Water Conservation and Pollution Aabatement in Indian Industry

–A Study of Water Tariff

by

D.B. Gupta, M.N. Murty and R. Pandey
with
V. Chandra, S. Sarkar and S. Mudali

A Study Sponsored by
Ganga Project Directorate

August 1989

NATIONAL INSTITUTE OF PUBLIC FINANCE AND POLICY
NEW DELHI

FOREWORD

The Study on **'Pricing of Water for Industrial Use'** presented here was entrusted to the NIPFP by Ganga Project Directorate (GPD), Government of India in October 1988. The main aim of the study has been to explore ways in which the price/tax system can be used for preventing wasteful use of water and promoting pollution abatement. More specifically, the objectives of the study were:

1. To examine the prevailing arrangements in charging water supply for industry,

2. To assess whether, and to what extent the existing arrangements for charging for water supply for industry bear a realistic relationship with the cost of production of water, its treatment for use, storage and distribution,

3. To assess how far the existing system of charging for water supply to industry is conducive to preventing wasteful use of water, and the extent to which it promotes conservation of water, both qualitatively and quantitatively, and

4. To suggest on the basis of conclusions drawn from the study a rational tariff system to meet the desired objectives.

The study was conducted by a research team led by Devendra B. Gupta and M. N. Murty. A preliminary report was submitted in April this year.

The results contained in the study are based on an assessment of the water pollution caused by selected industrial units in the Ganga basin located mainly in Uttar Pradesh and West

Bengal and the practices followed by them in the matter of pollution control or abatement. Zuari Agro Chemicals Ltd. located in Goa was also studied as a special case since this is the only unit in the sample which has consciously followed water conservation practices. A couple of units in the water scarce region in Tamil Nadu were also studied.

In a pioneering study of this type, the conclusions are best taken as only tentative. It is hoped that the findings of the study and its underlying approach will invite attention to the problems of pollution caused by industrial growth and raise a fruitful debate on ways of tackling it in a rational manner without coming in the way of industrialisation of the country.

The Institute is grateful to the Ganga Project Directorate for sponsoring the study and for the interaction provided by its officials in the course of the preparation of the study.

The Governing Body of the Institute does not take any responsibility for the views expressed by the authors in the report, that responsibility belongs primarily to the authors.

August, 1989

Amaresh Bagchi
Director

PREFACE

The present study is an attempt to suggest a framework for pricing water for industrial uses with a view to preventing wasteful use of water and promoting pollution abatement. The study is based mainly on the data collected from a number of industrial units in the country, especially in the Ganga basin. We wish to place on record our thanks to the executives of these units since without their cooperation this study would not have been possible.

We would also like to take this opportunity of expressing our gratitude to the Ganga Project Directorate (GPD) for sponsoring the study. Our special thanks are due to Dr. M. K. Ranjitsinh, Shri D. S. Bagga, Shri S. Sundereshan and Dr. S. A. Swamy for the extremely useful discussions with them. The two Seminars organised by the GPD and one at our Institute also helped use in clarifying many issues. To the extent possible the suggestions offered at these seminars have been incorporated in the report.

In this study we received field and research support from Dr. Rita Pandey, Ms. Vasundhra Chandra, Mr. Sandeep Sarkar and Ms. Sanjeeta Mudali. Upto the preparation of the preliminary report, the field and research staff was supervised by Dr. Rita Pandey, Senior Economist in the Institute. Needless without their help, it would have been difficult to carry out this study.

For constant encouragement and advice in our endeavour, we would like to place on record our gratitude to our Director, Dr. Amaresh Bagchi.

For excellent secretarial assistance, we would like to thank the administrative staff of the Institute, especially Shri R. S. Tyagi and Shri N. Natarajan.

Devendra B. Gupta

and

M. N. Murty

CONTENTS

PRICING OF WATER FOR INDUSTRIAL USES

Part I Methodological Issues

Page No.

Page No.

Page No.

CHAPTER I

INTRODUCTION

1.1 Water As One of the Environmental Resources

Water resources are the most important among the natural resources. These and others like air and land are regarded as environmental resources which have distinctive characteristics from other natural resources like minerals, metals, fossil fuels, etc. Environmental resources as waste receptors or receivers are public goods, the prices of which can not be determined by market forces. For example, market cannot impute any price for using air and water for the waste disposal by various economic agents (producers and consumers) because being public goods they are freely accessible to all. Also, there will be a large number of economic agents receiving damages due to waste disposal. In other words it is difficult to define property rights for the private use of environmental resources due to classical free rider problem peculiar to them. However, the other natural resources like minerals, etc., are private goods, in the sense that either market forces determine their prices or property rights, for their private use can be defined unambiguously. Therefore, these special properties of environmental resources are to be borne in mind in designing the prices for their private use (industrial or domestic).

Given the failure of the market to determine the prices of environmental resources for their efficient use, non-market alternatives have to be relied upon for the optimal management of these resources. The classical solution is the governmental intervention in the market process by levying pollution taxes on the users of environmental resources for the waste disposal (pollutors)[1]. Also, there can be programmes of direct governmental invervention like imposition of physical constraints on the quality of pollutants released by the industry, etc. However, given the history of failure of governmental programmes for the management of environmental resources, it has been now realised that there is a need for having non-market and non-governmental alternatives for their management. We have some examples of this type of programmes in which voluntary organistions or people's societies participate in the management of environmental resources like forest resources.[2]

1.2 Cost of Water for Private Uses

The private use of water can be either domestic or industrial. The cost of water for private uses consists of two components: (a) private cost/cost to the user and (b) social cost/cost to the society. The private cost is the production cost of water which depends upon its source (tubewell, river, lake or canal). For example, if the user draws water from the ground water sources, the cost of water is cost of investment on tubewell as well as its operation and maintenance cost. Alternatively, if he draws water from a nearby river or lake, the private cost is cost of pumping water from its source. Therefore, in his private profit calculations, the user imputes a price to water that is equivalent to its private cost of production.

The use of water for industrial or domestic purposes inflicts a cost on the society if the user freely disposes

---

1. See Pigou (1932).

2. See Chopra, Kadekodi & Murty (1988).

The use of water for industrial or domestic purposes inflicts a cost on the society if the user freely disposes residual water with pollutants into a water body (river or lake). Since the users of a polluted river are normally large in number, the damages from water pollution are received by the society at large. The sum-total of damages received by all the users of river is the cost to the society. Therefore, for the efficient management of water resources, the price for the private use of water should consist of this social cost apart from the private cost defined above. The public water supply authority can easily estimate its production cost of water because it possesses all the required data. However, the estimation of social cost is difficult given that damages from water pollution are received by a large number of people.

1.3 The Problem of Water Conservation in Industries

The price of water also depends upon supply and demand for it in a given situation. In wet regions or at locations of factories where there is either bountiful ground water or a big river, the price of water is unaffected by the demand for it. It only depends upon the production cost of water. On the other hand in the dry regions with megre water resources, it is demand for water that determines its price. For example, in the Gangetic basin where the ground water table is very high the cost of production of water is around Rs 0.20 per kl. as given in Table 3.1. Given this low cost of supply of water, naturally, the factories have no incentive to conserve or recycle water in this region. However, there can be gains of water conservation for the factories located in the dry regions for the full demand for water is not often met from the local sources. In such situations, the price of water is determined by the cost of conservation.

The water conservation by industries is obtained by recycling and reuse of water. Recycling is defined as the internal use of waste water by the original user prior to discharge to a treatment system or some other point of disposal. The reuse of water implies withdrawl by any user other than the discharger of waste water (Tyagi, Sengupta and Chakrabarti, 1989). The reclaimed residual waters of industries, and municipalities are generally used for (i) irrigation; (ii) industrial cooling; (iii) alga and pisciculture, and (iv) other industrial uses. Figure 1.1 shows the possible uses of reclaimed water.

The economic benefits from water conservation by the municipalities and industries can be in the form of generation of energy, production of manure, alga (for poultry feed) and fish, growth of hyacinth for bio-gas production, treated effluents for irrigation apart from pollution control. The waste water from 27 Class I cities in the Ganga basin has been estimated at 902 million litres per day. The benefits from this waste water are estimated at Rs 37 per capita (Tyagi, Sengupta and Chakrabarti, 1989).

The total number of large and medium water polluting industries in the country is around 4,000, out of which about 50 per cent have effluent treatment systems. The benefits from water conservation in the industries are significant as shown in Table 1.1.

1.4 Methods of Fixing the Price of Water

The original solution to the problem of water pollution control is the imposition of pollution tax (cess) on the use of water. The determination of pollution taxes for the optimal management of water resources requires the estimation of damages received by the pollutees. The pollution taxes and standards approach[3] avoids the formidable problem of estimating damages from water pollution. Given the environmental standards which may be determined through a political process, this method requires the levying of pollution taxes on pollutors such that they incur some cost on pollution abatement to realize pollution standards.

An interesting and difficult problem of pricing of water arises in the case where local administrations/municipalities offer the services of sewage treatment to pollutors. Industrial units normally generate a vector of water borne pollutants with distinctive physical and chemical characteristics. It may be therefore difficult to express all the pollutants in common homogeneous units so that a single pollution tax can be levied on all the industries for realising the pollution standards. Therefore, the municipality may have to charge different prices for treating different pollutants. Thus the problem of determining prices/taxes may be similar to the problem of determining prices of commodities jointly supplied by a public utility.

1.5 About the Study

The plan of the remaining study is as follows. Chapter II provides a brief review of the methods of environmental pollution control. It discusses the problem of measurement of benefits from pollution abatement and high-lights various non-market solutions for the management of environmental resources. The methods of fixing the pollution taxes under two scenarios: (a) a scenario without pollution standards and (b) a scenario with

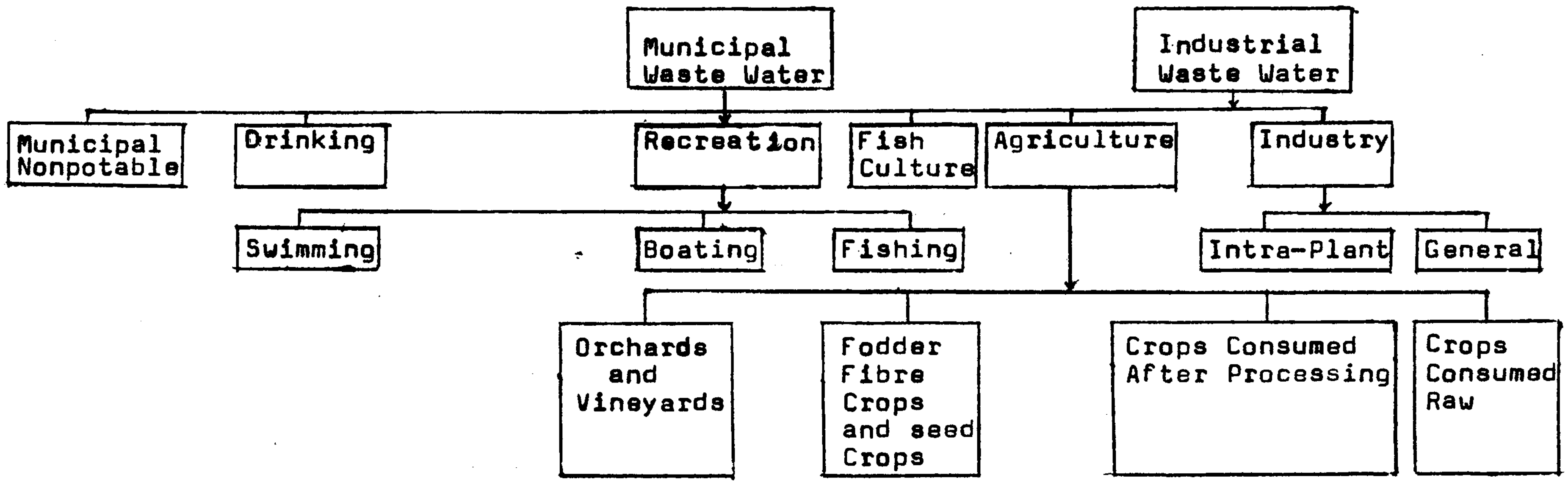
---

3. See Baumol & Oates (1979) and Murty & Nayak (1982).

pollution standards are presented. Chapter III discusses in detail the problem of pricing of water for industrial uses. It provides the methods of estimation of private cost and social cost of water supply which naturally form the basis of determining the supply price of water. Also, considering a municipality as a public utility offering services to treat various water borne pollutants, a method of fixing different prices/taxes for pollutants is suggested. Chapter IV reviews the current practices of Water Pollution Control in India. Chapters V - XVI deal with case studies of distilleries, textile mills, tanneries, fertiliser plants, vegetable oil mills, caustic soda, oil refineries, gun and shell, paper and pulp, sugar, man-made fibres and water supply undertakings which help to formulate guidelines for fixing price of water for industrial uses. Finally, Chapter XVII provides recommendations and conclusions.

Figure - 1.1

Reuse of Waste Water from Industry



Source: Science Reporter, April-May, 1989,pp.195, fig.1.

TABLE 1.1

Benefit of Recovery System in Industries

Industry	Total Waste-water Flow (m^3/d)	Total Cost of Plant (Rs.x10^3)	Net Anual Reco-very (Rs.x 10^3)	Invest-ment Payback Period Years	Remarks
Textile Industry	6450	4625	4375	1.05	Recycle in process house
Alcohol Industry	1725	2250	975	2.30	Reuse of energy in process house
Food Processing	1460	10500	4250	2.47	Recycle for irrigation/proces house and reuse of energy.
Viscose Rayon	4500	200	36	5.5	Recovery and Reuse of zine. Foreign exchange saving.

Source; Personal communication from Dr. P. Khanna, Director, NEERI, Nagpur. in "Science Reporter", April-May, 1989, p. 196, Table-3.

CHAPTER II

ON THE MANAGEMENT OF ENVIRONMENTAL POLLUTION

2.1 Environmental Pollution and Market Failure and Non-Market Options for Its Management

Environmental pollution is a process by which resources, natural or manmade, are made less useful due to physical, chemical or biological factors.[4] Environmental resources like air, water, land and forests may be regarded as public goods in the sense that benefits (damages) from preserved (destroyed) environment accrue to a large number of economic agents (producers and consumers in the economy). For example, the pollution of water has the effect of damaging municipal and industrial water supply, irrigation and commercial fishing, and a variety of water based recreational activities such as aesthetic enjoyment and sports fishing. The wide spread destruction of forest resources contributes to denudation of hill slopes, increased silt in the rivers and the consequent flood and reduced precipitations which affect the lives of many people. The air pollution affects the health of everybody.

Given that environment is a public good, there can be over-exploitation of environmental resources in the free market. Industries freely dispose their wastes into water, air and land. Forest resources can be over exploited for commercial benefit. The preservation of environmental resources or the control of pollution can be facilitated if pollutors or some other agents in the economy incur some costs. In other words, a given amount of nation's cake (national product) can be produced with clean

---

4. See Dasgupta & Murty (1988).

environment by incurring some additional cost on pollution control. The net result is lower national product with clean environment relative to that of with polluted environment[5]. The private profit maximizing producers of pollution intensive commodities like chemicals, fertilisers, paper and paper products, leather and leather products, thermal power, textiles, etc., have no incentive in the free market to incur any cost to control environmental pollution. Therefore, we have to look for non-market alternatives for the pollution control. The classical solution to pollution control is governmental intervention in the market process.[6] There are various governmental programmes for the management of environment. They are (a) Programmes akin to the market processes; (b) Direct government investment in the pollution control, and (c) Direct physical controls on pollutants. The first includes programmes like pollution taxes and subsidies, issuing property rights for the use of environmental resources, etc. The second refers to programmes like waste water treatment plants and afforestation while the third refers to upper limits on the levels of pollutants.

