d
CC(Q) = the flow dependant cost of the CETP in Rs.
B(i) = the BOD load of effluent from the ith industry in kg/d
B(T) = the BOD capacity of the CETP in kg/d
C(i) = the COD load of effluent from the ith industry in kg/d
C(T) = the COD capacity of the CETP in kg/d
CC(B) = the BOD and COD capacity dependant cost in Rs of the CETP in Rs
CC(A) = the cost of common facilities for the CETP in Rs
a = the factor that is a function of the ith industry's design flow

Cost of neutralisation has not been included in the formula as this operation must be a part of the individual industry's pretreatment.

Rather than complicating this formula to adjust for a connection fee, it is recommended that this be kept as a separate item to be charged according to actual cost of labour and materials at the time of connection, distance from collection system, size of piping and existing conditions at the site.

For the recovery of operating and maintenance cost, the following formula has been suggested :

$$CM(i) = \frac{Q(i)}{Q(T)} \times CM(T) \times PF(i)$$

where,

CM(i) = operation and maintenance cost of the ith industry in Rs.
CM(T) = total operation and maintenance cost in Rs.
PF(i) = the pollution factor for the ith industry, defined as follows :

$$PF(i) = 0.5 \times \frac{BOD(i) + 200}{600} + 0.5 \times \frac{COD(i) + 500}{1500}$$

If BOD(i) and/or COD(i) values result in $PF(i) < 1$, then $PF(i) = 1$.

The cost for capital recovery and operation and maintenance is expressed as the combined figure in the calculations made for each industrial estate under the different grant schemes and plant capacities. It is, therefore, convenient to do the same for the individual industry's contribution which will allow the CETP operator to recover all costs, or in case of a private operator, all costs plus a profit.

Since both the capital and operating costs to a very large extent are dependant on only volumetric throughput and level of organic pollution, and since the proportion between these two parameters remain reasonably constant for most of the type of design generally considered, it is possible to combine the above formulas to a single payment schedule which can be used at each estate and is as follows :

$$CO(i) = \frac{Q(i)}{Q(T)} \times PF(i) \times CO(T) + A$$

where,

CO(i) = total annual contribution by the ith industry in Rs.
CO(T) = total annual income required by the CETP operator in Rs.
A = a minimum contribution by each industry

$$PF(i) = 0.5 \times \frac{BOD(i) + 200}{600} + 0.5 \frac{COD(i) + 500}{1500}, \text{ for } PF(i) > 1.0$$

$$PF(i) = 1.0, \text{ for } PF(i) < 1.0.$$

5.12 GRADUATED PAYMENTS FORMULATION

If desired it is possible to arrange graduated payments whereby the major (large) industries pay marginally higher cess.

Generally, the major industries are few in numbers in any industrial estate, but they contribute the largest share to the total effluent flow in an estate. A small increase in the cess for these industries will ensure that approximately 50 - 65% of the industries producing less than 10 m^3/d of waste, only need to pay a minimal fixed amount for being connected to the CETP.

The Chemtech formulation for the annual contribution from each industry, CO(i), can be easily corrected by eliminating all but the minimum contribution A for small industries :

$$CO(i) = \frac{Q(i)}{Q(T)} \times PF(i) \times CO(T), \text{ for } Q(i) > 10 \ m^3/d$$

$$CO(i) = A, \text{ for } Q(i) < 10 \ m^3/d$$

Apart from making the CETP economically more acceptable for the large proportion of industries in the estate, this arrangement would also result in much simplified policing and accounting procedures for the CETP operator and the authorities. It would also reduce the amount of work required to determine the wastewater production from the many small individual industries, as well as avoiding arguments between the CETP operator and the smaller industries over actual volumes of effluent.

Other payment methods benefiting the smaller industries are, of course, possible. Following illustrations for a typical Indian industrial estate explain the concept (80) :

- If instead of all industries paying 4.89 Rs/m^3 for the effluent going to the CETP, those with more than 50 m^3/d effluent paid 5.4 Rs/m^3, then those below that figure would have to pay only 3.0 Rs/m^3 to ensure the same income for the CETP operator.

- If industries with more than 50 m^3/d effluent paid 5.1 Rs/m^3 and those with 10 - 50 m^3/d paid 4.6 Rs/m^3, then the small operator with less than 10 m^3/d effluent would have to pay only 3 Rs/m^3 or a fixed amount of 7,000 Rs/year.

- If the very large industries (more than 1,000 m^3/d) paid 5.5 Rs/m^3, and the medium scale producers (50 - 1,000 m^3/d) paid 4.6 Rs/m^3, then the small industries (in this case less than 50 m^3/d) would need to pay only a fixed minimum amount.

The above illustrations show that if required it will not be difficult, or not much more costly to the larger industries, to favour small industries to an extent that they can afford (80).

5.13 DRAINAGE SERVICE CHARGE FORMULATION

The formulation developed is as follows (81) :

$$\text{Wastewater service charge} = V\ Rv + V\ [(BOD-250)R_B + (SS-300)Rs]$$

where,

V	=	wastewater volume in '000 m^3
BOD	=	average BOD of wastewater, mg/L
SS	=	average suspended solids of wastewaters, mg/L
RV	=	charge rate per 1000 m^3 volume
RB	=	charge rate per kg of excess BOD
RS	=	charge rate per kg of excess SS
250	=	BOD standard, mg/L
300	=	suspended solids standard, mg/L

5.14 BARNARD AND ECKENFELDER FORMULATION

The factors which significantly influence the cost of the wastewater treatment are the flow rate, BOD, suspended solids and the biological reaction rate in case of biological treatment facilities.

The flow rate affects the size of all processing units and, therefore, it will have the most significant influence on capital cost. BOD value will affect the size of the aeration basins and the required aeration horsepower. Higher concentrations of BOD will result in the production of more biological sludge and will, therefore, affect the sludge handling facilities. The concentration of suspended solids will primarily affect the overall sludge handling facility. A relationship developed by Barnard and Eckenfelder (82) to assess the capital cost of a combined municipal activated sludge plant is as follows :

$$\text{Cost } (\$\ 1000) = 583\ Q^{0.84} + (110 + 37Q)\ \frac{So}{200} + (77 + 23Q)\left(\frac{SS}{200} - 1\right)$$

where,

Q = hydraulic flow rate, in MGD
So = influent raw waste BOD concentration in mg/L
SS = raw waste SS concentration in mg/L

Using this equation, it is possible to define the net increase in cost of a waste treatment facility for various percentages of industrial wastewater. It is also possible to compute the cost of CETPs from process and cost models of each unit. The capital cost models for combined waste treatment as developed by Smith (83) and modified by Barnard (84) are given in Table 5.9. Operating cost models are also presented in Table 5.10. When considering domestic or combined wastewater treatment facilities, excess capacity is usually provided to handle peak flows and to maintain adequate treatment during periods of maintenance or breakdown. The excess capacity factors to be included in the cost analysis are shown in Table 5.11

5.15 COST RECOVERY BASED ON PLOT SIZE

Plot sizes are indicative of the size of the particular industry, but it does not give any information on the water usage or wastewater volume and composition. Unless the plot size is used solely for the purpose of calculating a connection fee (which would be part of the capital repayment), use of this as a base for contribution is very inaccurate and most likely unfair to many industries and hence, usually not recommended (80).

Table : 5.9

Capital Cost Models[a] for Domestic & Combined Wastes

Treatment unit		Capital cost in 1000 dollars
Pretreatment	Cost =	$19 \times Q^{0.63}$
Primary sedimentation[b]	=	$173\ SA + 6.7(SA)^{0.1}$
Activated sludge	=	226 (Vol. in MG) + 67
Blower house	=	13.6 + 7.6 (CFM/1000)
Sludge return pumps	=	4.7 + 1.45 Q
Final sedimentation[b]	=	$16.2\ SA + 6.9/(SA)^{0.13}$
Chlorination	=	$11.6 \times Q^{0.47}$
Thickener	=	SA[24.2 + 11.7/exp(SA/13.3)]
Anaerobic digester[c]	=	$V(1.34 + 13.8/V^{0.87})$
Vacuum filters	=	$16.5 + 48\ [\text{area (ft)}^2/100]$
Sludge incinerator[d]	=	$(S/24000)(170 + 7.15\ S^{0.61})$
Control house[e]	=	$51.6 \times Q^{0.7}$

[a]Cost updated to Sep. 1969
[b]SA = Surface area in 1000 sft
[c]V = Vol. in 1000 cft
[d]S = Sludge production in lb/day
[e]Q = Flow rate in MGD

Table : 5.10

Operating Cost Models for Combined Wastes*

Treatment Unit	Annual Operating Cost ($ per MGD)
Pretreatment[a]	Cost = $500 + 2150/Q^{0.63}$
Primary sedimentation	= $909 + 2370/Q^{0.5}$
Digested sludge[b]	= $2700 + 2500/(\text{Vol. in MG})^{0.67}$
Anaerobic digestion[c]	= $1200(V/Q)(0.048 + 0.54/V^{0.5})$
Drying beds	= $1.2\ (S/Q)(0.21 + 29.7/S^{0.5})$
Vacuum filtration	= $0.18(S/Q)[700/F + 0.38(2 - 0.1Q) + 0.027\ C/F]$
Incinerator	= $1500 + 6450/Q^{0.63}$

*Source : Eckenfelder W.W., Jr. and Adams C.E., Jr, ASCE, SA 1,1972.
[a]Q - the flow rate in MGD
[b]V - the volume in 1000 cft
[c]S - total sludge in lb/day
F - area of the vacuum filter in 100 sq ft
C - capital cost in 1000 dollars

Table : 5.11

Excess Capacity Factors for Process Units*

Process	Factor
Preliminary	1.0
Primary clarification	2.0-0.008 Q
Activated sludge	1.3-0.002 Q
Aeration	1.8-0.004 Q
Sludge return	2.0-0.005 Q
Final clarifier	2 0-0.007 Q
Chlorinator	1.0
Thickener	1.5-0.004 Q
Aerobic digester	1.5-0.003 Q
Anaerobic digester	2.0-0 005 Q
Centrifuge	2.0-0.005 Q
Vacuum filter	2.0-0.005 Q
Sludge drying beds	1.0

*For flow rate, Q, ranging from 1 MGD to 100 MGD

5.16 COST RECOVERY BASED ON WATER CONSUMPTION

Although it is considered by many that water consumption is proportional to wastewater volume with reasonable accuracy, there are two unfair elements in assuming that the capital and operating cost of the CETP are also proportional to the water consumption :

- Though the pollution load of the wastewater is an almost as equally important as volume of waste, it is not taken into consideration while arriving at the construction and and operating cost of the CETP

- The water flow meters at industrial estates are most of the time found to be out of order, which makes the total water consumption figures more difficult to obtain and to rely on. Obviously, the water consumption figures in the industrial estates are unrealiable, especially as the basis for estimation of total waste water flow (80).

5.17 GBMSD METHODOLOGY

Green Bay Metropolitan Sewerage District (GBMSD) in 1970 found 25 percent reduction in capital cost while treating municipal waste jointly alongwith paper mill wastes. The District developed a rate structure for financial apportionment in CETP. The final rate to be charged each year reflected actual costs as developed from the regular annual audit of the District's financial records. Because major users of the treatment system committed themselves to a fixed capacity, the capital portion of the user charge remained essentially constant. As operating cost depends on actual use, this portion of the user charge varied from month to month based on load. The annual user charge relating to the construction of plant facilities and sewers was developed initially on the basis of cost estimates and subsequently it was refined by using actual costs once construction was completed. Major users of the system were billed in advance by the District on a monthly basis. An estimate of total charges was made at the beginning of each month, with these charges being prorated on the basis of the flow, BOD and SS expected during that month. At the end of the fiscal year, these estimated charges were reconciled against charges for waste quantities actually discharged during the year. A refund or an additional bill was then issued to clear the books (35).

5.18 FLECKSEDAR METHODOLOGY

Flecksedar (85) suggested apportioning of costs amongst the member industries of the CETP scheme as follows :

- As indicated below, differentiate into design and operation; where 'design' is based on the estimates set for the design, and operation in real practice, latter has to be founded on continued measurements of the actual state

- Parts of a combined system which are exclusively attributable to one partner (e.g separate primary sedimentation for a pulp mill for fibre recovery) are his financial responsibility

- Costs of pumping stations, sedimentation tanks and conduits are split based on flow from every partner (Design/Operation)

- Investment for aeration tank is split according to loads from partners being used in design calculations of aeration tank volume (Design)

- Investment for aeration equipment is split according to every partners contribution to aeration capacity (Design)

- Running cost for aeration is split same as done in above step but with average loads (Operation)

- Cost of thickening, sludge dewatering and sludge handling are split on the basis of excess sludge generated (Design/ Operation)

- Remaining costs are split according to 'normalized ratios' of the previous categories.

5.19 WATSON et al RECOMMENDATIONS

It is apparent that the regulations regarding user charges and industrial cost recovery provides a maximum flexibility for the establishment of equitable charges for industrial plants connected to municipal sewer systems.

There are obvious costs, such as administrative, billing and collection, that have little to do with the quantity and quality of discharge. The large user, therefore, should not be required to pay user costs for such items on the same basis as the small ones. Furthermore, the guidelines ignore use of the basic and long used concept of rate-making for the water and sewerage fields, that treatment capacity and its operation decrease in cost per unit volume as the total volume to be handled increase. Therefore, in the interest of complete sound equity for all users of the system, there is a justification for the use of a sliding scale in many cases (44).

6

Approach for Designing CETP

CETP handles wastewaters from various types of industries and obviously, the nature of the mixed wastewater is highly varying in terms of characteristics and flow. A systematic and holostic approach is therefore very much essential to design a CETP. NEERI in consultation with MEF has developed the criteria which can very well be looked as an approach for designing a CETP. These criteria are enumerated in Table 6.1. Some of the important criteria given in Table 6.1 can be used as important steps while designing a CETP and are discussed below in detail :

6.1 INVENTORY OF INDUSTRIES

Basic information regarding each industry existing in the industrial estate for which CETP is to be designed needs to be collected to know :

- Whether industry is a dry industry or wet industry
- Classification of industry
- Wastewater generation rate
- Characteristics of wastewater
- Existing treatment units, if any
- Scope for waste minimization measures such as recycle/reuse, recovery of byproducts, waste strength & volume reduction, process modifications, adoption of cleaner technologies etc.

6.2 CLASSIFICATION OF INDUSTRIES

6.2.1 Classification of industries based on products

In Industrial Estates it is a common practice to divide the industries into 10 individual groups (86) :

- Dye and dye intermediate
- Pharmaceutical
- Pesticides
- Fine chemicals
- Paper and pulp

Table : 6.1

Criteria for the Design of CETPs as Developed by NEERI in Consultation with MEF

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* Inventory of industries
* Flow and characteristics of wastewater
* Classification of industry based on wastewater quantum generated
* Classification of wastewater based on biodegradability (A, B, C & D)
* Design of conveyance system
  - free from problems
  - optimized scheme
* Treatability study
  - bench scale
  - pilot scale
* Segregation of wastewater
* Pretreatment of wastewater (C & D)
* Assessment of available technologies for design of CETP to develop treatment packages and optimization based on spatial distribution of CETP
* Ranking of technology options
* Reuse/recycling and resource recovery
* Disposal of treated effluents
* Cost estimation based on optimized CETP
* Cost benefit analysis
* Scheme for sharing financial burden
  - annualised capital cost
  - O&M for different types of wastewater (A, B, C & D) based on flow and mass
* Possibilities of using cleaner technologies
  - process
  - water consumption
  - raw material
  - energy requirement
  - consideration of waste from one industry to be used as raw material for another industry

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- Textile
- Engineering
- Leather
- Rubber and plastic
- Miscellaneous

It is difficult to find accurate definitions for the individual groups. Some groups can easily be separated, e.g. Textile and Engineering industries, while other groups have more vague borders, e.g. Dye Industries and Fine Chemicals Industries, and some industries could even be included in more than one of the groups listed.

The definitions for the above mentioned groups are given below (86) :

1. *Dye and Dye-intermediate Industries*

These industries manufacture substances which have a dyeing effect on cloths, yarn, paper, plastic, wood, leather, hair, walls etc.

The group can be divided into two subgroups :

i. Manufacturers of intermediate chemicals which consist of a huge range of specific and some inorganic substances used for production of final dyes.

ii. Manufacturers of final dyes which use dye-intermediates in the formulation process. The final products are Azo dyes, Direct dyes, Reactive dyes, Vat dyes, Solubilized vat dyes, Pigments and Sulphur dyes.

2. *Pharmaceutical Industries*

These industries produce substances related with health effects. The products are manufactured by chemical or biological method or by formulation of intermediate materials.

The group can be divided into three subgroups :

i. Manufacturers of bulk drugs which are prepared by using organic reactions. The products can be described by having an activity as a drug and used as an active ingredient in final pharmaceutical formulations.

ii Manufacturers of antibiotics, which are prepared by using fermentation process.

iii. Manufacturers of final pharmaceuticals formulations, which are prepared by the use of bulk drugs, antibiotics, etc. The products can be described as the final item for sale as tablets, injections, ointments, capsules, syrups, etc.

3. *Pesticide Industries*

These industries produce substances for pest control.

The group can be divided into two subgroups :

i. Manufacturers of bulk pesticides by use of chemical reactions (organic as well as inorganic). The products can be described by having a special effect on the pest to be controlled. The products can be described as germicides, weedcides, rohdenticides, insecticides, fungicides, etc.

ii. Manufacturers of final pesticides by use of bulk pesticides in dilution or reformulation. The products can be described as the final item for sale as powder, liquids, etc.

4. *Chemical or Fine Chemical Industries*

These industries cover a very wide range of products manufactured from natural sources, heavy chemicals, inorganic and organic chemicals. The products can be used as starting materials for manufacturing of drugs, dyes, pesticides, fertilizers, additives, etc.

Common for the industries in this group are the use of chemical reactions and that the industries cannot be placed in groups 1, 2, 3, 5 and 9.

5. *Pulp and Paper Industries*

These industries produce paper or paper related materials.

The group can be divided into two subgroups :

i. Manufacturers of new pulp, paper and cardboard from e.g. bamboo, bagasse and grass etc.

ii. Manufacturers of cardboard and packaging papers from waste paper.

6. *Textile Industries*

These industries produce textile substances. The products are achieved by processing of natural or synthetic fibres.

The group can be divided into two subgroups :

i. Manufacturers of yarn by spinning, sizing and weaving.

ii. Manufacturers of final textiles as yarn or clothes by processes like desizing, bleaching, dyeing, printing and finishing.

7. *Engineering Industries*

These industries manufacture items based on metals. The products are achieved by fabrication or moulding of metals, and the products can be described like reactors, tanks, valves, sheets, motors, pumps, etc.

8. *Leather Industries*

These industries produce items based on leather as raw material. The products are achieved by processes as tanning, sizing, dyeing, finishing, etc.

9. *Rubber and Plastic*

These industries produce items based on the chemistry of polymerization. The products are mainly achieved by polymerisation or in special cases moulding of organic substances by use of organic reactions.

10. *Miscellaneous Industries*

These industries include various kinds of industries which cannot be placed in the above mentioned groups. There are no special product or process characteristic. The group include industries like trading companies, transporters, printing press for books and papers, etc.

6.2.2 *Classification of Industries Based on Capital Investment Cost*

A second-commonly used grouping of the industries is to divide them according to the Capital Investment Costs (CIC). In this, two categories given by the Government of India are present :

- Large scale industries where CIC are more than 35 lacs Rs.
- Small scale industries where CIC are below 35 lacs Rs.

6.2.3 Classification of Industries Based on Water Consumption

Industries can also be divided on the basis of water consumption as large scale and small scale as follows:

- Large scale industries consuming more than 50 m^3/d
- Small scale industries consuming less than 50 m^3/d

This division is at present used in India in Gujarat State to impose different effluent standards on small and large scale industries.

In other states, the figure is 100 m^3/d in the division between large scale and small scale industries.

The industries can also be classified in four major categories, viz.

- High water consuming e.g. textile and paper board mills
- Medium water consuming e.g. chemical, dyes and pharmaceuticals
- Low water consuming e.g. paints & varnishes, rubber, plastic
- Dry industries e.g. table packing industry.

6.2.4. Classification of Industries Based on Wastewater Generation

The industries can also be classified on the basis of wastewater generation rates. One such classification is shown below for illustration :

Type of industry	Wastewater Generation, m^3/day
Small scale	< 50
Medium scale	50 - 100
Large scale	> 100

6.3 CLASSIFICATION AND CHARACTERISATION OF WASTEWATER

In case of industrial estate housing hetergenous type of industries, different types of wastewater are generated causing the admixture of wastewaters not easily ameanable to treatment. In view of the variations in wastewater characteristics with differing response to treatment, it is necessary to characterise the wastewater and classify into different categories. The wastewaters can be categorised as follows (87) :

WWC 'A' - Amenable to biological degradation directly or after acclimatisation

WWC 'B' - Pre-treatment essential prior to biological treatment or post treatment for TDS removal

WWC 'C' - Non-biodegradable

WWC 'D' - Toxic to biological treatment

Based on these categories, the wastewater from individual units should be segregated. The basis of segregation is given in Table 6.2 (87). For simplification, if units generating wastewaters belonging to WWC 'D' i.e. wastewater containing chemicals toxic to microorganisms are limited in number as compared to WWC 'C', these two can be clubbed together.

Industrial wastewaters under each category can further be classified depending on their amenability to biological treatment as illustrated in Table 6.3.

Some information regarding environmental data of some specified organic compounds available in literature is given in Table 6.4. Column 3 of this table gives the treatability of the compounds by a threshold limit value in a common biological treatment plant according to a system performed by the Swedish Water and Waste Water Association. The system divides the substances into three classes :

I : Treatable substances
II : Limited treatable substances
III : Non-treatable substances

The second class is divided into three subgroups (IIa, IIb and IIc) according to increase in toxicity of the specific compound.

Referring to the Swedish system, it is possible to classify eleven of the specified compounds. As can be seen from the Table 6.4, all eleven compounds are grouped in class II or III. Four of the compounds are classified as

Table : 6.2

Basis for Wastewater Categorisation

Chemical	Reaction	WWC	Explanatory Notes	Pretreatment	Acceptability in CETP
High SS	Highly settleable	A	Non-toxic solids highly settleable	NP	Acceptable
High SS	Colloidal needs coagulant	A	Non-toxic solids settleable after coagulation	NP	Acceptable
Organics	Highly biodegradable	A	Org. solids in solution and/or suspension, highly biodegradable	NP	Acceptable
Organics	Slowly biodegradable	A	Org. solids in solution and/or suspension, slowly biodegradable, example : benzene series	NP	Acceptable
Inorganics on	Acid	B	Mineral acids produced or used in excess	N & SEP	Acceptable on neutralisation
Inorganics	Alkali	B	Alkalies produced or used in excess	N & SEP	Acceptable on neutralisation
High TDS	Precipitable	B	Raw or product materials are soluble in water	CP & SEP	Acceptable on precipitation
High TDS	Membrane Separation	C	Highly soluble solids need membrane separation	NIP	Require expensive collective treatment using membrane separation
Organics	Refractory	D	Naphthalene anthracene used as raw material and/or product	NIP	Requires expensive collective treatment of ozonation then to CETP
Organics	Toxic	D	Metal complex organo-chlorine pesticides carbonates	NIP	Requires expensive collective treatment or incineration

NP : No Pretreatment
NIP : No Individual Pretreatment
N & SEP : Neutralisation and Solids Separation
CP & SEP : Chemical Precipitation and Solids Separation

Table : 6.3

Classification of Wastewater

Category		Description
A	-	**Biodegradable without pre-treatment**
A_1	-	High TSS, highly settleable, non-toxic
A_2	-	High TSS, colloidal, need coagulation, non-toxic, settleable after coagulation
A_3	-	Organic, high biodegradability, soluble or suspended
A_4	-	Organic, low biodegradability, soluble or suspended solids
B	-	**Biodegradable after pre-treatment**
B_1	-	Inorganic acids, acceptable after neutralization
B_2	-	Inorganic alkali, acceptable after neutralization
B_3	-	High TDS, acceptable after precipitation
B_4	-	High TDS, acceptable after membrane separation
B_5	-	High TDS, refractory, acceptable after ozone treatment
C	-	**Non-biodegradable**
C_1	-	Organic, refractory, non-biodegradable
D	-	**Toxic to biological systems**
D_1	-	Organic, toxic, metal complexes, pesticides, require incineration treatment

Table : 6.4

Literature Data on Selected Specific Organic Compounds

Organic Compound	Treatment Possibilities Class	Treatment Possibilities mg/L	Biological Effect on COD Removal in Activated Sludge Process*
1	2	3•	4
Aniline	IIa	100	< 20 mg/L, adoption possible
Anisidine	N	-	< 500 mg/L, adoption possible
Benzene	III	-	< 50 mg/L, adoption possible
Chloroaniline	N	-	< 16 mg/L, adoption possible
Chlorobenzene	III	-	possibly no adoption
Chloronitrobenzene	III	-	possibly no adoption
Dichloroaniline	IIc	10	N
Dinitrochlorobenzene	III	-	N
Naphthalene	II	10	possibly no adoption
Naphthol	II	10	< 30 mg/L, adoption possible
Naphthylamin derivative	N	-	No adoption-nonbiodegradable
Nitrobenzene	N	-	< 14 mg/L, adoption possible
Nitrophenol	N	-	< 17 mg/L, adoption possible
Phenol	IIb	10	< 80 mg/L, adoption possible
Toluene	IIc	10	N
Toluidine	N	-	< 15 mg/L, adoption possible
Xylene	IIc	10	possibly no adoption

*Source : Vershueren K. 'Handbook of Environmental Data on Organic Chemicals' IInd edition, 1983

•Threshold value given by Swedish Water and Wastewater Association

N : No information given

non-treatable substances. The remaining compounds which could be grouped, can be treated in a biological system, but only in small concentrations excluding aniline.

The last column of Table 6.4 includes data of experience in biological degradation (COD-removal) by the use of activated sludge (88). As seen from the column, there is some rather low limits in concentration for many of the compounds for which adoption into activated sludge has been possible (86).

Characterisation of untreated combined wastewater from an industrial estate is an extremely important and an essential step to determine the design parameters of the CETP scheme. At least following parameters must be determined in order to finalize the design 'parameter values' :

- pH
- BOD_5 at 20°C
- COD
- Suspended solids
- Total dissolved solids
- Oil & Grease
- Sulphate
- Chloride
- Total nitrogen
- Phosphorus

Equally important is the characterisation of the wastewater generated from individual industrial unit. This is required to evaluate the necessity of segregation/pretreatment and to estimate BOD/COD load and suspended solid load based on which financial apportionment is generally done.

Treatability studies should also be carried out to assess the feasibility of physico-chemical as well as biological treatment of combined wasteweater.

6.4 CONVEYANCE SYSTEM

Effluents of individual industries can be conveyed to CETP by the following :

- Tankers
- Open channels
- Piping systems
- Combination of all these.

Each of the above modes of transport have some advantages and disadvantages. If the industrial estate is in early stage of development and accommodates mostly small scale industries, tankers are probably the best alternative.

The collection and transportation system is one which cannot be easily and economically expanded at latter stage (unlike treatment and disposal system). Therefore the collection system has to be provided with adequate spare capacity to meet future requirements. On the other hand, if collection system is erected in the early stages of development (provided with extra capacity for future requirements), lot of money get blocked without much return. Secondly, since the system would be overdesigned with respect to the present flow, settling of suspended solids may occur within the piping systems. In such situations, conveyance of wastewater by tankers may be a better choice. At many places, topography of the area may permit use of only tanker conveyance system.

Open channel system is vulnerable for rainwater entry and may impose excessive loadings on treatment plant during rainy season. Piping system is especially suitable where all the individual units are located close to each other or when the industrial estate is completely developed and fully occupied with industrial units. Open channels covered with concrete covers generally turn out to be economical as compared to sewers.

A combination of these three system may be adopted in actual practice depending on local conditions e.g. open channel within factory premises, tanker conveyance upto terminal pumping station and terminal pumping station to CETP by pumping system.

If the industrial estate is divided into many phases or blocks, individual collection system and collection sump can be designed for each phase or block. The wastewater can then be pumped from these collection sump to a main sump for onward conveyance.

Final design of a collection network takes into consideration the topography, undulutions, road alignments, flow characteristics, ground water table, infiltration, appurtananees, flushing requirements etc.

6.5 TREATMENT PROCESS OPTIONS FOR CETP

In instances where economic processes of material recovery, by-product production and effluent reuse fail to prevent a residual waste load from an industry exceeding the stipulated effluent standards, it becomes necessary to resort to waste treatment methods before discharge.

The combination of unit processes and operations making up a treatment process option depends upon the characteristics of a particular waste and the effluent standards imposed. It is only normal for a designer to attempt to use lowest cost solution to a waste treatment problem but this is especially important under the economic restrictions in India.

Various treatment options can be outlined for a combined wastewater flow. The treatment schemes generally consist of the following steps :

- Removal of floating oil and other floating solids by screening
- Removal of gritty material
- Primary treatment for removal of suspended solids
- Secondary treatment to remove residual organics and nutrients
- Activated carbon adsorption
- Chlorination
- Sand filtration
- Removal of cations and anions by ion exchange, demineralisation or reverse osmosis.

Physico-chemical treatment followed by biological treatment will treat the wastewater to make it fit for inland surface water disposal. If process grade water is required to recycle/reuse the treated water, any of the following treatment options may be adopted depending on the grade of the process water to be reused :

	Treatment Option	End Use
1.	PC + AC + RO + IE	High grade process water TDS < 100 mg/L
2.	PC + AC + RO	Low grade process water TDS < 1000 mg/L
3.	PC + AC + IE	Low grade process water TDS < 800 mg/L
4.	BP + AC + RO + IE	High grade process water TDS < 100 mg/L
5.	BP + AC + RO	Low grade process water TDS < 1000 mg/L
6.	BP + AC + IE	Low grade process water TDS < 800 mg/L
7.	BP + AC	Low grade process water TDS $\simeq$ 9000 mg/L
8.	BP	Low grade treated wastewater TDS $\simeq$ 10000 mg/L BOD $\simeq$ 20 mg/L

PC - Physico-chemical; BP - Biological process;
AC - Activated carbon; RO - Reverse osmosis; IE - Ion exchange

The treatment processes can be implemented in phases, viz.

Ist phase - On land disposal for irrigation
BOD - 100 mg/L
SS - 100 mg/L

Treatment option - (PC + BP) or only BP

2nd phase - Inland water bodies disposal
BOD < 20 mg/L
SS < 30 mg/L

Treatment option - PC + 2 staged BP

3rd phase - To produce low grade process water for reuse
BOD - Nil
SS - Nil
TDS < 1000 mg/L

Treatment option - (PC or BP) + AC + (IE or RO)

4th phase - To produce high grade process water for reuse
BOD - Nil
SS - Nil
TDS < 100 mg/L

Treatment option - (PC or BP) + AC + RO + IE

In the first phase outlined above, the combined wastewater can be anaerobically treated to generate energy in the form of methane-rich biogas which can be used in the CETP campus in residential quarters of the operating personnel.