Let us discuss in detail the programmes akin to market processes to control pollution. The pollution taxes have to be determined taking into account both pollution abatement costs of pollutors and the damages suffered by the receivers. In order to understand this, let us assume that there is a tannery located on the river generating water borne pollutants that are released into the river. The cost function of the tannery may be written as C_1 (Y, E) where Y is the leather produced and E is the effluent

---

5. See Section 2.2 of this Chapter.

6. See Pigou (1932), Baumal (1972) and Murty & Nayak (1982).

generated. We have $\partial C_1/\partial Y > 0$ and $\partial C_1/\partial E < 0$. That means for any given quantity of leather produced, the less is the water pollution, the more is the cost of producing leather. A tannery can produce leather without water pollution by incurring additional cost on pollution abatement. The receivers of damages from pollution in this case are down stream water using industries, municipalities, fisheries development etc. If there are N receivers producing N commodities (X_i, i=1,2...N), their cost functions are given as $C_{2i}(X_i E)$, i = 1.2...N with $\partial C_{2i}/\partial X_i \geqslant 0$ and $\partial C_{2i}/\partial E \geqslant 0$. Thus water pollution is an external diseconomy received by a large number of users; the higher being damage/cost to the receiver, the greater the pollution. Given the levels of activities of polluting and receiving industries ($\overline{Y}$, $\overline{X_1}$, $\overline{X_2}$,......$\overline{X_n}$), an efficient management of environmental pollution requires minimisation of combined cost of all industries with respect to E. Thus we have

$$C = C_1\ (y_1,\ E) + \sum_{i=1}^{n} C_{2i}(X_i,\ E) \qquad (1)$$

for minimising C with respect to E, the first order conditions are given as

$$\frac{\partial C}{\partial E} = \frac{\partial C_1}{\partial E} + \sum_{i=1}^{N} \frac{\partial C_{2i}}{\partial E} = 0 \qquad (2)$$

or

$$\frac{\partial C_1}{\partial E} = -\sum_{i=1}^{N} \frac{\partial C_{2i}}{\partial E}$$

Condition (2) shows that optimal control of environmental pollution requires that the marginal pollution abatement cost to the generator should be equal to the sum of marginal damages suffered by the receivers. The following diagram explains this point further. For the sake of an illustration we assume that there is only one receiver of pollution and his cost function is $C_2(X,E)$. Assuming further the cost functions are convex,. the vertical distance between two curves representing C_1 and C_2 in the diagram is the combined cost of producing fixed $\bar{Y}$ and $\bar{X}$ for any given level of pollution E. The optimum level of pollution is the one that minimises this distance which is given by E* in the Diagram. At E*, the marginal abatement cost to the generator (given by the slope of C_1) is equal to the marginal damage to the receiver (given by the slope of C_2). Given the convex cost function, the generator has an incentive to reduce pollution to the level $\hat{E}$ (at which total production cost of $\bar{Y}$ is minimised) in the free market which is obviously far from optimum. Therefore market fails to bring down the pollution from $\hat{E}$ to E*, the optimum level.

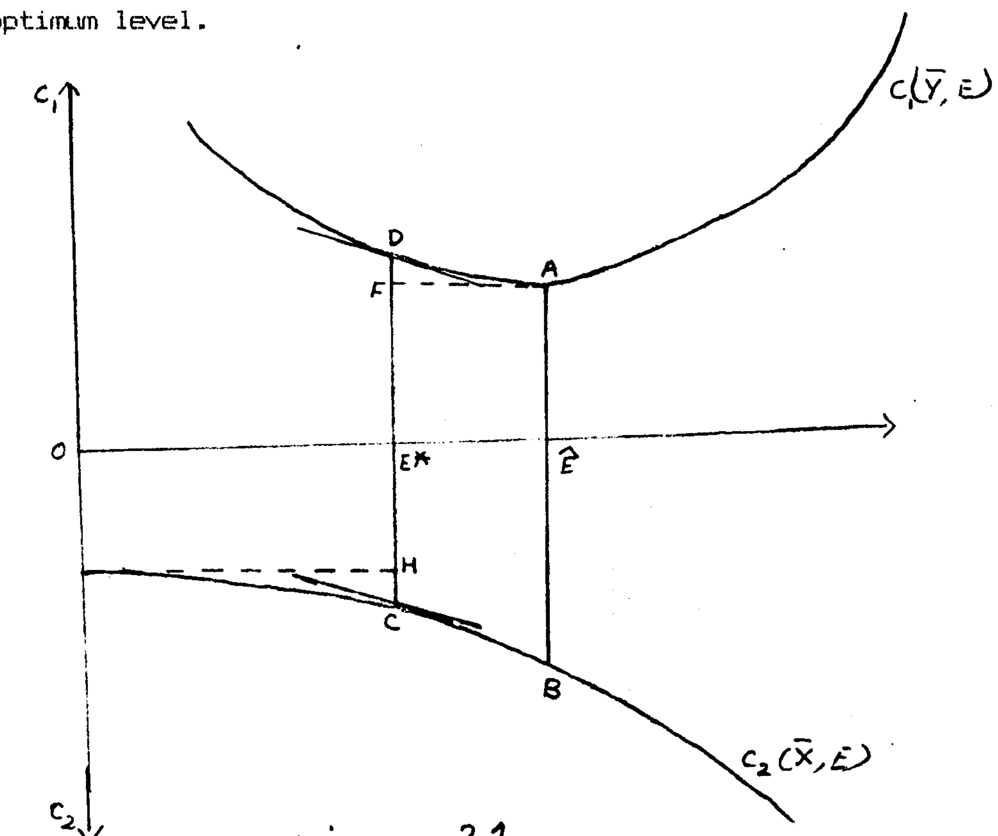


Diagram 2.1

A pollution tax on the generator that is equal to marginal abatement cost corresponding to the pollution level E* may compel him to incur an additional abatement cost worth DF in the Diagram to reduce pollution level from $\hat{E}$ to E*. Given the increasing marginal abatement cost in the range $\hat{E}$ to E*, the generator has an incentive to spend an amount equal to DF on pollution abatement rather than paying the tax. It is so because in this situation his tax liability will be higher than the abatement cost he has to incur to bring down pollution to E*. Thus a pollution tax which is determined as

$$t = -\frac{\partial C_1}{\partial E} = \frac{\partial C_2}{\partial E}$$

will do the trick of bringing optimal control of pollution. But corresponding to the optimum pollution level E*, there is a sharing of total cost of pollution control by the generator and the receiver. In Diagram 1 the total cost of pollution control is equivalent to (DF + HC), where DF is the share of generator and HC is the share of receiver. Therefore, the implicit assumption in the pollution tax programme is that the receiver automatically incurs cost equivalent to HC to avoid damages caused by pollution at the level E*.

Alternatively pollution may be controlled by defining property rights for the use of environmental resources for the waste disposal. An example is a case of imposing liability by law on the generator of pollution for the damages suffered by the receiver.[7] In this case, the total liability of the generator to control pollution to E* say in Diagram 1 consists of two parts; DF, the cost of bringing down pollution from $\hat{E}$ to E* and HC, the

7. See Marchand & Russel (1973) and Murty & Nayak (1982).

compensation made to the receiver for the damage due to generation of E* amount of pollution. However, the effluent levels achieved through property rights arrangements like this may not be same as the levels achieved through Pigouvian/pollution taxes.[8] However, given that environment is a public good and the pollutor is a free rider, one may think that it is natural to ask the pollutor to bear the entire cost of pollution control.

In many developing as well as developed countries, there is now a clear evidence of failure of governmental programmes for the management of environmental resources. The failure of government is strikingly evident in the management of environmental resources like forest resources[9] in many developing countries which can be attributed to several reasons.[10] Some of these are (a) public goods character of forest resources and consequent high policing costs; (b) Temptation of national governments to over exploit forest resources for their immediate development benefits and (c) Uncontrollable demand from the rural poor to exploit forest resources for necessities like fuel wood, grazing cattle, etc. In this type of situations, one may have to look for non-governmental and non-market alternatives for the management of environmental resources. Some studies have found

---

8. Pigouvian taxes or pollution taxes are the first best programmes for pollution control. The effluent levels achieved and the levels of production activities realised through these taxes are Pareto - optimal levels. The property rights arrangements for environmental pollution control may not necessarily be the First Best Solutions. See Murty & Nayak (1988).

9. See Chopra, Kadekodi & Murty (1988).

10. As mentioned earlier, over exploitation of forest resources may affect the precipitations and thereby water resources.

that in certain situations, it is possible for the village people to participate in the preservation of local forest resources. The preservation is possible with people's participation if it is complementary to the development of their income earning assets like cattle wealth, irrigation land, etc.

2.2 Benefits from Environmental Pollution Control

It may be convenient to distinguish between two types of benefits from the environmental management. One type of benefits may be identified as consumer surplus benefits of all users of pollution free environmental resources. The other category of benefits can be represented by the existence bequest and option demands for environmental resources. The 'existence value' of a natural resource is defined as users' willingness to pay for the knowledge that it is preserved, its 'bequest value' as the willingness to pay for the satisfaction of endowing future generations with preserved environment and its 'option value' as the willingness to pay for the opportunity to choose from among its competing alternative uses in future.[11]

Measurement of benefits from the preservation of environmental resources poses formidable problems. Given the public goods nature of these resources, there may be one or two pollutors but the receivers of damages from the polluted environment or beneficiaries of preserved environment can be in a very large number. Therefore, the first category of benefits have to be estimated by measuring damages avoided or consumer willingness to pay of a large number of users of preserved

---

11. See Dasgupta & Murty (1982) Weisbrod (1964) and Henry (1974).

environment. However, the cost of gathering the information to measure these benefits can be prohibitively high. Even if we attempt to get the information about users willingness to pay for the preserved environment through a direct interview method, the estimates of benefits arrived at may understate the actual benefits. The users, may actually understate their benefits keeping in mind the impending taxes to finance the preservation of environmental resources. They are free riders on the preserved environment and may get benefit without contributing their share of cost for preservation. Recently some attempts have been made to quantify the existence, option and bequest values of environmental resources[12] the details of which are beyond the cope of this study.

Environmental resources can provide multiple benefits. For example, water resources provide irrigation, power, fisheries, drinking water, navigation and recreation. However, there can be a trade-off between some of these benefits. The use of water for one purpose may permanently pre-empt the possibility of using it for other purposes. In other words, there can be irreversibilities in the use of environmental resources. For example, the building of a dam would mean that preservation of a river valley in its wild state for the present and future recreational facilities is excluded. In the case of water resources, there may be also cases where unabated pollution for a certain period of time may make the resources permanently useless. For example, because of commercial exploitation, pollutants can accumulate over time in a lake and if within a certain period, (the length of which depends on the nature and extent of pollution and the properties of lake itself), the attempts for pollution abatement are not made, the lake can be

---

12. See Greenly, Walsh and Young (1981).

permanently destroyed.

The problem of choice among alternative uses of environmental resources can be better explained by considering the choice between developmental and preservation uses of these resources. There may be an asymmetry between developmental and preservation benefits. The benefits from development are likely to be decreasing whereas preservation benefits are likely to be increasing over time.[13] Take for example, the hydro-electric power, one of the most important developmental benefits from water resources. The conventional measure of benefits of a hydro-electric power project at any point in time is simply the difference in costs between the next best alternative source and the hydro project. This assumes that power provided by the two sources is the same so that gross benefits are equal and the net benefits of the project is the saving in cost. However, over the relatively long life of a hydro project, the cost of the best alternative source of energy can be expected to decrease continuously with the technological progress in power generation. This implies that benefits from hydro project are correspondingly decreasing over time. On the other hand, the preservation benefits of water resources may be increasing over time. Empirical evidence suggests a rapid growth in the demand for wilderness recreation which is an important conservation benefit. Growing population, rising educational levels and increasing per capita income, with people having more income to enjoy recreation may contribute to increasing preservation benefits over time. Therefore, choice among alternative uses of environmental resources have to be affected after careful evaluation of all these benefits.

---

13. See Dasgupta & Murty (1988).

2.3 Standards-Taxes Approach for the Management of Environmental Resources

The first best solution that marginal pollution abatement cost incurred by the pollutor is equal to the marginal damages suffered by the receivers of pollution may not be possible to achieve in practice for the optimal management of environmental pollution. The classical solution of Pigouvian taxes to obtain this requires the information related to damages received by all the recipients of pollution. The estimates of damages received by various pollutees are required even in the case of other pollution control programmes of government involving direct government investment. They are required because the damages avoided due to direct government investment on pollution abatement are regarded as benefits from that investment.

The formidable problem of estimating the damages (benefits) from the environmental pollution (pollution abatement) may be avoided by using a political process to determine environmental standards. The selection of environmental standards can be viewed as a particular device utilised in a process of collective decision making to determine the appropriate level of activity involving external effects.[14] Thus in the case of water resources, on the basis of evidence concerning the effect of polluted water on recreational services and aquatic life, one may decide that the bio-oxygen demand (BOD) and chemical oxygen demand (COD) requirements of the foreign matter contained in a water way should not exceed certain levels. These acceptability standards of pollution are the set of constraints that the society places on its pollution generating activities. They represent decision

14. See Baumal & Oates (1975).

maker's subjective evaluation of the minimum standards that must be met in order to achieve what may be described as a reasonable quality of life.[15]

Given the environmental pollution standards, we have a choice among various governmental measures discussed in Section 2.1 to control pollution according to these standards. Indirect methods like taxes may be preferable to direct controls to achieve the standards. Government can levy a uniform set of taxes that would, in effect, constitute a set of prices for the private use of water. The taxes could be selected to achieve specific acceptability standards. For example one might tax all tenneries emitting waters into a river, at a certain rate, where the tax paid by a tannery depends on the BOD value of effluents according to a fixed schedule. Each polluting mill would then be given a financial incentive to reduce the BOD content of affluent it discharges. By setting the taxes sufficiently high, the government would be able to achieve the predetermined pollution standards.

---

15. See Dasgupta & Murty (1985).

CHAPTER III

THE PROBLEM OF WATER POLLUTION ABATEMENT AND THE SUPPLY PRICE OF WATER

3.1 Two Components of Price

The supply price of water for industrial uses consists of two components: (a) Cost to the producer and (b) Cost to the society. The cost to the producer consists of production and distribution cost of water. The production cost is cost incurred in drawing water either from surface or underground sources while carry water to the final user. The alternative sources of water for industrial uses are (a) rivers/lakes, (b) canals and (c) tubewells. Depending upon the source of water supply, the production cost of water can be different for different industrial units. In most of the towns and cities, the industrial units may have two options for water supply: (a) Supply by local/municipal administration and (b) Their own production arrangements. Most of the units surveyed by us for this study avail both the options.

The estimates of commercial costs of supplying water by local administrations and by own arrangements of industrial units show that costs are high for the supplies by local administrations in relation to costs associated with the own supply arrangements by the industrial units. Table 3.1 provides estimates of costs of supply of water for Kanpur Water Supply Undertaking and various industrial units at 1987-88 prices. The high cost of municipal water supply may be attributed to high distribution costs.

The water bodies are important environmental resources that receive industrial pollution. Given that water resources are public goods, the classical free rider problem operates and various industrial units freely dispose their wastes into the rivers and lakes. Since the users of these resources are many, the damages suffered by them can be enormous. The commercial/private supplier of water may not take into account the cost inflicted on society by the use of water by industrial units while fixing the price of water. Nor the users of water (industrial units) bother about social costs (damages suffered by many) due to water pollution contributed by them.

As explained in Chapter II, the damages of water pollution can be avoided either by polluting industries incurring some pollution abatement cost or the users spending money to avoid the damage. Given the large number of users of water resources, it is prudent to make polluting industries incur abatement costs. The structure of supply of water to various surveyed industrial units suggests certain practical methods of controlling water pollution. In the cases where local administrations supply water to industrial units, the price of water should consist of production cost plus pollution tax. Local authorities in this case have the responsibility of treating polluted water from various units the cost of which is met from the pollution taxes. Alternatively polluting units can have the option of either paying the pollution tax or have their effluent treatment plants. Units having their own arrangements for water supply should be charged pollution taxes if they do not posses their own effluent treatment plants. Table 3.2 provides information about implicit price of water charged by Kanpur Water Supply Authority during past five years.

3.2 Environmental Standards, Pollution Control Technologies and a Method of Setting Price of Water for Industrial Uses

In a given situation there can be a choice among alternative technologies for the environmental pollution control. We can classify these technologies as abatement technologies that are available to pollutor and the avoidance technologies that can be used by the receiver. In other words, the problem of environmental pollution can be tackled by incurring some cost either by the pollutor or by the receiver and by a cost sharing arrangement between them. The pollutors may have a spectrum of technologies consisting of (a) end of pipe treatment methods, (b) process changes in production and (c) quality changes in output. Similarly the receivers may have various options like change in the location of factory, etc. For example a thermal power plant will cause air pollution, the damages from which can be reduced either by using primitive technology like increasing the height of the chimney or by using the most modern technology like electro-static precipitators. The near by laundries which are some of the receivers of air pollution can avoid damages by either changing their location or having indoor dryers.

The optimal arrangement for controlling pollution is to minimise the cost to the economy for achieving given environmental standards. This arrangement suggests that pollutors and pollutees have to adopt a mix of abatement and avoidance technologies that minimise their combined cost of pollution control. Various governmental programmes described in Chapter II have to be considered to achieve this. Suppose government wants to use Pigouvian taxes to control pollution/achieve environmental standards. It then needs information about cost of achieving the standards under alternative mix of technologies available to pollutors and pollutees. Considering each mix of technologies as a package available to pollutors and pollutees, the resource cost of each package has to be estimated to facilitate a choice among technologies to control pollution. A method of estimation of this resource cost is given as follows:

Let

I_i: Investment cost of ith package at market prices after deducting indirect tax payment i= 1,2...S

O_{it}: Operation cost in the year t during the life of ith investment after deduction of indirect tax payments.

r: Social time preference rate

T: Life of Investment

R_t: The volume of polluted water/residual water released by the factory in the year t.

Assuming that all the investment cost is incurred in the initial year, the present value of resource cost of ith package can be computed as

$$PC_i = I_o + \sum_{t=1}^{T} \frac{O_{it}}{(1+r)^t} \qquad (1)$$

Given the time stream of effluents treated (R_1, R_2...R_T) during the life of investment, the choice among alternative packages to control pollution can be made as

$$\min_i \; (PC_i), \; i = 1, 2......S \qquad (2)$$

The per unit cost or cost per kilolitre of polluted water for the least cost package is given as

$$C^* = \min_i \; (PC_i)/R, \qquad (3)$$

where $R = \sum_{t=1}^{T} R_t$

Having made the estimates of resource cost of pollution control at market prices, the next step is to make the estimates of social cost[16] or cost at shadow prices as follows:

Let

I_i^d : Domestic material component of investment of ith package i = 1, 2...S

I_i^f : Foreign exchange component of investment at cif prices in domestic rupees

I_i^l : Unskilled labour component of investment

$$I_i = I_i^d + I_i^f + I_i^l$$

O_i^d : Domestic material (other than energy) component of operation cost of ith package

O_i^f : Imported input component of operation cost at cif prices in domestic rupees

O_i^e : Energy component of operation cost

O_i : $O^d + O^f + O^e$

P_e : Shadow price of energy

P_f: : Shadow price of foreign exchange

P_I : Shadow price of investment

P_l : Ratio of shadow wage rate to the factory wage rate

The present value of social cost of ith package is computed as

$$PSC_i = [P_I\ I_i^d + P_f\ I_i^f + P_l\ I_i^l]$$

---

16. See Dasgupta, Sen & Marglin (1972).

$$+ \sum_{i=1}^{T} \frac{\left[O_{it}^{d} + P_e O_{it}^{e} + P_f O_{it}^{f} + P_l O_{it}^{l} \right]}{(1 + r)^t}$$

Then the social cost per unit of effluent is given by

$$\hat{C} = \min_i \; (PSC_i)/R$$

The above described method gives us the resource cost of environmental pollution control per unit of polluted water released by a factory. Alternatively, for the sake of fixing the price of water for industrial uses, we can obtain the pollution control cost per unit of water used by the factory given the information about the quantity of water used by the factory during the life of investment on pollution control. As explained in Section 1 of this chapter, another important component of cost of supply of water to industries is its production cost. Given that there can be alternative sources of water supply to the industry, this cost is source specific. Let the investment and operation cost of jth source of water supply be G_j and F_j, $j = 1, 2....H$. Given the life of investment as T years, we have the present worth of production cost of a given time-strea of water supply (W_1, $W_2....W_T$) as

$$PV_j = G_j + \sum_{t=1}^{T} \frac{F_{jt}}{(1+r)^t}$$

Then the per unit cost of water supply from the least cost source is given as

$$K^* = \min_j \; (PV_j)/W, \; j = 1, 2, ...H \qquad (7)$$

where $$W = \sum_{t=1}^{T} W_t$$

Following the same procedure described above for the estimation of social cost of pollution control, we can estimate the social production cost of a unit of water as

$$\hat{k} = \min_{j} \; (FSV_j)/W, \; J = 1, 2, \ldots H \qquad (8)$$

where FSV_j is the present worth of social production cost of water from the jth source. From (3), (5), (7) and (8), the average cost of water supply is given as

$$p^* = C^* + k^* \text{ at market prices} \qquad (9)$$

$$\hat{p} = \hat{c} + \hat{k} \text{ at shadow prices} \qquad (10)$$

In the above analysis, we are considering the volume of effluents in terms of polluted water released by the factory. However, the toxicity of pollutants depends upon the nature of pollutants in the water. The type of pollutants carried by residual water and their toxicity vary among the industries producing different commodities. Therefore, given the pollution standards, the cost of pollution control per kilolitre of residual water can be different for different industries. Also in Section 2.1 of Chapter II, we have explained that pollution taxes at optimum are equal to marginal abatement cost to pollutors and marginal damages/pollution avoidance cost to pollutees. Since the polluting industries differ with respect to the type of pollutants and their toxicity, the cost functions of pollution abatement for pollutors and the damage functions for the receivers can be different for different industries. Thus the marginal pollution abatement cost and marginal damages per kilolitre of residual water at optimum can vary across industries suggesting deferential pollution taxes among different industries. This is also true with standards-taxes approach described in Section 2.3 of Chapter II. We shall have differential pollution taxes for industries if the

Pollution Control Board wants to impose taxes on the basis of a kilolitre of water used/released or a unit of commodity produced. However, if all the water borne pollutants can be expressed in homogeneous units recognising their relative toxicity, a uniform pollution tax per unit of pollution will be the optimal tax. Alternatively if we can identify a vector of water borne pollutants specific to the industry, a uniform tax on each pollutant across the industries may be optimal. For example, the optimal rate of pollution tax on BOD can be the same for all the industries. These are the practical problems for the implementation of pollution taxes and the choice among the methods of taxation has to be made depending upon the availability of information.

The first component of price of water defined in (10) is production cost while second component consists of two parts: the pollutors' cost of abatement (k_1) and polutees' cost of avoidance of damages (k_2). Assuming constant returns to scale (constant average cost) in the pollution control, the optimal pollution tax is given by $t = k_1 = k_2$. However, it is important to recognise that both in the case of Pigouvian taxes and taxes and standards method, it is assumed that the receivers use cost minimising damage avoidance technologies in the free market once pollution taxes on pollutors are used to control pollution/achieve standards. Thus they ensure the sharing of cost of pollution control by the pollutors and pollutees. But one may argue that in the absence of enforcement of any pollution control programmes, the pollutor as a free rider benefits at the cost of rest of the economy (pollutees) and therefore in an ideal pollution control programme he has to bear the entire cost of pollution control. Therefore a just pollution control programme to achieve standards may consist of a tax on the pollutor and subsidies to the receivers. In such a programme the taxes on pollutors and subsidies to receivers should be set such that the total cost of pollution control is met by the pollutor and pollutors and polutees are using cost minimising pollution control measures. In this case, subsidies to receivers have to be financed from taxes on the pollutors. Thus the polluting factory has the liability for the damages received by the pollutees as explained in Section 2.1 of Chapter II.

3.3 Shadow Prices

The estimation of social cost of water for industrial uses requires the values of shadow prices of inputs like investment (capital), unskilled labour, foreign exchange and energy as described in Section 3.2. The shadow price or social opportunity cost of an input is the incremental welfare in the economy by using one more unit of this input at margin. The shadow prices are also known as accounting prices in the social cost-benefit analysis.

In a capital scarce developing economy there may be a social premium on investment over and above its market price. In other words in such an economy, the shadow price of investment is higher than its market price. The UNIDO approach to project evaluation (Dasgupta, Sen and Marglin, 1972) defines the shadow price of investment (P_I) as

$$P_I = \frac{(1-Q)R}{r-QR}$$

where r: Social time preference rate

R: Rate of return on investment

Q: Marginal rate of savings in the economy

For example given $r = 0.10$, $R = 0.18$ and $Q = 0.20$ we have an estimate of P_I as 2.25. That means the social opportunity cost of a rupee of investment in the economy is Rs 2.25.

In a developing economy the actual level of investment may be far less than what is supposed to be optimal level of investment. The social time preference rate is the rate of return on investment that corresponds to optimum level of investment/savings in the economy. Therefore, assuming diminishing returns to investment, the rate of return corresponding to actual level of investment can be higher than that is associated with the optimal level (social time preference rate). Planning Commission (forthcoming) provides estimates of rate of return and social time preference rate as 18 and 11 per cent for the Indian economy. The national accounts statistics of Central Statistical Organisation (C.S.O.) provides estimates of average rate of savings in the Indian economy which form a range of 20 - 25 per cent for the recent years.

The shadow price of foreign exchange may be higher than its market price (official rate of exchange) in an under developed country with the scarcity of foreign exchange. The foreign trade policies of government for controlling the deficit in balance of payments in the situations of limited supplies of foreign exchange will introduce the distortions in the foreign trade sector so that there is a social premium on foreign exchange over and above its market price. The investment project appraisal methods (for example UNIDO method) provides detailed procedures for estimating the shadow price of foreign exchange. The recent estimates of shadow exchange rate for the Indian economy based on UNIDO method form a range of 1.30 - 1.50 (Planning Commission, Forthcoming) implying that there is a 30 to 50 per cent social premium on foreign exchange over its market price or official rate. However, the Indian Planning Commission currently imputes a 25 per cent social premium on foreign exchange for estimating the social benefits of investment projects.

In a labour surplus economy, the social opportunity cost of employing unskilled labour on industrial projects may be less than its projecct wage. There are direct and indirect costs to the economy from labour employment on industrial projects (UNIDO). The direct opportunity cost is agricultural income foregone by shifting labourers from agriculture to industry while the indirect opportunity cost is loss of savings in the economy due to redistribution of income from rich to poor as a result of labour employment. The loss in savings/investment carries with it social cost because there is a social premium on investment in a capital scarce developing economy. The direct opportunity cost of unskilled labour may be region specific in a big country given the cost of migration of labour from region to region. In this study, we have, therefore, used project specific estimates for the shadow price of unskilled labour.

Apart from capital and foreign exchange, there may be other inputs like fuel or energy which have shadow prices higher than their market prices in the developing countries. For tradeable fuel inputs like coal and fuel oils, the social cost of foreign exchange used to import them can be estimated using the shadow exchange rate. However, for a non-tradeable input like electricity, the shadow price is its domestic resource cost which has to be estimated using information about the production structure of the economy (for example input-output table).

3.4 Differential Taxation of Pollutants : An Alternative Method of Pollution Control

The water borne pollutants of an industry constitute a vector and as explained earlier they differ with respect to their toxicity. The uniform pollution tax across the industries requires the pollutants to be expressed in common units. However, it is difficult to define a common unit to measure water pollution given widely varying physical and chemical characteristics of pollutants. Therefore, differential taxation (different rates of taxes on different pollutants) may be necessary to optimally control water pollution. In order to explain this problem in detail let us define the following:

$E = (E_1, E_2 \ldots E_N)$: a vector of pollutants generated by a factory.

C_1 (Y,E): Cost function of a generating factory.

$C_{2j}(X_j,E)$: Cost function of jth receiving factory, $j=1, 2 \ldots H$

Given the levels of production of generating and receiving industries as $\bar{Y}$, $\bar{X}_1$, $\bar{X}_2 \ldots$ $\bar{X}_H$, the optimal control of pollution requires minimisation of

$$C_1(\bar{Y}, E) + \sum_{j=1}^{H} C_{2j}(\bar{X}_j, E) \text{ with respect to } E_i,\ i = 1, 2 \ldots H$$

This requires

$$\frac{\partial C_1}{\partial E_i} = \sum_{j=1}^{H} \frac{\partial C_{2j}}{\partial E_i} \qquad i = 1, 2 \ldots\ldots N \qquad (11)$$

which can be achieved by fixing taxes on each pollutant such that

$$t_i = \frac{\partial C_i}{\partial E_i} = \sum_{j=1}^{H} \frac{\partial C_{2j}}{\partial E_i} \quad , \quad i = 1, 2.....N \qquad (12)$$

To achieve given pollution standards, the tax on each pollutant can be uniform across the industries.

In order to understand the limitations and practicability of this method, let us consider the Sewage Disposal Department of a local administration/municipality. This department may be treated as a public utility supplying the services of sewage treatment to various industrial units. It has an effluent treatment plant based on end of pipe treatment method for pollution control. Being a public utility, it has no profit motive and just wants to recover the cost of treatment of effluents from the factories. The effluent (usually residual water in the case of water pollution) consists of a number of pollutants with different physical and chemical characteristics and the municipality has to design differential taxes to recover the pollution abatement cost following the rule given in (12). If there are decreasing returns to scale and there are no joint costs in the pollution control, the optimal tax rules to realize the given pollution standards guarantee the recovery of full cost of treatment. However, the pollution control by the municipality may be typically characterised by increasing returns to scale with joint production which is normally the case with many public utility services like posts and telegraphs, railways, roadways, etc.[17] Sewage disposal

17. See Jha, Murty and Satya Paul (1988).

by the municipality is a case of joint production because it has to treat a vector of water borne pollutants. There are also evidences of increasing returns to scale in water pollution control.[18] In such situations, the tax rules defined in (12) cannot guarantee recovery of full cost of pollution treatment by the municipality.

The problem of fixing pollution taxes is then similar to the problem of setting prices of commodities/services jointly supplied by a public utility. The municipal sewage department may be jointly supplying services of treating different effluents and its effluent treatment cost may consist of a joint (unallocable) cost and attributable cost. One of the central problems of public utility economics is to design pricing rules taking into account the problem of allocating joint costs among different services.[19] The cost effective prices for jointly supplied services are normally determined by using certain arbitrary methods for allocating joint costs among different services. One of such arbitrary methods is based on relative quantity/volume for allocating joint costs among different services. The prices determined relying on such arbitrary methods may contribute to higher prices for some services and lower prices for others in relation to their true costs of supply. Thus in the case of sewage treatment, pollution taxes based on these methods may encourage the release of certain pollutants while discouraging others. In other words there may be a cross subsidisation in the supply of these services. Therefore if pollution taxes have to be designed such that they are cross subsidy free, tax on each pollutant

---

18. See Dasgupta and Murty (1985).

19. See Jha, Murty and Satya Paul (1988).

should be cost effective or equal to true cost of its treatment.

It is shown in the public utility literature that for a public utility having certain type of cost functions, if prices for its various services are determined relying on cost estimates made by allocating joint costs on the basis of relative attributable costs of different services, the prices so set are cross-subsidy free[20]. Suppose

J: Joint cost of municipal sewage department

A: Total attributable cost of sewage department

C=J+A: Total cost of sewage department

A_i: Attributable cost of treating ith pollutant, i=1, 2...N

C_i:Total cost of treating ith pollutant.

Then following the attributable cost method for allocating joint costs among different services, we have

$$C_i = A_i + a_i J, \text{ where } a_i = \frac{A_i}{A}, \quad i = 1, 2 \ldots N$$

$$c_i = \frac{C_i}{E_i}, \text{ per unit cost of treatment of ith pollutant}$$

Now if pollution taxes are designed such that

$$t_i = c_i, \; i = 1, 2 \ldots N \qquad (13)$$

then t_i may be cross subsidy free and guarantee the recovery of full cost of pollution abatement.

20. See Jha, Murty and Satya Paul (1988).

TABLE 3.1

Estimates of Costs* of Supply of Water for Kanpur Jal Sansthan and Various Industrial Units

(At 1987-88 prices)

Name of Unit	Commercial costs	r = 10 and t = 15		r = 10 and t = 20		r = 10 and t = 25		r = 10 and t = 30	
		Resource cost	Shadow costs	Resource cost	Shadow costs	Resource cost	Shadow costs	Resource cost	Shadow costs
1. Karam Chand Thapar and Bros., Unnao	0.36	0.170	0.213	0.140	0.174	0.118	0.146	0.101	0.125
2. TAFCO Kanpur	0.63	0.310	0.480	0.250	0.390	0.210	0.320	0.180	0.270
3. Hindustan Vegetable Oil Corporation Ltd. Kanpur	0.50	0,240	0.430	0.197	0.340	0.167	0.280	0.143	0.240
4. Motilal Padampat Udyog Ltd. Kanpur	0.66	0.320	0.560	0.260	0.440	0.220	0.370	0.190	0.310
5. MUIR Mills Kanpur	0.40	0.204	0.250	0.167	0.200	0.141	0.170	0.121	0.140
6. J.K. Cotton Mills, Kanpur	0.55	0.270	0.430	0.220	0.340	0.190	0.290	0.163	0.250
7. Lakshmi Ratan Cotton Mill, Kanpur	0.65	0.316	0.490	0.262	0.400	0.223	0.330	0.191	0.280
8. New Cictoria Mills, Kanpur	0.48	0.226	0.280	0.184	0.220	0.155	0.180	0.132	0.160
9. Elgin Mills (Unit-1), Kanpur	0.93	0.460	0.610	0.380	0.500	0.326	0.430	0.280	0.370
10. Kanpur Jal Sansthan (Kanpur)	0.46	0.210	0.290	0.170	0.230	0.140	0.200	0.120	0.170

* Costs are given in Rs. per kilolitre of water.