The treatment options indicated are given only for illustration purpose. The actual treatment options available will vary depending on quality of raw water and end use desired.

Treated effluent has a considerable fertilizer value, in addition to providing water to areas where rain is limited in certain parts of the year. Provided adverse effects of the effluent are controlled, there is therefore a considerable economic and environmental benefit in utilizing this waste for a useful agricultural purpose.

In India, studies have been conducted on reuse of treated effluent for agricultural purposes under the sponsorship of the CPCB. One such example is the study conducted by GIDC in Baroda for use of the effluent from the Effluent Channel Project, which caters for the combined wastewater from many large industries around Baroda and also from several hundred industries at the industrial estate at Nandesari, near Baroda. In this case, cotton, tobacco and lentils were grown on land set aside for this three year trial. Fresh water and the required fertilizers was applied to plots as control, while other land was irrigated by 100% effluent or a mixture of effluent and fresh water in equal proportions. According to the GIDC, the results have been quite encouraging.

If the control plot is taken as 100% yield, then the 50/50 mixture of effluent/fresh water produced yields of 90-95%. The 100% effluent irrigation gives a lower yield of 60-70%, most likely due to excess nitrogen fertilization and too high total dissolved solids in the effluent.

6.6 TREATED WATER DISTRIBUTION SYSTEM

A treated water storage reservoir must be provided in CETP campus with a holding capicity of minimum 2-3 hours, if the treated water is intended for reuse/recycling. Otherwise, treated water may be disposed of either for onland irrigation or in inland water courses or in municiple sewers depending on the quality of treated water and options available for disposal. If the treated water is to be disposed off, the distribution system should preferably consist of open drains. If the treated water is to be recycled/ reused, the treated water should be pumped from storage reservoir to elevated storage reservoirs (ESR) to be located atleast one in each phase or block of industrial estate. The treated water distribution system must be optimised using various methods available.

6.7 COST BENEFIT ANALYSIS

The cost estimates for all the treatment options available should be made for evaluation purposes. The cost should cover both capital and O & M cost. The total annualised cost for option also need to be determined. Considering 'No loss - No profit' basis, cost of treated water of various process grade should be calculated.

The cost of treatment has to be paid by the individual member industry. The treated water of process grade comes as an additional benefit for the industrial estate and can be sold back to the individual member industry at a concessional rate. The money so generated will be the revenue for the CETP authorities.

An assessment for use has to be made for allocation of treated waters of various grades. This can be done by the CETP authority in consultation with industries. The allocation of treated waters can be categorised under the following heads :

- Land application including green belt development
- Treated water exclusively for washing purposes
- Treated water for process requirements depending upon its quality.

6.8 RANKING OF TREATMENT OPTIONS

Selection of a proper treatment alternative has got prime importance during planning for any pollution control programme. Due considerations and proper weightage must be given to the advantage (strong points) and also to the disadvantages (weak points) of each treatment alternatives available. Neither treatability at lower cost nor only process reliability at higher cost should be taken as a sole factor to be considered for a given situation. An integrated approach, is therefore, needed which takes into account various criteria such as environmental risks, health risks, aesthetic risks, annualised costs, reuse potential, institutional requirements, land requirements and process reliability during selection of a proper treatment alternative. One must realise that inadequate and improper management of any treatment alternative is likely to pose significant risks and adverse impacts on health, aesthetics and environment. Therefore, ranking of the various available alternatives should be carried out to arrive at the most appropriate alternative which minimises adverse impacts and maximizes social benefits through enhanced economic output. The exercise essentially involves ranking of the alternatives based on above mentioned criteria and comprises of the following steps, viz.

1. The various alternatives should be ranked on the basis of the defined environmental criteria and reuse potential in accordance with the laboratory findings, design data and cost estimates.

2. A total score of 1000 is apportioned between the assessment criteria in each case based on their importance as well as subjective judgement.

3. The alternatives are evaluated against each criterion and assigned scores.

4. Total score for each alternative is computed.

5. Alternatives are ranked by comparison of total scores.

6.9 SHARING OF THE FINANCIAL BURDEN

In order to operate the CETP effectively and efficiently, it is necessary that the individual industrial units pay for the capital and O & M costs. The various methods available for sharing of the financial burden is already discussed in Chapter 5 in detail.

The financial outlay including subsidies and grants available from Central and State Governments, loans that can be raised from financial institutions is described in Chapter 2.

7

Implementation, Operation & Maintenance of CETP

7.1 IMPLEMENTION OF THE CETP

An integrated and holostic approach for implementation of CETPs in industrial areas housing heterogenous industries needs standardisation, in absence of which the system may fail to operate successfully. In India, industrial areas with cluster of heterogenous industries are more prevalent. The technical approach for designing CETP for such industrial areas should be as follows:

1. The most important step is the segregation of wastewaters and the basis as suggested by Chaudhary (87) is described below :

   The conglomeration of so many types of industries causes the admixture of wastewaters not easily amenable to treatment. Wastewaters which are amenable to biological degradation, termed henceforth as biodegradable waste, without any special treatment should be segregated from those which are not amenable to biodegradation, termed henceforth as non-biodegradable waste The basis of segregation is given in the Table 6 2. The raw material used and/or products produced formed the basis of such segregation.

   Industrial units producing wastewaters which do not require any pretreatment within the premises of the industrial units are designated as wastewater category A or WWC 'A'. Units producing wastewaters which are biodegradable after acclimatisation are also categorised as WWC 'A'. Industrial units using the chemicals, viz. benzene, phenol, furan, pyrrole, thiophene, thiazole, pyridine, indole, amine, sulphide, sulphoxide, oxime, hydrazone, nitrile, dinitrile, and aromatic nitrile as raw material and/or produced as product belong to this category. Among the biodegradable wastewater producing industrial units, there may be units whose wastewaters may need pretreatment within the premises of the industrial units. The acidic or alkaline waste falling outside the range of pH 5.5 to 9.0 needs to be pretreated; wastewater containing total dissolved solids of concentration 10000 mg/L or more needs to be pretreated.

Wastewaters from such industrial units are designated as WWC 'B'. Industrial units using some chemicals which are not biodegradable e.g. those belonging to naphthalene, anthracene, quinoline groups are to be categorised as non-biodegradable and are designated as WWC 'C'. Industrial units using and/ or producing metallic organic complexes such as phthalocyanines are to be grouped as toxic to biological treatment systems and are designated as WWC 'D'.

2. Check each industrial unit for raw materials used and/or products produced. Classify units in the 4 categories of WWC 'A', 'B', 'C' and 'D'.

3. The volume of wastewater from each industrial unit is to be computed as 70 per cent of water intake, in case actual measurement of the volume is not available. The total volume of wastewater in each of the 4 categories is to be estimated. Based upon these categorised volumes, the possibility of treating combindly the different categories of the wastes and the pretreatment requirements will have to be taken into account in designing the CETP.

4. Wastewater belonging to category WWC 'C' and 'D' which are either acidic/alkaline wastewater or wastewater with total dissolved solids concentration more than 10000 mg/L needs to be pretreated within the factory premises same as WWC B.

5. Industrial unit belonging to WWC 'B' and also those of WWC 'C' or WWC 'D' which would need pretreatment should be given discharge permit with the mention of permissible concentration of the specific parameters like dissolved solids, pH and the quantity of discharge. As a general rule, all industrial units should be given consent mentioning limits to the 5 essential parameters : pH, TDS, SS, oil & grease and discharge quantity.

6. Industrial area producing less than 2500 m^3/day wastewater in WWC 'A' or 'B' combined, or less than 1500 m^3/day in WWC 'C' alone need not be considered in the first phase. In general, wastewater of WWC 'D' will not be significant in volume warranting separate treatment. In such a situation, it may be combined with WWC 'C'. However, if it is found to be significant in specific case, then it has to be managed as indicated in Table 6.2. These should be taken up in the second phase after gaining experiences in the first phase.

7. Instead of one terminal CETP, multimodular CETPs are recommended.

8. Each State should select estates located in the problem areas. In the first phase, estates producing wastewater between 2500 m^3/day and 10000 m^3/day in WWC 'A' or 'B' or combined should be chosen. For WWC C, the range should be between 1500 m^3/day and 10000 m^3/day. With experiences gained in first hase large sized and small sized areas may be handled in the second phase.

9. The 3 options for conveyance of wastewaters in any industrial area are underground sewers, lined and covered open channels and collection by tankers from the industrial units. The choice of the conveyance system should be based on topography of the area, nature of waste to be conveyed, location of ETP in the area and the cost. The detail engineering should look into these alternatives.

10. There should be an approved list of consultants who should be entrusted with the work of detail engineering and preparation of tender documents.

11. There should be an apex group who should be entrusted with the responsibilities of reviewing the design done by the consultants and would suggest necessary changes if required and ensure that these are incorporated.

12. There should be an approved list of constructing agencies who should bid for the construction work.

13. The consultant should be responsible to operate the plant till the effluent treatment company selected for running the CETP is able to handle the operation of the facility (87).

Based on experience in CETP implementation, a leading consulting firm in India (89) proposed following line of action for implementation :

1. Let the industries contribute equity capital, form a Company (or Cooperative) and take loans from funding institutions (Government ownership of CETPs does not appear desirable).

2. Enforce pre-treatment only where absolutely necessary. Pre-treatment should be required to remove only those substances which interfere with the CETP processes or the final discharge standards.

3. Bring the pre-treated wastewaters to the CETP by tankers especially in case of toxic or objectionable substances so that the contents can be analysed before discharged to CETP (Sewers appear to make "cheating" easier).

4. Design sturdy treatment processes to be capable of withstanding fluctuations, power failures and the nature of wastes expected (so as to reduce pre-treatment requirements as far as possible).

5. Share operating costs based on flow, BOD/COD and any other parameter of relevance.

6. While State Pollution Control Boards will no doubt control CETP's performance, they should also be required to penalise individual errant industries wherever reported, if necessary, an enabling provision may have to be made in the Act.

A few of the following instructions if observed go beyond assistance during implementation of CETP (7) :

- Determine effect of in-plant pollution control measures on manufacturing operations
- Evaluate land availability and locations
- Determine characteristics of wastes by survey and analysis
- Determine treatability of combined wastes
- Determine requirement for pretreatment and pretreatment methods
- Assess toxicity, other hazards, sewer effect
- Provide long-range planning considerations
- Make economical study
- Compute equitable service charges
- Advice on methods of financing
- Prepare service agreement for industry - Municipality joint treatment
- Assess capability of existing operating staff
- Provide operator training, prepare operation manual
- Provide resident engineering supervision over construction.

7.2 OPERATION & MAINTENANCE OF THE CETP

7.2.1 Chief Prerequisites for Successful Combined Treatment Venture

- All the member industries should be willing to pay its fair share of the costs of treatment

- An equitable system of service charge/sewer charges must be established so that all the industries concerned can benefit from the economic advantages of the combined treatment

- Any waste which because of the amount or characteristics cannot be satisfactorily handled in a CETP should be pretreated by the industry to a level acceptable in the CETP. If information is lacking on the treatability of that industrial waste, the industry should be willing to run laboratory tests/ pilot plant tests, if required, to determine the compatability of the industrial waste in the CETP

- The CETP authority should feel the obligation to treat all wastes which can be handled satisfactorily by the CETP with greater economy than could have been done by the industry on individual basis

- Perhaps the most important ingredients to successful combined treatment is the spirit of cooperation and trust among the member industries (4).

7.2.2 *Problems Encountered in the Combined Treatment*

There are many practical problems in setting up and designing a CETP. These include :

- Deciding on details of pretreatment needed

- Deciding which of these should be done at the originating factory rather than at the CETP

- How to cope up with normal fluctuations in effluent flows and compositions

- How to cope up with factories introducing new effluents or deleting/curtailing existing effluent flows

- Economic conveyance distance from factory to the CETP and optimum plant location

- Funding and management of the CETP and basis for charging for the treatment service (68).

Sawyer and Kahn (89) have identified the materials and conditions conducive to problems at various stages in the combined treatment and are enumerated below :

A. Preliminary Treatment

- Inert solids such as sand, cinders, glass, water softening sludges and other materials having specific gravity considerably greater than water often cause sewer stoppages and excessive wearing of pumping equipment

- Fibrous materials such as cotton wastes, tramp wool, wood fibres, hair and feather cause considerable difficulty in pumping operations and sludge digestion.

B. Preliminary Sedimentation and Floatation

Oil & greases : Waste mineral oils and greases, such as those from garage and filling stations, create treatment problems during its removal. They also pose potential explosive hazard and flammability.

Floating materials : Wastes from the vegetable and fruit canning industries contain lots of floating material like the hulls and skins which may completely blanket normal sedimentation tanks.

Flow variations : Industries which operate only one shift per day or industries having batch discharges over a period of 16 or 24 hours complicate the problem of equalization and further treatment.

Thermal variations : The operation of primary settling tanks is affected rather severely by variations in the temperature of influent. This is due to changes in density and is particularly serious when the transfer is from low to higher temperatures. Under such conditions the warmer, less dense wastes will pool at the surface and float rapidly across the tank from inlet to outlet. Detention time may be just a matter of minutes under the circumstances and very poor removals of suspended solids will result.

Density variations : The density of industrial waste varies radically with total solids content as well as with temperature. This is particularly true with variations in the inorganic salt content. Such variations have the same effect as changes due to temperature when cold wastes are added to a warm tank.

C. Secondary Treatment

pH : Low pH conditions are destructive to sewers and structures and the biological forms have no mechanism by which they can destroy mineral acids. High pH wastes are not so critical as CO_2 produced during biological oxidation gradually convert caustic and carbonate alkalinity to bicarbonates.

Toxic materials : Heavy metal ions of copper, zinc and mercury, cyanides, dyes particularly the sulphur dyes and some organic compounds are toxic above certain levels of concentration and may seriously interfere with the biological processes.

Variations in BOD loadings : Slug doses of highly concentrated industrial wastes may upset the biological systems and hence should be avoided as far as possible.

Biodegradability : Some industrial wastes may contain such matters which are resistant to the biological treatment and may hamper the treatment processes. It is to be noted that an effluent which is readily biodegradable in isolation is not necessarily readily treatable, since this depends on its degradability in the presence of other organic compounds. It is balance of nutrients and physico-chemical factors which is important. The ratio of BOD/COD is an indication of the treatability of a waste. Industrial wastewaters have characteristically low ratios, whilst municipal sewage has a high BOD/COD ratio. The mixing of industrial wastes with municipal sewage therefore has the advantage of rendering industrial effluents more treatable.

Nutritional requirements : Domestic sewage generally contain necessary nutrients in ample amounts. However, when it gets mixed with industrial waste, mixed waste may become deficient in nutrients. If such deficiencies exist in the combined waste, provisions must be made to supply necessary nutrients.

Ferrous compound : Ferrous ion serves as a source of energy for iron bacteria. These bacteria often develop on diffuser plates and tubes in the activated sludge process and interfere with the passage of air. In trickling filters treating wastes containing appreciable amounts of ferrous ion, the growth of iron bacteria becomes so prolific that normal sloughing do not occur, and the filters get clogged to the point that they become useless.

Fibrous material : Clogging of distributor nozzles of trickling filters due to fibrous material is common and calls for heavy maintenance. These material often plug the openings in the filter media which results in the ponding of the filter.

Odour producing ingradients : Many industrial wastes containing odour producing chemicals such as unhairing effluent from tanning industry create severe odour nuisance at certain pH and temperatures.

D. Sludge Digestion

Fibrous material : These materials produce scum layers in sludge digesters which are particularlly tough and difficult to disperse. In some cases, they may be so tenacious that gas cannot pass through and internal gas pressure in digester increases posing a danger of tank bursting.

Oil & greases : Unusual amounts of saponifiable oils also tend to segregate in scum layers where they are out of reach of the organisms capable of causing their decomposition. Vacuum filtration is also hampered by "binding" of the filter media with grease, necessitating the use of sprays and/or frequent cleaning with detergents.

Toxic substances : The concentration of the toxic materials in the raw waste may not be so high but when it precipitates, its concentration in the sludge may go beyond tolerable limits. Such sludges when fed to the digester are likely to create problems in biological activity (90).

A great many operating problems arise from the presence of the industrial wastes but most of these problems are solvable within the treatment plant. However, some serious problems which are not solvable at the plant occur primarily in sludge digesters, trickling filters and activated sludge units, and are caused primarily by materials which inhibit bacterial activity or by solids of various types which clog filter nozzles or form heavy scum layer. Table 7.1 describes the problems, based on experience in USA, which could not be solved by the treatment plant alone. The problems were so varied that they defy any generalized description or tabulation. Accordingly, a synopsis of each difficulty is given in Table 7.1 (10).

7.2.3 Precautions to be Taken During Combined Waste Treatment

Combined treatment is a success only when all the member industrial units realize that each treatment plant does have its limitations. Some

Table : 7.1

Operating Difficulties not Solvable at Treatment Plant

Treatment Plant	Offending Waste	Description of Difficulty
Fayetteville	Feathers	Float in digester; clog spray nozzles of trickling filters
Stockton	Peach and apricot processing waste	Wastes contain much nonsettling organic matter with high pH. Trickling filter has little effect in reducing BOD Hence, during canning season, high BOD wastes are discharged to river
Los Angeles County	Solvents and unidentifiable toxic compounds	Gas production depressed when toxic material received
Orange County	Citrus cannery wastes	Suspended solids from these wastes do not settle well, giving effluent with excessive suspended solids
Southeast Works, San Francisco	Tallow solvents and pigments	Plug bar racks, possibility of explosive mixture
Oxnard	Cannery acid wastes	Lower pH and interfere with digestion
Tampa	Citrus press liquors	Inhibit digestion, forming heavy scum layers
Dalton	Lint	Interferes with electrodes used in automatic controls. Clogs pump lines
	Feathers	Stoppage of trickling filter nozzles; interfere with electrodes used in automatic controls
Gary	Metal pickle liquor	Clogs carborundum aeration tubes with iron oxide
Wichita	Chromium, copper, cyanide, cadmium	Destroy anaerobic digestion
Macon	Feathers, blood, grease	Clog trickling filter
Trenton	Dyes from pickling liquor	Discolour effluent
Austin	Unknown	Inhibits anaerobic digestion
Forth Worth	Chromium Feather	Inhibits gas production in digester Feathers form scum blanket in digester
Harrisonburg	Feathers and grease	Feathers form scum blankets in digesters. Grease forms leathery membrane on sludge drying beds and inhibits sludge drying

wastes above a given concentration have adverse effects on both the equipment and the process of the treatment plant. Many wastes, while not damaging the installations, may not yield to treatment and thus, pass to the receiving stream unaffected (90).

The major regulatory risk is the acceptance of hazardous waste for treatment at the centralized nonhazardous waste treatment facility. Treatment systems are not designed to treat hazardous waste in a reliable fashion. If a hazardous waste were accepted, it is likely that it would not be treated adequately, resulting in the pass-through of hazardous pollutants to the sewer and the contamination of the sludge cake that is to be disposed at a municipal solid waste landfill. A control strategy aiming at prior qualification of waste before acceptance for treatment are outlined in Table 7.2 (69).

Flammable or explosive materials, such as solvents, should never be discharged to the sewers. In fact, active, positive approach of a preventive nature should be initiated. Toxic materials such as the heavy metallic salts and metallic catalysts must be prohibitd in concentration which can have an adverse effect on the biological process.

Fats, oils or greases discharged in quantities which could settle out at normal sewer velocities and clog the sewers should be prohibited.

Generally, acid wastes (low pH) should never be discharged to a sewer regardless of whether or not eventual dilution to harmless proportions occur by the time the wastes enter the CETP. Before the dilution occurs, the acid can corrode and in a short time badly damage concrete sewers. Here, too, active steps are necessary to prevent accidental spills (90).

7.3 Laboratory and Workshop Facilities for O&M of CETP

In order to achieve optimal functioning of the CETP, a well equipped laboratory must be constructed separately, Fig. 7.1. It should be separate establishment under CETP authorities and should have space for the following purposes :

- Laboratory space for carrying out regular analysis
- Cold room
- Space for all scientific/managerial staff including administration
- The laboratory should also be equipped with workshop facilities, instrumentation including computer facilities for data base management
- The laboratory should also be equipped with library and storeroom.

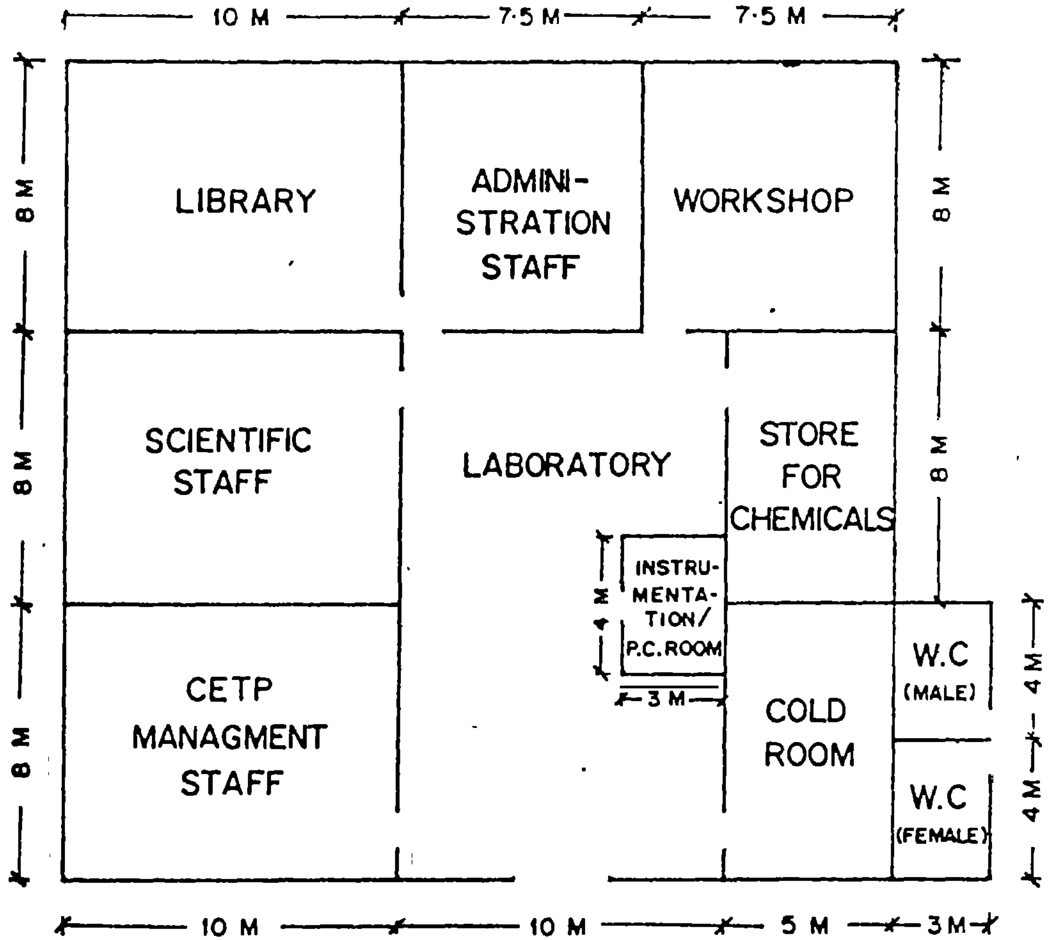

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FIG. 7.1 : LABORATORY/ADMINISTRATIVE WING FOR CETP (PLAN)

Table : 7.2

Control Strategies Against the Acceptance of Hazardous Wastes

Control Keys

1. To approve waste before acceptance for treatment
2. To screen waste on arrival for petroleum oils and toxics
3. To documents information for reference and requalification

Control Strategies

1. Require the permittee to qualify the waste generators and their wastes through a prequalification questionnaire to be signed by the generator, a sample analysis if needed and a preliminary treatability evaluation using a jar test.

2. Preapprove the permittee to accept select generic categories of nonhazardous wastes, but require submittal of information for other industrial nonhazardous wastes for review and prior approval.

3. Require quick physical and chemical screening tests for waste on arrival to check for petroleum oil and toxic pollutants as appropriate to determine conformance with the qualified waste sample and generator information.

4. Require periodic requalification of the wastestream to check for major changes in quality and/or generator information.

5. Require information and test results to be filed in binders or log book for inspection.

6. Require monthly monitoring of toxic pollutants in the wastewater discharged.

Once the process units are commissioned it is desirable to conduct a monthly review or periodic reviews on the performance of the CETP facility These reviews should include a discussion of any problems (process/equipment) encountered, solutions to those problems, review of operating data, adjustment of operating strategy, and identification of any system design modification that may be required.

This method will short circuit any minor nuisance before they become major problems. This practice will result in an improved overall operation and successful long term performance.

7.3.1 Environmental Quality Monitoring

Monitoring the environmental quality is aimed at surveillance of the environmental media into which the treated wastewater is released or disposed off. The necessary systems and methods are outlined below :

Periodic Site Inspection

This should be planned on a seasonal or annual frequency. Visual observations are adequate to note areas of surface subsisdence or plant die-back if the treated wastewater is used for irrigation or development of green belt.

Periodic Water Quality Analysis

Water quality monitoring preferably daily/weekly basis will be useful for assessing the quality of treated wastewater discharged as well as its suitability for general plant uses. Conventional as well as health related parameters for water, wastewater and treated effluent are required to be determined.

Monitoring for Specific Contaminants

The release of heavy metals and toxic organic compounds in the treated effluent can have adverse health impacts and cause environmental damage. It is now possible to detect the presence of particular chemical substances by specific electrodes, analogous to the measurement of acidity/pH with a pH meter. A list of equipment necessary for an environmental management laboratory to be set up for CETP is appended in Annexure-VII.

7.3.2 Operation and Maintenance Cell

It is mandatory to have a separate environmental management cell for control, monitoring and maintenance of CETP. To assist the environmental managers effectively, administrative backup may also be considered alongwith infrastructural facilities. The organizational set up for proper functioning of CETP includes supervisors, chemists, mechanics etc., Fig. 7.2. The functional organization will have the following staff pattern :

Chairman	-	1
Managing Director	-	1
Director - Operation	-	1
Director - Technical	-	1
Director - Finance	-	1
Plant Manager	-	1
Laboratory Incharge	-	1
Maintenance Supervisor	-	1
Project Engineer	-	1
Environmental Engineer	-	4
Account Staff	-	4
Chemist		
Monitoring/Operation	-	6
R & D	-	2
Operating Staff	-	
Mechanics/Electrician, etc.	-	6

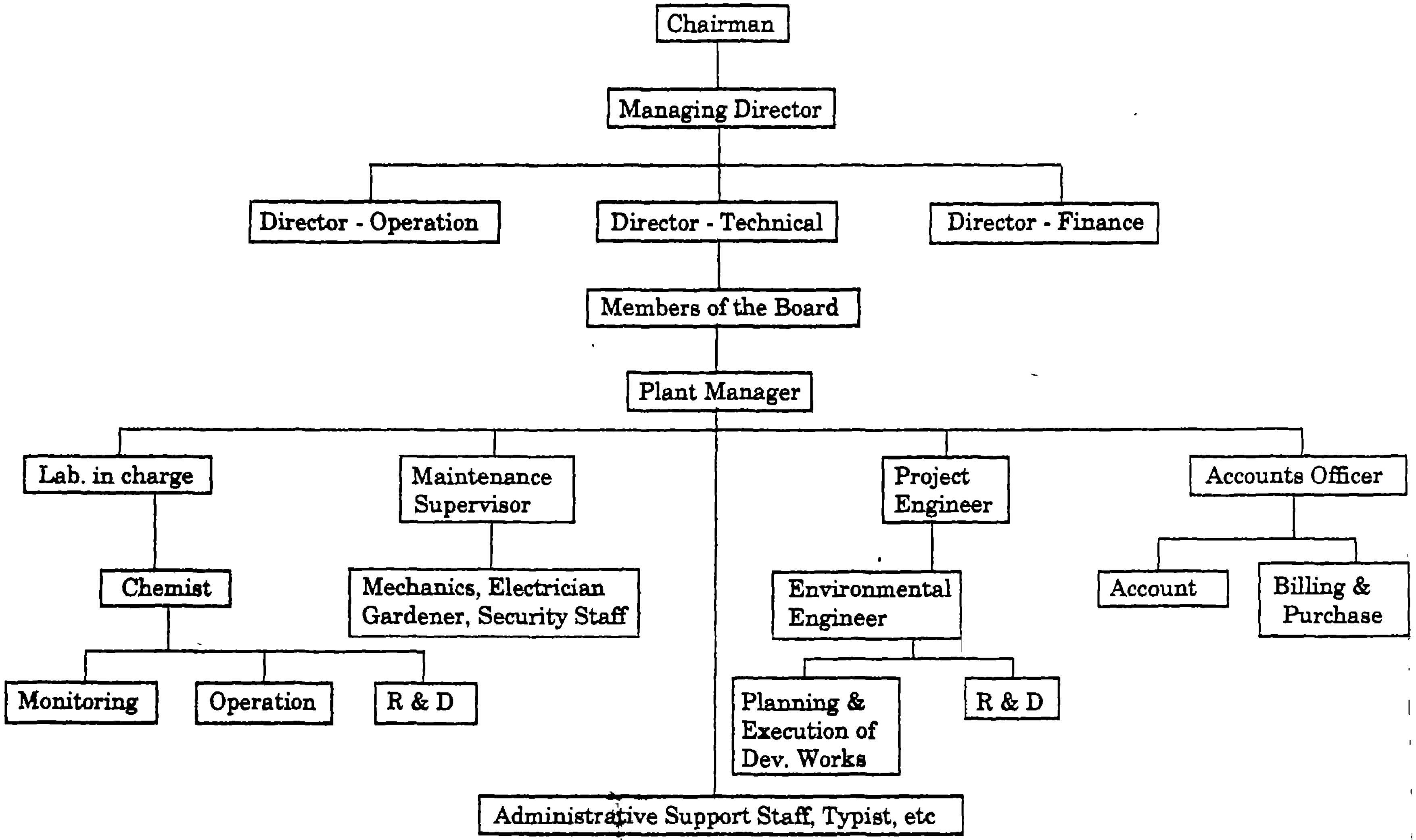


FIG. 7.2 : ORGANIZATION CHART

7.3.3 Training Programme

The start-up of a new facility and the training of operating personnel to operate the processes is the last critical step in the implementation of any pollution control technology. These must be planned and scheduled in order to operate the plant in a safe and effective manner.

Training should be imparted to operators at various stages, viz. prior to start-up, during start-up and following the establishment of steady state operation. The type of training conducted is highly dependent on the background and experience of the operating staff to be trained. The range of capabilities may be very broad, ranging from new-hires or trainees to highly experienced supervisors. For this reason, every training programme must be tailored to the needs of the process and the personnel who will be in the training sessions. The training programme should be a combination of theoretical and practical education.

Task 1

Implementation of the first training programme should start simultaneously with the construction of CETP.

Task 2

Training manual must be prepared before completion of the construction of CETP.

Task 3

Training should start during the commissioning of CETP and continue till the CETP starts functioning as per specifications. In this task executives and chemical-analysts will be involved.