TABLE 3.2

AVERAGE PRICE OF WATER CHARGED

BY KANPUR JAL SANSTHAN

Year	Price per Kl. of water	Price* per Kl. of water
1985-87	0.24	0.29
1986-87	0.29	0.34
1987-88	0.29	0.27

Note: *Inclusive of Sewer tax

CHAPTER IV

CURRENT PRACTICES OF WATER POLLUTION CONTROL IN INDIA

4.1 Introduction

Water pollution is an inevitable by-product of industrialisation. Pollution causes ecological upsets resulting in various hazards to the society. Possible environmental effects of industrial development have since long been recognised as a serious problem. However since the seventies, the environmental movement has gained momentum and consequently there has been a concern for evolving more rigorous approaches for environmental impact assessment in seventies. In the early stages this movement was confined to the more developed countries but recently developing countries including India have recognised the sensitiveness of the problem. This is especially the case in respect of industrial water pollution which is posing a major problem. The pollution control measures in India consisted of evolution of environmental standards and designing various governmental instruments to control pollution. Legislations were made empowering governmental agencies for stricter enforcement of pollution control measures. Following this, various industrial units which failed to conform to the environmental standards have been served with notices for the closure while some of the units which continued to pollute the environment despite several notices have actually been closed. These measures clearly demonstrate the keenness of the Government to control pollution and aoid upsetting ecological balance, even though this may mean slowing down the pace of development of the priority sector - namely the industry.

4.2 Existing Institutional Arrangements for Environmental Pollution Control in India

a. Administrative machinery. The Central Board for the Prevention and Control of Water Polution (hereafter CBPCWP) is the national apex body for the assessment, monitoring and control of water pollution in India. The executive responsibilities for enforcement of the Prevention and Control of Water Pollution Act (1974) and Water Cess Act (1977) are carried out through the Central Board and similar statutory boards established in the states. The Central Board also co-ordinates the activities of the state boards established for the implementation of pollution control measures. The Board has evolved comprehensive guidelines in respect of the setting up of pollution intensive industries. It has also formulated the minimum national standards for environmental pollution (MINAS) in respect of 10 specific industries.

b. Policy instruments. In India, as far as we are aware, the following policy instruments have been used to deal with water pollution.

i. To promote pollution control, subsidies have been provided in the form of tax rebates, soft loans, etc.

ii. Water cess is charged on consumption of water by use as a disincentive to polluting industries. The pollution cess currently levied by pollution control boards in India vary from 0.75 paise to 2.5 paise per Kl. of water used.

iii. Government has evolved pollution standards for effluents emanating from production processes limiting discharge levels of certain substances into water bodies, agricultural land, sewage, etc. Discharge levels vary depending on the mode of disposal.

iv. In the case of certain new industries, license issuing authorities take not of the choice of technology and in-plant measures taken to reduce waste loads of residual water.

c. Legal measures. The effectiveness of above mentioned instruments depends upon the legal support they are able to get. The Prevention and Control of Pollution Act, 1974 is found to be inadequate to provided legal support to various instruments to control pollution. The Environmental Protection Act, May, 1986 fills this gap. It is a more comprehensive law providing for stringent penalties in the case of non-adoption of pollution control measures. It covers all types of pollution including air and noise pollution. The broad objective of this legislation is to take comprehensive measures for the prevention and control of pollution and assign responsibilities to the Central Government, State governments, Local authorities, individuals and public and private organisations. The government or an authority designated is expected to lay down standards, regulations and rules for enforcement of the provisions of the Act. The rule making powers broadly cover screening, testing, classification, standardization, powers of entry, inspection, examination, control, direction, closure or prosecution. The punishment provided under the Act is imprisonment upto five years or fine worth of rupees one lakh or both. In case of continued pollution, the quantum of both imprisonment and fine may be further increased. A private citizen can also make a complaint to a court under the Law for any violation of the Act.

4.3 Evolution of Environmental Standards in India

Standards for discharge of industrial effluents in India have been developed by both Indian Standard Institution (ISI) and Water Pollution Control Boards. While tolerance limits/standards stipulated by ISI serve as guidelines, the limits prescribed by the Boards are mandatory.

The ISI standards were first brought out in 1963.[21] It was laid down that the treatment of effluents has to be done when the quality of receiving waters was beyond prescribed tolerance limits. The standards were first revised in 1974, which unlike the earlier version of standards, laid down tolerance limits for

---

21. Indian Standard, Part I, General Limits, Third Reprint, February, 1988.

disposal of industrial effluents into public sewers (IS: 3306 - 1974), on land for irrigation purposes (IS: 3307 - 1977), and into marine coastal areas (IS: 7968 - 1976) also.

Tolerance limits given in the above mentioned standards are based mainly on the following considerations:

a. The information available from overseas agencies;
b. Techno-economic feasibility of the treatment techniques;
c. Protection of the environment;
d. Likely damage to the receiving media; and
e. Usage of the receiving waters.

Later the above standards were integrated into one standard IS: 2490 (Part I)[22] and IS: 3306, IS: 3307, IS: 7968 were withdrawn. IS: 2490 (Part I) is a general standard applicable to all industries except the specific industries, covered by subsequent parts of this standard[23] which either call

---

22. See Table 1.

23. For the following industries standards have been formulated for discharge of effluents into inland surface waters only.

IS:2490 - Tolerance limits for industrial effluents discharged into inland surface waters (first revision)

Part II - 1974 Distillery industry
Part III- 1974 Tanning industry
Part IV - 1974 Straw board industry
Part V - 1974 Electroplating industry
Part VI -1976 Dyestuff & dye intermediate manufacturing industry
Part VII- 1976 Coke ovens
Part VIII-1976 Phosphatic fertilizer industry
Part IX - 1977 Nitrogenous fertilizer industry.

for some change in requirements for some characteristics or which contain some uncommon pollutants which have to be kept within limits.

While preparing this standard (IS: 2490, Part I), the committee recognised that tolerance limits for industrial effluents may vary for each unit depending on:

a. the capacity of the plant;
b. the technology adopted;
c. other industries polluting the receiving system;
d. recipient capacity of the receiving system;
e. the nature of the receiving system; and
f. usage of the receiving system.

Thus, on account of one or more of the above considerations, the authorities responsible for water pollution control management have been allowed to prescribe changes in tolerance limits/standards. However, deviations from tolerance limits prescribed in ISI general standards should be adequately justified.

The MINAS are prescribed for an industry taking into consideration the treatability of the effluent from the industry, i.e., technical feasibility, the cost of treatment and the cost burden that can be borne by the industry, (technical and economic feasibilities). The MINAS are binding for all industrial units throughout the country. Wherever the local regulatory authority deem it necessary because of specific environmental factors, they may make the discharge standards more stringent. They may not, however, relax them. In this manner, the MINAS becomes both industry specific and location - specific. The industry specific standard is given by MINAS while the location - specific standard on a case-to-case basis is prescribed by the local regulatory authority.

4.4 Current Methods of Fixing Price of Water for Industrial Use in India

The right price of water for industrial uses may be such that it guarantees the recovery of its cost and it discourages its misuse. However, water pricing currently practiced in India depends on socio-economic and political factors rather than on cost of production and distribution of water and willingness of the people to pay for the service. Under the Indian Constitution, water supply is a subject assigned to the State governments. Traditionally, the State governments have assigned these functions to the urban local bodies as obligatory responsibilities. The powers to fix water tariffs under certain circumstances have also been conferred on such bodies (e.g., U. P. Jal Nigam and Jal Sansthans) which usually have the responsibility for construction and operation of the water systems as well as collection of revenues.

Water tariffs usually classify the consumers as domestic, commercial and industrial and provide differential rates. The most commonly used methods of charging prices for water are: charges based on property values, flat rate charges, charges related to property characteristics, unit rate charges (metering) and combinations of the above methods.

Pricing of water for industrial use in India seems to be based on some ad-hoc criteria. In most of the municipalities, and boards, water tariff is not revised for years. Wherever it is revised it is done without following any guidelines. In fact, due to inadequate system for compilation of information on production and distribution, costs in the case of most of the local bodies it is not possible to make financial or economic analysis of the tariff structure which would form an important guideline for water tariff fixation/revision.

4.5 Limitations of Current Practices

While the government has various basic instruments and legislations empowering its agencies to control water pollution, certain measures/tools may be of questionable about the suitability in regard to their economic and social realities. This section discusses some of the limitations of the measures of prevention and control of industrial water pollution currently in practice in India.

It is well recognised that efficient enforcement of any law/act is a tremendous contribution towards the achievement of desired objective for which the law/act is brought into being. However, the availability of various policy options which constitute the law/act determines the adequacy and efficacy of the law/act itself in dealing with the problems. The problem of prevention and control of industrial water pollution is such where water pollution standards, water cess and price of water for industrial uses play a crucial role in determining the strength of pollution control Act. Suitability of these factors in present circumstances is argued below.

a. As mentioned earlier water pollution standards have been developed by both ISI or Bureau of Indian Standards (BSI) and Central Board for Prevention and Control of Water Pollution.

While revising general standard (IS: 2490, Part I) the committee recognised that tolerance limits for industrial effluents may vary for each unit depending upon a number of factors (refer footnote of Section III). Desirability of the two factors, namely, the capacity of the plant and the technology adopted may be argued. Environmental problems associated with small units might differ in some respects from those associated with larger units. To be more specific there are significant economies of scale in pollution abatement due to which smaller units are bound to incur much higher per unit fixed and operation cost than that of bigger units. However, the issue which emerges from this is that smaller units should be helped in their efforts of pollution control. Relaxing standards may not surely be the best way of doing it as this would ultimately amount to falling short of achieving the objective of pollution control. There could be other more practical ways of helping out smaller units such as giving subsidy, providing facilities of a common treatment plant, etc.

Relaxing standards across units on account of varied technology adopted by them may not be desirable. With inferior/old technology the pollution load is expected to be higher than that of with better/new technology. In order to reduce the pollution load it may be necessary to replace old technology with new technology which may not be both possible and economically viable to do in case of certain units. Thus a pollution subsidy may be given to such limits.

b. Water cess or pollution tax is normally levied and collected by the pollution control boards. Differential rates of tax are charged depending on the use of water. The tax rate structure[24] indicates that the rate of tax is higher for certain uses where pollution load is expected to be more resulting in higher cost of pollution abatement. Thus the objective of charging pollution tax seems to require industrial units to compensate for the damages they cause to the society by polluting water bodies etc. But the tax rates which vary from 0.75 paise to 2.5 paise per kl. of water are so low that they do not appear to bear any relationship with the cost of pollution abatement. This is the reason why prevailing pollution taxes have been ineffective in inducing companies to adopt polution control measures.

c. Water is an important input in industrial production. The conservation of water by the industrial units depends on the supply price of water the higher the price of water higher will be the incentive to practice water conservation. The conservation of water comprises of; i) economy in water use and ii) recycling and reuse of water after treatment. As far as economy in water use is concerned as such, there is no fixed demand for water for each industry but the demand varies in a given range due to the substitution possibilities of differrent technologies. We, however, feel that even with alternative technologies it should not be difficult to fix standards for 'consumptive water' (the water consumed during the proces) and 'intake water' – which is the amount of water that is needed for the production process to operate. These standards may be used as guidelines to assess inefficient use of water in industrial units. The above standards

---

24.

Use	Tax Rate Per Kl.
1. Industrial Cooling Boiler Feed Process Water	0.75 paise
2. Domestic	1.00 paise
3. Where effluent is biodegradable	2.70 paise
4. Where effluent is toxic and non-biodegradable.	2.50 paise

may also be used to introduce a graded charge/price depending on the levels of 'intake water'. For example, a lower price may be charged for an initial quantity of water sufficient to provide for basic needs while water withdrawn over and above this may be charged a higher price. This is expected to encourage economy in the use of water. However, graded price or charge for water can be applied only to the corporation water and river water. The units drawing water from own tubewells would be left out unless a tax is levied on water drawn through tubewell also.

The water conservation through recycling of water would enable industrial units to save on the cost of water which they either buy from local authorities or draw from their own tubewells. However, treatment of water to make it fit for reuse involves certain cost which would normally be higher than the cost of treatment of water to the level such that it meets the standards prescribed by the pollution control boards. The treatment of water to a level such that it can be recycled in the process would save industrial units the price of water and also water cess or pollution tax. Thus, a unit's decision on water conservation through recycling of water would depend on the net savings. That is the difference between savings due to fall in the cost of water and non-payment of pollution tax and the cost of treatment of polluted water for reuse. The industrial units will have incentive in recycling of water if the above difference is positive. Given the current price of water charged by local bodies in many cities and the prevailing rates of pollution taxes, recycling of water does not appear economically viable.

CHAPTER V

DISTILLERY

5.1 Introduction

Karam Chand Thapar and Brothers (C.S.) Ltd., is a company belonging to the Thapar Group of Companies and has a potable alcohol distillery located at Unnao in Uttar Pradesh. It is producing potable alcohol from its very inception which is supplied as country liquor to Government warehouses. In addition to potable alcohol other products such as Whisky, Rum, Gin Brandy, etc., are also produced. These products which are known as Indian Made Foreign Liquors (IMFL) are sold to public as well as to armed forces.

The prime distillation raw material used at the distillery is sugarcane molasses. Small quantities of grain and malt are also used for the purpose of malt spirit and grain spirit production. These are mainly used in the production of IMFL.

The installed distillation capacity of the plant is 15000 litres of alcohol per day based on three shift operation for 300 days in a year. The average daily distillation is around 13000 litres per day.

5.2 Processes in Distillery

Molasses based distilleries are more common in India. The main process steps in this operation are shown in Figure 5.1 and listed below:-

(i)	Dilution	– Preparation of molasses for fermentation
(ii)	Fermentation	– Production of alcohol from fermentable sugars in molasses solution
(iii)	Distillation	– Product recovery.

In Karam Chand Thapar Ltd. the molasses received from the Sugar Mills are stored in tanks for dilution. In the diluter tanks solid concentration (which varies between 76 per cent and 90 per cent in molasses available from Indian Sugar Mills) is brought down to the required concentration. After dilution it is pumped into the fermentation vats where yeast is added to it and it is left to ferment. In this process fermentable sugars are converted into alcohol. The fermented solution which is called wash contains 6 per cent to 8 per cent alcohol. The alcohol is separated from wash in distillation columns by the introduction of low pressure steam at the bottom of the column. The alcohol which vaporises in this process is then collected in a rectification column. The residue, produced after the alcohol has been stripped off, is known as spent wash. Spent wash is one of the strongest organic effluents in the industry. Based on further requirements, the rectified spirit produced is distilled again in a batch kettle or in a continuous still to produce neutral spirit which is used for the production of high quality IMFL. This process is called as secondary distillation. There is no generation of effluent during the secondary distillation stage. Figure 5.2 presents the process flow diagram.

5.3 Consumption of Water by Use and Source of Water Supply

The distillery industry is fairly water intensive. The water consumption is for process water as well as non-process water, e.g., for cooling, washing, steam generation, etc. In molasses based distilleries the major process water use is in the following processes.[25]

(i)	Dilution of molasses	–	about 13 m^3/Kl. rectified spirit
(ii)	Yeast propagation	–	1.3 m^3/Kl. rectified spirit
(iii)	Distillation	–	4.5 m^3/Kl. rectified spirit.

The non-process water use comprises of cooling water for fermenters (110 m^3/Kl.) and condensers (50 m^3/Kl.). Table 5.1 gives the range and average water used in the process and non-process applications. On the average the total water requirement is 85 m^3/Kl. of rectified spirit plus about 50 m^3/day of soft treated water. For a distillery of 5,000 Kl. per annum capacity this will work out to about 90 m^3/Kl. of rectified spirit produced. The basis of the figures are also mentioned in the Table. Figure 3 represents the water use balance sheet for distillery of 5,000 Kl. capacity.