Task 4

This component comprises of the training to be imparted to the workmen on the field with laboratory supervisors.

Task 5

Depending upon the performance evaluation of CETP in practice, the training manual must be revised.

Task 6

It is advisable that a training programme should also be conducted for the personnel from industrial units. This part will enhance the importance of CETP functionality and also the environment management requirements. It is felt that this part can be taken up jointly by GIDC, the consultant for CETP and NEERI.

Operation and Maintenance Manual

The Operation & Maintenance Manual should be a well deisigned referenced document to be used by the operators for a variety of day-to-day needs. Since there are a variety of unit processes and unit operations involved, in the proposed CETP, all relevent information must be included in the preparation of the CETP manual. Supervisors, operators, workmen and other maintenance personnel need different types of information, and it is not advisable to compile it all in a single document. It should be written or prepared in a language with which the users are familiar. Also graphical presentation of information is often more valuable and useful than narrative or tabular information. It is also preferable if this information is in a loose-leaf binder to facilitate updating of the manual, thus making it more of a working document and easier to copy for use in the field.

8

Ownership and Management

Whichever arrangements are made for the ownership and day to day operation of the CETP, certain conditions must be fulfilled in order to ensure a lasting success of such a facility. The most important is the realization by the parties involved that the laws and directives that stipulate the conditions under which the plant is to be operated must be obeyed. Both the individual waste producer who delivers his waste to the plant, the CETP operator, and the public authorities which are involved in the management of the waste and the CETP must be prepared to support the measures necessary for a trouble-free operation. Without such cooperation it will be extremely difficult to fulfil the aims of the project.

Another important point is the realization that information and promotion of the principles of a cleaner environment in industrial estates are preferable means of obtaining compliance, rather than strict enforcement. If these principles are accepted by the industry and the agencies involved, it will be possible to operate a CETP successfully.

8.1 OWNERSHIP OPTIONS

Three basic options which can be envisaged for the ownership and management of a CETP are as follows :

- Public sector
- Private sector
- A combination of public and private sector

Number of possible arrangements within each of these options are possible and are discussed below (80) :

8.1.1 Public Sector

The most obvious public sector agency to operate a CETP is the State Industrial Development Corporation (SIDC). This agency is generally responsible for the day to day operation of the industrial estate which includes water supply, road maintenance and management of attached housing estates etc. Operation of a CETP could become an addditional service to be provided by SIDC.

Advantages

- The necessary management and technical expertise would be relatively easy to obtain from internal resources

- Since the SIDC maintains other services to the estate, such as water, power, roads and drainage, the operation of a CETP could conveniently become part of the corporations' service programme

- Because of this control over other services, the enforcement of legal and financial obligations on the individual industries may be less difficult than by other arrangements

- The enforcement may also be enhanced through the ease of coordination and cooperation with other Government agencies such as water and electricity boards.

Disadvantages

- Potential inefficiency in public sector enterprises

- Being a government instrumentality, a SIDC will be subject to legal action, if required, by another State Government body. This may lead to compromises in standards and compliance

- Lack of flexibility in operation and choice of staff.

Other Government agencies, such as Pollution Control Boards and Water Supply & Sewerage Boards, could in theory act as a public sector agency operating the plant. However, such arrangements are both undesirable and unlikely because :

a) It would be even more compromising for such Government agencies which act under their own environmental legislation, and

b) SIDCs have a deep involvement in the industrial estates and therefore, it would appear totally impracticable to have two public sector agencies operating side by side within the estate.

The possible involvement of such agencies in a more indirect role is discussed in Section 8.1.3.

8.1.2 Private Sector

Under a purely private sector operation, two arrangements are possible :

A. An outside company, for example a supplier of effluent treatment equipment, or a company which already has experience in operating effluent treatment plants, could be contracted to manage the CETP. For this to be a viable proposition, a minimum profit must be guaranteed in order to make it attractive for the company to enter into a contract. Such an arrangement is not common in India today, but there is a trend, however, for industries to operate treatment plants on contract basis. Outside India this type of arrangement is common in many countries.

Advantages

- The advantage of this system is that an organisation with experience is contracted to operate the treatment plant, thus ensuring stability of operation and freeing both the controlling public sector agencies and the individual waste producing industries from day to day operational problems. Cost recovery and legal arrangement can be established through contractual agreements.

Disadvantages

- The company taking over all the functions of the CETP management would have to ensure legal compliance by the individual companies joining the CETP system

- A very similar arrangement involving the public sector is discussed further in section 8.1.3 as it is in reality a combination of public and private sector control

- Another major concern is that the waste producers would consider a private company's charges as excessive due to it's profit over and above the operational costs

- A purely private sector arrangement for the total management of a CETP is therefore not likely at present where the cost of non-compliance is less than the marginal cost of participation in the CETP.

B. A cooperative company could be formed by the individual industrial units in the industrial estate or by the local Industrial

Association at that estate. The company would be a separate corporation entity. The lead for the formation of such a company could be taken by the Industries Association or individual units within that estate.

Advantages

- If operated on a cost recovery basis only, it will be possible to ensure the lowest cost of treatment to individual waste producers

- It is beneficial that the industries producing the waste for treatment have a direct financial and legal involvement in the company managing the CETP

- There could be better transfer and use of technical know-how and manpower, and the possibility of using member industries' materials and equipment to overcome short term problems at the CETP

- The increased awareness of environmental responsibilities of the Industries Association and the individual industries will increase the probability of success of the CETP by an active involvement in the operation and management.

Disadvantages

- With a large number of industries participating, it could take a long time to constitute a company which satisfies all parties, bearing in mind the considerable variation in size and type of industries

- There could be potential conflict of interest between an individual industry's involvement in its own production and the cost and performance of the CETP.

8.1.3 Combination of Public and Private Sector

A joint sector company operating the CETP could be a company where the SIDC and/or both the participating individual industries and the Industries Association will be members of a registered cooperative society or shareholders in a company formed solely for the management of the CETP.

A variation on the concept of joint public and private sector management of a CETP is a "Tripartite" arrangement. In such a case, the SIDC would have a contract with a private company to design, construct and operate the CETP for a designated number of years.

Finance can be arranged jointly by the SIDC and the company, possibly by SIDC obtaining capital funds and the company recovering operating and maintenance expenses - and a profit - from the charges levied on individual waste producers in accordance with volume and composition of the waste. The charges can also include an amount which would ensure the repayment of capital borrowings.

The operating company, working under contract to the SIDC, would itself enter into contracts with individual waste producers in order to guarantee that volume and composition of the waste is maintained and that legal action can be successfully initiated in the case of breach of contract. This would be further enhanced through the contract between SIDC and the company, and the powers available under the SIDC's legislation.

The company operating the CETP under this arrangement can incorporate individual industries and the Industrial Association as shareholders.

Any of the three alternatives discussed can be selected depending on the requirements of the parties involved at the specific sites.

From a social and legal responsibility point of view, however, private sector involvement seems to be the most appropriate.

In order to ensure the benefits derived from the involvement of SIDC also, the joint sector arrangement appears to be the best possible solution.

Either the cooperative company or the contractual "Tripartite" arrangement would be acceptable ways of establishing the ownership of a CETP.

The legal relationship between the operator of the CETP and the users must be well defined by a contractual agreement between the parties. The agreement must specify the responsibilities of both the operator and the users and lay down terms and conditions.

Such a joint arrangement is theoretically ideal since it can enhance the advantages of both the private and public sectors and assist in reducing their disadvantages.

Advantages

- Basically all of the advantages listed in section 8.1.1 for the Public sector option

- Improved possibilities of securing funds.

Disadvantages

- As for the cooperative arrangement discussed in section 8.1.2 there could be delays in reaching agreement between all parties.

8.2 OPERATIONAL ARRANGEMENTS

No matter what ownership arrangements are made, two distinct areas of organisation and management are required. One which deals with policy and another with operation. Depending on the final choice of ownership arrangement, the policy making body may reside in or outside the institution or company managing the CETP. The operational part would always rest with the CETP operator.

The policy making body can take the form of a Board of Directors or Advisory Committee. Generally, the Board would consist of the Chairman, Managing Director and other directors, as well as members selected from the shareholders of the company. Whether SIDC is part of the company or not, it should be represented on the Board, at least in an advisory capacity. However, other State Government agencies, and especially the Pollution Control Board, should not be represented on a Board of Directors as this would in most cases result in a direct conflict of interest. If deemed necessary for those agencies to have input into the operation beyond their official capacity, they can be included in an advisory committee alongwith consultants and other experts as well as representatives from industries in the industrial estate.

The day to day operations would be controlled by a plant manager assisted by the required operational, laboratory, maintenance and general support staff. A typical organisation chart is presented in Fig. 8.1. A similar organizational set-up for a proposed CETP in western Maharashtra is illustrated in Fig. 8.2.

In order to ensure the successful operation of the CETP, there are a number of conditions which must be fulfilled by the CETP operator and the individual waste producers utilizing the plant.

Some operational issues are highlighted here as they are very important for the successful operation of a CETP :

a) All new industries in an industrial estate must meet the pretreatment standards for the CETP as a condition for consent to operate and to be connected to the common effluent collection system.

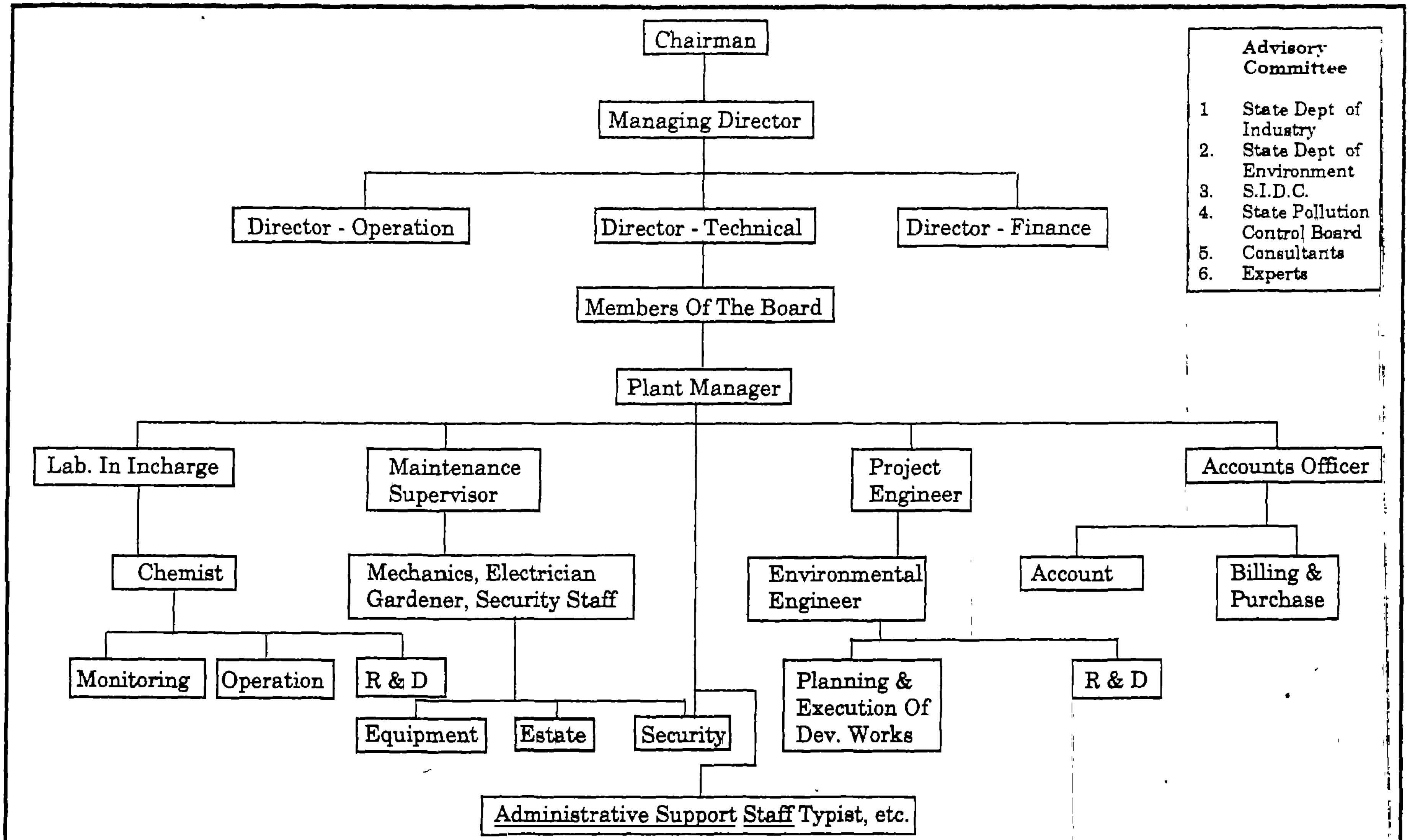
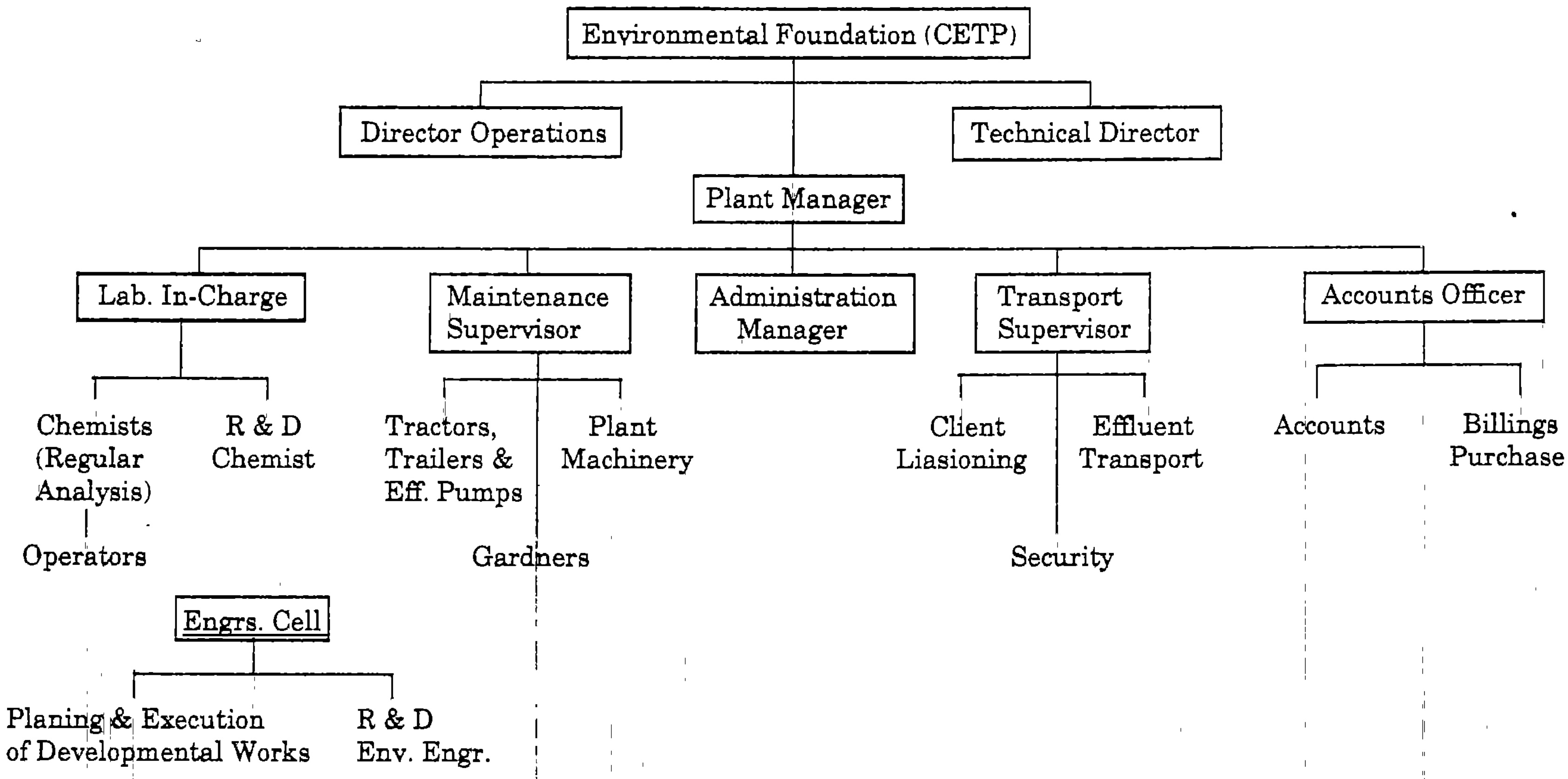


FIG. 8.1 : TYPICAL ORGANIZATION



Source : Report on TBIA and SSEA upon Master Plan and Design of CETP at Pawne, Environmental Engineering Consultants, July 91.)

FIG. 8.2 : PROJECT ORGANISATION

b) Existing industries in an industrial estate must also meet the pretreatment standards for the CETP as a condition for being connected to the common effluent collection system.

c) The CETP operator should be granted the right of entry for sampling purposes and the right to impose sanctions such as fines and service cutoffs.

d) The operator should be allowed to adjust the cost recovery formula to take into account inflation, unforeseen costs and variations in flow and loading to the plant which is not automatically corrected by the formula for calculation of charges.

e) A standard service contract that clearly spells out the obligation of the users of the CETP and the CETP operator should be decided upon in consultation with all concerned parties. It should include the following specifications on the part of the facility users and the CETP operator :

- The user is responsible for meeting the pretreatment requirements

- If the user does not meet the pretreatment requirements, the treatment service will be withdrawn, and the offending user will be responsible for all additional costs imposed on the CETP operator due to the failure to meet its obligations

- The user is responsible for prompt payment of fees. The treatment service may be withdrawn by the CETP operator in case of non-payment and legal action may be taken

- If the user meets the pretreatment standards, the CETP operator is responsible for treating the influent to a level that meets the standards for such effluents. If it is unable to do this due to problems with its operation not caused by lack of pretreatment on the part of its users, then he is responsible for all costs ensued

- If the upset in operations and resulting non-compliance is a result of a user not meeting pretreatment standards, then the CETP operator is responsible for excluding the offending user from the CETP influent and for recovering any additional costs that ensue from the offending user

- The CETP operator is responsible for maintaining an ongoing effluent flow and characteristics monitoring programme so that the operation and maintenance cost formula may be corrected to reflect actual rather than established conditions as well as an aid to maintaining proper CETP operations

- The point at which the effluent becomes the responsibility of the CETP operator should be clearly defined.

9

Cleaner Technologies of Industrial Production

The options for environmental management in industry include, on one hand, reactive control measures such as end-of-the-pipe (EOP) treatment technologies and media-specific regulations for waste discharges, and on the other, anticipative and preventive strategies such as adoption of cleaner technologies of production and integrated planning based on considerations of regional carrying capacity.

Considerations of resource conservation, economic efficiency and environmental protection warrant the adoption, as far as possible, of a preventive strategy because of end-of-the-pipe control technologies, more often than not, transfer pollutants from one environmental medium to another and consume resources out of proportion to the accrued benefits.

As new industries come up, to meet developmental imperatives, it will be necessary to impose more stringent emission/discharge standards progressively to maintain acceptable levels of environmental quality. If the option of more intensive pollution control is to be avoided in the future, then it is necessary to adopt a strategy of pollution prevention based on technologies that conserve resources, minimize pollution, and reuse wastes as secondary resources to the extent possible.

9.1 CLEANER TECHNOLOGIES OF PRODUCTION

In 1976, Economic Commission for Europe defined Non-Waste Technology (NWT) as the practical application of knowledge, methods and means so as, within the needs of man, to provide the most rational use of natural resources and energy, and to protect the environment. NWT is deemed as the theoretical limit to which low-waste technology can be carried. The techno-economic infeasibility of development and implementation of NWT gave rise to the pragmatic concept of Low and Non-Waste Technologies (LNWT) of production.

The concept was broadened by ECE in 1979 by coining the term Cleaner Technologies (of production) incorporating aspects of :

- less pollution discharged into natural environment
- less waste generation
- less demand for natural resources.

The concept of cleaner technologies is based on the awareness that the environment cannot be considered independent of other development sectors, including consumption of energy and resources, and the economy of the country. From the environmental point of view, it means use of minimum resources with maximum efficiency to achieve the twin benefits of resource conservation and environmental protection. From the economic point of view, it means cost effectivity and increased productivity within available resources.

Cleaner Technologies warrant on improved manufacturing methods that require less raw materials and energy to generate equitable levels of output of identical or better quality. These also make greater, if not full, use of wastes and recyclable materials and are dependent upon innovation and high level of cooperation between different industries, particularly when exchanges of certain wastes are involved.

There are three broad categories of cleaner technologies, viz.

- LNWT of production aimed at waste minimization at all points in the cycle of production through process changes, good housekeeping, recycle and reuse, equipment redesign and product reformulation

- Recycle technologies designed to recover raw materials, energy, water and byproducts in the course of EOP waste treatment

- Waste utilization technologies for reclamation and utilization of wastes as secondary raw materials, or for processing of wastes to manufacture products with various end uses.

Selection and application of cleaner technologies require a comparative analysis and evaluation of various competing technologies based on economic, technological, social and environmental considerations.

The results of cost-benefit analysis depend essentially on the percieved costs and benefits which elude definition for environmental intangibles. Whereas decisions at the industry level may be based on economic analysis of resources conserved, pollution control costs avoided, and costs incurred on new technologies. Government at the national level may be guided by benefits to society and impacts on environmental quality as also stock and quality of natural resource base.

9.2 REVIEW OF AVAILABLE TECHNOLOGIES

9.2.1 Low and Non-Waste Technologies

LNWT of production warrant waste minimization at all stages of production through process modification, recycle/reuse of raw materials, equipment redesign and product reformulation.

However, recycling/reuse of raw materials is the preferred option, followed by process modification. An approach to LNWT for management of liquid wastes is illustratred in Fig. 9.1. Selected examples of LNWT of production are presented in Table 9.1.

9.2.2 Recycle & Reuse Technologies for EOP

9.2.2.1 Wastewater Recycle

In the situations where non-availability of water forces curtailment of industrial production in summer, a waste management scheme resulting in the reuse of treated wastewater would encourage initial investment in treatment that could be recovered in course of time.

The application of EOP treatment for wastewater recycle has been evidenced in a number of industrial sectors in India. Some examples are :

- Physico-chemical treatment in textile industry for recycle and reuse of wastewater as process water directly after softening or in admixture with fresh water

- Physico-chemical treatment in chrome tannery and metal-plating industries for recycle and reuse of wastewater as process water

- Recycle of wastewater in oil mills for ancilliary uses through physico-chemical treatment

- Filtration and softening of cooling tower blowdown in thermal power plants for reuse as cooling water, use of cooling tower blowdown for ash handling, rinse recycle for regeneration of ion exchange columns

- Use of treated wastewater for making lime solution in fertilizer industry.

The main apprehensions of the industry regarding wastewater reuse relate to the quality of recycled water for use in process house and cost of such treatment. The experience of the Indian workers in this regard is summarised in Table 9.2.

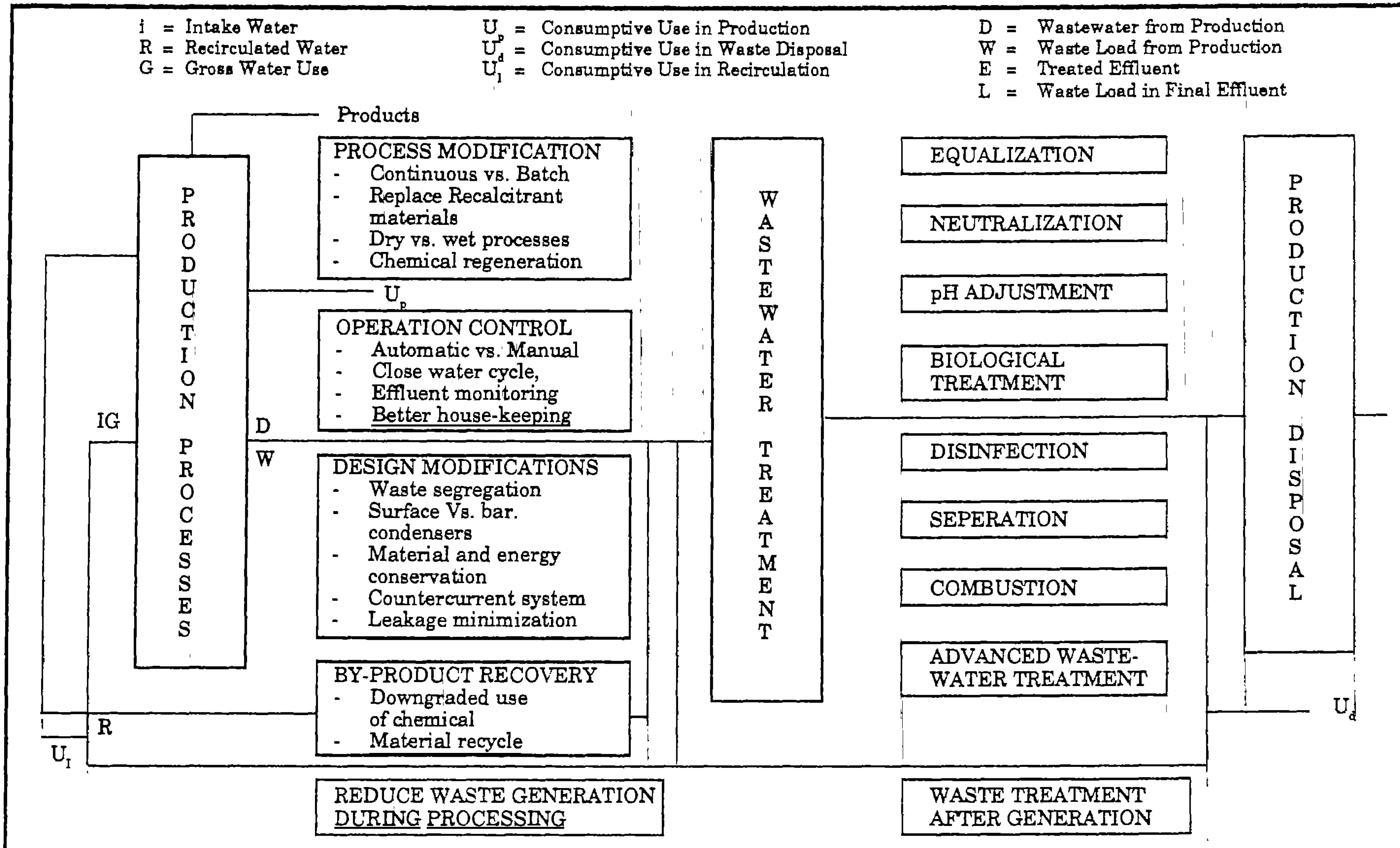


FIG. 9.1 : INTEGRATED APPROACH TO WASTE WATER MANAGEMENT IN INDUSTRY

Table : 9.1

Low-And Non Waste Technologies Of Production

Sr. No.	Name of Industry	Steps towards Non-waste Technology			
		Process Modification	Recycle/Reuse	Equipment Redesign	Product Forulation
1.	Pulp and paper	Removal of silica before evaporation process in cooking of rice straw	Whitewater recyling for washing of pulp	Press drying technology for paper making	Brightness of pulp regulated to 75-80%
		Substitution of chlorine with chlorine dioxide or hydrogen peroxide in bleaching of pulp	Recovery of sodium sulfide/ sodium carbonate in cooking		Separation of paper requiring permanent brightness
			Separation of lignin in bleaching process for use as adhesive agent and raw material for dyestuffs		
2.	Textile	Thermal printing process for cotton cloth	Caustic soda recovery in mercerizing		
		CMC/PVA to replace starch in sizing	Solid cotton waste separation for use as stuffing for cushions and dolls		
		Counter current washing			
3.	Tannery	Aluminium salts to replace chromium salts in pretanning	Cuttings, trimming as raw materials for leather boards	Use of drums and mixers instead of pits	
		Batch washing of hides instead of continuous washing	Green scrappings from sawing for glue production		
		Enzynes to replace sulphate in unhairing	Tail and body hair for carpet industry		
4.	Metal Finishing	Counter current washing for rinsing	Cadmium and cyanide recovery through reverse osmosis		
		Non-cyanide salts for nitriding	Recovery of noble metals through electrolysis		

contd .

Sr. No.	Name of Industry	Steps towards Non-waste Technology			
		Process Modification	Recycle/Reuse	Equipment Redesign	Product Forulation
5.	Chor-alkali	Ion-exchange and electrolysis for production of chlorine and caustic soda			
6.	Iron and steel	Mechanical cleaning to replace acid pickling	Blast furance slag as construction materials		
		Neutral electro-tytic process for pickling	Recovery of hydro-chloric acid from pickling process		
7.	Fertilizer	Nitrophosphate process for NPH complex production	Nitric acid recovery in ammonia fertilizer plant		

Table : 9.2

Benefit-Cost Analysis for Selected Industries

Industry	Total Wastewater Flow (m^3/d)	Total Cost of Plant ($Rs.x10^5$)	Net Annual Recovery ($Rs.x10^5$)	Investment Payback Period (yrs.)	Remarks
Apparel	6450	4625	4375	1.05	Recycle in process house
Alcohol	1725	2250	975	2.30	Reuse of energy in process house
Tanning	2710	3875	NQ	NQ	Recycle for irrigation
Food Processing	1460	10500	4250	2.47	Recycle for irrigation/ process house and reuse of energy
Viscose Rayon	4500	200	36	5.5	Recovery & reuse of zinc, foreign exchange savings

NQ : Not Quantified

9.2.2.2 Raw Material Recovery

The efficiency of process of conversion of raw materials into finished products has its limits. The unutilized raw materials and process water find their way to waste streams due to process inefficiency.

Raw material recovery technologies result in reduction of stack and fugutive pollution load while saving valuable resources. The raw material recovery technologies are based on unit operations, viz. screening, filtration, sedimentation, evaporation, floatation, electrolysis, ion exchange resins and membranes etc. The recovery options for selected industries are presented in Table 9.3.

9.2.3 Waste Utilization

The quantity of industrial and mineral wastes available in India, summarized in Table 9.4, amounts to nearly 50 million tonnes per annum. These wastes include flyash from thermal power stations, blast furnace slag from steel manufacture, paper sludge from pulp and paper production, baggasse from sugar industry, phosphochalk and phosphogypsum from fertilizer industry, red mud from aluminum industry, and low concentration ores as well as marginal remains of rich ores from mining operations. The industrial and mineral wastes possess immense potential as raw material for manufacture of building materials such as slag cement, portland pozzolana cement, lightweight aggregates, bricks etc. as shown in Table 9.5.

The waste from one industry may be useful or may even be the raw material to other industry. Symbiotic agglomeration of industries will enable the process of waste utilization, e.g. sugar-distillery, phosphogypsum-cement complexes.

9.3 CLEANER TECHNOLOGIES - INTERNATIONAL SCENARIO

Emergence of the concept of cleaner technologies could be traced back to UN conference on Human settlement in 1972 that proclaimed resource conservation as a basic principle for environmental management.