In Karam Chand and Thapar Ltd. the average daily distillation is around 13000 litres per day which will work out to about 3900 Kl. per annum based on three shift operation for 300 days in a year. The daily consumption of water in industrial use is 570 Kl. per day, which works out to about 44 m^3/Kl. of distilled alcohol. The break up of water used in various applications is not available for this unit. The source of supply

25. Comprehensive Industry Document : Fermentation Industries, Central Board for Prevention and Control of Water Pollution, New Delhi, 1981-82.

of water to this unit is underground water which is drawn through own tubewells. In Unnao area, where this unit is located, good quality water is available in abundance usually at 120 feet depth. The water requires treatment only when used in boiler feed while for other industrial and domestic uses tubewell water does not need any treatment.

5.4 Waste Water Generation and Its Treatment

The waste waters of distilleries are of two types: the process waste waters and non-process waste waters. The process waste waters comprise disposaal of streams from process vessels, e.g., steep water, spent wash, etc., as well as spillage. The non-process waste waters comprise such streams as cooling water or cooling tower blowdown, boiler blowdown and steam condensates, wash waters, etc.

However, the major process waste streams are the spent wash from the analyser column and fermenter sludge and spent lees from the rectifier. Of these the spent wash represents most of the pollution load. The quantity is about 15-16 times by volume of the rectified spirit and it has a BOD in the range of 45-60 X 10^3 mg/1 and a solid content of 6-9 per cent most of which however is in dissolved state. It has a pH in the range of 4.3 - 5.3 and contains about 5000-8000 mg/1 chlorides and 2000-5000 mg/1 sodium. The spent wash contains practically all the unfermented soluble matter present in the molasses. Table 5.2 provides this information.

The non-process waste waters comprise the cooling water, wash waters from fermenter house and bottling plant, boiler blowdown, water treatment plant wastes, etc. The overall quantity varies, depending mainly upon whether cooling water is recycled or used once-through. In general, the total volume of non-process waste water is about 90 Kl. per Kl. of rectified spirit if cooling water is used once through, and about 47 Kl. per Kl. of rectified spirit if it is recycled. Table 5.3 gives the quantity of process waste discharge. The characteristics and quantities of process wash water are indicated in Table 5.4.

Karam Chand and Thapar Ltd. is presently operating below its installed capacity. The average daily distillation is around 13000 litres per day. The spent wash is one of the strongest organic effluents in the industry, which is about 250 cubic metres per day. In addition to this some effluent is generated from its malt spirit plant, which is 50 m^3 per day. The spent wash contains high concentration of BOD and COD.

The analysis of spent wash reveals the following characteristics:-

Characteristics	Range
pH	4.5 - 5.5
BOD	40,000 - 50,000 mg/l
COD	90,000-1,00,000 mg/l
Suspended Solids	200 - 300 mg/l
Total Nitrogen	1200 mg/l
Sulphates	2000 - 4000 mg/l
Volatile Acids	5000 - 5500 mg/l

There are two basic processes available for the treatment of high BOD effluents such as distillery spent wash. The processes are:

(i) Evaporation and Spraydrying Systems where the spent wash is allowed to evaporate in multiple effect evaporators and the thick liquor is burnt in specially designed boilers to generate steam at high pressure. The high pressure steam is used to drive a turbine which generates power. The ash which is rich in potash is recovered and can be sold as a fertiliser. The evaporator condensate is subjected to aerobic treatment to contain the BOD within permissible limits.

(ii) Anaerobic digestion in closed digestors to recover methane (bio-gas) which is followed by further biologicaal treatment by aeration for reduction in BOD to acceptable values.

The process selected by this unit is the latter. Presently this unit has only first stage anaerobic treatment plant. As a result the BOD and COD of effluent water have come down to 4000 mg./litre and 17800-20000 mg./litre respectively. This treated water is presently being discharged, along with the waste water from other sections into a nallah adjacent to the plant boundary. In stage II of the effluent treatment scheme it is proposed to further treat this water aerobically to bring down the pollutants to U.P. Pollution Control Board standards given in Table 5.5.

5.5 Industrial Water Costs

In the case in which the individual plant is relying on a public supply and not drawing water from underground or surface water sources, the cost of water is the price charged by the public authority. Whereas, in the case of industries relying on their own sources of water, the cost of water would be the expenditure incurred in the industries for this purpose. Also, investment for the further treatment of water may often be necessary even in plants relying on public supplies. The costs for a given unit of capacity are influenced by such factors as size of installation, location and quality of raw water, and the quality required for a particular industrial use. The range of specifications for water quality to meet requirements in industry is wide, and the specifications vary from product to product and from process to process. As a result the cost of treatment per unit of water also differs. However, water requirement for a given industry, based on quality of water can broadly be divided into four categories, namely, cooling water, boiler water, process water and water for general use. Statistics on water use are however often poor. Various terms like intake, use, withdrawal, and pumpage are used in different industries which make it difficult to compile the data on a comparable basis. No accounts have been maintained of the break up of total water quantities into their specific uses within each industry. Further, no serious attempts have been made to fix some standard norms of quantity and quality of water used for specific purposes in different industries of given capacities.

Regarding the cost of water supply, it can however be said that the privately owned water for industrial use may be more economical than water purchased from public authorities, primarily, because in the case of public supply where large reservoirs, distribution pipes and pumping stations at different locations are major cost items, the cost of water supply is bound to be higher than the cost of water which is drawn by individual units from own sources. And secondly, because the pricing policy of the public utility may be such that it charges relatively higher prices for the water to industrial users to compensate for the losses due to lower or no prices charged for water supplied to public utility services like fire protection, municipal schools, institutions, parks, stand posts, cleaning of various public places, etc.

5.6 Estimation of Cost of Supply of Water to the Distillery

As mentioned earlier, the underground water is the only source of water supply to the factory. The supply of water from underground sources involves two major costs: (i) drawing and pumping cost of water and (ii) the cost of treatment of water, if treatment is required.

It is mentioned in Chapter III that three types of cost estimates of supply of water, namely; (a) resource cost, (b) social cost and (c) commercial cost have been attempted in this study. Methodology used for the estimation has also been discussed in Chapter III. However, the cost estimates here represent the costs of supply of raw water only. The cost of treatment of raw water is not estimated due to the following reasons. Firstly, because in the case of most of the units data on cost of treatment of water is not maintained because it is not considered very significant; and secondly, because the treatment cost of water does not seem much relevant for us as our purpose is to find out the production/supply cost of per unit of raw water used in the industry. We have, therefore, estimated the costs of supply of raw water to the various units.

5.7 Data Requirements, Sources and Limitations

To make the estimates of the above mentioned costs, data on both the fixed and operation cost of the plant/equipment used for drawing water is required. Some of this data is made available by factories in a reply to our questionnaire. However, the data show lot of excess capacity in drawing water. Also, the survey of a sample of factories in Kanpur shows a lot of variation in the fixed cost of equipment and its capacity utilisation. To make the statistics comparable across the factories we have made some assumption based on engineering norms regarding the cost and capacity of equipment. It is assumed that a tubewell costing Rs 1.20 lakhs at 1987-88 prices has a capacity of drawing about 22000 Kl. of water per month if put to use only for 10 hours a day. Working at this capacity the tubewell is assumed to last for minimum 15 years. Further, as mentioned in Chapter III, to make the estimates for resource cost of water, corrections for indirect taxes need to be made in market prices of plant and equipment and other fixed cost. In order to attempt corrections for taxes, detailed data about the break up of fixed cost is required. We have observed that not a single factory has maintained data on break up of fixed cost of a tubewell. We have, therefore, relied on engineering norms to break up the fixed cost. Table 5.6 provides the estimates of break up of fixed cost.

Regarding operation cost, it was noted that the needed break up was made available by almost all the units surveyed. The only problem with this data is about wages of unskilled labour. Since we are also interested to make estimates of the social cost of water it is necessary to use uniform wages for unskilled industrial worker across factories in Kanpur. Since labourers employed on tubewells are regular workers, we have assumed their per day emoluments as Rs 35 for the Kanpur city area.

The estimation of social cost of water is attempted making corrections for shadow prices of various inputs, namely; capital, labour, electricity and chemicals, in the estimates of cost flows of resource costs. The cost flows of resource costs are presented in Table 5.7, column 1. The methodology used for making corrections for shadow price of capital, unskilled labour, electricity and chemicals is discussed in Chapter III. The cost flows of social cost of water at shadow prices are shown in Table 5.7, column 2. Table 5.7, column 3 presents cost flows of commercial cost of water. And estimates of all the three types of costs per Kl. of water are presented in Table 5.8.

5.8 Estimation of Cost of Pollution Abatement Per Unit of Water Used/Released

The nature and concentration of pollutants specific to distillery industry as well as existing technological options for water pollution abatement in this industry have been briefly mentioned in Section 5.4. This factory has opted for end of pipe treatment method of pollution abatement. The anaerobic treatment technology is being used for the treatment of effluents discharged in the production process. Presently, only first stage anaerobic treatment is installed. As in the case of cost of water, we have estimated the commercial cost, resource cost and social cost of pollution abatement per unit of water used as well as per unit of water discharged. The fixed cost of pollution abatement plant includes two major components: (a) land and (b) mechanical equipments and civil works. Since data on land requirements is not available, on the basis of observations made during personal visits to various factories, the land requirement for effluent treatment plants is taken as 500 sq. yards. The market price of land prevailing in different localities where various factories are located is halved to estimate the resource cost of land in order to correct market prices for municipal taxes. The detailed data about break up of other fixed cost is needed to make corrections for excise duty and sales tax in order to estimate resource cost of pollution abatement per unit of water discharged/used. However, all the units in Kanpur and this unit in Unnao have got the effluent treatment plant erected on turn key basis. Therefore, we were unable to get the break up of the fixed cost. However, total fixed cost which includes mechanical and electrical equipments, civil work and installation is available. Using engineering norms we have made the estimates of different components of fixed cost. Fixed cost break up for effluent treatment plant is given in Table 5.9. Data on operation cost was made available by various factories surveyed. As in the case of estimation of cost of water supply, the wages paid to unskilled labour working on effluent treatment plant is taken as Rs 35 per day. The investment in effluent treatment plant in various factories surveyed is made at different points of time. To make the data comparable we have estimated costs at 1987-88 prices making corrections for the general inflation rate in the Indian economy. The annual social cost of land is estimated as 15 per cent of value of land. However, the methods of computation of all the three types of costs is the same as described in Chapter III. Estimated cost flows as well as costs of pollution abatement per Kl. of water used and discharged are shown in Tables 5.10 and 5.12.

5.9 Results

a. The estimate of resource cost of production of water per Kl. is 12 paise, given the value of social rate of discount (r) as 0.10, and the life of a tubewell as 15 years.

b. As expected, the social cost of production of water is higher by about 4 paise/Kl. compared to the resource cost of water at the same r and T.

c. The commercial cost of water is 26.5 paise per Kl.

d. The estimate of resource cost of pollution abatement per Kl. of effluents released is about Rs 5.54, while social cost is Rs 12.12 given the life of effluent treatment plant as 30 years and the value of r as 0.10.

e. Commercial cost of pollution abatement per Kl. of effluent water released works to be Rs 25.18.

f. The estimates of resource cost and social cost of pollution abatement per Kl. of water used are 2.10 and 4.59 respectively for given values of t=30 and r=0.10. However, commercial cost is worked out to be Rs 9.54.

It can be clearly seen in Table 8 that the social cost of water at shadow prices is higher than resource cost by about 4 paise which indicates that the pricing of water needs to be given a much more careful thought such that conservation of water is encouraged.

The estimate of social cost of pollution abatement per unit of effluent water released given, r and T as 0.10 and 30 respectively, is Rs 12.12 which is higher than the resource cost of pollution abatement. If social cost of pollution abatement is regarded as the cost that would have to be incurred by the government to achieve specific standards, the estimates of this cost, given alternative values of r and T may be regarded as a guide to the magnitude of the pollution tax required to be levied so as to achieve prescribed environmental standards.

TABLE 5.1

PROCESS & NON-PROCESS APPLICATION OF WATER FOR MOLASSES BASED DISTILLERIES

		Use	m^3 of Rectified spirit produced (Range)	(Average)	Basis and Remarks
A.	Process Application				
	1.	Yeast Propagation	1.0 - 1.4	1.3	Data collected from 10 distilleries
	2.	Preparation of molasses	10.5 - 14	13.0	Data collected from 12 distilleries
	3.	Water (as steam) required for distillation	3 - 6	4.5	Data from 3 distilleries and literature and energy balance calculations
B.	Non-Process Application				
	4.	Cooling Water for:			
		i) Fermenter	5 - 20	10	Data from 10 distilleries wide variation probably due to different ambient temperature at distillery location
		ii)Condensers	45 - 60	50	
	5.	Treated Water for making IMFL and for Boiler use	50 - 150 m^3/day		Figures could not be given in of rectified spirit due to varied product mix of the distilleries
	6.	Wash Water	2.5 - 10.0	6.0	
	7.	Water (as steam) for sterlising vessels	0.15	0.15	Based on data collected from 15 distilleries

Source: Comprehensive Industry Document Fermentation Industries, Central Board for the Prevention and Control of Water Pollution, 1981 - 82.

TABLE 5.2

SPENT WASH CHARACTERISTICS

Sl. No.	Characteristics	Range*
1.	pH	4.3 - 5.3
2.	Total solids	60,000 - 90,000
3.	Total suspended solids (TSS)	2,000 - 14,000
4.	Total dissolved solids (TDS)	67,000 - 73,000
5.	Total volatile solids (TVS)	45,000 - 65,000
6.	Chemical oxygen demand (COD)	70,000 - 98,000
7.	Biochemical oxygen demand (BOD)	45,000 - 60,000
8.	Total nitrogen as (N)	1,000 - 1,200
9.	Potash as (K_2O)	5,000 - 12,000
10.	Phosphate as (PO_4)	500 - 1,500
11.	Sodium as (Na)	150 - 200
12.	Chlorides as (Cl)	5,000 - 8,000
13.	Sulphates as (SO_4)	2,000 - 5,000
14.	Acidity as ($CaCO_3$)	8,000 - 16,000
15.	Temperature (After Heat Exchange)	70°C - 80°C

Note: * All figures except pH and temperature are in mg./I.

Source: Comprehensive Industry Document Fermentation Industries, Central Board for the Prevention and Control of Water Pollution, 1981-82.

TABLE 5.3

PROCESS STREAM DISCHARGE FROM DISTILLERIES BASED ON MOLASSES

Sl. No.	Capacity of the unit in kl./annum	Fermenters sludge in kl./day	Fermenters sludge as per cent of the molasses solution fed to fermenters	Spent wash discharge in kl./per kl. of rectified spirit produced	Spent lees in kl. of rectified spirit	Spent lees recycled or not
1.	5700	1.2	0.53	15	1.7	TR
2.	4500	3	1.69	15	x	TR
3.	9000	5.43	1.28	14	3.6	NR
4.	9650	8	2.1	17	x	TR
5.	2175	1.24	1.44	15.6	x	TR
6.	2970	5.6	4.78	17	x	TR
7.	1310	1.1	2	16	x	TR
8.	7500	10	3.38	15	x	TR
9.	12000	9.5	2	16	x	TR
10.	6800	5.4	2	22	1.84	NR
11.	8864	7	2	17	x	NR
12.	4450	2.1	1.2	17	x	NR
13.	15450	10.3	1.7	15.2	1.95	TR
14.	1881	1.15	1.6	16.5	x	TR
15.	8316	6.5	2	20	x	TR
16.	9228	7	18	15	1.93	TR

Note: This table gives the process waste streams quantity for 16 distilleries. Also indicated in the table is whether the spent lees is recycled or not.

Source: Comprehensive Industry Document Fermentation Industries, Central Board for the Prevention and Control of Water Pollution, 1981-82.

TABLE 5.4

QUANTITY AND CHARACTERISTICS OF PROCESS WASHWATER

Source		Flow in Kl./Kl. rectified spirit	BOD mg./l	Kg./Kl. of R.S.	SS mg./l	Kg./Kl of R.S.	Type of Flow
1.	Spent wash from analyser column	17.0	50000	850	12000	204	Continuous
2.	Fermenter sludge	0.3	125000	37.5	50000	15.0	Intermittent
3.	Spent lees from rectifier	1.9	5000	95.0	16000	28.5	Continous (recycled)
4.	Fermenter cooling water	10.0	2500 to 5000	52.5	500	7.5	
5.	Washwater fermenter		(3500 as)				
6.	Condenser cooling water:						
	i) Not recycled	50.0	-	-	-	-	Continous (recycled)
	ii)Recycled	2.5	-	-	-	-	Intermittent
7.	Boiler Blowdown	0.15	-	-	-	-	Intermittent
8.	Water treatment plant	2.1	-	-	-	-	Intermittent
9.	Bottling plant washwater	2.8	100	0.28	200	0.56	Continous

Source: Comprehensive Industry Document Fermentation Industries, Central Board for the Prevention and Control of Water Pollution, 1981-82.

TABLE 5.5

TOLERANCE LIMITS FOR INDUSTRIAL EFFLUENTS PRESCRIBED BY U.P. POLLUTION CONTROL BOARD

	Characteristics	Tolerance Limits for Industrial Effluents Discharged			
		Into Inland Surface Waters	Into Public Sewers	On Land for Irrigation	Into Marine Coastal Areas
i)	Colour and odour				
ii)	Suspended solids, mg./l, Max	100	600	200	a) For process waste waters - 100 b) For cooling water effluents - 10 per cent above total suspended matter of influent cooling water
iii)	Particle size of suspended solids	Shall pass 850 micron IS Sieve	-	-	a) Floatable solids, Max 3 mm.
iv)	Dissolved solids (inorganic), mg./l, Max	2100	2100	2100	-
v)	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
vi)	Temperature, °C, Max	Shall not exceed 40 in any section of the stream within 15 metres down-stream from the effluent outlet	45 at the point of discharge	-	45 at the point of discharge
vii)	Oil and grease, mg./l, Max	10	20	20	20
viii)	Total residual chlorine, mg./l, Max	1	-	-	1
ix)	Ammoniacal nitrogen (as N), mg./l	50	50	100	50
x)	Total kjeldahl nitrogen (as N), mg./l, Max	100	-	-	100
xi)	Free ammonia (as NH_3), mg./l, Max	5	-	-	5
xii)	Biochemical oxygen demand (5 days at 20°C), Max	30	350	200	100
xiii)	Chemical oxygen demand, mg./l, Max	250	-	-	250
xiv)	Arsenic (as As), mg./l, Max	0.2	0.2	0.5	0.2
xv)	Mercury (as Hg), mg./l, Max	0.01	0.01	0.01	0.01
xvi)	Lead (as Pb), mg./l, Max	0.1	1	-	1.0

TABLE 5.5 (Contd.)

xvii)	Cadmium (as Cd), mg./l, Max	2	1	5.0	2
xviii)	Hexavalent chromium (as Cr), mg./l, Max	0.1	2	1.0	1.0
xix)	Total chromium (as Cr), mg./l, Max	0.5	2	2.5	2
xx)	Copper (as Cu), mg./l, Max	3	3	3	3
xxi)	Zinc (as Zn), mg./l, Max	5	15	10	15
xxii)	Selenium (as Se), mg./l, Max	0.05	0.05	0.1	0.05
xxiii)	Nickel (as Ni), mg./l, Max	3	3	3	5.0
xxiv)	Boron (as B), mg./l, Max	2	2	2	-
xxv)	Per cent sodium, Max	-	60	60	-
xxvi)	Residual sodium carbonate, meg./l, Max	-	-	5	-
xxvii)	Cyanide (as CN), mg./l, Max	0.2	2.0	0.5	0.2
xxviii)	Chloride (as Cl), mg./l, Max	1000	1000	600	-
xxix)	Flouride (as F), mg./l, Max	2.0	15		15
xxx)	Dissolved phosphates (as P), mg./l, Max	5	-	-	-
xxxi)	Sulphate (as SO_4), mg./l, Max	1000	1000	1000	-
xxxii)	Sulphide (as S), mg./l, Max	2	-	-	5
xxxiii)	Pesticides	Absent	Absent	Absent	Absent
xxxiv)	Phenolic compounds (as C_6H_5OH), mg./l, Max	1	5	-	5
xxxv)	Radiactive materials:				
	a) Alpha emmitters, Mc/ml, Max	10^{-7}	10^{-7}	10^{-9}	10^{-7}
	b) Beta emitters, Mc/ml, Max	10^{-6}	10^{-6}	10^{-8}	10^{-6}

Source: IS: 2490 (Part I) 1981.

TABLE 5.6

FIXED COST BREAK-UP FOR TUBEWELLS

			Per cent
1.	Machinery equipment		67
	(i)	Pipe	24
	(ii)	Pump	64
	(iii)	Fittings	12
2.	Construction		13
	(i)	Cement	40
	(ii)	Bricks	20
	(iii)	Steel	40
3.	Labour		20

TABLE 5.7

COST FLOWS OF TUBEWELL WATER (KARAM CHAND AND THAPAR)

(In Rupees)

			Resource cost	Social cost	Commercial Cost	
A.	**Fixed Cost**				Fixed cost	120000
	1.	Machinery equipment			15% of fixed cost	18000
		a. Pipe	17000	39100	Operating cost	45036
		b. Pump	50000	115000	TOTAL	84600
		c. Fittings	7982	18358	Per unit market cost of water	0.265
	2.	Construction				
		a. Cement	4936	11353		
		b. Bricks	2525	5807		
		c. Steel	5392	12404		
	3.	Labour	24000	10320		
		TOTAL	111835	212340		
B.	**Operating Cost (Monthly)**					
	1.	Maintenance				
		a. Oil	50.5	75.5		
		b. Repair	142.0	142.0		
	2.	Fuel	2500	3432.5		
	3.	Labour	1050	451.5		
		TOTAL	3753.5	4102		
	OPERATING COST (ANNUAL)		44909	49219		

TABLE 5.0

ESTIMATES OF COST OF PRODUCTION OF TUBEWELL WATER (KARAM CHAND THAPAR)

Life Time (T) in Years →	15		20		25		30		
Social Rate of Discount ↓	Resource Cost	Social Cost	Resource Cost	Social Cost	Resource Cost	Social Cost	Resource Cost	Social Cost	Commercial Cost
0.08	0.139	0.178	0.116	0.126	0.098	0.108	0.086	0.095	
0.10	0.127	0.164	0.103	0.113	0.087	0.095	0.074	0.082	0.265
0.12	0.117	0.153	0.093	0.102	0.077	0.085	0.066	0.072	

Note: Estimates of resource cost and social cost are made with the assumption that social time preference rate is 10 per cent.

TABLE 5.9

FIXED COST BREAK - UP FOR E.T. PLANT

	Per Cent
1. Machinery Equipment	35
2. Piping	13
3. Civil Work	40
i. Bricks	20
ii. Cement	40
iii. Steel	40
4. Electrical Equipment	7
5. Installation	5

TABLE 5.10

COST FLOWS OF POLLUTION ABATEMENT (KARAM CHAND AND THAPAR)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	50000	57000	Fixed cost	11550000
2. Other Fixed Cost			15% of fixed cost	1732500
a. Machinery Equipment	3484848	8015150.4		
b. Piping	1306816	3005681	Operating cost	533352
c. Civil Work			TOTAL	2265852
i. Bricks	774411	1781145		
ii. Cement	1513780	3481694	Quantity of water released per year	9000
iii. Steel	1653487	3803020		
d. Electrical Equipment	80500	1851500	Quantity of water used per year	237600
e. Instalation	575000	247250		
TOTAL	10163344	22242440	Per unit market cost for water released/Kl.	25.18
B. OPERATING COST (MONTHLY)			Per unit market cost of water used/Kl.	9.54
1. Labour				
a. Skilled	8333	8333		
b. Unskilled (Rs. 35/Day)	1050			
2. Maintenance				
a. Oil	2496	3744		
b. Repair	7044	7044		
3. Chemicals	7015	10522.5		
4. Fuels	16667	22884		
TOTAL	42605	92979		
ANNUAL OPERATING COST	511260	1115784		

TABLE 5.11

COST ESTIMATES OF POLLUTION ABATEMENT (KARAM CHAND AND THAPAR)

Life Time (T) in Years	15	20		25		30			
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commer-cial cost
				WATER RELEASED					
0.08	10.78	23.58	8.43	18.43	6.93	15.14	5.90	12.91	
0.10	10.40	22.75	8.06	17.63	6.58	14.40	5.54	12.12	25.18
0.12	10.10	22.09	7.75	16.94	6.29	13.75	5.28	11.55	
				WATER USED					
0.08	4.09	8.93	3.19	6.98	2.62	5.74	2.24	4.89	
0.10	3.94	8.62	3.05	6.68	2.49	5.45	2.10	4.59	9.54
0.12	3.83	8.37	2.93	6.42	2.38	5.21	2.00	4.38	

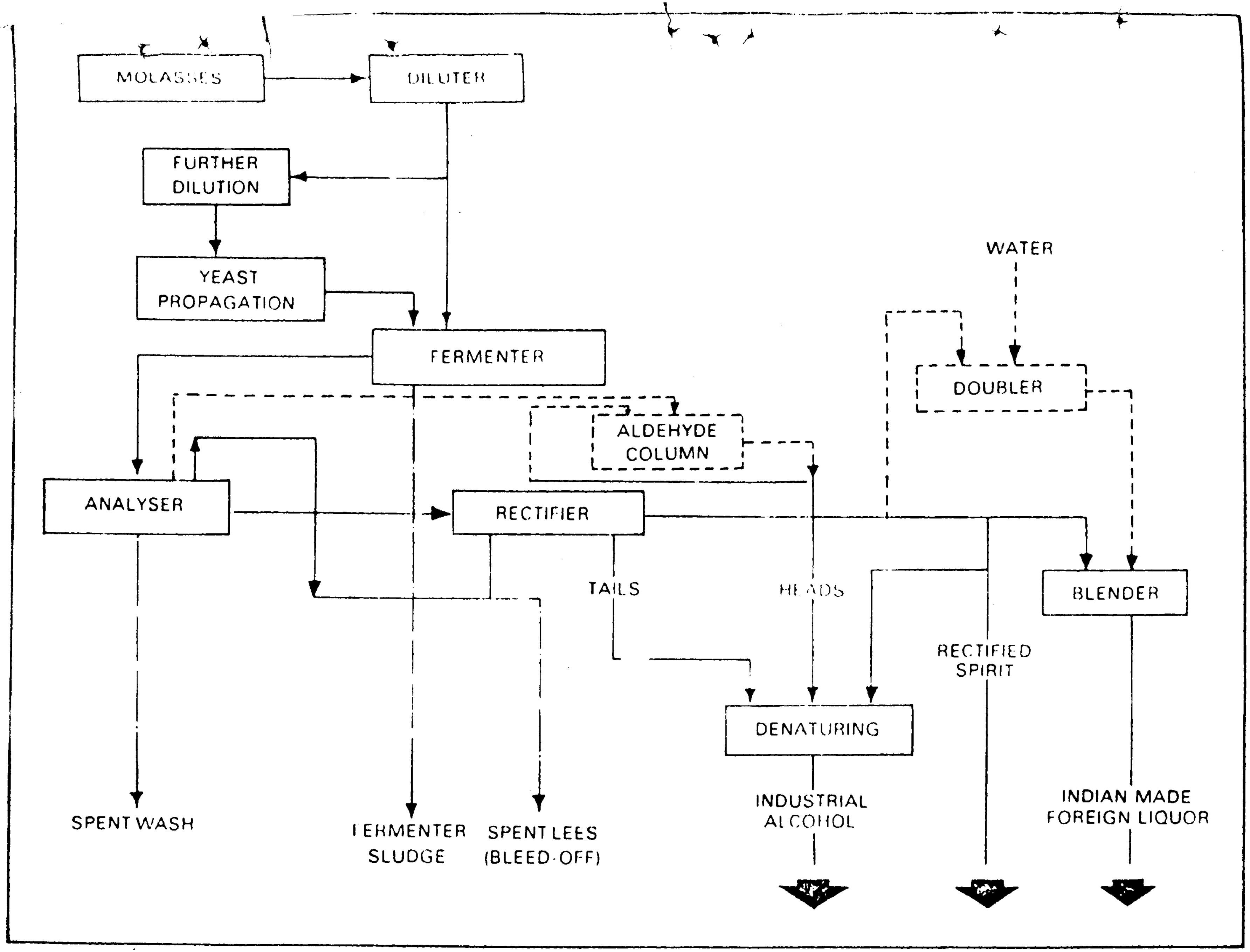


FIGURE 5.1. PROCESS BLOCK DIAGRAM OF DISTILLERY (MOLASSES-BASED)

Source: Comprehensive Industry Document Fermentation Industries, Central Board for the Prevention and Control of Water Pollution, 1981-82.

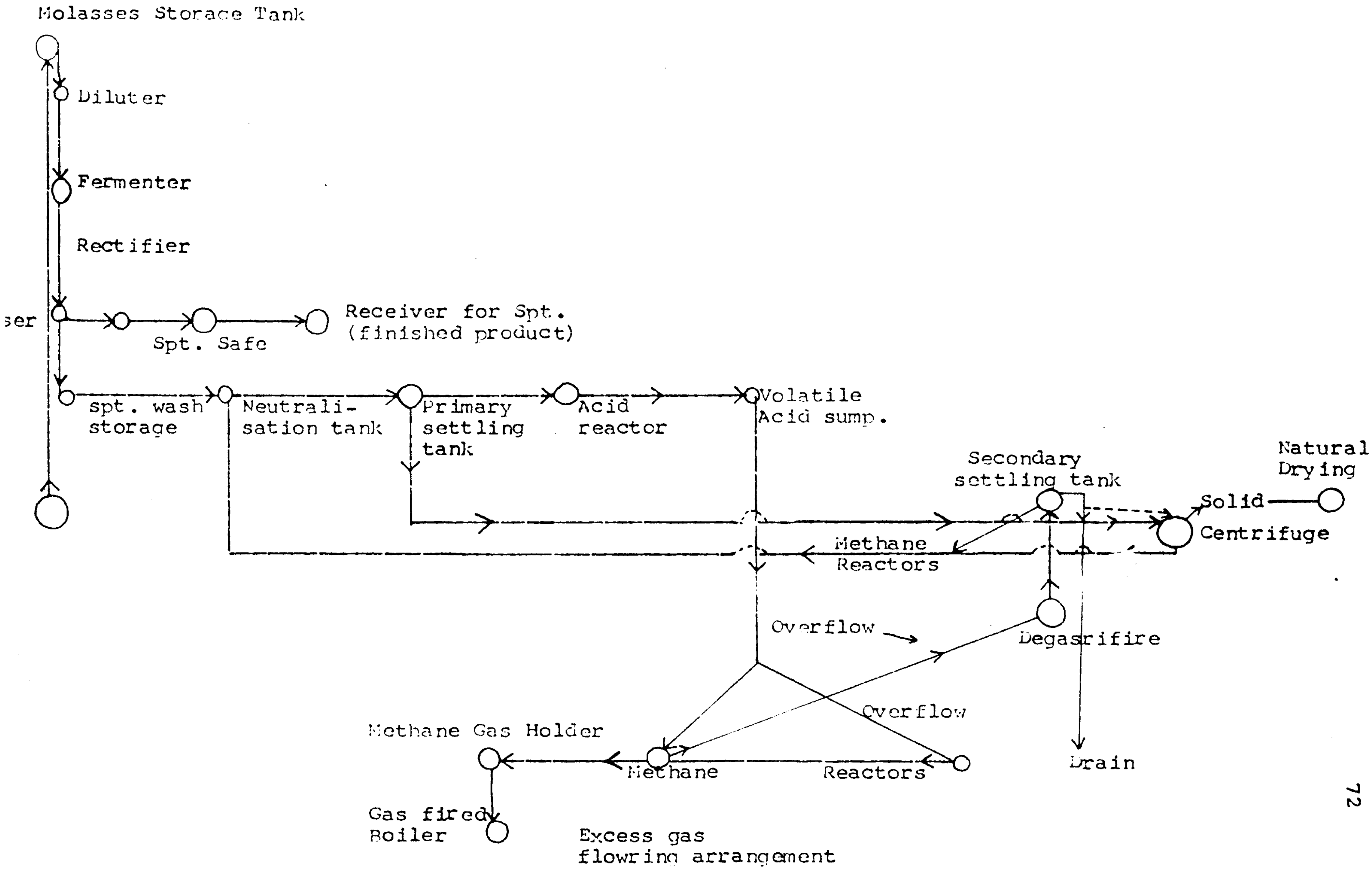


FIGURE 5.2: Process Flow Diagram of K.C. Thapar Ltd.