In 1976, Senior Advisors to ECE Governments deliberated on the Principles and Creation of Non-Waste Technology and Production. The seminar identified the term Non-Waste as a kind of technological optimum, which can be used as a norm for measuring the final degree of production efficiency.

A joint UNEP-ECE project on Compilation of a Compendium on Low and Non-Waste Technology in ECE region was started in 1977. The objective of the compendium was to provide examples of practical applications in major industrial sectors, reveal gaps in knowledge and thereby identify

Table : 9.3

Raw Material Recovery Options for Selected Industries

Sr. No.	Industry	Product	Recovery Scheme
1.	Pulp and paper	Fibres & Fillers	Filtration/sedimentation/floatation
2.	Metal finishing	Planting metals	Ion exchange/electrodyalysis/ ultrafiltration/electrolysis
3.	Photoprocessing	Silver	Electrolysis
4.	Cement	Cement dust	Electrostatic precipitator/filters
5.	Chrome tannery	Chromium	Electrolysis/physico-chemical processes
6.	Vegetable Tannery	Common salt	Evaporation of soak liquor
7.	Fertilizer	Ammonia	Wet scrubbing
8.	Dyes & Dye intermediates	Dyes	Membrane technology

Table : 9.4

Availability of Industrial Wastes in India

Sr. No.	Waste	Availability Millions tonnes/year	
		Total	Usable form
1.	Flyash	19.0	3.0
2.	Blastfurnace slag	7.5	2 8
3.	Ferro-alloy and other metallurgical slags	3.5	-
4.	Metallurgical slags	3.5	-
5.	Lime sludge (from sugar, acetylene, fetilizer, paper, chrome and soda ash industries)	4.8	4.8
6.	Byproduct gypsum	4.5	4.5
7.	Red Mud	1.5	-

Table : 9.5

Present Utilization and Alternative Economic Products Obtainable from Some Industrial Wastes

Sr. No.	Industrial Waste	Physical Form of Waste	Source Industry	Present Disposal Method	Potential for use
1.	Flyash	Powder	Thermal Power Station	i) Pumped in the form of slurry to nearby lowlying areas in the wet system of disposal ii) Flyash discharged from the precipitators is conveyed for disposal to the dumps in the dry method	i. In portland pozzolana cement ii. In construction industry iii. a Dam construction b. Land reclamation c. Road construction iv. Cellullar concrete v. Lime flyash bricks vi. Sintered light weight aggregates
2.	Blast furnace slag - granulated - ungranulated	Solid lumps	Steel Industry	Dumping in open area	i. As a component in blast furnace slag cement ii. As a component in binding material i. Road aggregate ii. Slag wool
3.	Lime sludge	Slurry paste	Fertilizer, Sugar, Paper, Acetylene Industry	Stored in large outdoor settling ponds	i. As raw material in cement manufacture ii. In lime pozzolana mixture
4.	Chemical gypsum	Slurry paste	Fertilizer Industry	Pumped in the form of slury to the dumping ponds	i. As a set controller in the manufacture of cement in place of mineral gypsum ii. For making gypsum block board
5.	Red mud	Paste	Aluminium Industry	Dumped in open area	i. As a component of raw mix in the cement industry ii. In the manufacture of building bricks iii. Light weight structural blocks

thrust areas for R&D. Till January 1987, the compendium contained 129 monographs.

Realizing the need for an international network to promote LNWT, UNEP/IEO in 1989 established industrial sector working groups for tanning, textile, halogenated solvents, electroplating industries, with a view to harmonizing data and government policies.

UNEP/IEO also established International Cleaner Production Clearing House (ICPIC) which is computer-based information exchange system. It contains over 400 case studies, calender of training events and seminars, a directory of experts, bibliography of references and description of international programmes on LNWT. ECE and UNEP/IEO have instituted an award to industry for cleaner technology as a means of encouragement.

ECE, since 1979, is engaged in R&D on cleaner technologies. It has taken up programmes through the Council Regulations on Action by the Community relating to Environment (ACE) which include financial support for demonstration projects on cleaner technologies to the tune of 30 % cost of full scale plant. ECE has set up a network for Environmental Technology Transfer (NETT) in 1988. NETT provides for exchange of information and transfer of technologies, cost-effective pollution abatement methods, and waste treatment technologies.

US-EPA has recently changed focus of its activities from EOP to pollution prevention. It established Pollution Prevention Office (PPO) and Pollution Prevention Advisory Committee of senior EPA managers in 1987. Office of Research and Development of EPA has also commissioned a Waste Minimization Research (WMR) programmes comprising :

- Waste Reduction Innovative Technology Evaluation Programme (WRITE)
- Waste Reduction Assessment Programme (WRAP)
- Waste Reduction Evaluation at Federal Facilities (WREAFS)
- Waste Reduction Institute for Scientists and Engineers (WRISE)
- Pollution Prevention Information Clearinghouse (PPIC)

Developed countries including USA, Denmark, France, Germany, Netherlands, UK, Sweden, Norway and Japan have enacted legislations for recycling of solid wastes. Also, regulations for households and industries regarding source separation and use of recycled paper in public organizations have been framed. Incentives for use of products manufactured using recycled material are also offered.

Waste Utilization policies and programmes have resulted in recovery rates of the order of 40 to 53 percent in Japan and Netherlands in paper, aluminum, wood, glass and steel sectors. The high rate of success in these countries is attributed to unavailability of land for waste dumping together with economic and political costs of importing primary raw materials. Netherlands has also established the world's first waste exchange programme, a free brokerage service, to match buyers and sellers of waste. In addition, it has attempted to stabilize the typical boom-and-boost cycles in recyclables by establishing buffer stocks.

Recovery and recycle of wastes all over the world has registered upward trends in past three decades with 5 to 10 percent increase over 1960 recovery rates for paper, aluminum and steel.

9.4 CLEANER TECHNOLOGIES - INDIAN SCENARIO

In India, the concept of LNWT has been applied in the area of liquid waste management. Examples of waste volume reduction, waste recycle and reuse, and byproduct recovery in several industries such as textile, tannery, metal finishing, beverages, pulp and paper, distillery are well documented.

However, by and large, the industry in India has taken recourse to pollution control through EOP treatment. Examples of pollution prevention through adoption of cleaner technologies are meagre.

Also, the approach of Government, so far, has been reactive, repair oriented and media specific. Separate consents for water and air pollutants overlook the cross-media transfer of pollutants. Financial incentives, as delineated in Table 9.6, are available mainly for EOP treatment. No financial incentives are yet available for use of cleaner technologies.

Recognizing the potential for resource conservation with concomittant reduction in cost of pollution control, MEF retained NEERI in 1988 to prepare draft paper on preventive environmental policy. The paper discussed, among other things, cleaner technologies of production, recycle and reuse technologies for EOP and cross media inter-relationships The elements of cleaner technology are now being integrated by MEF with the bilateral funding agency programmes.

NEERI, in 1988, prepared policy paper on waste utilization in India for the Ministry of Environment & Forests. The paper analysed the informational, economic, technological, managerial and socio-political constraints to waste utilization and delineated appropriate strategies for minimization and reclamation of wastes so as to achieve the twin benefits of conserving material & energy resources and circumventing environmental pollution.

Table : 9.6

Financial Incentives from Government

POLLUTION CONTROL

* Depreciation of air pollution and water pollution control equipment used in industries and other business at a special rate of 50% instead of the normal rate of 33.33%.

* Section 35CCB allows a deduction to an assessee having income from business or profession in respect of expenditure incurred for conservation of natural resources. This section has been recently amended by the Finance Act, 1990, to include expenditure incurred on afforestation also.

* Section 54G exempts capital gains arising on sale of land, building, plant and machinery etc. when an industrial undertaking is shifted from urban areas. This is intended to promote shifting of polluting industries from congested areas.

* Concessional customs duty of 40% has been prescribed in respect of 35 specified pollution control instruments/equipments.

* Further 26 specified pollution control instruments/equipments enjoy concessional excise duty of 5%.

* Under the Water Cess Act, 1977, a rebate of 70% is provided for treating the effluent to the prescribed standards.

WASTE UTILIZATION

* Bricks containing more than 50% flyash are exempted from Central Excise duty upto Dec. 1991.

Subsequent to Waste Utilization Policy paper, National Waste Management Council (NWMC) with Minister, MEF as Chairperson has been established in June 1990. NMWC has constituted subgroups to assess status and identify action plan for waste minimization and utilization in industry, urban human settlements and rural areas.

9.5 MAJOR ISSUES IN DEVELOPMENT AND IMPLEMENTATION OF CLEANER TECHNOLOGIES

Environmental policy for industry has focused mainly on pollution control through end-of-the-pipe (EOP) treatment technologies which allow the wasteful use of resources and then consume further resources to solve the environmental problems in a particular medium. The future raw material and energy scenarios, the impact that the industry and its products have on the natural resource base and environmental quality, and the necessary thrust being given to industrial growth in our country, warrant a comprehensive strategy to deal with environmental and economic problems of the country.

Then, there are industrial processes which cannot be changed easily, if at all. Changeover may be too costly, or there may be no pollution prevention technology which is applicable. This should be recognized and understood. The concept should not - and cannot - be forced where it is inapplicable or unworkable.

There is a certain percieved risk that discourages enterpreneurs from adopting the relatively new concept of cleaner technologies. A combination of informational, financial, economic and legal measures, therefore, need to be devised in order to promote waste minimization through cleaner technologies.

The cleaner technologies cannot be directly imported from successes abroad as perhaps possible for ad-on units such as technologies for ETP. Also technologies which were invented for temperate conditions may not be applicable to tropical countries.

One of the major bottleneck in development and implementation of the cleaner technology is the domination of the public health engineers rather than chemical engineers in the field of environmental engineering.

Development of cleaner technologies warrants interdisciplinary research A systems approach comprising two inter-related subsystems, a production sub-system and an environmental sub-system is required for objective evaluation of technologies.

A major factor that discourages entrepreneurs from preventing pollution is the percieved financial risk associated with the relatively new cleaner technologies. In many cases, such technologies may not even have been developed or sufficiently tested. Then, of course, there is the tendency of industry to avoid environmental costs in favour of short-term gains.

One of the major issues in waste utilization is market stability. Market forces favour waste utilization only in the event of shortage of raw materials or exorbitant prices. The prices of materials tend to fluctuate due to irregularity of supply and demand and this inhibits proliferation of waste reclamation industry.

Also, waste utilization is considerably impeded by lack of information exchange between various interest groups on opportunities for waste recycling and utilization. A centralized data base on availability and accessibility of wastes, technologies for utilization and their economic viability, and market demand for recovered materials does not exist in India.

There is also lack of coordination and direction in R&D efforts and inadequate thrust for technology transfer from laboratory to commercial scale. These problems arise mainly due to insufficient mission oriented approach of laboratories; inadequacy of design, engineering and fabrication facilities; inadequacy of funds for pilot-scale demonstration of laboratory results; and low value placed on technology transfer by scientific and technological personnel engaged in R&D work.

Hence, the challenge is to find technology-transfer mechanisms as innovative as the technologies themselves. A balance among development objectives, environmental protection and patent rights must be expected to surrender hard-won technological advantages freely. Innovative thinking is needed to resolve private claims on patents, trade marks and other industrial property rights and code of conduct for the transfer of environmentally-benign technologies. UNEP is already working with the World Intellectual Property Organization and other UN and multilateral agencies to address this.

9.6 STRATEGIES FOR IMPLEMENTATION

- A combination of informational and institutional measures needs to be devised to promote pollution prevention through cleaner technologies.

- The first step in this direction could be the creation of a centralised data base on cleaner technologies to enable any industry to gain access to available information on the subject rather than being forced to adopt polluting technologies for want of information on better alternatives.

- The second step for promotion of cleaner technologies could be provision of financial assistance for R&D and installation of demonstration plants. A major part of such aid should go to the industry as the industry knows best its processes and how to improve them.

- A major strategy for pollution prevention is the internalisation of environmental costs through a system of taxation on wastes. It has been established that through such a policy, it is possible to achieve the same degree of environmental protection at one-half to one third the cost of a policy based on uniform emission/discharge standards. Among the waste taxes, the concept which has found widest application is that of effluent charges. This approach is successful provided there is sufficient competition in the market to prevent the charge from being passed on to the consumer, and the level of charge is equivalent to the level of damage or at least to the cost of treatment. In implementing these charges it is necessary to ensure that they are not merely taken as a license to pollute. An important aspect of effluent charges is that these encourage the industry to look at pollution as basically an economic problem. Insignificant as it may seem, there is vast psychological difference between introducing a charge on effluents and applying a standard.

- Another approach, which is perhaps too radical yet pragmatic, is the introduction of resource taxes to induce the development of resource saving technologies; rather than allowing the industries to continue in a false paradise of low prices, only to be suddenly faced with a price rise on cost of non-renewable resources at some future date when technological solutions to reduce the costs are not available.

- Economic incentives such as subsidies, tax rebates and loans, could also be provided by the Government to promote cleaner technologies. Such incentives are known to increase economic activity by creation of new markets, employment generation, and development of improved technological capability. However, these benefits cannot be realized if a country imports all its pollution control equipment and services thus bearing the cost of pollution control while some other country receives the benefits. Also, if the subsidies are large and paid to industries operating in the international market, they can lead to trade distortions.

- One of the most important strategies for pollution prevention is the ecological grouping and siting of industries. This involves assessment of the supportive and assimilative capacities of a region for location of economic activities which create wastes in the vicinity of those which can utilize these wastes so that the net use of resources and the net pollution load is minimized while the unavoidable residuals are treated jointly and disposed of.

- Most countries recognize that promotion of cleaner technologies requires legal measures that go beyond conventional media-specific regulations. Stipulation of standards in terms of concentrations, for example, discourages wastewater recycle because recycling may raise the concentration of pollutants while the total pollution discharge is reduced. Standards in terms of waste discharge per unit quantity of raw material or product are, therefore, likely to be more effective in promoting LNWT. Legal measures should also incorporate positive sanctions and ensure that cross-media transfer of pollutants is minimized.

  Waste minimization is a long-term strategy which could be implemented most effectively if its concepts and principles are reflected in the developmental planning process. For example, the ecological grouping and siting of industries could ensure that the net use of resource and net pollution load is minimized while the unavoidable residuals are treated jointly and disposed of.

9.7 CONCLUSIONS

As against EOP treatment technologies, cleaner technologies of industrial production conserve resources, generate less pollution, provide direct economic benefits to the industry, and stimulate the growth of the industry as well as the national economy. Implementation of cleaner technologies requires informational, economic, legal and institutional measures that are substantially different from those used within the present legislative environmental policy framework. The current R&D on cleaner technologies is restricted to fringe issues of minor process modifications, resource conservation through good house keeping practices, and waste recycle. The real issue of the ranking of production technologies based on resource-environment considerations in various industry sectors and transfer of technology through developmental assistance warrants serious coordinated interdisciplinary endeaovour.

Source : Kulkarni V.S., Saraswat N. and Khanna P..
'Development and Implementation of Clean Technologies of Industrial Production', Invited paper - presented in IAEM Annual Conference, 1990.

10

Waste Minimization

An increasingly important aspect of waste management is waste minimization. In other words, rather than attempting to treat the wastes as they are produced, maximum efforts should be made in avoiding, minimizing and/ or using the byproducts. For toxic and hazardous materials, this has the obvious effect of preventing their escape into the environment. But for other general waste streams, it is increasingly important also from an economical point of view to consider a change of processes to limit the production of waste.

This chapter gives a brief review on the principles of waste minimization in general and illustrated them with case studies of some selected specific industries (80).

The principles of waste minimization can best be described by five points of action to be considered in a descending order of acceptability.

1. By avoiding or eliminating the production of a waste, its potential risk to health and the environment is totally removed. This may be carried out by choosing an alternative process when designing a production unit initially, or by altering the process of an existing plant. Although the change of existing processes in most cases involves additional capital cost and often appears to be uneconomical to the company, careful consideration of the long term prospects for the industry must be taken into account. This will often show a far more justifiable investment in the procedures which the company rightly can utilise as a forward thinking, long lasting investment, popular with politicians and the public in general.

2. Reduction and minimization of waste streams within an industry is possible by careful consideration of all the processes and activities which give rise to the production of the waste.

3. Waste recycling and re-use have become popular and topical issues throughout the World in the last few years. The industrialised countries' enormous usage of raw materials, and the apparently senseless waste of these resources in the "throwaway society" has made recycling a very important issue from both an environmental and economic point of view and

also, very importantly, politically. The emergence of green parties in many countries is ample evidence of this.

4. If waste cannot be eliminated or recycled, only destruction of the waste will ensure that the environment does not suffer from the addition of the waste. This of course is especially true in the case of toxic and hazardous waste. Typical examples of waste destruction are cyanide oxidation, reduction and precipitation of chromium from hexavalent to trivalent form, the combustion of organic solvents and the degradation of organic compounds by the use of biological agents.

5. When all avenues delineated above have been exhausted as being non-viable due to excessive economic constraints, then disposal into the environment should be considered.

It should be enforced, as a matter of principle, that the method of disposal is not acceptable and allowable unless it is proven beyond reasonable doubt that all other methods of waste management will seriously affect the economic conditions of the individual company. And it should only then be accepted if it is proven not to cause environmental damage.

Apart from the five methods outlined above for improving waste management practices from a mere disposal operation to an environmentally friendly utilization or avoidance of the waste, there are a number of other initiatives which can be implemented to increase this worthwhile change.

1. For promoting waste utilization the Union Government should seriously consider part or total exemption of sales tax and excise duties for products made wholly or partly of materials which otherwise would be part of the waste stream.

2. Subsidies or concessions for collection, storage and transport of waste should be considered by the Government if it can be proven that such changes in waste management practices will lead to significant improvement in the protection of health and the environment.

3. Special concession should be given for plants proposed for processing of waste into useful products. This should include reduction in import duty on machinery required to be purchased from outside India in order to establish such plants.

The National Waste Management Council has already proposed the development of a national waste management strategy and the establishment of a special Waste Management Institute to advise the Government on the formulation of policies relating to the financial, social and legal aspects of waste minimisation.

10.1 WASTEWATER MINIMIZATION AND RECYCLING

Continuous abstraction of water from the ground water table, in increasing amounts has resulted in rapid decrease in the static water level in the underground water sources and also deterioration in quality. As a result the industry is required to provide extensive treatment of the water, by demineralisation and more recently by application of Reverse Osmosis. In this context, conservation of water and reuse of wastewater after suitable treatment, and practice of waste minimization will be very beneficial.

The recycling of water through a specified number of cycles for the same purpose, such as the cooling system, is practised widely by the industries now, for reducing their total water consumption and associated costs. A judicious combination of reuse of industrial effluents and recovery of valuable by-products, wherever practicable will minimize the hazards of pollution.

Specific methods have been developed for waste minimization and reclamation of water from industrial effluents for reuse is to reduce the waste load present in the effluent. The methods generally adopted are :

- Changes in process technology
- Modification of process equipments
- Segregation of process wastewater from the uncontaminated waste streams from off site utilities like water purification, boiler house and cooling systems.

The next step consists in providing treatment to the wastewater. The treatment schedule consists of physico-chemical treatment, biological treatment followed by sand filtration, chlorination and tertiary treatment by activated carbon adsorption and deionisation using ion-exchange and/or reverse osmosis.

10.2 REUSE OF WATER IN INDUSTRY

The National Association of Manufacturers in USA in their survey report have recommended the following criteria for possible reuse of water by different industries :

Type of Industry	Maximum Reuse (Percent of Water Consumption)
Petroleum	98 percent
Pulp & Paper	52 "
Chemical & Pharmaceutical	35 "
Iron & Steel	25 "
Food & Fermentation	22 "
Textile	14 "
Leather	12 "
Others	22 "

From the above data, it can be seen that a substantial proportion of the wastewater could be reused in each type of the water-intensive industries and hence there would be a sizeable reduction in the waste volume discharged into the environment.

However, the scope of waste minimization by continuous recycling of industrial effluents, in the medium and small scale industries is limited and requires to be identified only by carrying out an industry specific survey in each type of industry.

The implementation of waste minimization programme in an industry requires a detailed survey of the wastewater sources, and the present arrangement for the collection, conveyance and disposal system. Conceptually, waste minimization programme has received a great impetus in recent years only as a result of the increasing demand for water supply and its non-availability. In many industries the drainage system network consists of segregation of the waste streams only from the off-site utilities such as water purification plants, power plants and cooling system. As far as the process waste streams are concerned, the waste streams from different sewers are generally combined into a common collection system and no serious consideration is given in the industry for segregation. Therefore the wastewater collection system in such situation requires suitable modification so as to facilitate segregation of the concerned process wastes from the less contaminated wastes which are derived from the washing and rinsing operations.

Besides the quality of water used and the pattern of its usage differs from one type of industry to another e.g. the power plants, chemical group, pulp and paper and the textile group. The chemical group of industries consists of large variety of industries in which the water usage is highly variable and also it differs appreciably between the large units and the medium and small scale units. Therefore, it is difficult to propound a general scheme of wastewater minimization and reduction in pollution load, which can be applied in common to the different groups.

The programme for waste minimization requires to be considered individually for each industrial unit so as to evolve a rational and feasible plan.

In the light of the above consideration, case studies of a selective group of industries are described below :

10.3 WASTE MINIMIZATION IN SPECIFIC INDUSTRIES

10.3.1 Chemical Industry

The manufacturing processes in the chemical industry comprise of a sequence of unit operations in which various raw materials react under controlled conditions of pH, temperature, pressure and reaction time etc. to yield products which are subsequently isolated and purified. The mother liquor contains impurities derived from the raw materials, catalytic substances, side products formed during synthesis and by-products. The production is carried out in specially designed reaction vessels, as a batch process. The chemical reactions involved in the synthesis are very complex and the organic reactions in the process are governed by the incompleteness of the equilibrium conditions.

Wastewater Generation : Process wastewaters from the chemical industry are characterised by the possible presence of acids, alkalies, salts, organic compounds and dissolved gases. Most of the highly polluting wastes originate from process areas. This includes water formed or eliminated during reactions, wastewater from cleaning operations, steam condensate from stripping operations, water contacted with reactor contents, as in direct cooling, mechanical losses from valves and seals and accidental losses due to spills and faulty operation.

Waste from Utilities : Wastes are derived from utility systems that concentrate water by evaporation. Typically such systems provide indirect evaporate cooling water or steam generation. The water from these sources have minimal contact with raw material or products. Hence they have low potential for pollution except for thermal effects, dissolved solids or conditioning chemicals.

Cleaner Wastes : Cleaner wastes are characterized by once-through indirect cooling flows which are not exposed to process or other sources of contamination except for heat. Their volumes are often large and hence it is important that they are segregated so as not to require treatment for removal of process contaminants prior to discharge.

Contaminated Runoff : Storm runoff derived from shipping or tank farm areas is generally subject to contamination by spills or leakages of products. Such waste streams must be treated along with process wastes. This waste stream is subject to wide fluctuations in volume and concentration and hence poses special problems to the design of the collection system. The contamination occurs initially during the first few hours of rainfall. Provision of equalisation facilities is useful to cope up with the problem.

Waste Minimization and Product Recovery : Efficient conservation of water, process cooling systems and plant water management are the essential prerequisites for minimizing water consumption and effluent discharges.

Conservation of water often begins with the selection of production processes which are compatible with closed circuit objectives. The efficient recovery of the finished product requires an analysis of the design of the production process, plant water system and the plant operational procedures.

Another step is the formulation or a design concept which incorporates a maximum level of conversion of raw material to end products and minimum losses of products and by-products during transfer and handling operations. Such a design approach may also utilize extended reaction times to attain equilibrium product yields and provide facilities for complete draining of reaction kettles and drainage pipes for reducing losses during washing cycles.

Significant reduction in water consumption and product loss can some times be achieved by providing facilities for counter current washing of product.

At the design stage itself it is essential to identify the pattern of water usage and water quality requirement for each specific unit operations in the process flow sheet. This will enable the reduction of fresh water input, maximization of water reuse and an appreciable reduction in wastewater flow and pollution load from the processes.

The process design should also incorporate control of water usage and water quality requirements in conformity with actual requirement and segregation of the contaminated and cleaner effluents.

Equipment Modification : In the chemical industry, process cooling is an area of vast potential for minimization of water consumption and pollutional loads. For example the installation of air fin coolers operating in conjunction with indirect heat exchangers offers the potential of zero discharge from cooling systems. But their implementation may be limited due to environmental considerations, excessive cost or other process factors. Cooling towers or cooling ponds are alternatives which are generally less expensive than air fin coolers.

Incorporation of recycle in combination with serial reuse of component discharges is the basic approach in water reuse. The recycling of process water between absorber and stripper is one such example.

The objective is to effect a cascading of water from one component to another in accordance with the water quality requirement for the particular usage. The full implementation of this approach requires classification of input quality requirement and effluent characteristics of each wet process in the plant.

Modern water management practice at chemical plants provide independent system for potable water supply, sanitary installations, offsite utilities requiring cleaner industrial water and for strong process waste, plus an independent closed-loop supply and collection systems for wastewater containing oils and high TDS.

The provision of a functional system by itself does not ensure efficient water conservation. Efficient operation and management are essential for successful performance. Excessive input to recycle system results in a corresponding increase in waste discharge. Insufficient input can create problems of corrosion, scaling or biological fouling. Management leadership is required to provide the incentive, training and education and the enforcement necessary to operate the systems of increased complexity.

Wastewater Management in Chemical Industries : The most efficient means of controlling wastewater discharges is waste prevention. In contrast, providing terminal treatment in a combined waste treatment plant is the alternative, but the investment required is a non-production cost. However, improved product recovery or recovery of byproducts/raw materials etc. can offset a portion of the cost of pollution abatement.

10.3.2 Paper Industry

The paper industry in India includes large integrated mills with an installed production capacity of 80 to 200 MT/day and small paper mills with a capacity ranging from less than 10 MT/day to 30 MT/day. The mills comprise of pulp section, paper machine section, packaging and storage.

The principal cellulosic raw materials like wood is not available in the requisite amounts in the country and hence the mills use bamboo to a larger extent and wood to a smaller extent. The raw material used in the smaller units consist of straw, grass and used paper, hemp, jute and waste cotton. (The use of such alternate raw materials has an impact on the wastewater characteristics).

The paper industry is highly water intensive and consumes large volumes of water. The water consumption varies from mill to mill as shown below :

Production Capacity MT/day	Water Consumption M^3/MT
10	210 to 410
20	220 to 300

Approximately 80 to 85 percent of water consumed comes out as wastewater. Bulk of the water consumed is used in washing and bleaching operations and also in the paper machines.

Sources of Wastewater - The main sources of wastewater in a pulp and paper unit are :

- Pulp mill
  - (a) Spent black liquor - the most highly concentrated waste
  - (b) Washing of pulp
- Bleach plant
- Paper machine — White water

The principal pollutants in the pulp and paper mill effluent are BOD, COD and suspended solids, other problems are colour, pH, temperature and dissolved solids. The wastes have a high COD/BOD ratio due to the presence of lignin which is non-biodegradable.

Treatment of Wastewater - Pulp and paper mill effluents are amenable for treatment in conventional wastewater treatment system consisting of :

* Primary treatment - for removal of suspended and settleable solids
* Secondary treatment - for removal of BOD, an extended aeration system appears to be the most favourable system with a retention time of 12 hrs.

Wastewater Management in the Pulp and Paper Mills - The salient features of the waste minimization programme carried out in the pulp and paper mills are :

1. Maximizing recycling and economic analysis of each recycling possibility.

2. Possible process changes, e.g. replacement of wet debarking of wooden logs by a dry mechanical process.

3. Counter current brown stock washing and recycling of bleach plant wastes.

4. There is a little need for fresh water make up in a pulp mill and the entire system of water usage can be converted to recycled water including wash down.

5. Preparation of the water balance and flow scheme for all water usage in the plant.

6. In the context of energy shortage and increased fuel costs, a special effort should be made to neutralise hot and warm waste streams to maximize energy conservation, whereas the cost of recycling of some streams may not be worth while strictly on a water conservation basis. Ample justification for recycling may often be found. Care should be taken, however, in selecting industrial recycle streams to avoid introducing scale formation and plugging problems due to increased dissolved and suspended solids content.

7. Determination of raw waste load and its origin by analysis of wastewater from each of the major process units for BOD and suspended solids.

8. Reduction of raw waste load through the following modes:

   a. **Minor process changes** - Provisions should be made to avoid evaporator carry over, leakages from pulp storage chests and black liquor storage tank overflows, leakage from pump seals, control valves and pipe couplings. Efforts should be made to get such problems removed or corrected.

   b. **Liquid spills control** - Provision should be made to trap liquid spills resulting from human error or mechanical failure by providing sump, pumps and storage facilities in strategic places.

   c. **Major process changes** - The next step is to consider how much further raw waste loads can be reduced by implementation of in-plant techniques in a particular mill. These include :

i. Installation of additional screening for improving fibre removal and if possible upgrading of existing fibre removal devices.

ii. Air or steam stripping of contaminated condensates, if these are not reused in the brown stock washers.

iii. Changes in sequence of bleach plant stages to reduce colour or introduction of oxygen bleaching into the sequence.

iv. Installation of a cooling tower might be necessary if effluent temperature is a problem.

9. Segregation of sanitary sewage from all other mill wastes.

10. Recovery of pulping chemicals from the black liquor of kraft mills.

11. Segregation of power plant wastewater such as boiler and cooling tower blow down, water purification, demineralisation plant regenerants and turbine cooling waters. Their volume may be very small in proportion to the combined waste flow. However, in once-through turbine cooling systems, the volume of this waste stream may be high and should be recycled into the raw water source.

10.3.3 Food Processing Industry

The industry as a whole uses large quantities of water, but all is not for a consumptive use. The water is required for washing all forms of food, in the different unit operations like bleaching, pasturizing, cleaning of process equipments and cooling of final product. On account of availability of water in abundant quantities at cheap rates, the food industry had adopted the once-through system involving the use of water of a very high degree of purity. Little consideration is given for conservation of water usage and recycling of wastes. There is, however, an increasing need for evaluation of the feasibility of reuse of water and practice of waste minimization in the food processing industry.

Wastewater Minimization - Wastewater loads can effectively be reduced by segregation of waste streams for the possible reuse of less polluted water for certain phases of the operation. Because water is so vitally important to food production, the food processing industries in the advanced nations make every endeavour to avoid its wastage and water is reused as much as possible.

Examples of Waste Minimization

i. Water used as a cooling medium to cool cans and for air conditioning is later used for the primary washing of vegetables and other products. The same water is used subsequently for fluming waste material and finally a portion of it is also used for quenching ash from the power plants.

The reuse ratios used in certain food industries in USA are given in Table 10.1. This data indicate that recycling of water is a feasible proposition in the food industry in India also.

ii. Maximum utilization of recirculation water is achieved in continuous flow systems. Since water flows counter current to the product, the washing and flushing water becomes progressively contaminated and therefore chlorine is added to the water to maintain satisfactory bacteriological condition in each phase of the operation.

iii. Reports in the literature on case studies in two typical food processing units indicate that strict water pollution control regulations and high cost of the process water necessitated reuse of reclaimed water. Reduction in total pollution load from a canning plant may be achieved by segregation of

Table : 10.1

Reuse Ratios for Food Industries

Type of Food Industry	Reuse Ratio*
Corn & wheat flour mills	10.22
Distilleries	1.51
Food processing	1.19
Meat	4.03
Sugar cane	1.26

*For each gallon or water withdrawn e.g. in the cane sugar industry, the water was used 1.26 tonnes before ultimate disposal.

Source : "Water in Industry" - National Association of manufacturers in USA Jan. 1965 - reported in the handbook of industrial pollution control, published by McGraw Hill Co.

concentrated process wastes and their separate treatment. For example, the effluents from bleaching of vegetables and/ or fruits which are low in volume but contribute significantly to the total waste load can be segregated and treated separately by concentration and drying or by anaerobic digestion, thus, achieving a considerable reduction in waste load.

iv. Changes in process equipment and technology also can contribute towards reduction in waste volume and pollution load, e.g. substitution of a dry caustic pealing system for potatoes by exposure to Infra-red energy at about 900° C to condition the surfaces of potatoes. The peal can be removed later mechanically rather than by water. By this modification, a substantial reduction in water usage to the extent of 75 percent and waste strength by 40 percent can be achieved.

10.3.4 Pharmaceutical Industry

A large number of pharmaceutical units make use of formulations for providing packaged products, which are marketed. The unit operations involved in the preparation of the formulations are :

1. Mixing of ingradients and granulation
2. Drying of granules
3. Coagulation
4. Pills and tablet making
5. Preparation of sterial products and
6. Packaging of finished products.

None of the above operations can be considered as sources of serious water pollution, for the reason that they do not make use of water on any basis that would cause pollution. Nevertheless there are some areas wherefrom water pollutants may be generated, as described below:

Washing operations are one likely source of pollution. Liberal application of water in a large area can flush out the spilled materials of a sizeable quantity and concentration.

The solid residues spilled over, if they are not readily soluble in water, will be present as suspended solids and could easily be removed by sedimentation or by chemical coagulation, flocculation and sedimentation. The settled effluent will be fit for recycling.

The routine clean up in a pharmaceutical plant can be carried out most effectively by vacuum cleaners preferably of a portable type, similar to "house" vacuum cleaning system which can be conveniently shifted to each plant unit, if it is a source of dust generation. This arrangement avoids use of water, thereby reducing, if not totally eliminating, the problem of wastewater generation.

Another step towards waste reduction in a pharmaceutical plant is to use portable type of reaction equipment - even large portable tanks which can be moved to a centralised waste up unit. This arrangement facilitates control of indiscriminate dumping of material into the drains.

10.3.4.1 Fermentation Based Pharmaceutical Industries

Pharmaceutical industries in which fermentation processes are used in the production of antibiotics and steroids etc. and these industries which manufacture basic drugs, are water intensive and generate wastewater which is most likely to create serious water pollution problems e.g. the spent fermentation broth.

Pollution Abatement : The fermentation units in the pharmaceutical industry are amenable to various methods of pollution abatement such as reduction in waste volumes pollution load by segregation of strong waste and other process waste streams from the uncontaminated wastes, recycling of water from off site utilities etc.

10.3.4.2 Basic Drugs Manufacturing Industries

These units are essentially synthetic organic chemical process units and the problem of pollution originates from the following areas :

1. Normal problems of pollution are caused by wastewater from processing units, washing operations of equipments, floor washings, and condensates from ejectors.

2. Exceptional problems of pollution originate from unplanned and uncontrolled situations like spills and leakages from heat exchanger that results in carry over of chemicals into the cooling water systems. They are however, avoidable sources. Sometimes water sealed vacuum pumps can also add to the pollution problem.

Pollution abatement in chemical process units of the pharmaceutical industry can be achieved by the following steps:

i. pH control by chemicals.
ii. Recovery of organic solvents.
iii. Prevention of accidental spills and leakages by good house-keeping.

iv. Spills of solids inside production areas and also in general plant areas are often washed down as the waste volume and pollution load. This can however, be prevented.

In other words, solids spills should be treated as a solid wastes problem and in NO event be shifted into the wastewater collection system.

10.3.5 Textile Industries

These units carry specific wet processes like kiering, bleaching, mercerizing and dyeing. Printing processes includes screen printing. All the unit operations are carried out manually.

The water usage in the different processes used in smaller textile mills is very small as compared to the water usage in the wet processes of larger textile mills. Hence the wastewater generated from each process in smaller mills is more concentrated than those of the larger mills.

The reaction equipment in the units consist either of masonry tanks or wooden and steel tanks. The degree of mechanization in the process hours of the medium scale units is also limited to the use of jiggers. In the same unit, the different wet twin process are carried out as batch processes. On completion of the reaction, the spent liquor is discharged as waste, together with the washings without any treatment.

Waste Minimization and Reuse of Water : There appears to be limited scope for waste minimization and recovery of process chemicals like caustic alkali from spent mercerisation process waste or any useful product from the dying process waste. These textile processing units receive their supplies of water according to their daily needs from the central water supply system of the industrial estate. Hence the textile units are not concerned about either shortage or non-availability of their water demands.

11 Environmentally Balanced Industrial Complexes

Several of the developed countries have started taking corrective measures after polluting the rivers with industrial wastes, destroying the forests, endangering the thin layer of atmosphere through gaseous emissions and deteriorating the metropolitan areas through heaps of garbage. The corrective measures being undertaken in these countries have become very expensive In this context, developing countries like India is in an advantageous position as they are passing through the beginning stages of industrial development. It should be possible to avoid the pitfalls faced by the developed countries and take preventive measures itself at the early stages of development. Environmentally balanced industrial complexes (EBIC) are one of the several measures that can be adopted during planning stage to protect the environment to the maximum extent possible and also to reduce the industrial production cost.

Environmentally balanced industrial complexes are simply a selective collection of compatible industrial plants located together in a complex so as to minimize environmental impact as well as industrial production costs. These objectives are accomplished by utilizing the waste materials of one plant as the raw materials for another with a minimum of transportation, storage, and raw materials preparation costs. When the same industry neither treats its wastes, nor imports, stores, or pre-treats its raw materials, its overall production costs must be reduced significantly.

In conventional industrial solutions to waste problems, industry uses separate treatment plant units such as physical, chemical and biological systems. These add production costs onto already highly competitive manufacturing problems. These costs are also easily identified and even if relatively small when compared to other production costs are strenuously opposed or rejected by industry. On the other hand, reuse costs, if any, in an environmentally balanced industrial complex, will be difficult to identify and more easily absorbed into reasonable production costs.

Large, water-consuming, and waste-producing industrial plants are ideally suited for location in such industrial complexes. Not only are their wastes hazardous to our fragile environment, but they are also amenable to reuse by close association with satellite industrial plants using wastes and producing raw materials for others within the complex. Examples of such major industries are steel mills, fertilizer plants, pulp and paper mills, tanneries and sugar mills.

Preliminary concepts of the five complexes centered about the following five major industries are described here :

1. Fertilizer industry
2. Steel mill
3. Pulp and paper mill
4. Tannery
5. Sugar mill

11.1 FERTILIZER PLANT COMPLEX

As the world population increases rapidly from its already high level the demand for more food and hence greater production of agricultural products is also spiralling. Increased fertilizer use is inevitable as the major means of providing extra food. Phosphatic rocks provide the basic starting material for ammonium phosphate fertilizer for commercial use. In the usual sulfuric acid process for dissolving the rock, a gypsum-like sludge is wasted as a by-product and some sulfur dioxide and fluorine are driven off in the gases evolved at the high reaction temperatures. Both gypsum sludges and sulfur dioxide-fluorine effluents are troublesome wastes to dispose off in our environment. Massive quantities of gypsum, relatively impure, result from the production of P_2O_5 fertilizer (in ratios of 5:1). These defy usual waste treatment processes. Fluorine in the gas as hydrofluoric acid is present in concentrations varying from 1 to 10% which is too low for commercial use without further treatment. This may be both costly and expensive. Location of such a fertilizer plant in an industrial complex with cement industry or other plants able to utilize these wastes as raw materials in the manufacture of new products is a feasible solution to the environmental problem. One such complex is presented in Fig. 11.1 (91).

11.2 STEEL MILL COMPLEX

Steel mills are actually five separate industrial plants in one consisting of : (1) coke plant; (2) iron ore reduction plant; (3) steel production; (4) hot rolling mill; and (5) cold rolling mill. Predominant wastes originate from the coke and steel plants, although certain dusts, slag, and iron also come from the other plants. Troublesome waste products include ammonia, cyanide, phenol, heat, and acidic ferrous sulphate or chloride pickle liquor. Steel mills also use huge volumes of water-mostly for cooling and quenching and produce volumes of air, water and solid contaminants. They have developed a world-wide reputation as one of the most polluting industries existing in modern times. They require so much land area and employ so many people that their location in a separate industrial complex

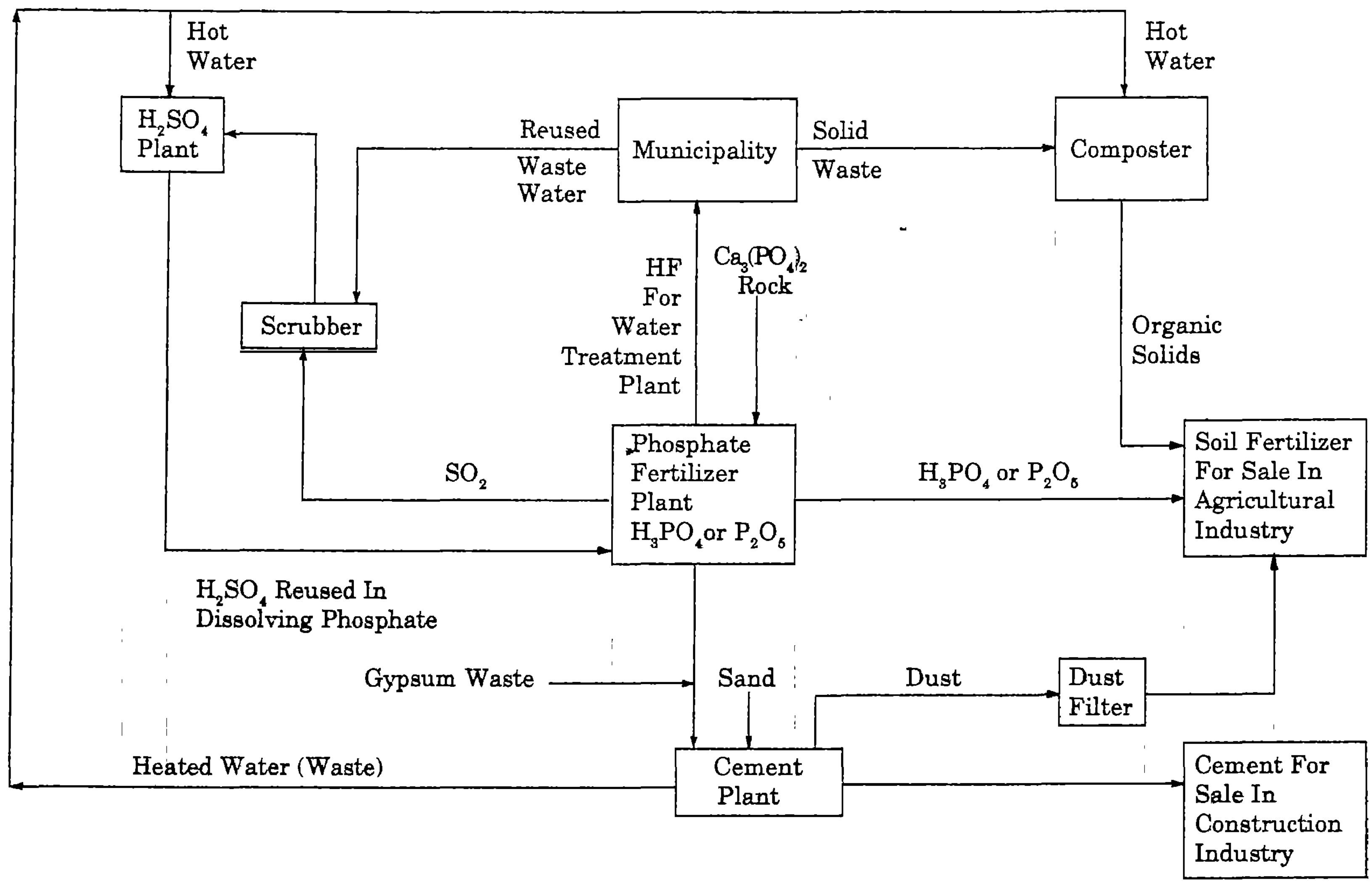


FIG. 11.1 : FERTILIZER PLANT COMPLEX

would be a natural development. Fertilizer and building material plants are likely candidates for auxiliary industries for a steel mill complex. Such a complex is proposed and presented in Fig. 11.2 (91).

11.3 PULP AND PAPER MILL COMPLEX

The pulping of the wood and the formation of the paper product produce wastes containing considerable quantities of sulfates, fine pulp solids, bleaching chemicals, mercaptans, sodium sulfides, carbonates and hydroxides, sizing casein, clay ink, dyes, waxes, grease oils, and other small fibres. The overall wastes can be coloured with high or low in pH, and high concentrations of suspended, colloidal as well as dissolved solids and inorganic fillers. Because of its high water consumption and wastewater discharge of 160 to 180 m^3/MT of product, the wastes contain large total quantities of organic, oxygen-demanding matter. These wastes create considerable environmental impacts because of their concentrated loads of air, water, and land pollutants. The siting of new pulp and paper mills today has become a major endeavour. They must be located near vast quantities of relatively clean water as well as receiving water resources, downwind and at a distance from residential habitation (because of common air pollutants such as SO_2 and mercaptans), usually on a rail line and near major highways for shipping, and near adequate land area for waste treatment and sludge disposal. Such sites are also difficult to find. Fig. 11.3 describes one possible complex with little or no adverse environmental effect, centered about an average-sized paper mill producing 1000 tonnes of paper product per day. The preliminary mass balance is also given in Fig. 11.3 for additional clarification. Eight separate industrial plants were included as part of this complex; five of which would produce products to be used within the complex.

Timber is brought into the complex to the pulp mill, where it is converted into pulp for use by the paper mill. Major wastes from the pulp mill are bark which is burned subsequently in the steam plant and sulfate waste liquor which is used in three internal complex plants; road binder, vanillin, and sulfate concentrating. Products from the road binder and vanillin plants can be sold locally or internationally while those from sulfate concentrating are reused in the complex by the pulp mill or by the hardboard manufacturing plant. Fine paper product from the paper mill can be sold in the world market. Wastes from the paper mill include heat, fillers and fines which can be used internally in the groundwood pulp mill, which also uses a percentage of used newspaper stock. The pulp product from the groundwood pulp mill will be used partially in the complex by the pulp mill and sold externally as paperboard. The groundwood pulp mill produces waste suspended solids which are used internally by the wrapping paper plant. The product of the wrapping paper plant can be sold regionally. Thus, this industrial complex produces six products for external sale and for internal use while minimizing or eliminating entirely wastes disposal into the environment (91).

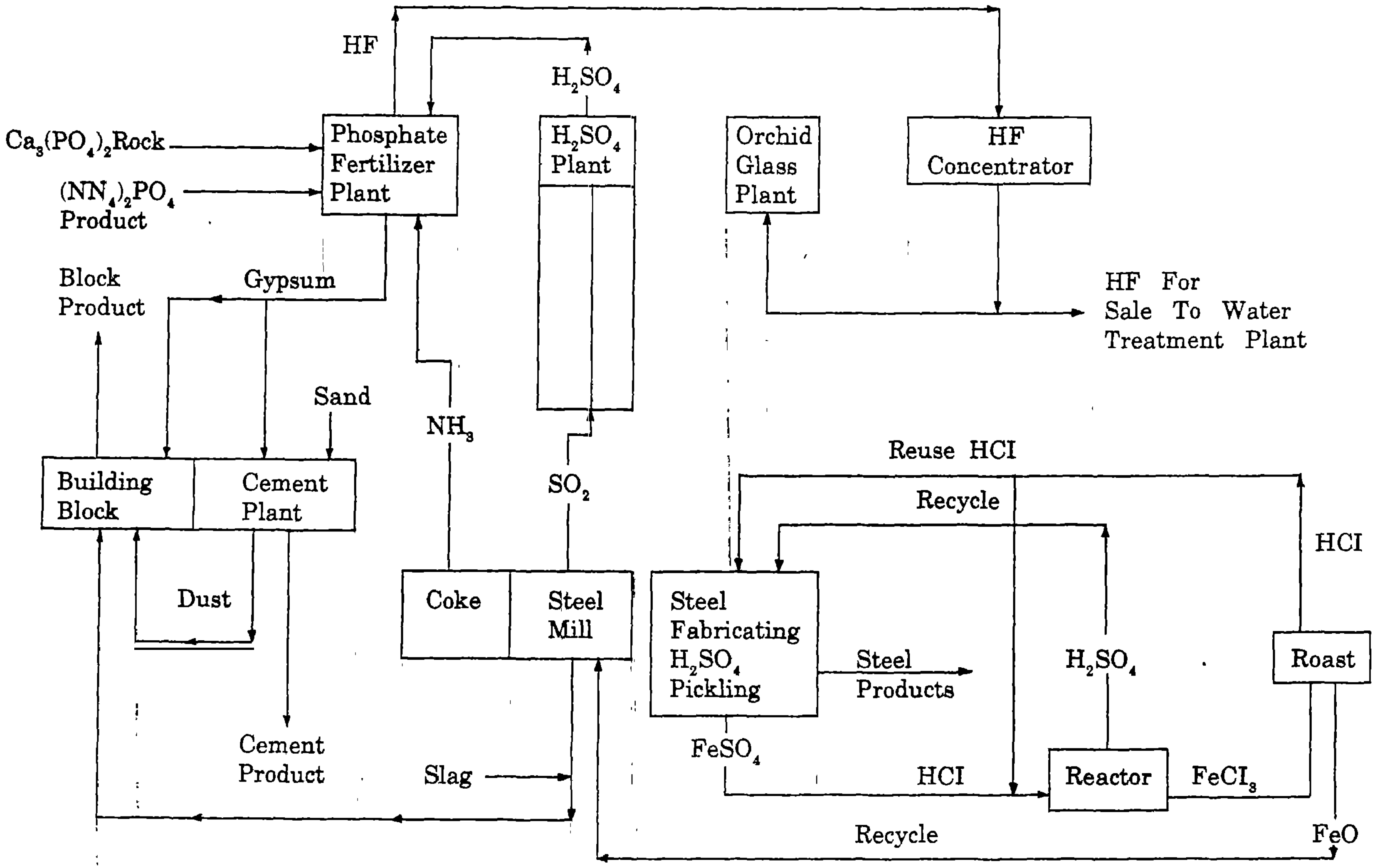


FIG. 11.2 : ENVIRONMENTAL COMPATIBLE STEEL MILL FERTILIZER COMPEX

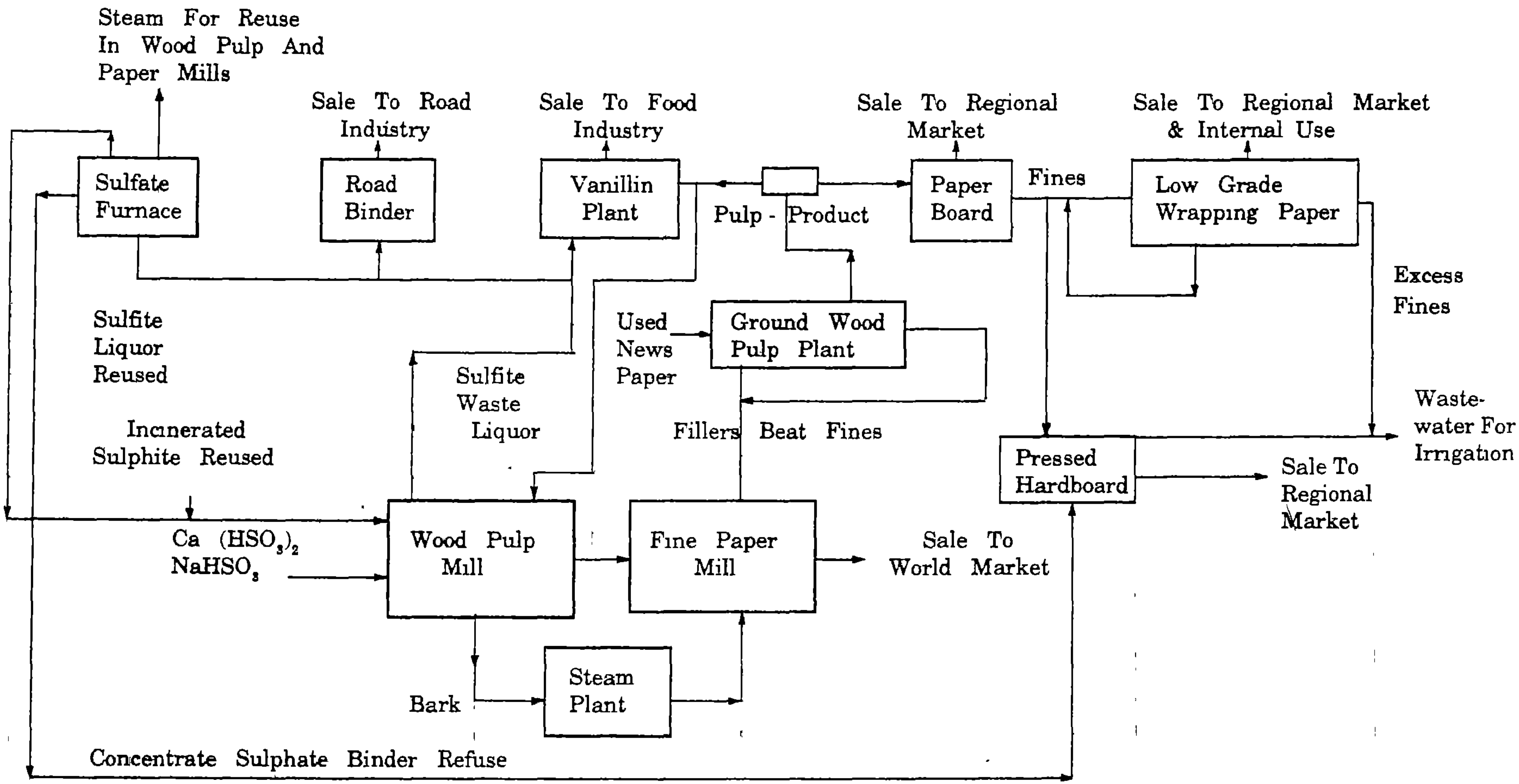


FIG. 11.3 : ENVIRONMENTALLY COMPATIBLE PULP AND PAPER MILL COMPLEX

11.4 TANNERY COMPLEX

Tannery wastes from upper sole, chrome tanning mills contribute to a significant pollution problem. The wastes are hot, highly alkaline, odourous, highly coloured and contain elevated quantities of dissolved organic matter, BOD, total suspended solids, lime, sulfides and chromium. The treatment of such wastes has been difficult because of the conflicting pollutional parameters of pH, organic matter, and potential toxic compounds. Most successful treatment plants utilize some form of biological treatment to reduce the oxygen demand on receiving wastes. This necessitates the use of well-designed and operated preliminary treatments to ensure safe and efficient biodegradation. High sludge quantities result from these treatments. Therefore, properly designed and operated tannery waste treatment systems may be costly to build and operate; while the lack of these facilities will cause excessive stream pollution. Placing the tannery in an environmentally optimized industrial complex eliminates both of these negatives (91).

11.5 SUGAR MILL COMPLEX

An integrated agro based industrial complex (sugar cane) is feasible from the environmental protection and economic considerations. Sugar mills produce press mud, baggasse and molasses. It is possible to have atleast four types of industries in one complex, viz.

- Cane sugar mill
- Baggasse based pulp and paper
- Distillery based on cane molasses
- Organic chemicals industry (e.g. acetic acid) using molasses as raw material.

The distillery effluent is low in pH and also highly coloured. The pulp and paper mill effluent is alkaline in nature and intensity of colour of the wastewater generated is far less as compared to distillery spent wash. Mixing of distillery spent wash, pulp and paper mill effluent and wastewaters from sugar mill in right proportions will result in reduction of chemicals required for pH adjustment and also the intensity of colour. The treatment of combined wastewater requires various treatability studies to determine the best treatment alternative keeping in mind resource recovery. Press mud can be used as a fertilizer and also as a basic raw material for production of valuable products.

12
Case Studies

12.1 INDUSTRIAL ESTATE, JEEDIMETLA, A.P., India (92)

A large industrial estate is situated at Jeedimetla near Hyderabad Andhra Pradesh. There are about 596 medium and small scale industrial units within the estate. These units, being small scale find it difficult to treat the wastewater themselves due to shortage of land and finance required for construction of individual treatment plants. A common effluent treatment plant was therefore designed and implemented for this industrial estate. This plant is the first of its kind which is being managed by a Public Limited Company formed by enterprenuers themselves (92).

Number of industrial plants and sheds alloted in the industrial estates are 446 and 399 respectively, of which at present 596 units are in operation.

Most of the industrial units (batch operated) in the estate come under the category of small scale (576) and a very small fraction of the industrial units (20) can be placed in medium scale operation. However, it is difficult to segregate these units and therefore, the effluent of all these units is combined for CETP. It may be emphasised that out of the 596 industrial units (batch operated), only 38 industrial units were considered as polluting industries. It may also be mentioned that the influent wastewater conforms to WWC 'C' based on wastewater characteristics as it contains large amount of dissolved matter (TDS) alongwith high BOD.

Conveyance System - It has been observed that at present there is no drainage system in the estate and industrial wastewater is discharged into open drains and on open land which gets collected in low lying areas and get absorbed in soil. However, there are some streams which find their way to water bodies in the vicinity.

The estate is located in a region where rock formation is quite common even at a few feet below ground level and providing a proper slope to the sewers would mean excavation in rocks or intermediate pumping stations. Both these options would increase the capital cost. Secondly, the estate is in the early stages of development. The estate is still to be occupied fully with industrial units. At this stage, if the drainage system is designed for the anticipated flow at fully developed stage, the syst em will be over-designed with respect to present flow. As over-designed drainage systems are worst in comparison with under-designed systems because of silt deposition due to very low velocity in the sewers. In addition, the capital cost of the drainage system designed for future anticipated flow will have to be shared by the existing industrial units. Thirdly, if the drainage system is designed for the present flow, unlike other treatment units, drainage system is very difficult to upgrade to account for industrial expansion and consequent excess wastewater flow. Fourthly, it will be difficult to monitor the characteristics and the flow of wastewater contributed by individual members in the drainage system. Lastly, the ultimate effluent discharge is around 1000 m^3/day which is quite a small amount for a combined treatment facility.

In view of these, the batch wise tanker conveyance system was preferred and is in operation satisfactorily and also facilitating the billing operation to a great extent. In future, if the industrial estate develops to a large industrial estate discharging more than 3 MLD of effluent, the drainage system may become mandatory and would be constructed from the profits earned by the company maintaining CETP and some subsidy from Government agencies if the performance of CETP is upto the mark

Performance Evaluation - The first phase of CETP comprises of :

- Equalization cum Neutralization basin (2 Nos.)
- Lime slurry tanks (2 Nos.)
- Chemical house with laboratory (1 No.)
- Aerated lagoon (1 No.) along with nutrient addition facility

Fig. 12.1 shows the schematic diagram of Jeedimetla Effluent Treatment Plant which also includes the options to be considered under phase-III

The anticipated characteristics of the treated wastewater are :

Parameters	Concentration
pH	6.5 - 9.0
Suspended Solids, mg/L	100
BOD, mg/L	920

The performance results obtained over a period of April 1989 to January 1990 are summarised in Tables 12.1 and 12.2. It can be easily observed that the raw wastewater contains high suspended solids, BOD, COD and total dissolved solids.

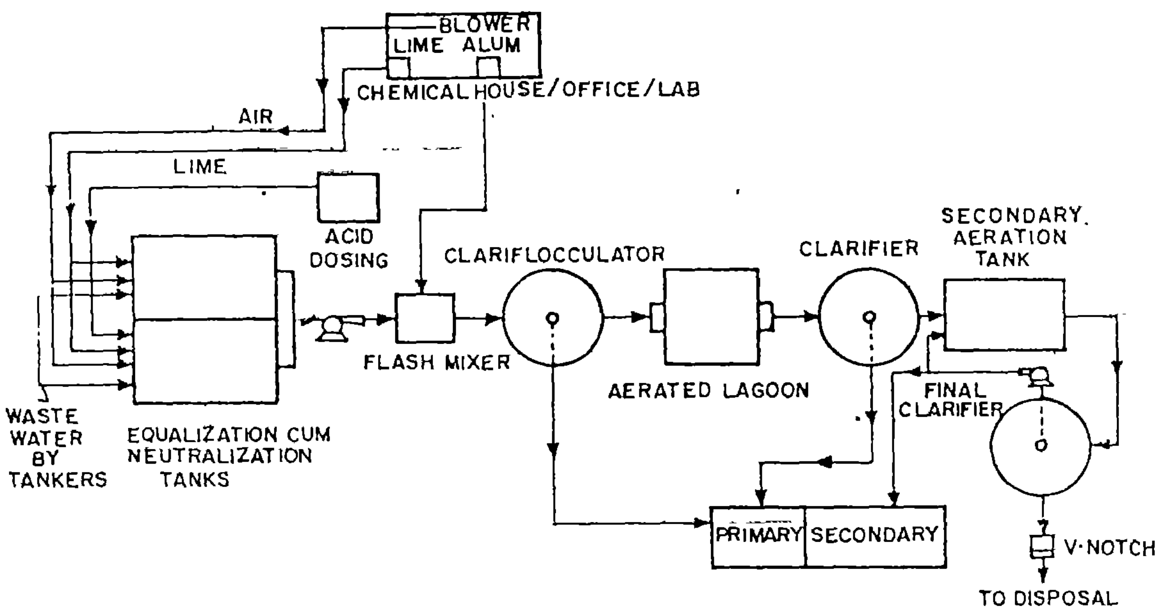


FIG. 12.1 : SCHEMATIC DIAGRAM OF JEEDIMETLA EFFLUENT TREATMENT PLANT

As the first phase of the CETP (aerated lagoon) could not achieve the anticipated level of effluent quality with respect to suspended solids, BOD, COD and TDS, the treatability studies were carried out involving :

- Characterization of individual wastewater from contributing units
- Monitoring dissolved oxygen levels in Aerated Lagoon
- Neutralization with spent acids from various member units
- Coagulation and settlement of suspended solids in combined wastewater
- Second stage aerobic biological treatment
- Anaerobic Filter
- Pure oxygen application.

Table 12.3 shows comparison of the design and actual values of BOD and COD. This table as well as Tables 12.1 and 12.2 indicate that, in majority of the cases, the actual concentrations are significantly higher than those adopted for design.