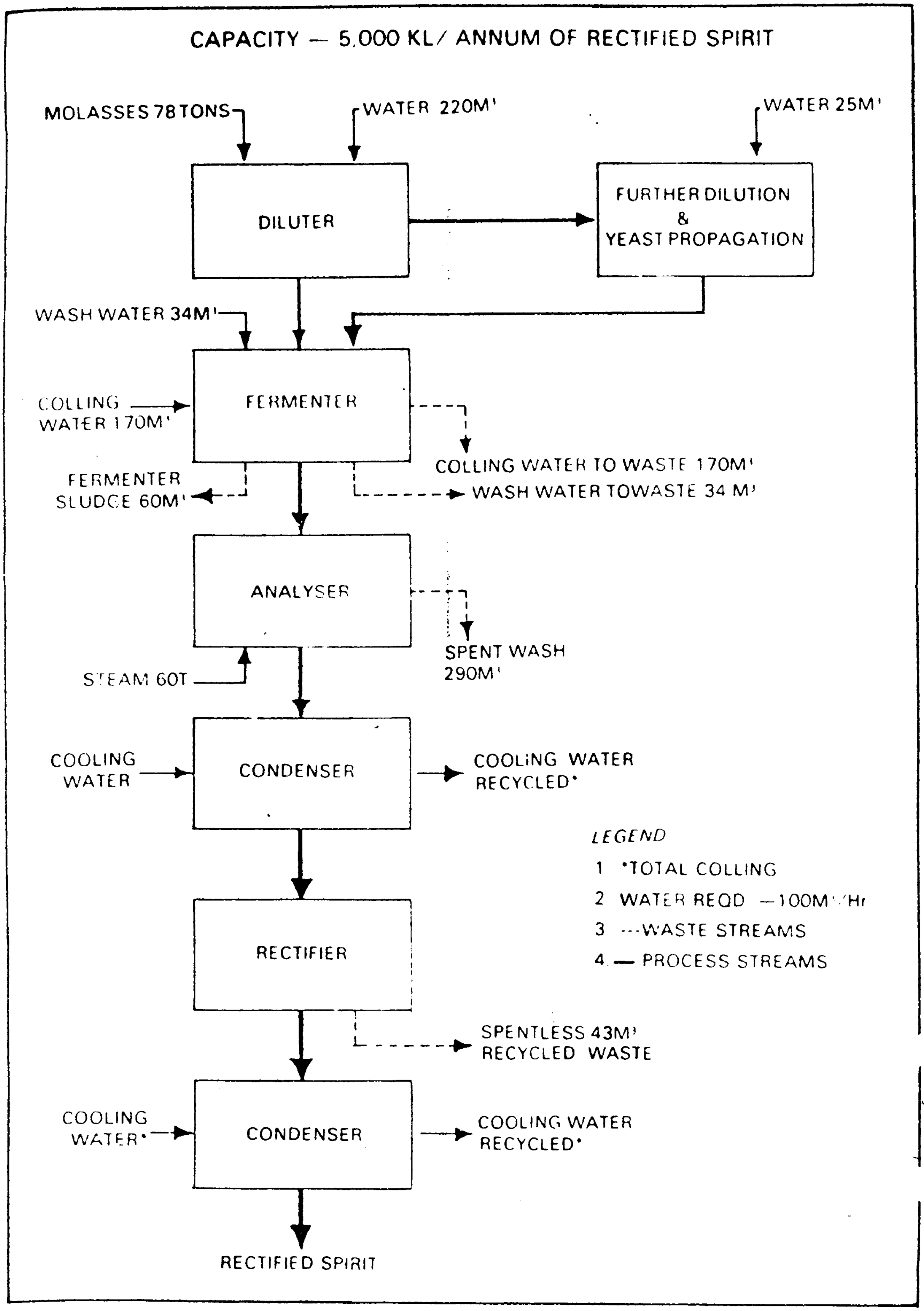


FIGURE 53. WATER USE BALANCE SHEET FOR DISTILLERY MODEL CASE

Source: Comprehensive Industry Document Fermentation Industries, Central Board for Prevention and Control of Pollution 100.–01

CHAPTER VI

TANNERY

6.1 Introduction

This Chapter attempts estimation of the cost of water and the cost of pollution abatement to the tanning industry. A tannery consumes large quantity of water and the same is discharged as waste water or effluent causing environmental pollution. To make the estimates of cost of water and pollution abatement, we require information on the quantity of water used and discharged in tanning and the pollution abatement method adopted. However the quantity of water consumed and the quantity and characteristics of the waste water discharged varies from process to process. To identify the water requirements and effluent generation in tanning process it is necessary to further investigate the processes and the quantity and quality of chemicals used in individual units. The choice of effluent treatment technology would depend on the quantity and characteristics of effluents. In view of this, two tanning units have been investigated. These are, Tanning and Footwear Corporation of India, Kanpur (TAFCO hereafter) and Bata India Ltd., Batanagar.

TAFCO is a tanning unit engaged in the processing of raw hides to finished vegetable tanned and chrome tanned leather and subsequently to finished goods. It is a Government of India undertaking situated in the heart of City. TAFCO has an installed capacity of processing 1700 raw hides and 3200 partially treated hides (Wet Blue Leather) into finished leather. Table 6.1

presents these details. Presently, TAFCO is mainly working on a two shifts per day basis for about 330 days in a year. It produces leather, footwear, rubber sheet and shoes. The major by-product of the unit is leather board.

The Bata India Ltd. is situated about 30 Kms. away from central Calcutta. At present this unit processes only Wet Blue leather to finished leather. The final product is footwear.

6.2 Tanning Activity

The process of making vegetable tanned and chrome tanned leather from raw hides involves various stages. The process adopted for making finished leather varies from tannery to tannery. The tanning process adopted by TAFCO is shown in Figure 6.1. Both vegetable tanning and chrome tanning are done at this unit. The tanning process is preceded by the treatment of raw hides, which is known as beam house operations. The beam house operations consist of soaking, liming, unhairing and fleshing, and deliming.

a. Vegetable tanning. The hides are treated with vegetable tan liquor of varying concentrations.

b. Chrome tanning. The hides are tanned using basic chrome sulphate. Following this the hides are neutralised using sodium bicarbonate.

The Batanagar Unit of Bata India Ltd. has recently stopped processing raw hides. At present only Wet Blue processing is done. This has drastically reduced the pollution load in the effluents generated by the unit.

6.3 Water Requirements and Cost of Supply of Water

In the planning of tannery, water plays a vital role as the tanning industry is one that consumes large quantity of water. It is therefore necessary that there should be abundant supply of soft water as many of the processes of leather manufacturing are affected by hard and saline water. As per general standards, consumption of water is aproximately 30 to 40 litres per kg. of raw hides processed.

In Kanpur where TAFCO is located, soft water is available in abundance. This factory relies mainly on underground water which is supplied through its own tubewells. Average daily consumption of water at TAFCO is about 1394 Kl., out of which 1200 Kl. is drawn from tubewells and the rest is taken from municipal supply. The supply of water from underground sources involves two major costs; namely, drawing and pumping costs of water.

It is mentioned in Chapter III that three types of cost estimates of supply of water, namely, (a) resource cost, (b) social cost and (c) commercial cost have to be attempted. Methodology used in estimation of the above mentioned costs has also been discussed in the same Chapter. While cost flows of resource cost, social cost and commercial cost of water supply are presented in Table 6.2, cost estimates of water supply are displayed in Table 6.3.

It is apparent in Table 6.3 that the resource cost of water, given t = 15 and r = 0.10, is Rs 0.139 per Kl. As expected the social cost of water is higher by 4 paise. However, the estimate of commercial cost is worked out to be 29 paise per Kl. of water.

In Bata India Ltd., the consumption of water for industrial use is about 82500 Kl. per month. The water requirement is met completely by river water. The cost of supply of water from river too involves drawing and pumping costs of water, the fixed cost break up of which is given in Table 6.4. The cost flows and estimated costs of water are presented in Tables 6.5 and 6.6 respectively. On inspection of Table 6.6 it can be seen that the estimated resource cost of river water is 21 paise while social cost is about 32 paise per Kl. of water for given values of r = 0.10 and T = 15 years. The commercial cost of water works out to be about 44 paise which is higher than resource cost by about 23 paise.

6.4 Effluent Generation, Characteristics and Treatment Requirements

Large quantity of water is discharged in tanning process with waste chemicals, dyes and other impurities causing environmental pollution. Depending upon the type of tanning process about 30 to 40 litres of effluent is likely to be generated per kg. of hide processed.

In general, the quantity and nature of the effluent discharged varies from process to process and tannery to tannery. The average waste water discharge per Kg. of hide under different processes are as follows[26]:

(a)	Raw to finishing:	30-35 litres per kg. of wet salted weight
(b)	Raw to wet blue:	20-25 litres per kg. of wet salted weight

26. Advisory Technical Report on Common Effluent Treatment System for Leather Complex Jalandhar, Central Leather Institute Madras, January, 1988.

(c) Wet blue to finish: 20-25 litres per kg. of wet blue weight.

Except for the finishing operations water is used at all stages in processing. The various sources of waste water at TAFCO along with their quantities are listed in Table 6.7. The total volume of effluents is estimated at 800 Kl./day from the processing section. The effluents from the sanitary and domestic blocks are estimated at 200 Kl./day. Therefore, the effluent flow is of 1000 Kl./day. The characteristics of effluent water from various major sources and the composite waste water are presented in Table 6.8.

The choice of method of effluent treatment depends upon the characteristics of effluent, required level of treatment depending upon the pollution standards and the final mode of disposal. The Bureau of Indian Standards (BIS) has laid down standards for various modes of final effluent disposal, viz., discharge into city sewer, on land for irrigation or into inland surface water. Most of the Pollution Control Boards adopt the standards prescribed by the Bureau of Indian Standards in general with minor modifications to suit local conditions. The important Indian Standards specifications are given in Table 6.9.

TAFCO has adopted the end of pipe treatment method of pollution abatement. The effluent treatment plant (ETP) has been designed to achieve treated effluent levels fit for disposal into sewers/river/inland surface water as stipulated by U.P. Pollution Control Board. The expected concentration of various pollutants after treatment is presented in Table 6.10. However, the characteristics of composite waste water considered for designing the ETP are presented in Table 6.11.

The ETP has been designed consisting of both primary and secondary treatment systems. The primary treatment consists of physico-chemical process for reduction in levels of pollutants while, the second stage treatment involves a two stage biological treatment. Presently the TAFCO has only primary treatment plant under operation. The secondary treatment plant is under construction. Flow diagram of the primary stage treatment is presented in Figure 6.2. This process involves the following steps.

a. **Equalisation.** The bulk of effluents discharged from process house and sanitary effluents are collected in equalisation tank to have better homogenation of the tannery effluent from various sources. In this tank an agitator is provided for mixing of effluents and keeping settlable solids in suspension.

b. **Physico-chemical treatment.** The effluents are pumped from the equalisation tank into a reaction tank. In the reaction tank chemicals (alum, lime/acid) are added. Lime/acid are added for maintaining the pH at 7.8 which is controlled by pH monitor. From the reaction tank the effluents are taken into a settling tank for solid-liquid separation. The sludge collected in the hopper bottom is withdrawn hydrostatically and applied on sludge drying beds. The super natant is presently thrown into municipal sewage. The characteristics of effluent before and after first stage treatment are presented in Table 6.12. The effluent which is presently thrown into sewage is proposed to be subjected to biological treatment. In biological treatment, effluents are pumped into aeration tanks where suitable bacteria are activated artificially, which eat up the organic matter present in effluent thereby improving BOD and COD, etc. The characteristics of effluent before and after biological treatment or second stage treatment are presented in Table 6.13. It is mentioned earlier that biological treatment is not yet done at TAFCO. However, data on both fixed and operation cost of second stage treatment is made available to us. Using this we have made the estimate of commercial cost of pollution abatement at TAFCO (Table 6.14). In the absence of information on the break-up of fixed and operation cost the estimates of resource cost and social cost of pollution abatement could not be made.

In Bata India Ltd. the volume of tannery effluent is 615 Kl. per day. Information on the characteristics of effluent is, however, not available. The treatment of effluent from Tannery is done by Physico-Chemical method in Phase 1. The raw effluent is passed through grit and screen chamber and collected in the Equalising Tank. After retention for 4 hrs. in the Equalising tank the effluent is transported through a pipe to the Flash mixer where lime and Ferric Chloride are added from chemical dosing tanks. The mixture is stirred at a high speed. Lime is added to precipitate the Chromium and Ferric Chloride/Ferrous Sulphate is added to coagulate Sulphides. The chemical dose is adjusted such that a p^H of 8.5 - 9.0 is always maintained in the clarifier. From the flash mixer the effluent is then passed into the Clariflocculator for agitation. The flocculation takes place in the central zone and the liquid overflow gets clarified and is discharged. The sludge is collected in a pit and dried in sludge drying beds for disposal. The under flow from the sludge drying bed is again pumped back to Flash mixer. The flow diagram of effluent treatment plant is given in Figure 6.3.

6.5 Estimation of Cost of Pollution Abatement

The nature and concentration of pollutants specific to tannery as well as methods used for water pollution abatement in this industry have been briefly mentioned in the earlier Section. Both TAFCO and Bata India Ltd. have opted for end of pipe treatment method of pollution abatement. Only primary treatment process is being used for the treatment of effluent water discharged in the production process. As in the case of cost of water, three estimates of cost of pollution abatement have been made namely, commercial cost, resource cost and social cost. The method of computation of the above costs is same as described in Chapter III. Estimated cost flows as well as costs of pollution abatement per unit of water used and discharged are displayed through Tables 6.15, 6.16, 6.17 and 6.18. For TAFCO the estimates of resource cost and social cost of pollution abatement per Kl. of effluents released are Rs 0.64 and Rs 1.02 respectively for r = 0.10 and T = 30 years. The commercial cost is Rs 2.05. The estimate of commercial cost of pollution abatement after second stage treatment[27] worked out to be Rs 3.33. For Bata India Ltd. estimated resource cost of pollution abatement per Kl. of effluents released is 98 paise, social cost Rs 1.63 for r = 0.10 and T = 30 years and commercial cost is Rs 4.03.

---

27. It is mentioned in Section IV that due to lack of required data estimates of resource cost and social cost could not be made.

TABLE 6.1

INSTALLED CAPACITY OF PROCESSING AT TAFCO

Sl.No.	Raw Material	Processing	
		From	To
1.	1400 Cow Hides	Raw Hides	Finished Chrome Tanned Leather
2.	1400 Cow Hides	Wet Blue	Finished Chrome Tanned Leather
3.	1800 Spilts	Wet Blue	Finished Chrome Tanned Leather
4.	300 Buff Hides	Raw Hides	Vegetable Tanned Leather
5.	300 Buff Hides	Veg. Tanned Leather	Finishing

TABLE 6.2

COST FLOWS OF TUBEWELL WATER (TAFCO)

(In Rupees)

	Resource cost	Social cost	Commercial Cost	
A. Fixed Cost				
1. Machinery and Equipment	-		Fixed cost	240000
a. Pipe	33734	77588	15% of fixed cost	36000
b. Pump	98011	225425		
c. Fittings	17016	39137	Operating cost	90024
2. Construction			TOTAL	126024
a. Cement	10267	23614	Quantity of water used per year (Kl.)	432000
b. Bricks	5253	12082		
c. Steel	11215	25795		
3. Labour	48000	20640	Cost per Kl. of water used	0.29
TOTAL	223496	424281		
B. Operating Cost (Monthly)				
1. Maintenance cost				
a. Oil	100	150		
b. Repair	281	281		
2. Fuel	5000	6865		
3. Labour	2100	903		
TOTAL	7481	8199		
TOTAL COST (Annual)	89772	98388		

TABLE 6.3

ESTIMATES OF COST OF PRODUCTION OF TUBEWELL WATER (TAFCO)

(In Rupees)

Time (T) in Years ->	15		20		25		30		
	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
Social Rate of Discount									
0.080	0.153	0.196	0.127	0.160	0.108	0.135	0.095	0.118	
0.130	0.139	0.180	0.114	0.145	0.096	0.122	0.082	0.104	0.290
0.120	0.128	0.168	0.102	0.133	0.085	0.110	0.072	0.093	

TABLE 6.4

BREAK-UP OF FIXED COST FOR RIVER WATER (BATA INDIA LTD.)