As the DO levels in Aerated Lagoon are appreciably high (5.15 - 7.8 mg/L), it indicated that the biomass for oxidation of organics was absent and therefore aerated lagoon was re-energised with sewage and the performance was improved appreciably as depicted in Tables 12.1 and 12.2.

Neutralization with spent acid wash did not result in any appreciable change in COD values (therefore COD cannot be attributed to them). With the use of spent acid and coagulants like alum and ferrous salts for the removal of suspended solids and also COD, about 97% suspended solids could be removed. About 15.7% COD removal is possible with coagulant dose of 300 mg/L of alum as shown in Table 12.4. It was quite evident that alum alone can act as a good coagulating material giving equally good COD removal efficiency as compared to ferrous salts and lime. Besides, ferrous salts are expensive and impart colour. Lime on the other hand poses the disposal problem. On these grounds, alum seems to be a better choice as coagulating agent.

The treatability studies carried out on a trickling filter pilot plant of 1 m^3 capacity with arrangements for passing supplementary air showed BOD and COD removal upto 42 - 86% and 27 - 79% respectively. This facility was tried as a second stage to aerated lagoon (effluent BOD of about 1600 mg/L). However, for the wastewaters with the typical chemical characteristics, this was considered as "not a good" choice for biomass development because of subsequent problems (in case it fails to work i.e. re-starting problems).

The anaerobic systems (fixed film/suspended growth system) are not easily amenable for chemical type of wastewaters containing organic compounds. However, the results with anaerobic filter revealed that it could remove

Table : 12.1

Performance Evaluation of First Phase of CETP Using Aerated Lagoon Facility (Range)

Parameters		April 1989	May 1989	June 1989	July 1989	August 1989	Sept 1989
		Months					
Flow (m³/d)		30 - 120	96 - 153	96 - 153	150 - 440	20 - 500	250 - 500
pH	(1)*	7.2 - 8.7	7.7 - 8.5	7.7 - 8.5	7.0 - 8.1	6.8 - 8.2	7.3 - 8.0
	(2)*	7.95 - 8.5	7.5 - 8.6	7.5 - 8.6	7.8 - 8.2	7.8 - 8.1	8.0 - 8.2
Suspended Solids (mg/L)							
	(1)*	1270 - 4468	2863 - 14349	2863 - 14349	2850 - 6570	2800 - 9230	2316 - 7774
	(2)*	98 - 728	- -	- -	2882 - 7652	2416 - 10263	3580 - 6122
BOD (mg/L)							
	(1)*	7500 -17500	NA	NA	2400 - 4200	3180 - 10800	5400 - 6800
	(2)*	1200 - 2100			800 - 2000	420 - 2800	1480 - 2000
COD (mg/L)							
	(1)*	5976 -35200	16913 - 41000	16913 - 41000	7344 - 13154	10454 - 26560	8960 - 16240
	(2)*	899 -10560	8870 - 17600	8870 - 17600	3252 - 75955	412 - 13440	4640 - 11368
Oil and Grease (mg/L)							
	(1)*	NA	61 - 255	61 - 255	NA	NA	NA
	(2)*		21 - 108	21 - 108			
TDS (mg/L)							
	(1)*	NA	84340 - 103600	84340 - 103600	26480 - 64900	39860 - 98390	51920 - 75160
	(2)*	NA	81400 - 86600	81400 - 86400	24285 - 52090	19450 - 76770	43150 - 76590

* (1) - Influent wastewater after equalization/nutralization; (2) - Treated effluent quality after aerated lagoon; NA - Not available

Table : 12.2

Performance Evaluation of First Phase of CETP Using Aerated Lagoon Facility (Range)

Parameters		Months				
	Oct 1989	Nov 1989	Dec 1989	Jan 1989	Summary (July 89 - Jan 90)	
Flow (m^3/d)	250 - 450	300 - 400	300 - 400	250 - 400	20 - 500	(360)
pH (1)*	7.0 - 7.8	7.0 - 7.9	7.2 - 8.1	6.2 - 7.2	6.2 8.2	
(2)*	8.0 - 8.2	8.0 - 8.2	7.7 - 8.3	8.0 - 8.2	7.1 - 8.2	
Suspended Solids (mg/L)						
(1)*	1600 - 8960	3400 - 14125	2416 - 4840	3220 - 16226	828 - 16226	(8000)
(2)*	1880 - 7400	4200 - 29735	2890 - 6490	4432 - 23538	172 - 29735	(7440)
BOD (mg/L)						
(1)*	2300 - 4800	2800 - 4800	NA	NA	2300 - 10800	(6100)
(2)*	300 - 1300	720 - 1300			300 - 2800	(2800)
COD (mg/L)						
(1)*	9800 - 209600	7557 - 22800	13280 - 23200	11200 - 23200	7344 - 26560	(19110)
(2)*	6080 - 12000	3698 - 15184	12320 - 16968	7200 - 15200	3232 - 16968	(14000)
Oil and Grease (mg/L)						
(1)*	NA	NA	NA	NA	NA	
(2)*						
TDS (mg/L)						
(1)*	36800 - 72000	36000 -131290	NA	28640 - 63320	NA	
(2)*	28080 - 64860	32840 - 68460		24320 - 50627		

* (1) - Influent wastewater after equalization/nutralization; (2) - Treated effluent quality after aerated lagoon
Paranthesis ( ) - Average value; NA - Not available

only 41% COD at a loading rate of 1.5 kg COD/m^3.d. The results of the studies on ASP also revealed that about 50-60% BOD reduction in about 24 hour of aeration.

Table : 12.3

Performance Relationship Between Actual and Design Values

	BOD (mg/L)		COD (mg/L)	
Parameter	Influent	Effluent	Influent	Effluent
Design	4660	1300	13813	8273
Actual (90%)	6100	1496	17702	9154
Average	4140	1222	12677	7947

Pure oxygenation was also tried in aerated lagoon but no data pertaining to performance is available. MLVSS of the aerated lagoon remained by and large in the range of 800-970 mg/L. The oxygen uptake rate was about 48.6 mg/L/hr which is fairly good indicating a healthy biomass growth. The settling velocity of the biomass was reasonably good, 96 m/hr.

With these treatability studies, Phase II has been incorporated and Phase III was designed. The state of three phases is given below :

Phase	Treatment Options	Remarks
I	Equalization/Neutralization + Aerated Lagoon	Completed
II	Equalization basin + Clariflocculator + Aerated Lagoon with provision for Solids disposal (SDB)	Completed
III	Alternatives :	
	(a) Equalization basin (EB) + Clariflocculator (CF) + TF + Clarifier + ASP + Clarifier (with SDB)	Not good Option
	(b) EB + CF + ASP + Clarifier + AL + ASP (with SDB)	Not good Option
	(c) EB + AL + ASP (with SDB)	Good Option

Table 12.5 gives the details about physical and chemical characteristics of the effluent obtained from phase II shown above.

It may be mentioned that the individual industrial members have to neutralise their wastewater before filling it up in the tanker and also to bring

Table : 12.4

Summary of Chemical Treatment Using Coagulants

(A) Alum (Optimum dose - 300 mg/L)

Parameters	Min.	Avg.	Max.
1. COD (mg/L)			
- Influent	16913	20029	24192
- Effluent	14544	16911	20966
- % Removal	5.1	15.7	29 1
2. Suspended Solids (mg/L)			
- Influent	6244	10483	14349
- Effluent	154	289	497
- % Removal	94.0	96.5	98.0

(B) Ferrous Sulphate (Alone)

Wastewater pH - 9	Dosage (mg/L)		
	0	100	200
COD (mg/L)			
- Influent	16913	16913	16913
- Effluent	16913	14991	14991
- % Removal	0	11.5	11.5

(C) Lime

	Dosage (mg/L)					
	0	150	300	450	600	750
COD (mg/L)						
- Influent	29440	29440	29440	29440	29440	29440
- Effluent		27840	25920	25280	23360	24400
- % Removal		5.4	12.0	14.1	20.7	18.7

Table : 12.5

Summary of Treatment Plant Performance from August 1990 to October 1990 (Phase II)

Sr No.	Parameter	Unit	Concentration			
			Min.	Avg.	Max.	90%*
1.	**Flow**	m^3/day	100	507	680	600
2.	**pH**					
	Raw wastewater		7.0	-	9.0	-
	Treated wastewater		7.9	-	9.5	-
3.	**Suspended Solids**	mg/L				
	Raw wastewater		56	610	2768	1876
	Treated wastewater		50	400	1170	1010
	Percentage removal		21	65	98	21
4.	**Biochemical Oxygen Demand**	mg/L				
	Raw wastewater		1350	4291	7650	6600
	Treated wastewater		210	783	1500	1470
	Percentage removal		41	80	98	90
5.	**Chemical Oxygen Demand**	mg/L				
	Raw wastewater		6160	12479	19200	16480
	Treated wastewater		640	1118	12000	11200
	Percentage removal		8	50	94	35

* "90% of the values were less than or equal to"

oil and grease levels to the stipulated CPCB standards of less than 10 mg/L. As COD can be analysed relatively rapidly and easily, it was chosen as the parameter for calculating the financial burden to be shared by each member industry. The rate structure is as follows :

Quality of Effluent COD, mg/L	Rate in Rupees per Tanker of 10000 litres or part thereof
1 to 5000	150
5001 to 10000	175
10001 to 15000	200
15001 to 20000	225
20001 to 35000	250
Above 35000	Additional charge of Rs.25 per tanker for every 1000 units of COD. However, for such high loads, specific prior approval to be obtained by the customer from the Treatment Company.

In addition to above, minimum charges are being levied on participating units, even if they do not send effluents for treatment as treatment capacity is reserved for them. The organisational set up at Jeedimetla is given in Fig. 12.2.

The experience of the past nine months indicates that billing per month was around Rs. 2.95 Lacs and total expenditure on salaries, power, etc. was around Rs. 2.65 Lacs/month. This amount will have to be revised after commissioning of phase III (stage I & II). Again review must take place when phase IV will come into operation with the possibility of using treated effluent of various process grades.

12.2 BAYPORT INDUSTRIAL ESTATE, TEXAS, USA

Bayport Central Waste Treatment System serves ten industries of heavy industrial class in Bayport industrial estate, Texas, USA with collection, treatment and disposal of liquid wastes. This treatment system is provided by the developer of the estate as a service function toward the preservation of a desirable environment and conservation of natural waterways of the area. Biological treatment facilities are comprised of two plants with a combined capacity of 3.75 MGD and a BOD load capacity of approximately 12000 lb/day. When BAYPORT is fully developed, the treatment system will handle about 50 MGD of which about 20 percent will require biological treatment.

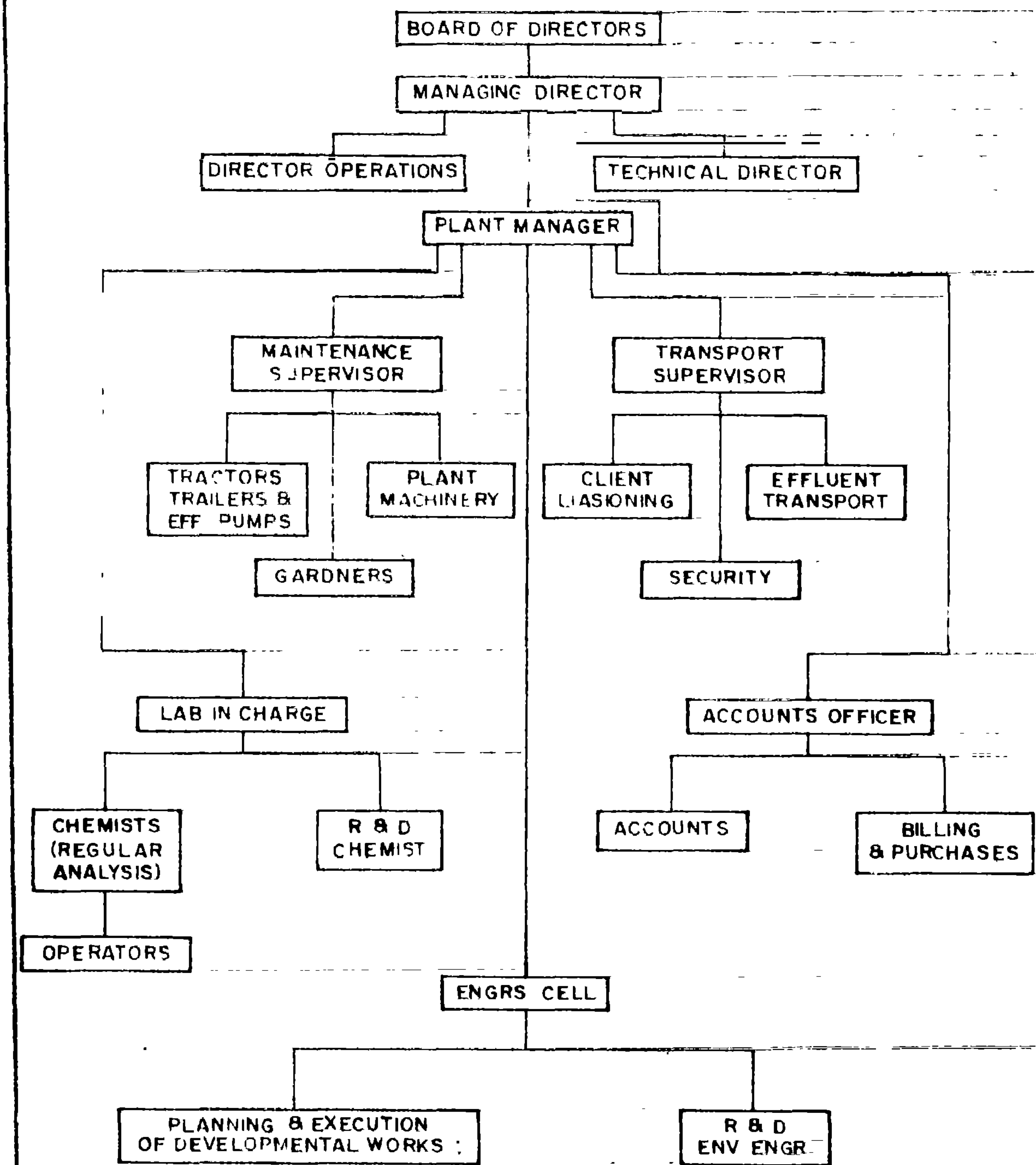


FIG 12.2 JEEDIMETLA EFFLUENT TREATMENT PLANT ORGANIZATIONAL CHART

As far as collection system is concerned, the Bayport system provides for two general types of waste; one, a "clean' stream which requires little or no treatment (limited to BOD of less than 50 mg/L) and two, a "biological" stream containing wastes that will go directly to biological treatment (No BOD limit). In addition to BOD levels, there are other criteria which govern the segregation of streams as to the proper receiving channel. Altogether, the limitations are designated as acceptability criteria and are listed in Tables 12.6 and 12.7.

The wastes which are toxic to biological growth, are classified as non-acceptable wastes and are generally described in Table 12.8. The Bayport system makes no provision for handling such wastes and their disposal is left to the individual plant.

To minimize the difficulties in administration of the system, all industries are made aware of the criteria prior to site purchase. Thereafter, individual in-plant controls to assure compliance are included in the process design of each plant.

Treatment Methodology - The "clean" stream is collected into a final holding pond from which it can be pumped to the disposal point or held for diluting the effluent from the treatment plant. It is monitored by electronic pH meter, and if unacceptable, can be diverted to a temporary holding basin.

The "biological" stream flows directly to the treatment plant which is basically an activated sludge system operated as extended aeration. Output is into the final holding pond for dilution with the "clean" stream. Content of this pond is monitored and if State criteria are met, the commingled effluent is pumped to the discharge point for final disposal.

The average raw wastewater BOD is about 3000 mg/L, which is diluted with well water and fed to the treatment plant at about 1500 mg/L. The average customer volume (before dilution) is about 1.0 MGD. Efficiency, measured by BOD reduction, is normally above 90 percent and has reached a high of 97 percent.

Since the BOD is too unwieldy to be of practical value, the COD and TOD are used for in-plant operational control. The COD and/or TOD are used to obtain a correlative BOD which is then used to determine acceptability or to pinpoint voilations of the criteria.

TABLE : 12.6

"CLEAN" Stream Acceptability Criteria

1. Plant wastewater, before entering central collector, shall contain

   a. Not more than 50 mg/L BOD
   b. No floating organics
   c. Not more than 5 mg/L oil (as determined by APHA Method for Oil & Grease) nor more than 10 mg/L oil (as determined by API Method 733-58: Determination of Volatile and Non-volatile Oily Material - Infrared Spectrometric Method)
   d. Not more than 50 mg/L suspended matter
   e. No measurable toxicity (as determined by APHA Method Bio Assay Method for Evaluation of Acute Toxicity of Industrial Waste Waters and Other Substances to Fish).

2. Addition of plant wastewater shall not cause the water in the central collector to have :

   a. Colour above 20 units (measured on the pt-co scale)
   b. pH below 6.0 or above 9.0.

TABLE : 12.7

"BIOLOGICAL" Stream Acceptability Criteria

1. Plant wastewater shall contain organic matter amenable to biological treatment

2. Addition of plant wastewater shall not cause the water in the central collector to have :

   a pH below 5.5 or above 9.5
   b. Temperature above 130°F

The central treating concept does not address itself to wastes which are not readily biodegradable. This would include materials that create nuisances, or that would be hazardous to handle, or that are known to be toxic to biological growth These are classified as non-acceptable wastes and are generally described in Table 12.8 The BAYPORT system makes no provision for handling such wastes and their disposal is left to the individual plant.

TABLE : 12.8

Nonacceptable Wastes (At Source)

1. Highly volatile and inflammable materials.
2. Asphalt, tar, clay, catalyst, slag, mill scale sludges, slurries and other materials that may settle or adhere to conduits.
3. Noxious or malodorous gases or substances capable of creating a public nuisance.
4. Pickling and plating solutions.
5. Spent caustics (five percent NaOH equivalent or higher).
6. Spent acids (five percent H_2SO_4 equivalent or higher).
7. Concentrated organic solutions (5 % organics or higher)
8. Emulsions of oil, polymer, etc. (one percent or higher).
9. Toxic or refractive materials not subject to biological treatment, including materials which cause acute or chronic toxicity to aquatic life.
10. Any substance which may cause a nuisance aquatic growth.

The five day BOD is obviously five days too late in fixing the cause of operating problems such as pinpoiting the offending stream whose toxicity has caused a plant upset. Another problem with the BOD is its susceptibility to toxicity. The result of this problem was first detected by material balance of individual customer streams and the combined stream applied to the treatment plants. Repeated balance checks indicated that the total BOD received (and billed for) was as much as 35 percent less than the load applied to the treatment plants. It was concluded and later verified, that the more toxic components were being diluted in the combined stream, thereby yielding the higher BOD figure. As expected certain individual streams showed a toxic response to the BOD test and produced low BOD values.

Cost Sharing - Each waste stream is monitored for strength and volume on a regular schedule. Volume measurements are made by flowmeters with continuous recorders and grab samples are obtained at two or four hour intervals. A seven day composite is made from the grab samples of each respective stream and analysis of the composite, alongwith volumetric measurements, serves as a basis for treatment charges.

Treatment charges are negotiated with each customer and are based on the volume and strength of waste material. In 1970, the rate schedule was six cents/1000 gal for "clean" stream waste, and 40 cents/1000 gal for "biological" stream of BOD less than 250 mg/L. For biological waste in excess of 250 mg/L, the charge is 40 cents/lb of BOD.

The Bayport Central Waste Treating System is operated as a service Function to plants in the Baypart complex and waste treatment charges are scheduled to recover only the operation cost and a nominal return (cost of money) on the developer's investment. The schedule of charges is reviewed each year with adjustments made as necessary to assure achievement of this objective along with equitable treatment rates to the Bayport customers (93).

12.3 AMERICAN CYANAMID COMPANY, NEW JERCEY, USA

The American Cyanamid Company manufacturing more than 800 chemical products in its plant at Bound Brook, New Jersey produces an industrial waste from various sources in the plant to the tune of 17 MGD with an average BOD of about 300 mg/L. The company chose to construct and operate its own waste treatment plant rather than joining the adjoining sewerage authorities. Before taking this decision, Cyanamid carried out laboratory and pilot-plant studies to determine the treatability of its Bound Brook wastes by biological methods. It was found that modified versions of both, trickling filters and activated sludge process could provide satisfactory treatment but the nature of Cyanamid's wastes would require an installation much larger than that necessary for an equivalent volume of sanitary sewage.

The results from subsequent pilot-plant studies carried out in 1955 indicated that in the activated sludge units, addition of 10 to 20 percent municipal sewage to Cyanamid's wastes produced same quality of effluent, inspite of shorter aeration periods with larger flow being treated. These findings indicated that while the company should construct and operate its own treatment plant, it still would be feasible to undertake biological treatment of industrial and presettled municipal wastes. Cyanamids then made a generous offer to municipality to treat the settled domestic sewage in its own treatment plant. Accordingly, an intercepting sewer system and primary treatment plant for municipal sewage was constructed and operated by the adjacent sewerage authority. Cyanamid's plant accepted the effluent from the primary treatment plant (of the Sewerage Authority) for joint secondary treatment (activated sludge process) with its wastes. This arrangement provided the advantages of joint treatment while allowing each party flexibility to operate, modify and enlarge its system as desired.

An agreement to this effect was reached between Cyanamid and the Sewerage Authority. The agreement was made initially for 20 years, to be reappraised at the end of 17 years. At that time, it would be continued by mutual agreement for another 20 year period or, if desired, terminated by either party on expiration of a 3 year written notice. Cyanamid stated that no charge would be levied for capital investment and amortization of the treatment works or routine operating costs, but only for the additional out-of-pocket costs of extra electrical power, chlorine and laboratory labour required for sampling and analyzing the Authority's primary effluent (94). The agreement between the Authority and Cyanamid requires the Authority to pay Cyanamid a surcharge for BOD in excess of 200 mg/L and suspended solids in excess of 100 mg/L (95).

The Sewerage Authority (Somerset Raritan Valley Sewerage Authority) included only three municipalities and the initial schedule of rates between the Authority and its three participant municipalities as agreed in 1957 is reproduced below :

Quantity	Charge*
First 3mil. Gallons/month	$ 180/mil. gal.
Next 9mil. Gallons/month	$ 150/mil. gal.
Next 40mil. Gallons/month	$ 120/mil. gal.
Next 40mil. Gallons/month	$ 105/mil. gal.
All over 92 mil. Gallons/month	$ 90/mil. gal.

* In addition to these charges the following surcharges are assessed for annual average in excess of 250 mg/L;
BOD - $ 0.01/lb, and SS - $ 0.02/lb

It was agreed that each of the participating municipalities would agree to underwrite or agree to pay a minimum annual service charge based on an assured minimum sewage flow.

The plant capacity is 5 MGD so that 1.22 MGD or about 25 percent of the plant capacity is unallocated or "unassured" so that each of the three participants can use this unallocated capacity, or by contract neighbouring townships may become customers of the Authority.

Cyanamid granted the Authority permanent easement for discharge of its effluent through its property in the event this 20 year agreement is terminated in the future. The settled effluent delivered by the Authority into Cyanamid's treatment plant was not to contain injurious or deterious concentrations of any of the following substances :

- Gasoline, cleaning solvents, fuel oil, miscellaneous other oils, and similar substances
- Materials containing objectionable concentration of colour
- Ashes, sand, cinders and similar substances
- Tar, plastics and other viscous substances
- Mineral oils
- Featers, hair, rags and similar substances
- Metal, broken glass, shavings and similar substances
- Unshredded garbage
- Toxic, corrosive, explosive or malodorous gases
- Acctylene generation sludge and similar substances
- Radioactive substances.

Likewise, without limiting the generality of the foregoing and by way of illustrative specifications only, settled effluent containing concentrations in excess of the following maximums was not to be delivered to or received into Cyanamid's treatment plant :

Item	Maximum (mg/L)
Total iron	5
Copper	3
Chromium	5
Cyanides	2
Phenol	25
Oils, mineral	15
Grease and soluble oils	25
Free mineral acid	None
Acetylene generation sludge	None

Likewise, without limiting the generality of the foregoing and by way of illustrative specification only, the settled effluent to be delivered by the Authority was rejected by Cyanamid if its strength and character exceeded the following concentrations :

Item	Limits
Temperature	110°F
pH	5.5-9.0
BOD (based on average of 5 consecutive daily composite samples)	200 mg/L
SS (based on average of 5 consecutive daily composite samples)	100 mg/L

Cyanamid at its option received the primary settled effluent from the Authority plant with a BOD in excess of 200 mg/L and in such case, the Authority paid Cyanamid $0.01 per pound of BOD in excess of 200 mg/L concentration computed on an annual average basis.

The Authority agreed to pay Cyanamid a portion of the operating cost as follows :

Item	$/MG
Electrical power	3.45
Test, control and service charges	0.99
Chlorine cost	2.70
Total	7.14

These operating costs are appreciably less than comparable costs on many municipal activated sludge plants. These charges were revised in the following years to accommodate changes in electrical and labour costs.

Cyanamid also agreed that in the event of the abandonment of its activated sludge plant, about one third of the plant would be assigned to the Authority for its use (95).

12.4 INDUSTRIAL COMPLEX OF TANNERIES AT KANPUR, U.P.

The Problem : Tanning industry is one of the oldest industries in India and ranks amongst the five top most export-oriented industries of the country. The main centres of tanning industry in India are located in the State of Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Bihar, Gujarat, Maharashtra, Karnataka, Punjab, Rajasthan and West Bengal. The tannery complex at Kanpur (Jajmau), besides being the largest in the country, is responsible for the pollution of the Ganges, a river with great mythological significance.

Animal skin consists of an epidermis, a layer of fatty issues called 'areolar', and the inner corium. The semi-soluble protein, called 'collagen', present in corium is converted into tough, flexible, insoluble and highly durable leather through tanning operations.

The tannery complex at Kanpur consists of 60 tanneries, each tannery processing 5 to 600 hides/day through vegetable, chrome and mixed tanning operations. Most tanneries process buffalo hides while the remaining few utilize calf, goat and sheep hides. Information on capacity, type of hides processed, tanning operations and existing conveyance and treatment systems was collected by circulating questionnaire (66). The relevant summary is presented in Table 12.9. This information was supplemented through an examination of wastewater from respective tanneries and detailed survey of project area.

The sewer for the conveyance of wastewater from tanneries is presently choked due to the formation of lime mortar. Most of the tanneries have no wastewater treatment system. Accordingly, the untreated wastewater is discharged in Ganges creating severe pollution problems. The research presented in this paper was undertaken to abate water pollution in Ganges through a functional and cost-effective joint wastewater management system. It was contended that such a system would provide an economical solution to the problem due to economy of scale and concomittant equalization and proportioning. The system would also provide a basis for rational cost sharing.

Table : 12.9

Leather Production at Kanpur

Type of Tannery	Number	Leather Production (Kg/d)
Vegetable	42	53,635
Chrome	9	11,650
Mixed	9	58,960
Total	60	1,24,245

Approach to the Problem : The logistics of tanning operation at Kanpur prompted classification of tanneries, delineation of appropriate pretreatment system in each class of tanneries, provision of appropriate conveyance system, separate/joint chromium recovery system from segregated chrome tanning liquor and joint wastewater treatment system to meet the stipulation of Uttar Pradesh Water Pollution Control Board for discharge of industrial wastewaters in receiving bodies of water. The total management system is depicted through a block diagram in Figure 4.1.

Classification of Tanneries : Most tanneries in Kanpur are small and the availability of finances and open space for the provision of complete treatment systems is limited. Accordingly, a joint wastewater conveyance and treatment system was envisaged with minimal pretreatment at individual tanneries. The classification of tanneries and wastewater contributed by each class are detailed in Tables 12.10 and 12.11.

The detailed chemical analysis of effluents from 6 class A tanneries, 5 class B tanneries and 3 class C tanneries are presented in Tables 12.12, 12.13 and 12.14 respectively.

Pretreatment at Tannery Premises : Pretreatment is an essential prerequisite in the joint management of tannery wastewaters to preclude conditions leading to the formation of lime mortar which clogs the wastewater conveyance system. The constraints on land and finances warranted provision of plain settling for class C tanneries, chemical precipitation and settling for class B tanneries, and chemical precipitation, setting and aerobic biological treatment at class A tanneries as depicted in Figures 12.3, 12.4 and 12.5 respectively.

A detailed treatability study was undertaken for class I settling (class C tanneries), class II settling (class B and A tanneries), and aerobic biological treatment (Class A tanneries). The extensive data collected in the treatability study has been analyzed to arrive at design criteria and cost-effective selection of coagulant in the pretreatment system.

The overflow rate in the design of plain sedimentation tank based on class I clarification is expressed as :

$$OR = -0.0233\ (SS) + 254.22$$

where,

OR = Overflow rate (m/d)
SS = Concentration of suspended solids in influent (mg/L)

Studies on chemical treatment using alum, ferrous sulfate and ferric chloride provided following relationships :

Table : 12.10

Classification of Tanneries

Class	Maximum Hides Processing Capacity (Hides/day)	Number of Tanneries				
		Vegetable	Chrome	Mixed	Total	Percent of Tanneries
A	> 250	2	-	5	7	12
B	50-250	12	2	3	17	28
C	< 50	28	7	1	36	60

Table : 12.11

Wastewater Flows

Class	Flow Range (m^3/d)		Average Flow Rate per Tannery (m^3/d)	Total Flow (m^3/d)	Percent of Total (m^3/d)
	Minimum	Maximum			
A	231.00	654.50	354.00	2478.35	47
B	46.20	210.00	107 74	1831.55	35
C	1.75	43.75	25.01	910.87	18
Total				5220.77	

Table : 12.12

Chemical Analysis of Effluent Samples from Class 'A' Tanneries

Tannery	pH	Alkalinity (as $CaCO_3$) (mg/l)	TS (mg/l)	SS (mg/l)	COD (mg/l)	BOD (mg/l)	Chlorides (mg/l)	Chromium (mg/l)	Tannins (mg/l)	Sulfides (mg/l)
1. Sultan Tannery[a]	8.4	1210	10980	952	3087	930	2410	-	773	200
2. UP Tannery[a] Tannery[a]	8.0	1100	8480	2860	4956	1225	4490	-	437	90
3. New Universal Tannery[a]	7.5	1950	35672	5982	7361	2460	2690	-	1731	245
4. Shewan Tannery[a]	8.0	500	16000	1100	3500	2000	2500	-	125	-
5. Super Tannery[a]	7.5	1200	50000	2780	4500	3000	4000	150	185	-
6. Upper India Tannery[b]	7.5	1400	22000	2560	3800	1500	2000	60	90	-

[a]Vegetable Tannery; [b]Mixed Tannery

$$\text{Alum} \quad : \quad S = \frac{D}{4.75 + 0.01356\ D}$$

$$\text{Ferrous sulphate} \quad : \quad S = \frac{D}{3.38 + 0.01438\ D}$$

$$\text{Ferric chloride} \quad : \quad S = \frac{D}{3.58 + 0.01366\ D}$$

where,

S = COD removal (percent)
D = Coagulant dose (mg/L)

Above equations hold good for coagulant dose of 500 to 3000 mg/L.

A comparison of capital costs and annual operation ccosts for pretreatment system in class B tanneries (chemical coagulation, sedimentation tank, and sludge drying beds) reveals that the annual operation cost of system employing ferrous sulfate is substantially lower (0.33 times) despite higher capital investment (1.4 times) as compared to the system employing alum for comparable COD and tannin reduction (55-65% and 52-68%, respectively). Similar cost comparison ruled out the use of ferric chloride. The comparisons have been made based on regression relationships derived from actual cost data for Kanpur region and detailed designs of constituent units (66).

The kinetic coeficients for the design of aerobic biological system in class A tanneries viz. Y, K, Ks, and Kd have been estimated as 0.4642 mg VSS/mgCOD, 0.3251 per day, 283.8 mg/LCOD and 0.01365 per day, respectively, resulting in a COD removal efficiency of 81% and tannin removal efficiency of 78.5% at a MCRT of 6.5 days and MLSS of 4000 mg/l. The settling characteristics of biological sludge at these design parameters have been observed to be good (SVI = 75-100).

Aerobic treatment of vegetable tan liquor facilitates the biodegradability of highly reduced pyrogallol and catechol in vegetable tannins as evidenced by the high tanning removal efficiency.

The composited characteristics of effluent from pretreatment systems discharged in the joint conveyance system and predicted characteristics of influent to the joint wastewater treatment system are presented in Table 12.15 The unit costs of pretreatment systems amount to Rs. 3.84, 2.23 and 1.41 per cubic meter wastewater and 0.13, 0.08 and 0.05 per kg hide for class A, B and C respectively (66).

Table : 12.13

Chemical Analysis of Effluent Samples from Class 'B' Tanneries

Tannery	pH	Alkalinity (as $CaCO_3$) (mg/l)	TS (mg/l)	SS (mg/l)	COD (mg/l)	BOD (mg/l)	Chlorides (mg/l)	Chromium (mg/l)	Tannins (mg/l)	Sulfides (mg/l)
1. Model Tannery[a]	9.0	1540	6560	4500	3028	1040	3100	-	269	130
2. Javed Tannery[a]	7.5	1300	10500	2760	2600	1200	1800	-	130	-
3. Kamal Tannery[a]	11.5	800	16000	1500	3600	3100	2000	-	210	-
4. Allied Tannery[a]	9.5	900	9000	1360	5800	2700	1600	-	180	-
5. Ideal Tannery[a]	8.0	8000	6000	2500	1100	3000	-	125	-	-

[a]Vegetable Tannery

Table : 12.14

Chemical Analysis of Effluent Samples from Class 'C' Tanneries

Tannery	pH	Alkalinity (as $CaCO_3$) (mg/l)	TS (mg/l)	SS (mg/l)	COD (mg/l)	BOD (mg/l)	Chlorides (mg/l)	Chromium (mg/l)	Tannins (mg/l)	Sulfides (mg/l)
1. New Golden Tannery[a]	7.0	755	6100	640	609	380	-	104	-	95
2. Globe Tannery[a]	6.0	-	13570	1230	1130	640	2450	-	-	1176
3. Habib Tannery[b]	8.8	-	8490	1630	536	460	5350	-	-	224

[a]Chrome Tannery
[b]Vegetable Tannery

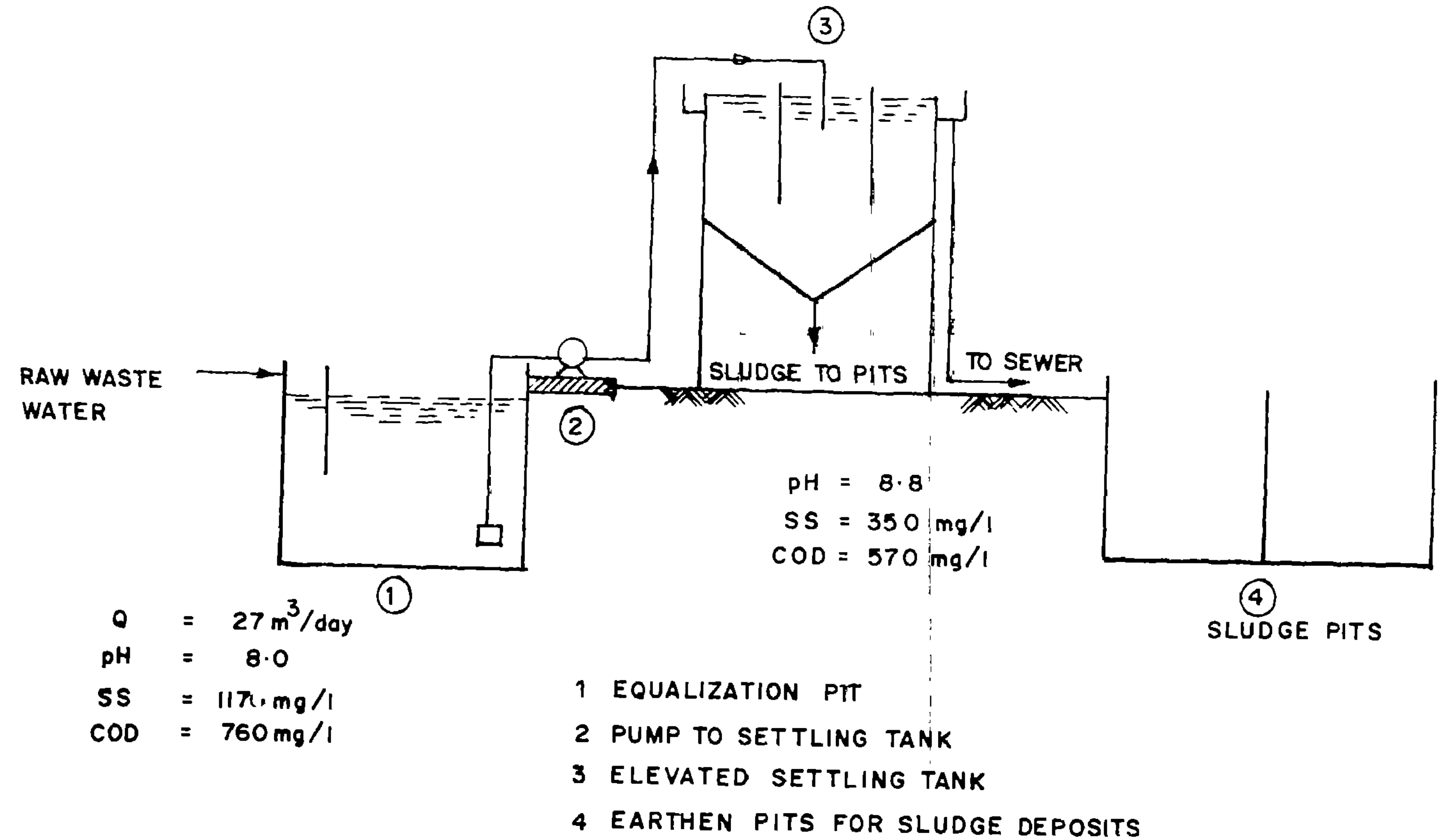


FIG 12.3 : PRETREATMENT SYSTEM FOR CLASS 'C' TANNERIES

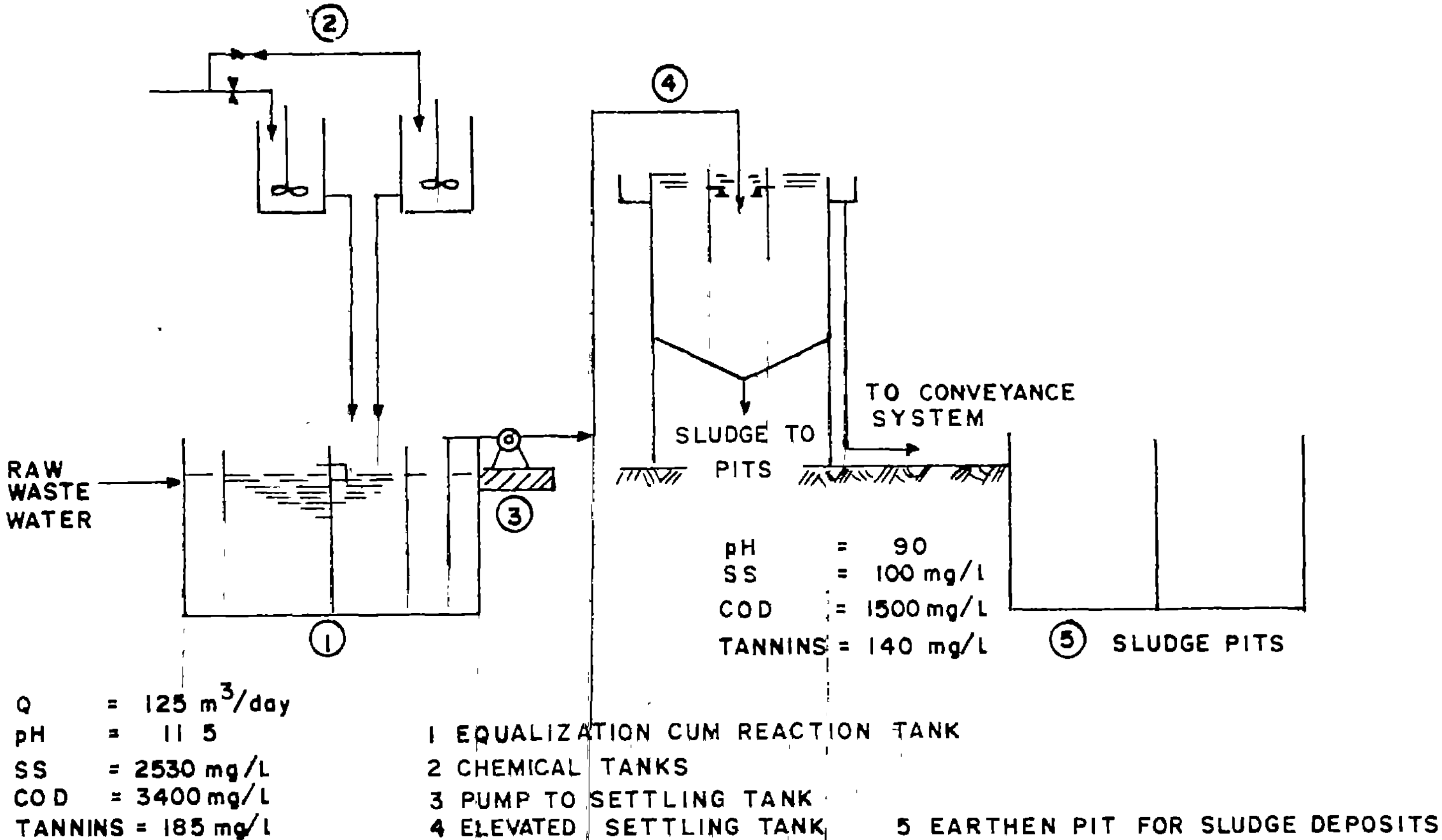


FIG. 12.4 PRETREATMENT SYSTEM FOR CLASS 'B' TANNERIES

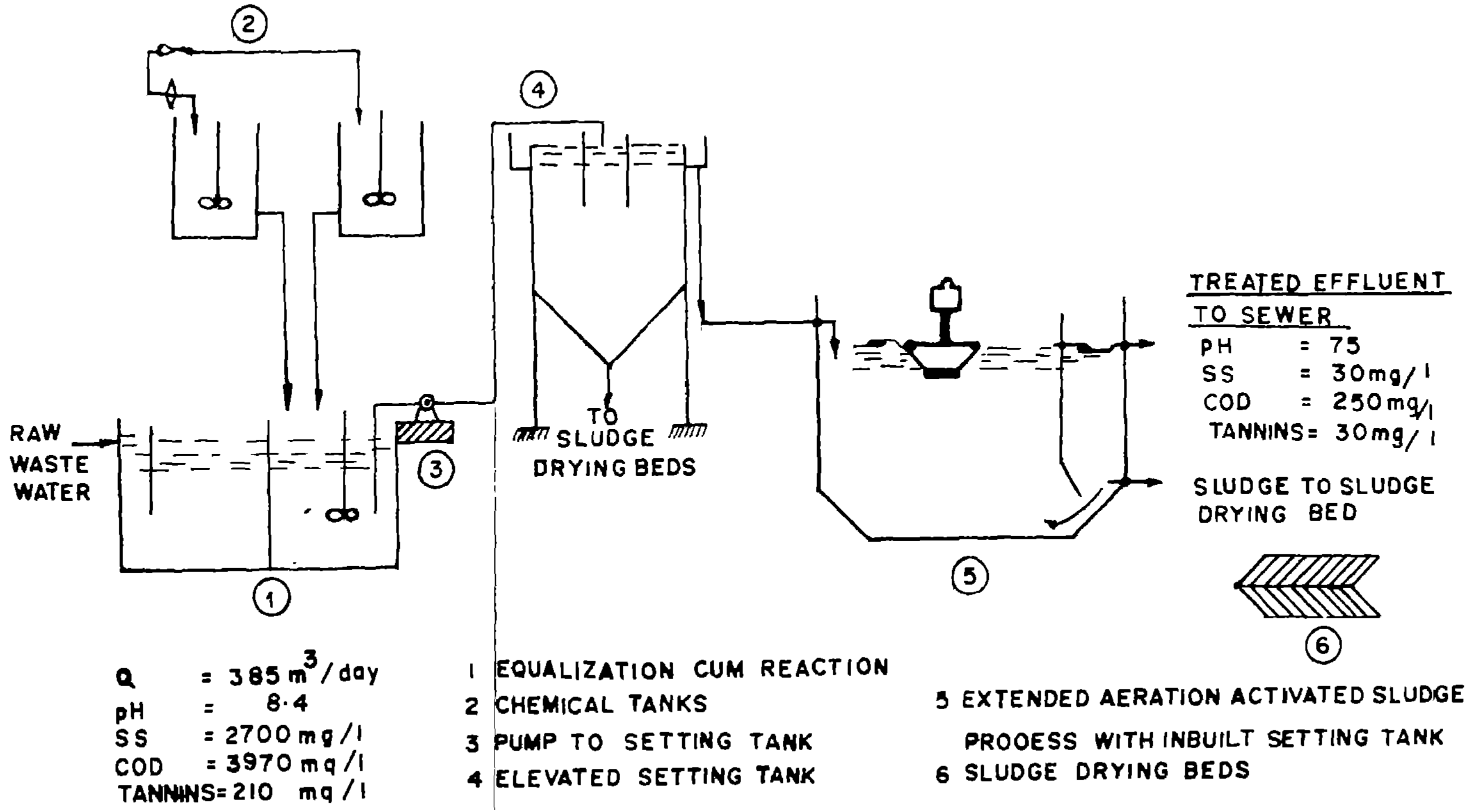


FIG. 12.5 : PRETREATMENT SYSTEM FOR CLASS 'A' TANNERIES

Table : 12.15

Characteristics of Wastewater in Conveyance System & at Joint Wastewater Treatment System

Class of Tanneries	pH	SS (mg/L)	COD (mg/L)	Tannins (mg/L)
A	7.5	30	250	30
B	7-9	100	1500	140
C	8-9	350	570	200
Predicted characteristics at joint waste-water treatment system	7.5	110	745	100

Conveyance System : Pretreated wastewater is discharged in a joint conveyance system designed as a covered composite open channel comprising of a Salt Glazed Stoneware section for conveying the industrial wastewater and a brick trapezoidal section for the excess surface runoff during the monsoon. Derivation of best hydraulic section yields trapezoidal section slideslope of 27.8° corresponding to minimum wetted perimeter for a given cross-sectional area. This value of sideslope has been utilized in the computer-based collection system designs using Mannings and Modified Hazen-Williams formula (96). The former has limitations of accuracy and non-dimensional homogeneity and accordingly yields considerably higher channel slopes (up to 200%) compared to the Modified Hazen-Williams formula for a given set of constraints (97, 98). The flow charts for Main Computer Algoritham and Subroutine are presented in Figs. 12.6, 12.7 and 12.8.

The topography at Kanpur tannery area and proposed site for joint wastewater treatment system detailed incorporation of two intermediate and one final pumpinng stations as shown in Fig. 12.9. The designs for sumpwells, pumps and rising mains have been made in keeping with the stipulation of the Ministry of Works and Housing, Government of India (99). The capital, annualized and unit cost per cum of wastewater conveyance system for industrial wastewater and surface runoff (20% of industrial wastewater) have been estimated as Rs.2.09×10^6, 0.38×10^6 and 0.17 respectively.

Recovery and Reuse of Chromium from Spend Chrome Tan Liquor : The chrome utilization in tanning operation is in the range of 55 to 60% depending upon type of hide processed, temperature, additives used etc. The remainder finds its way in spent tan liquor resulting in chrome concentrations as high as 1000 to 5500 mg/L. The segregation of chrome

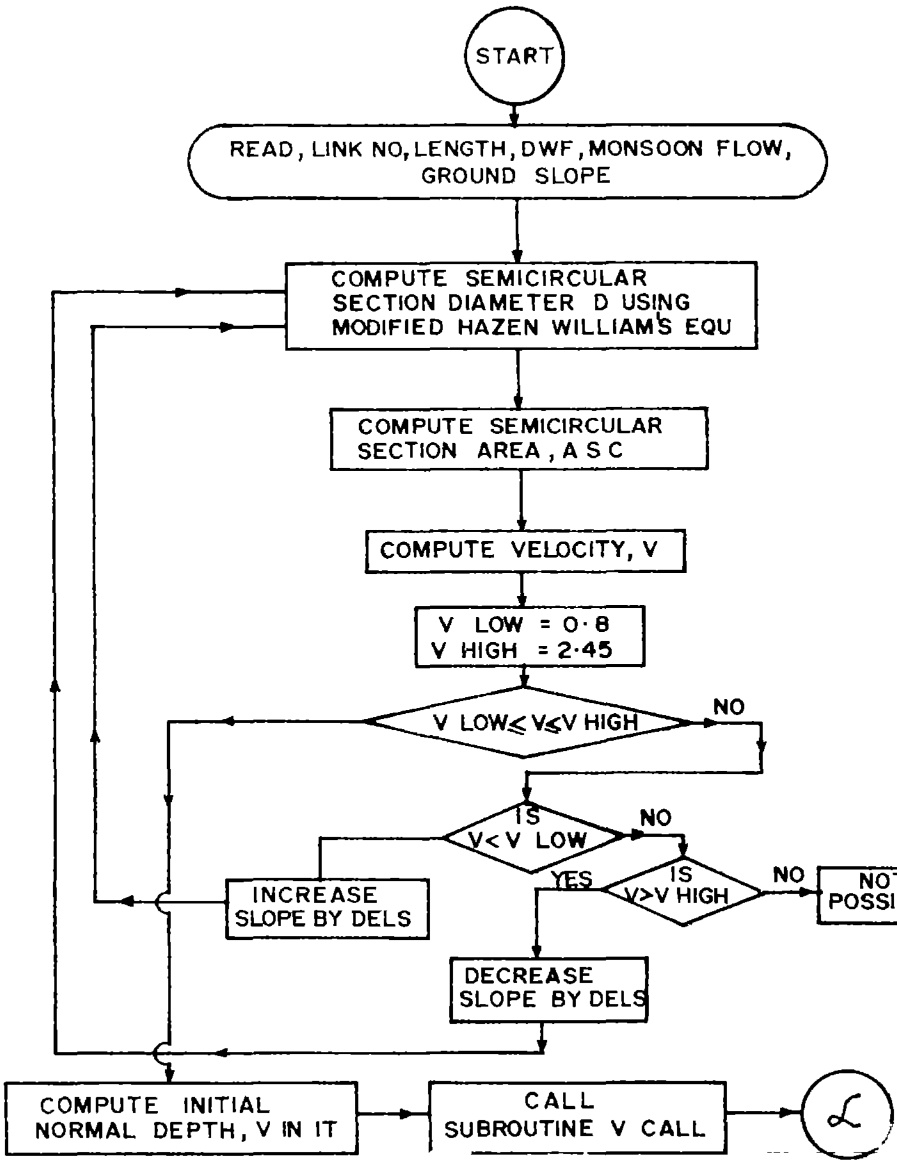


FIG. 12.6 : FLOW CHART (PART I) FOR MAIN ALGORITHM USING MODIFIED HAZEN-WILLIAMS FORMULA

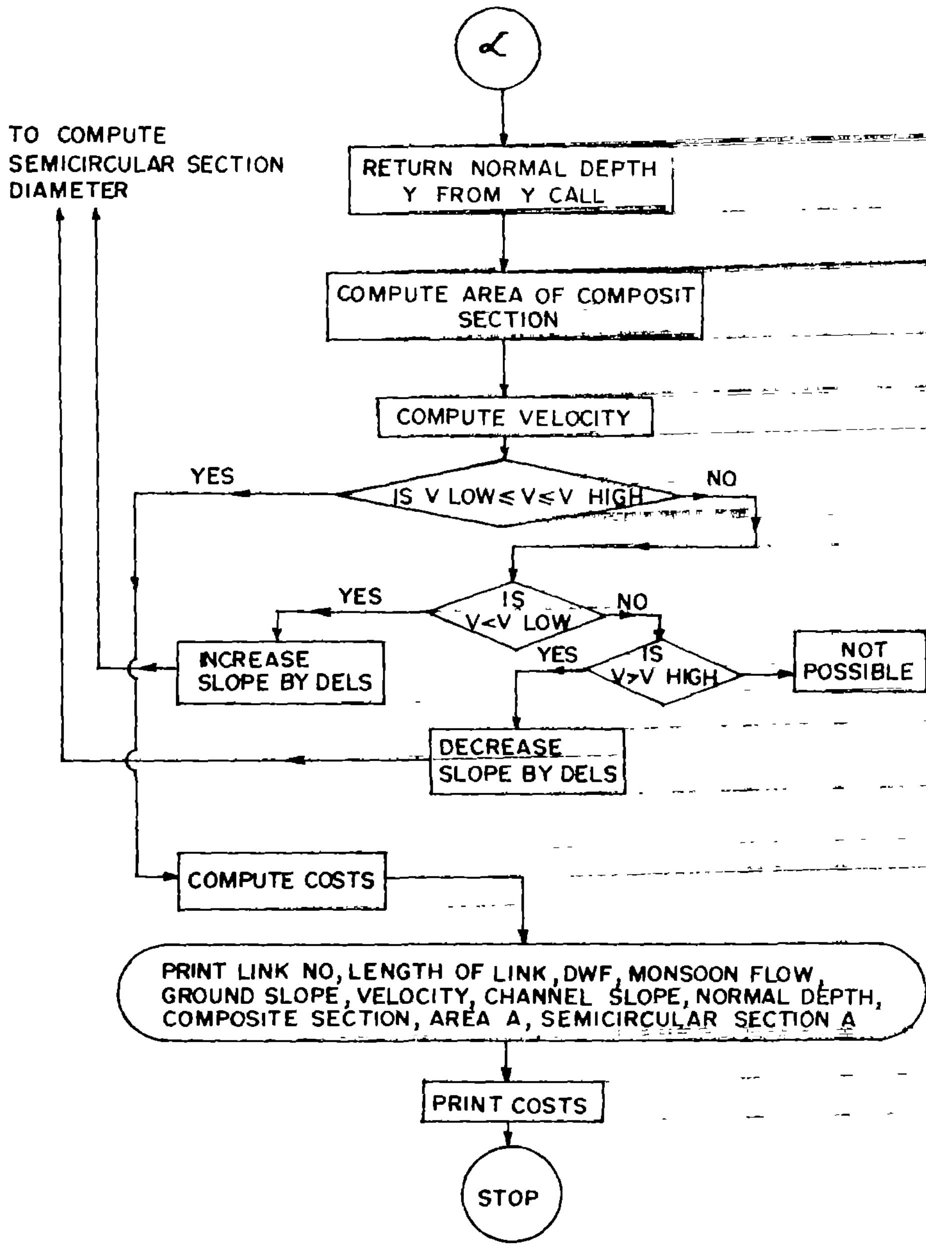


FIG. 12.7 : FLOW CHART (PART II) FOR MAIN ALGORITHM USING MODIFIED HAZEN-WILLIAMS FORMULA

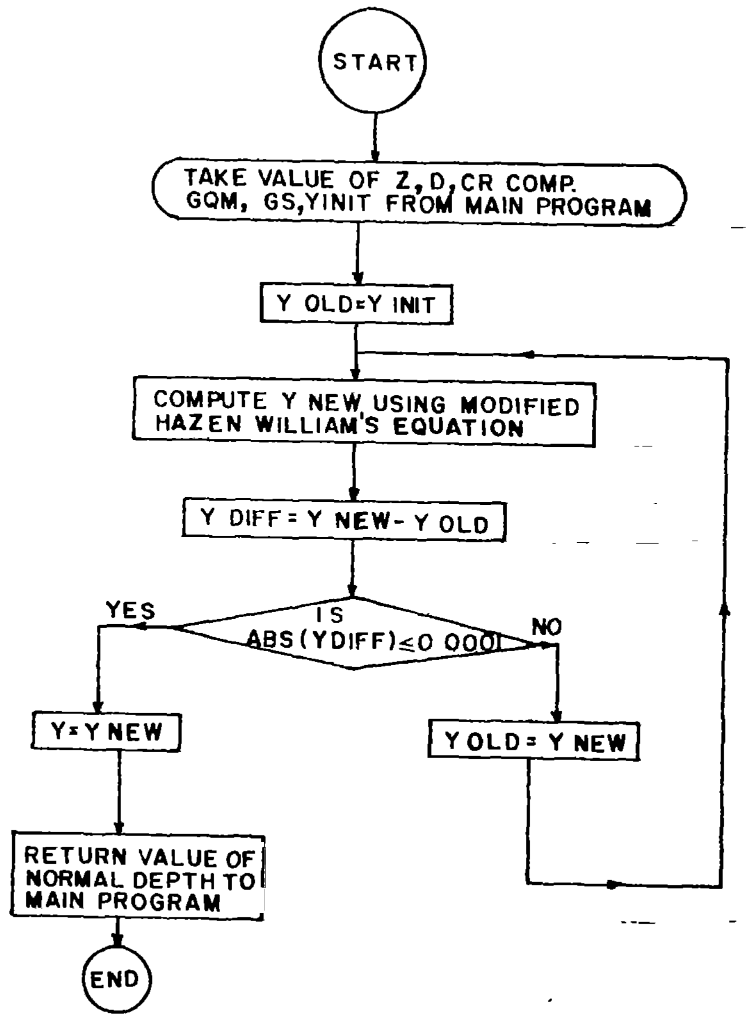


FIG. 12.8 : FLOW CHART FOR SUBROUTINE V-CAL (REGULA-FALSI METHOD)

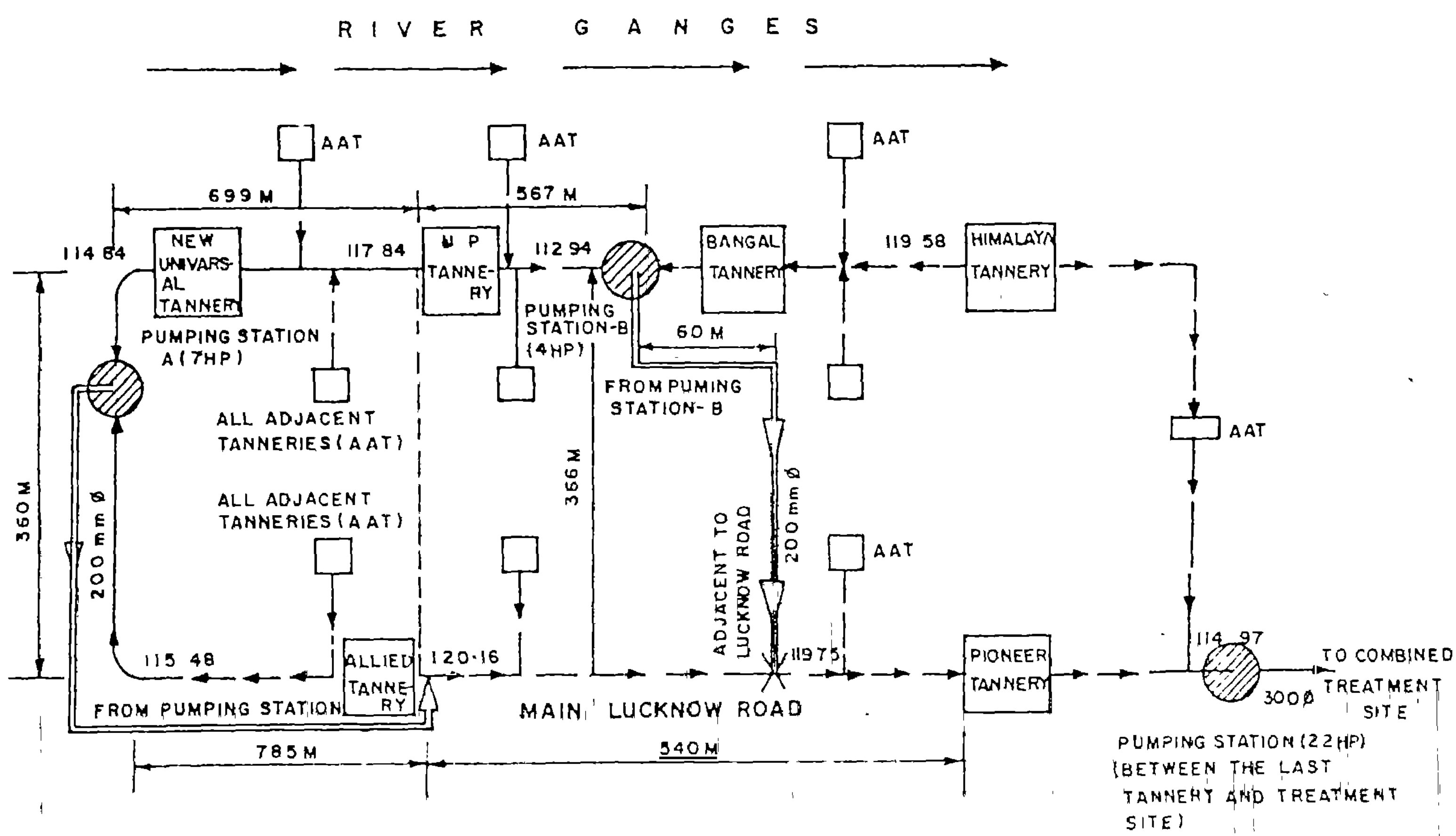


FIG. 12.9 JOINT WASTEWATER CONVEYANCE SYSTEM

stream and chrome recovery would not only result in savings for the industry but would also ensure a functional biological system.

The recovery scheme, comprising of precipitation of basic chrome sulfate as chromium hydroxide, segregation of chrome sludge, and dissolution of concentrated sludge in sulfuric acid, results in reusable chromium sulfate. Detailed design and costing of recovery scheme for a tannery processing 5000 kg hides/day and spent chrome flow of 25 m^3/d brings out saving of Rs.3000/d for the industry at a capital expenditure of Rs. $1.3x10^5$ and operation cost of Rs.2775/d (net savings Rs.225/d). The details of cost analysis are presented elsewhere (96). The flowsheet for chrome recovery is depicted in Fig. 12.10.

Optimal Design of Joint Wastewater Treatment System : The wastewater from the tanneries after pretreatment would be conveyed through the covered open channel collection system to the joint treatment system comprising of a corrousel oxidation ditch and secondary settling tank. Carrousel ditch system has been adopted in view of its various advantages over other modifications of activated sludge process.

Plots of experimental results on percent COD reduction, hydraulic retention time, θ, and mean cell residence time θ_c, yield θmin of 1.8 days and θ_c min of 4.33 days. Further, graphical iteration incorporating experimental results, mass balance in aeration tank and graphical cost optimization identifies θ_c optimal as 6.5 days and corresponding recirculation ratio, r, of 0.44. The factor of safety of 1.5 used in the design of carousel ditch is thus determined through optimization (minimal cost) considerations including capital and O&M costs of the ditch, secondary settling tank and sludge drying beds. The design results in acceptable variability of effluent from joint wastewater treatment system as ascertained through the method of propogation of variance. The details of various analysis are presented elsewhere (96). Flow sheet for joint treatment system is shown in Fig. 4.2 alongwith the characteristics of effluent from the treatment system.

The capital cost, annualized cost and unit cost per cum of joint wastewater treatment system amounts to Rs.$2.58x10^6$, $0.604x10^6$ and 0.26 respectively (96).

Apportionment of Financial Burden : 'Polluter-pays' principle provides an acceptable measure for pollution control if a rational and simple method could be established to estimate the cost of fulfilling the legal obligations of each member polluter in the joint venture envisaged at Kanpur. A procedure based on the volume and degree of noxiousness of wastewater contributed to the system for equitable distribution of annualized financial burden has been adopted in this work (73).

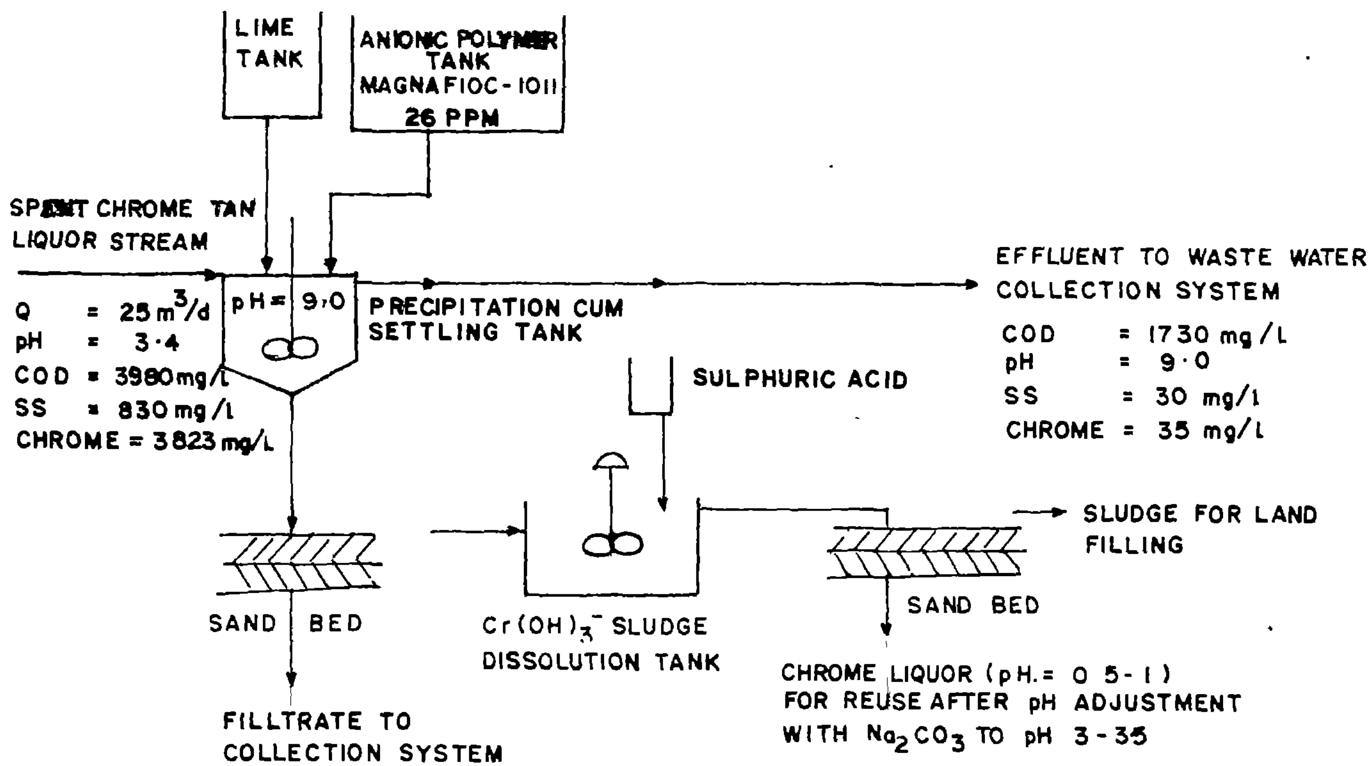


FIG 12.10 FLOW SHEET FOR CHROME RECOVERY

Since the combined treatment is biological in nature, wastewater dilution factor, V to ensure survival of fish (48 hours exposure) is expressed as

$$V = \frac{A}{A_o} + \frac{1}{2}\left(\frac{B}{B_o} + \frac{C}{C_o}\right) + F - 1$$

where,

A	=	settleable matter in wastewater (mg/L)
B	=	BOD of settled wastewater (mg/L)
C	=	COD of settled wastewater (mg/L)
F	=	Fish toxicity factor
A_o, B_o, C_o	=	effluent standards set by U.P. Pollution Control Board for settleable matter, BOD and COD (mg/L)

Noxiousness degree, S is then estimated from dilution factor, V, expressed in appropriate slabs rather than in discrete numbers to account for deviation in sampling and analysis of wastewater.

V	1-4	5-8	9-12	13-16	17-20	21-28	29-36
S	1	2	3	4	5	6	7

Annualized cost approtioned to each polluter is calculated as,

Annual apportionment = S x annual flow x total annualized cost of joint wastewater collection and treatment system per unit flow.

The average annualized cost to be shared by various class of tanneries at Kanpur is listed in Table 12.16.

Table : 12.16

Average Annual Financial Burdens

Class of Tannery	Average Flow per Tannery (m^3/d)	Annualized Financial Burden (Rs.)
A	354.00	43,395.37
B	107.74	52,829.56
C	25.01	6,131.74

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Annexure-I

PROCESSING SEQUENCE FOR CETP SUB-PROJECT APPROVAL UNDER THE WORLD BANK AIDED INDUSTRIAL POLLUTION CONTROL PROJECT

1. The Promotor Company/Society prepares submission with or without consultant assistance for CETP in accordance with approved guidelines.

2. The Promotor Company/Society submits proposal to the relevant SPCB for approval.

3. The Promotor Company/Society submits proposal to IDBI and NEERI with a copy to MEF, after the approval of the proposal by the concerned SPCB.

4. NEERI reviews proposal on behalf of MEF in accordance with the guidelines, NEERI discusses the findings of their review with the Company/Society and when satisfied that the proposal is acceptable, advises IDBI and MEF of their review findings.

5. The Company/Society makes submission to IDBI for project financing and if required, requests TA funds for engaging consultants to prepare detailed engineering design.

6. NEERI reviews the detailed engineering package.

7. IDBI appraises the proposal and sanctions the loan assistance and approves the financing plan and advises the Company/Society, MEF and the concerned SPCB of acceptance of the proposal and the final cost of the sub-project.

8. Steering Committee of the MEF formally approves the release of grant component in the financing plan and intimates the State Government for release of matching grant.

9. IDBI submits the sub-project proposal to IBRD for approval.

10. Central and State Government grant funds as well as loan funds are released by the IDBI to the Company/Society in accordance with the financing plan for the sub-project implementation.

11. The Promotor Company/Society implements and commissions the facility.

Annexure-II

ELIGIBILITY CRITERIA FOR CETP PROPOSALS UNDER THE WORLD BANK AIDED INDUSTRIAL POLLUTION CONTROL PROJECT

The following conditions would apply to funding proposals for common treatment facilities :

(a) A thorough survey of the effluent situation at the site has been undertaken and provisions have been made for adequate pre-treatment or disposal of effluents not suitable for common treatment.

(b) A feasibility study has been conducted, the economic and financial viability has been established and operating and maintenance costs have been estimated.

(c) An adequate sponsor has been constituted or identified with institutional and technical capability to operate the facility.

(d) Legal and financial responsibilities have been properly defined and the facility owner is responsible before the enforcement institutions for the quality of the common effluent after treatment.

(e) Adequate cost recovery formula have been adopted by the sponsoring enterprise with the associated mechanisms for cost sharing or fees structure from the beneficiary industrial enterprises.

All proposals for common treatment facilities will be subject to prior review and approval.

Annexure-III

APPLICATION FORM FOR SEEKING FINANCIAL ASSISTANCE FOR INDUSTRIAL POLLUTION AND EFFLUENT TREATMENT CONTROL UNDER THE WORLD BANK LINE OF CREDIT (PROPOSED)

I. GENERAL — Amount of assistance reqd.

1. Name of industrial concern :
2. Constitution:
   (Certified and upto date copy of Memorandum & Articles of Association/Bye Laws etc. as applicable may be enclosed)
3. Date of incorporation/ registration:
4. Location of
   (a) Registered Office :
   (b) Factory :
   (c) Whether Factory is located in notified backward area :
5. Nature of industry & products :
6. Name of business house/group to which the concern belongs (whether MRTP) :

II. MANAGEMENT

1. Names of present directors :
2. Details of shareholding of promotors, Directors & other major shareholders (Enclosure I) :
3. Particulars of present collaboration if any (Name & address, nature of collaboration period, terms of collaboration, etc.) :

4. Name of the Chief Executive Officer and five senior most Executives (Enclose Bio-data) :

5. Existing assistance (term loans, leasing, working capital, deferred credit, etc.) if any, from IDBI and other institutions/banks :

6. Brief history of the company/concerns indicating various developments, prospects in chronological order :

III. FINANCIAL

1. Working results :
   (Enclose: Balance Sheets, etc. for the last 3 years. In case the last audited balance sheet is more than 6 months old, proforma balance sheet and profit and loss account as on a recent date, if possible, or alternatively, comments on the operations of the unit since the audited balance sheet, should be furnished)

2. Capacity utilisation (product-wise) during the last 3 years :

   (a) Licensed
   (b) Installed
   (c) Utilised
   (Furnish reasons for low capacity utilisation, if applicable)

IV. PRODUCTS, PROCESS AND POLLUTANTS GENERATED

1. Products manufactured - capacity/specifications :

2. Brief description of process(es) employed :

3. Comparative merits/demerits of the process vis-a-vis other processes available, particularly from environmental angle :

4. Sources of emission in the process, composition of effluents/emissions physical and chemical characteristics :

5. Brief description of pollution control measures in operation both process-built-in and separate treatment plant :

6. Source of existing technology for treatment results achieved. (Furnish copy of last 3 reports submitted to PCB).

7. Furnish analysis of pollution characteristics existing, air/liquid/ solids separately with a comparison with IS standars.

8. a. Improvements sought to be incorporated in process/effluent treatment plant to reduce/eliminate pollution.

   b. Source of technology proposed, whether the same has been tried out elsewhere on pilot plant/commercial scale.

   c. Consultants, if any, proposed, their scope of services; guarantees offered (Enclose copies of consultants' report on agreement/draft of proposed agreement).

9. Quantity benefits of proposed scheme (such as reduction in recycle of materials, recovery of new by products, improvement in operational efficiency, input cost from financial, economic and environmental considerations.

10. Status of approval from CPCB/SPCB for the proposed treatment scheme and discharge standards.

V. PROPOSED CAPITAL EXPENDITURE

1. Process flow diagram with equipment proposed and their functional details.

2. Details of plant and equipment its cost whether proprietory or tailor made to the requirement, source and cost thereof.

3. Recruitment of additional land, utilities and infrastructural facilities

4. Cost of the scheme (Rs. lacs)

   (i) Land
   (ii) Building/Civil Works
   (iii) Plant and machinery
      (a) Imported (CIF)
      (b) Indigeneous (FOR)
         (Monitoring & control facilities to be specified separately)
   (iv) Miscellaneous fixed assets

(v) Engineering consultants fee
(vi) Pre-operative expenses
(vii) Contingencies
(viii) Any other (specify).

TOTAL

VI. MEANS OF FINANCE

Additional share capital
Internal accruals
Term loans
- Rupee
- Foreign Exchange
Any other source (specify)
Additional working capital, if any.

VII. SCHEDULE OF IMPLEMENTATION

VIII BENEFITS EXPECTED - IMPACT ON PROFITABILITY IN OPTIMUM YEAR

Profitability and cash flow for the next 5 years (Enclose: Statements as in Enclosure : II & III).

IX. GENERAL

1. Security proposed.

DECLARATION

We hereby declare that the information given herein before and the statements and other papers enclosed are, to the best of our knowledge and belief, true and correct in all particulars.

(Signature)
Name and designation
Name of the company/concern

Place :

Date :

ENCLOSURE - I

DETAILS OF SHAREHOLDINGS

(Rs. lacs)

			Equity	Preference	Total
A.	1.	Indian Promotors (Names of major groups)			
		(i)			
		(ii)			
		(iii)			
		(iv)			
	2.	Foreign Collaborators			
	3.	Directors			
	4.	Financial Institutions			
		(i) IDBI			
		(ii) IFCI			
		(iii) ICICI			
		(iv) LIC			
		(v) UTI			
		(vi) Others (Banks etc.)			
	5.	Public			
B.		List of 10 largest share holders			

* Please indicate date of redemption of preference shares

ENCLOSURE - II

ESTIMATE OF COST OF PRODUCTION AND PROFITABILITY

(Rs. Lacs)

Production (Quantity)	Years Ist	2nd	3rd	4th	5th
Manufacturing Expenses					
1. Raw material (a) Domestic (b) Imported.					
2. Power and fuel, etc.					
3. Stores and soares					
4. Wages & Salaries (Factory)					
5. Repairs & Maintenance.					
6. Other inputs, if any.					
7. Rent, taxes, and insurance, etc.					
8. Interest.					
9. Depreciation.					
10. Other administrative expenses.					
11. Selling expenses.					
TOTAL 'A'					
Sales (Quantity and value) other income, if any					
TOTAL 'B'					

Operating profit (B-A)
Less Taxation.

Net Profit.

Less Divident on

- Preference capital
- Equity capital
  (with rate).

Retained profit.

Add Depreciation
Preliminary
expenses written
off.

Net cash accruals.

Note : Please indicate the basis for

(a) Wastage of raw materials; and
(b) Rejection rate of finished products

Detailed working may be provided for calculation of depreciation (straightline and income tax method), interest, taxation etc.

ENCLOSURE - III

CASH FLOW STATEMENT

(Rs. Lacs)

	Years				
	Ist	2nd	3rd	4th	5th
Source of Funds					
Share issue.					
Profit before taxation with interest added back.					
Depreciation provision for the year.					
Development rebate reserve.					
Increase in secured medium and long-term borrowing for the scheme (as also proposed loan).					
Other medium/longterm loans.					
Increase in unsecured loans and deposits.					
Increase in bank borrowings for working capital.					
Increase in liabilities for deferred payments (including interest) to machinery suppliers.					
). Sale of fixed assets.					
1. Sale of investments.					
2. Other income (indicate details)					
TOTAL 'A'					

(Rs Lacs)

	Years				
	Ist	2nd	3rd	4th	5th
Disposition of Funds					
1. Capital expenditure of the scheme.					
2 Other normal capital expenditure.					
3. Increase in working capital.					
4. Decrease in secured medium and long term borrowings (including deferred payments/proposed loans).					
All India Istitutions SFCs and Banks.					
5. Decrease in unsecured loans and deposits.					
6. Decrease in bank borrowings for working capital					
7 Decrease in liabilities for deferred payments (including interest) to machinery suppliers.					
8. Increase in investments in other companies.					
9. Interest on term loans.					
10. Interest on bank borrowings for working capital.					
11. Taxation					
12. Dividents - Equity - Preference					
13. Other expenditure.					
TOTAL 'B'					
Opening balance of cash in hand and at bank					
Net surplus/deficit (A-B)					
Closing balance of cash in hand and at bank					

Note:- Detailed working of the figures shown should be provided Borrowings (as well as repayments) for the scheme and for other purposes should be shown separately.

Annexure-IV

Sample Agreement Paper I

This Agreement made this day of 19 between M/s JEEDIMETLA EFFLUENT TREATMENT LIMITED having its Registered Office at Plot No. 267, Phase-I, I.D.A., Jeedimetla, Hyderabad - 500 855 represented by its Managing Director Sri. G. KRISHNA BAPAIAH CHOWDARY (herein called the "Treatment Company" of the one part) and M/s ______________________________ having its Registered Office at ______________________ represented by its Managing Director/Partner/Executive Director Sri ______________________ (herein called the "Customer") **WITNESSETH** as follows :-

1. That the "Customer" is a Private/Public/Partnership Firm/ Company.

2. The Customer has subscribed for shares in the Treatment Company and the Treatment Company in turn has granted ________ of its Shares of the Company.

3. The Customer states that no action has been initiated against it under the water prevention and control of pollution act 1974 & Environment (Protection) Act 1986 by the A.P. Pollution Control Board on the date when the "Customer" has become a share holder in the "Treatment Company" and the Customer commits itself to send its industrial effluent to the "Treated Company" for necessary treatment and discharge.

4. The Customer shall get its industrial effluent treated and processed by the Treatment Company. The Treatment Company shall give the "Participation letter" in favour of the Customer to the A.P. Pollution Control Board.

DEPOSIT :

5. The Customer shall deposit an amount of Rs. ------- with the Treatment Company towards two months interest free Service Deposit. This deposit amount in based on present Minimum COD indications. It shall be reviewed after final analysis.

TRANSPORTATION :

6. The Customer who is already in production shall send ___________ full tankers containing its industrial effluents to the Treatment Company every Day/Week/Month. The Customer shall send ________ full tankers immediately after going into production.

7. The Treatment Company shall provide 10,000 litres capacity tankers to the customer for transporting the industrial effluents of the Customer to the treatment plant. That this undertaking is limited to the Customers situated in the Industrial Development Area of Jeedimetla. The Customer situated outside the Industrial Development Area of Jeedimetla shall arrange for their own transport. The factory site of the Customer as per Agreement is situated/ not situated in the industrial development area of Jeedimetla.

8. The Customer shall make adequate arrangements for storing its industrial effluent in its premises and shall give access to the tanker of the Treatment Company of its storage facility all 24 hours of the day.

9. The Customer shall be responsible for loading its industrial effluents in to the tankers and shall load the industrial effluents into the tank at its own cost within reasonable time.

QUANTITY AND QUALITY :

10. That the capacity of each tanker shall 8000/10,000 litres (Eight thousand/Ten thousand litres).

11. The customer undertakes to bring the pH level of its industrial effluent between 7 and 7.5 before loading it into the tankers and for transporting it for treatment by the Treatment Comapny.

12. The Customer shall not send any industrial effluent containing heavy metals, cyanides, poison and ions like formaldehyde, analine, phenol etc. and any other defferent constituents that may be notified by the treatment company from time to time.

13. The Treatment Company may reject the industrial effluent of the customer if such industrial effluent is found not to be in consonance with the conditions mentioned in Clauses 11 and 12 of this Agreement.

14. The decision of the Treatment Company in rejecting the industrial effluents of the Customer for non compliance with Clauses 11 and 12 shall be final and the Customer shall pay the treatment company the amount charged by the Treatment Company for the expenditure incurred in analysing transporting and returning of the rejected industrial effluents.

15. The Customer shall be bound by the Chemical analysis of its industrial effluent carried out by the Treatment Company.

16. The Customer shall be bound by the calibration taken by the Treatment Company for determining the quantity of the industrial effluent sent for treatment by the Customer.

PRICING :

17. The Customer shall pay the Treatment Company for treating its industrial effluent according to the following :

Quality of Industrial Effluent		Rate in Rupees per tanker of 10,000 litres or part thereof
1)	From 1 to 5,000 Chemical Oxygen Demand (COD) in mg/L	Rs. 150/- per tanker
2)	From 5,000 COD to 10,000 COD in mg/L	Rs. 175/- per tanker
3)	From 10,000 COD to 15,000 COD in mg/L	Rs. 200/- per tanker
4)	From 15,000 COD to 20,000 COD in mg/L	Rs. 225/- per tanker
5)	From 20,000 COD to 35,000 COD in mg/L	Rs. 250/- per tanker
6)	Above 35,000 COD in mg/L	There would be an addition charge @ Rs. 25/- per tanker for every 1,000 units of COD over Rs. 250/- However for such high COD content loads, specific case to case approval should be obtained by the customer from the Treatment Company

MINIMUM CHARGES :

18. The Customer states that its has not yet gone into production. The Customer promises to send to the Treatment Company its industrial effluent for treatment as per Clause 6 of this Agreement. The Treatment Company has basing on the promise reserved the required part of its treatment capacity for the Customer. And the Customer in turn agrees to pay Rs. 50/- for each tanker stipulated in Clause 6 till such time that it goes into production and starts sending its industrial effluent to the Treatment Company.

19. The Customer has agreed to send only small quantity of effluents (about 3 tankers) per month to the Treatment Company as per Clause 6. The Customer agrees to pay Rs. 100/- to the Treatment Company for every tanker it fails to send as per Clause 6. However it shall pay minimum charges of Rs. 50/- per tanker per day for the rest of the days in a month as one tanker capacity is resolved for the Customer.

20. The Customer has agreed under Clause 6 to send -------- Tankers per day. The Customer has agreed to pay the amount as per Clause No. 17 for each tanker of industrial effluent treated. Now the Customer undertakes to pay a minimum of Rs. 100/- for each tanker it fails to send as agreed in Clause No. 6.

21. The Customer states that under the concerned environment law in force it has become obligatory on its part to have its industrial effluents treated and processed.

22. The Customer states that the investigation conducted by the Customer has established that it is most economical for it to have its industrial effluent treated and process by the Treatment Company than have it done somewhere else.

23. The Customer for avoiding pollution from the discharge of its industrial effluents has examined possibilities of having its industrial effluents treated at its factory site and found it not to be economically viable. The Customer states that this is the reason which prompted to buy the shares in the Treatment Company and enter into this Agreement by which it is undertaking to send its industrial effluents to be treated and processed by the Treatment Company.

24. The Treatment Company and the Customer state that the Treatment Company's sole objective is to prevent environmental and pollution hazards and for the observance of the laws on environmental and pollution control. Share holding in the

Treatment Company is with the object of extending assurance to the Customer by the Treatment Company on a priority basis. The Shareholding is part of the consideration for the services rendered by the Treatment Company.

25. The "Treatment Company" shall not be liable in any manner if, any negligence or otherwise of the Customer, the untreated industrial effluents are discharges at the factory site of the Customer or any where else by the Customer.

FOR-FEITURE :

26. In case of failure of the Customer to send the specified number of tankers as per clause 6 of this Agreement, the Treatment Company shall be at liberty to adjust from the Service Deposit the first week's/month's amount due from the Customer.

27. The Service Deposit shall be forfeited by the Customer if it fails to send for a continuous period of two weeks/months the tanker which it has promised to send under clause 6 of this Agreement.

PAYMENT :

28. The Customer shall pay the amount due once a month. The Customer shall pay the monthly amount due by it to the Treatment Company by the 15th day of the succeeding month.

ARBITRATION :

29. Any dispute arising from or under this Agreement or in respect of this Agreement between the Customer and the Treatment Company shall be referred to an Arbitrator mutually agreed upon by the Customer and the Treatment Company.

JURISDICTION :

The Treatment Company and the Customer mutually agree that the only the civil court at Hyderabad shall have Jurisdiction over all disputes arising out of this agreement.

SIGNATURES

1. For M/s

( )
Customer

2. For JEEDIMETLA EFFLUENT TREATMENT

(G.K.B. CHOWDARY)
MANAGING DIRECTOR

SAMPLE AGREEMENT PAPER II

Articles of Agreement made at Bombay on this ——————— day of ——— BETWEEN M/S ——— having its registered office at 3, Jayanti Shopping Centre, 1st Floor, Bhimnagar, Tarapur-Boisar Road, Boisar, Taluka-Palghar, Dist. Thane, hereinafter referred to as the 'Promotor' (which expression shall unless repugnant the context or meaning thereof shall mean and include their heirs, executors, administrators and assigns of the First Part AND ———————————————— (which expression shall unless repugnant to the context thereof shall mean and include their heirs, executors, administrators and assigns of the Second Part).

WHEREAS the Promotor, a partnership company specialised in the business of consultancy and such other work in air and water pollution control and all kinds of chemical process and carrying on business for the last three years AND WHEREAS the Government of India has introduced the Water Pollution Control Act in the year 1974 and has accordingly constituted the Maharashtra Pollution Control Board for the state in an effort to check the pollution in industrial estates etc., AND WHEREAS it is practically impossible for Industries to handle the operation of treatment effluent AND WHEREAS it is necessary to confirm to the specification of the Act as far as the Effluent Treatment is concerned AND WHEREAS violation of the provisions said Act invites penal consequences and penalty AND WHEREAS penal the promoter has envisaged the setting up and establishment of a Joint Effluent Treatment Plant at ——— for the benefit of the industries located at ——— AND WHEREAS the proposal was made out to the industries located at M.I.D.C. Tarapur Dist. Thane, by the promoter by their letter dated ——— AND WHEREAS the response from the members were spontaneous and accordingly the promoter has taken up the proposal with the Maharashtra Pollution Control Board as also with the State and Central Government etc., AND WHEREAS the authorities have consented to the proposal AND WHEREAS the promoter has accordingly submitted a Project Report for setting up and establishing a Joint Effluent Treatment Plant at Tarapur M.I.D.C. to the Maharashtra Pollution Control BLoard who in turn have submitted the same to the State and M.I.D.C. AND WHEREAS considering the project is that one concerning the social and environmental problems facing the society, at large the Governments. AND WHEREAS the contribution required to be made by the members of the total cost of the project AND WHEREAS the contribution so required to be made by the members AND WHEREAS the members have made payment, on account against contribution in favour of the promoter AND WHEREAS the promoters are interested in reducing in writting the terms and conditions of the working of the above project, NOW this agreement witnesseth as under :

1. The total projected cost of the Effluent Treatment Plant at ———————————— as per the Project Report dated ——— shall be Rs. ——— (Rupees ————) The members are agreed to the projected cost as per the project report.

2. The Promoter and Members do hereby agree to work together for the promotion and completion of the project within a period of 2 years from the possession of plot. The members do hereby agree to contribute and make payment in advance of the projected cost as per the project report.

3. That is agreed by and between the Promoter and the members that the contribution payble by the member shall be arrived at on the basis of the flow rate and characteristic of the effluent available with each member industry/units, the same shall be worked out and fixed at the sole discretion of the promoter.

4. The location of the plant will be at M.I.D.C. Tarapur. Allotment of the exact plot considering the nature of the plant and of the need of the industry in the ——— area is pending with the M.I.D.C.

5. The plant shall be Effluent Treatment Plant as per the specification made out in the Project Report, the members do hereby agree to contribute their share of the capital and expenses of the plant for its operation.

6. The plant shall operate on a no loss, no profit basis for the benefit of all the members and of the society at large for cleaner environments.

7. The Promoter shall open one or more account in one or more banks and maintain proper accounts of the expenditures and payments made in respect of the setting up of establishment and execution of the plant. The accounts as also of the project report shall be open to the members for verification if they desire so.

8. The promoter shall appoint such consultants and legal advisors for the project and for its proper execution of in all respect including the formation of a society or a company of the members.

9. The promoter shall always keep liaison between the Government of Maharashtra, Water Pollution Board and such other institutions and financial institutions and the members for proper execution of the project.

10. The promoter shall cause a cooperative society or a company to be formed of the members and the accounts and the assets shall be transferred to the said society or company when formed for further governance of the plant.

11. The members shall contribute for the cost of the formation of the company or society and pay the membership fees and become members of the society or company and make and sign such applications as and when necessary and submit the same to appropriate authorities and bare expenses for the same. The defaulting members shall lose their membership and no claim shall be entertained by the promoter or the society and they are not entitled to any benefits.

12. It is agreed that the Chem-Tech Consultants, Thane shall be consultants of the project.

13. The promoters shall inform the members and keep them informed of about the progress in the work of the execution of the project.

IN WITNESS whereof the above said parties have herein unto set and subscribed their respective hand at Bombay the day and year first herein mentioned.

1. SIGNED AND SEALED AND DELIVERED by
   the within named Promoter in the
   presence of ---------------------------------
   ----

2. SIGNED AND SEALED AND DELIVERED by
   M/s ---------------------------------
   the within named Member in the
   presence of ---------------------------------

Annexure-VI

LIST OF EQUIPMENT FOR CETP MONITORING LABORATORY

Sr. No.	Name of Equipment	Purpose
1.	Atomic absorption spectrophotometer	Accurate metal analysis
2.	Gas chromatograph	Organic substances
3.	Mercury analyser	Hg
4.	Flame photometer	Na, K, Li Ca analysis
5.	Spectrophotometer	Colorimetric analysis
6.	Bomb calorimetereter	Calorific value
7.	Turbidity meter	Turbidity
8.	Conductivity meter	Conductivity measurements
9.	D.O. meter	DO
10.	pH meter	pH
11.	BOD incubator	BOD
12.	Auto clave	Sterilisation of glassware
13.	Water demineraliser	Water demineralisation
14.	Water distillation units	Water distillation
15.	Mechanical hot air oven	Controlled drying
16.	Muffle furnace	Closed heating
17.	Hot plates	Open heating
18.	Heating mantle	Open heating
19.	Water bath	Constant temp. heating

contd...

contd...

Sr. No.	Name of Equipment	Purpose
20.	Magnetic stirrer	Stirring
21.	Mechanical shaker	Shaking
22.	Vacuum pump	Vacuum filtration
23.	Jar test apparatus	Water treatment studies
24.	Kjeldahl distillation unit	Nitrogen
25.	Fluoride distillation unit	Fluoride
26.	Cyanide distillation unit	Cyanide
27.	Phenol distillation unit	Phenol
28.	Gutzeit generator	Arsenic
29.	Physical balance	Rough weighing
30.	Micro balance (single pan)	Accurate weighing
31.	Micro balance (top loading)	Accurate weighing
32.	Orsat apparatus	CO_2, N_2, O_2 & CO
33.	Refrigerator	Refrigeration
34.	Glass thermometer	Temperature
35.	Dry and Wet thermometer	Humidity and temperature
36.	Fume chamber	Digestion
37.	Gas connection	Heating
38.	Conductivity meter	Conductivity measurement
39.	Dessicator	Dehumidifying
40.	Compressor	Dry air
41.	Auxiliary items	
	Glassware accessories Laboratory furniture Chemicals and filter paper Personal computer Air conditioner Voltage stabilizer Exhaust fan Laboratory stationery	Lot

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