1.	Machinery & Equipment		37 per cent
	a. Pipe	24 per cent	
	b. Pump	64 per cent	
	c. Fittings	12 per cent	
2.	Construction		50.5 per cent
	a. Cement	40 per cent	
	b. Bricks	20 per cent	
	c. Steel	40 per cent	
3.	Labour		12.5 per cent
	TOTAL		100.0 per cent

TABLE 6.5

COST FLOWS OF RIVER WATER (BATA INDIA)

(In Rupees)

	Resource cost	Social cost	Commercial Cost	
A. **Fixed Cost**				
1. Machinery and equipment			Fixed cost	586400
a. Pipe	45398	104417		
b. Pump	131901	303372	15% of fixed cost	87960
c. Fittings	22899	52669	Operating cost	351840
2. Construction				
a. Cement	97408	224038	TOTAL	439800
b. Bricks	49832	114612		
c. Steel	106398	224716	Quantity of water used over a year (Kl.)	990000
3. Labour	74000	31820		
TOTAL	527836	1603480	Cost per Kl. of water used	0.43
B. **Operating Cost (Monthly)**				
1. Maintenance cost				
a. Oil	2811	4216		
b. Repair	7084	7084		
2. Fuel	16400	22517		
3. Labour	2800	1204		
TOTAL	29095	35021		
TOTAL COST (Annual)	349140	420252		

TABLE 6.6

ESTIMATES OF COST OF PRODUCTION OF RIVER WATER (BATA INDIA LTD.)

(In Rupees)

Time (T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.237	0.351	0.199	0.288	0.170	0.244	0.150	0.213	
0.10	0.214	0.323	0.176	0.261	0.149	0.219	0.128	0.186	0.44
0.12	0.195	0.300	0.157	0.238	0.131	0.197	0.112	0.167	

TABLE 6.7

EFFLUENT GENERIC POINTS AND QUANTITIES (TAFCO)

Sl.No.	Process	Approximate Quantity of Effluent Generated Kl./Day
1.	Soaking	96
2.	Liming	
	a. Chrome tan section	70
	b. Veg. tan section	30
3.	Fleshing and unhairing	120
4.	Deliming and washing	200
5.	Vegetable tanning	18
6.	Carriering	20
7.	Pickling	15
8.	Chrome tanning	15
9.	Neutralisation	45
10.	Retanning, neutralisation, dyeing and fatliquoring	125
11.	Chrome finishing and drying	20
12.	Miscellaneous waste	26
13.	Sanitary and domestic effluents	200
	TOTAL	1,000 Kl./Day

TABLE 6.8

CHARACTERISTICS OF EFFLUENTS FROM VARIOUS SOURCES

Sl.No.	Items of analysis	Soaking	Liming	Deliming	Chrome tanning	Veg. tanning	Composite waste
1.	PH	7.5-8.5	10-12.5	3.0-9.0	2.6-3.2	5.0-6.8	7.5-10.0
2.	Suspended solids	2500-4000	4500-6500	200-1200	300-1000	5000-20000	1250-6000
3.	BOD	1000-2500	3000-9000	1000-2000	800-1200	6000-12000	2000-3000
4.	COD	3000-4000	8000-14000	1800-3000	1800-3500	10000-20000	3000-4000
5.	Tanniers	-	-	-	-	6400	
6.	Chromium	-	-	-	2800	-	10-30
7.	Chlorides	10000-14000	90-150	50-100	-	4000	1200-1500

Note: All parameters except pH expressed as mg./l.

TABLE 6.9

BUREAU OF INDIAN STANDARD SPECIFICATIONS FOR INDUSTRIAL EFFLUENT DISCHARGE: TANNING INDUSTRY [IS: 2490 (PART 3 - 1985)]

Important Characteristics	Tolerance limits for industrial effluents discharged		
	Into inland surface	Into public sewers	Onland for irrigation
pH	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0
Biochemical Oxygen Demand - BOD 5 days 20°C	30	350	100
Chemical Oxygen Demand - COD	250	-	-
Suspended solids	100	600	200
Total dissolved solids	2100	2100	2100
Chlorides as Cl	1000	1000	600
Hexavalent chromium as Cr	0.1	2.0	0.1
Total chromium as Cr	2	2	2
Sulphides as S	2	5	-
Colour and odour	Absent	-	Absent
Oil and grease	10	20	10

Note: 1. All values except pH are expressed in mg./l.

TABLE 6.10

EXPECTED CHARACTERISTICS OF TREATED EFFLUENTS (TAFCO)

Sl.No.	Parameter	Concentration*
1.	pH	5.5-9.0
2.	Suspended solids	100
3.	BOD (5 days at 20°C)	30
4.	COD	250
5.	Sulphides as S^{-}	2
6.	Chromium as Cr^{6+}	0.1
7.	Chromium total	2
8.	Oils and grease	10

Note: * All parameters except pH expressed as mg./l.

TABLE 6.11

CHARACTERISTICS OF COMPOSITE WASTEWATER FROM PROCESS AND DOMESTIC EFFLUENTS CONSIDERED FOR DESIGNING OF ETP (TAFCO)

Sl.No.	Parameter	Concentration*
1.	pH	8-10
2.	Suspended solids	1700
3.	BOD	1840
4.	COD	2900
5.	Chromium total	15
6.	Sulphides as S^{-}	65
7.	Chlorides as Cl^{-}	2340

Note: * All parameters except pH expressed as mg./l.

TABLE 6.12

CHARACTERISTICS OF WASTE WATER BEFORE AND AFTER PRIMARY TREATMENT

Sl. No.	Parameter	Physico-Chemical Combined Treatment Waste	
		Before	After
1.	pH	8-9	8.0
2.	Suspended solids	1250-6000	200
3.	BOD	1800-2000	900-1200
4.	COD	3000-4000	1500-2000
5.	Chromium	10-30	1
6.	Sulphides	400-500	200-250
7.	Tannins	50-100	10-15

TABLE 6.13

CHARACTERISTICS OF WASTEWATER BEFORE AND AFTER BIOLOGICAL TREATMENT (TAFCO)

Sl. No.	Parameter	Aerated Lagoon		Oxidation Ditch Followed by Settling Tank	
		Before	After	Before	After
1.	pH	8.0	-	8.0	7-9
2.	Suspended solids	200-600	100	100	100
3.	BOD	900-1250	200-300	200-300	20-30
4.	COD	1500-2000	300-500	300-500	250
5.	Chromium	Trace	Trace	Trace	Trace
6.	Sulphides	-	-	-	-
7.	Tannins	10-15	Trace	Trace	Trace

TABLE 6.14

COST FLOWS OF POLLUTION ABATEMENT AFTER SECOND STAGE TREATMENT (TAFCO)

(In Rupees)

Commercial cost	
Fixed cost	52,00,000
15% of fixed cost	7,80,000
Operating cost	7,20,000
TOTAL	15,00,000
Quantity of water released per year	4,50,000
Quantity of water used per year	5,01,819
Per unit cost of water released	3.33
Per unit cost of water used	2.98

TABLE 6.15

COST FLOWS OF POLLUTION ABATEMENT (TAFCO)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost				
1. Land	125000	142500	Fixed cost	2242232
2. Other fixed cost			15% of fixed cost	336335
a. Machinery and equipment	641585	1475646	Operating cost	584232
b. Piping	240595	553369	TOTAL	920567
c. Civil work			Quantity of water released per year (Kl.)	450000
i) Bricks	142575	327923		
ii) Cement	278698	641005	Quantity of water used per year (Kl.)	1254547
iii) Steel	304419	700164		
d. Electrical equipment	148206	340874	Cost per Kl of water released	2.05
e. Installation	105862	243483	Cost per Kl of water used	0.73
TOTAL	1986940	4424964		
B. Operating Cost (Monthly)				
1. Labour				
a. Skilled	2500	2500		
b. Unskilled	4750	2043		
2. Maintenance				
a. Oil	460	690		
b. Repair	1297	1297		
3. Chemicals	25253	37880		
4. Fuel	9583	13157		
TOTAL	43843	57567		
TOTAL COST (ANNUAL)	526116	690804		

TABLE 6.16

COST ESTIMATES OF POLLUTION ABATEMENT (TAFCO)

Time (T) in Years ->	15		20		25		30		
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
				WATER RELEASED					
0.08	1.20	1.94	0.99	1.58	0.84	1.32	0.73	1.15	
0.10	1.11	1.81	0.90	1.45	0.75	1.21	0.64	1.02	2.05
0.12	1.03	1.71	0.82	1.34	0.68	1.10	0.57	0.93	
				WATER USED					
0.08	0.86	1.37	0.71	1.11	0.60	0.93	0.53	0.81	
0.10	0.79	1.30	0.64	1.02	0.54	0.85	0.46	0.72	1.83
0.12	0.74	1.21	0.58	0.95	0.48	0.78	0.41	0.66	

TABLE 6.17

COST FLOWS OF POLLUTION ABATEMENT (BATA INDIA LTD.)

(In Rupees)

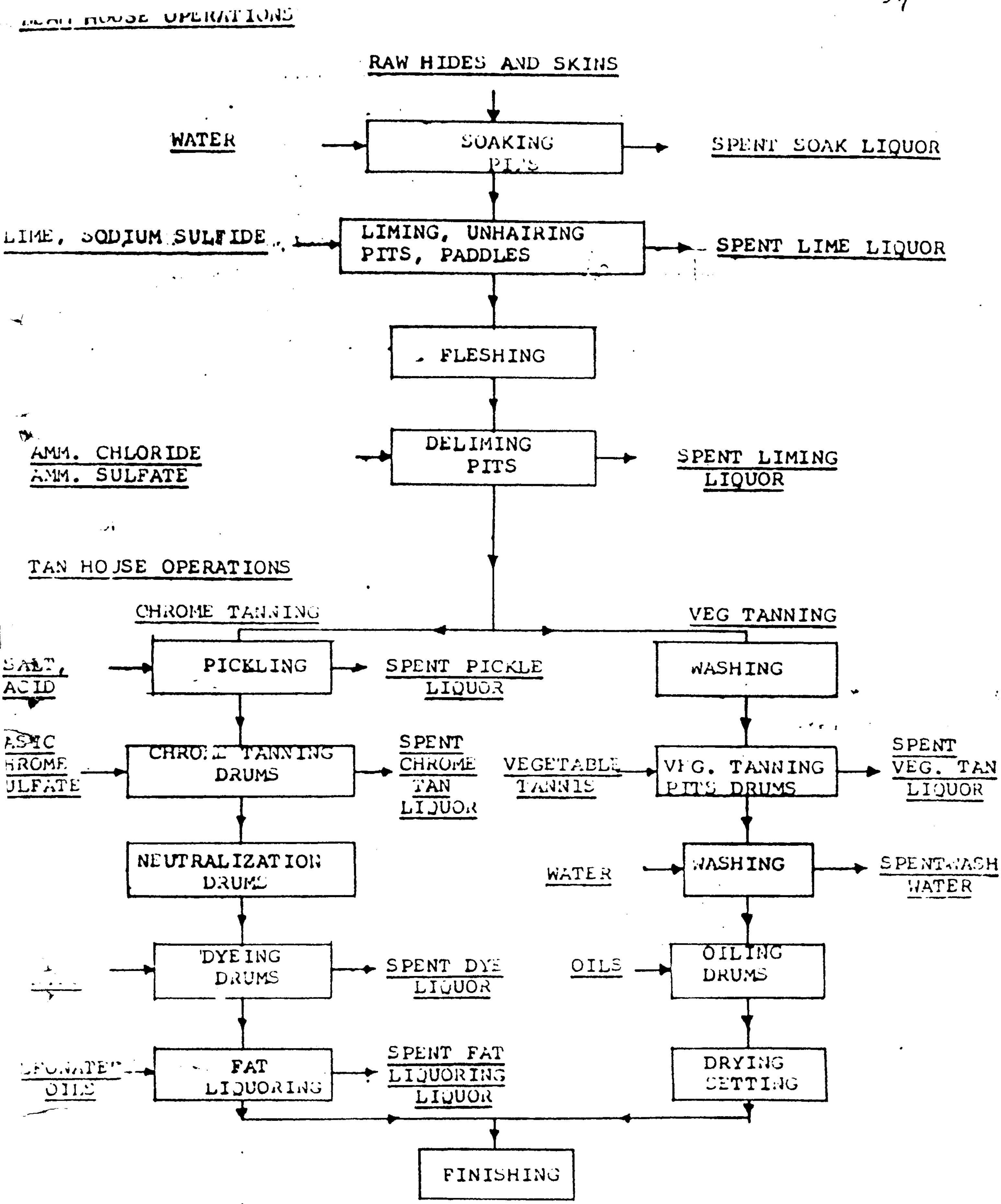
	Resource cost	Social cost	Commercial Cost	
A. Fixed Cost				
1. Land	250000	285000	Fixed cost	3250000
2. Other fixed cost			15% of fixed cost	487500
a. Machinery & equipment	909090	2090907	Operating cost	491460
b. Piping	340909	784091	TOTAL	978960
c. Civil work			Quantity of water released per year(Kl)	243000
(i) Bricks	202020	464646		
(ii) Cement	394899	908268	Quantity of water used per year (Kl)	990000
(iii) Steel	431344	992091	Cost per Kl. of water released	4.03
d. Electrical equipment	210000	483000		
e. Installation	150000	345000	Cost per Kl. of water used	0.99
B. Operating Cost (Monthly)				
1. Labour				
a. Skilled	5700	5700		
b. Unskilled	2100	903		
2. Maintenance				
a. Oil	650	975		
b. Repair	1838	1838		
3. Chemicals	16834	25251		
4. Fuel	10530	14458		
TOTAL	37652	49125		
TOTAL COST (Annual)	451824	589500		

TABLE 6.10

COST ESTIMATES OF POLLUTION ABATEMENT (BATA INDIA LTD.)

(In Rupees)

Time (T) in Years->	15		20		25		30		
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	commercial cost
				WATER RELEASED					
0.08	1.86	3.13	1.50	2.49	1.26	2.07	1.10	1.78	
0.10	1.73	2.97	1.38	2.34	1.15	1.93	0.98	1.63	4.03
0.12	1.63	2.84	1.28	2.20	1.05	1.80	0.89	1.52	
				WATER USED					
0.08	0.46	0.77	0.37	0.61	0.31	0.51	0.27	0.44	
0.10	0.43	0.73	0.34	0.57	0.28	0.47	0.24	0.40	0.99
0.12	0.40	0.70	0.31	0.54	0.26	0.44	0.22	0.37	



61. BLOCK DIAGRAM FOR LEATHER MAKING PROCESS VEG & CHROME TANNING

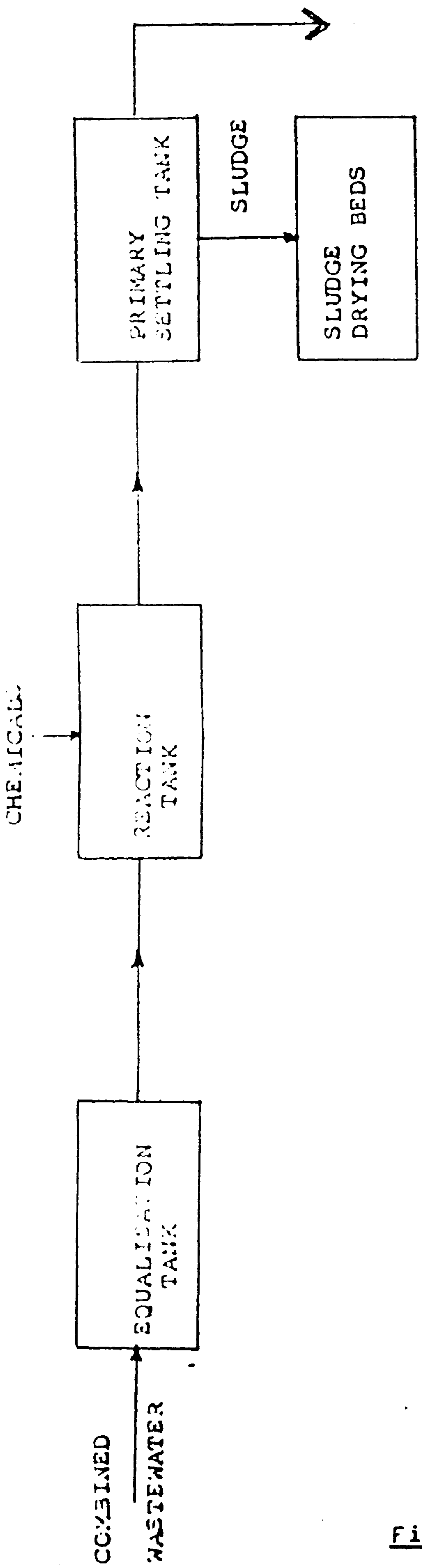


Fig 2: Flow Diagram of Primary Stage Treatment

TANNERY EFFLUENT TREATMENT PLANT (BATA)

FIGURE 6.3

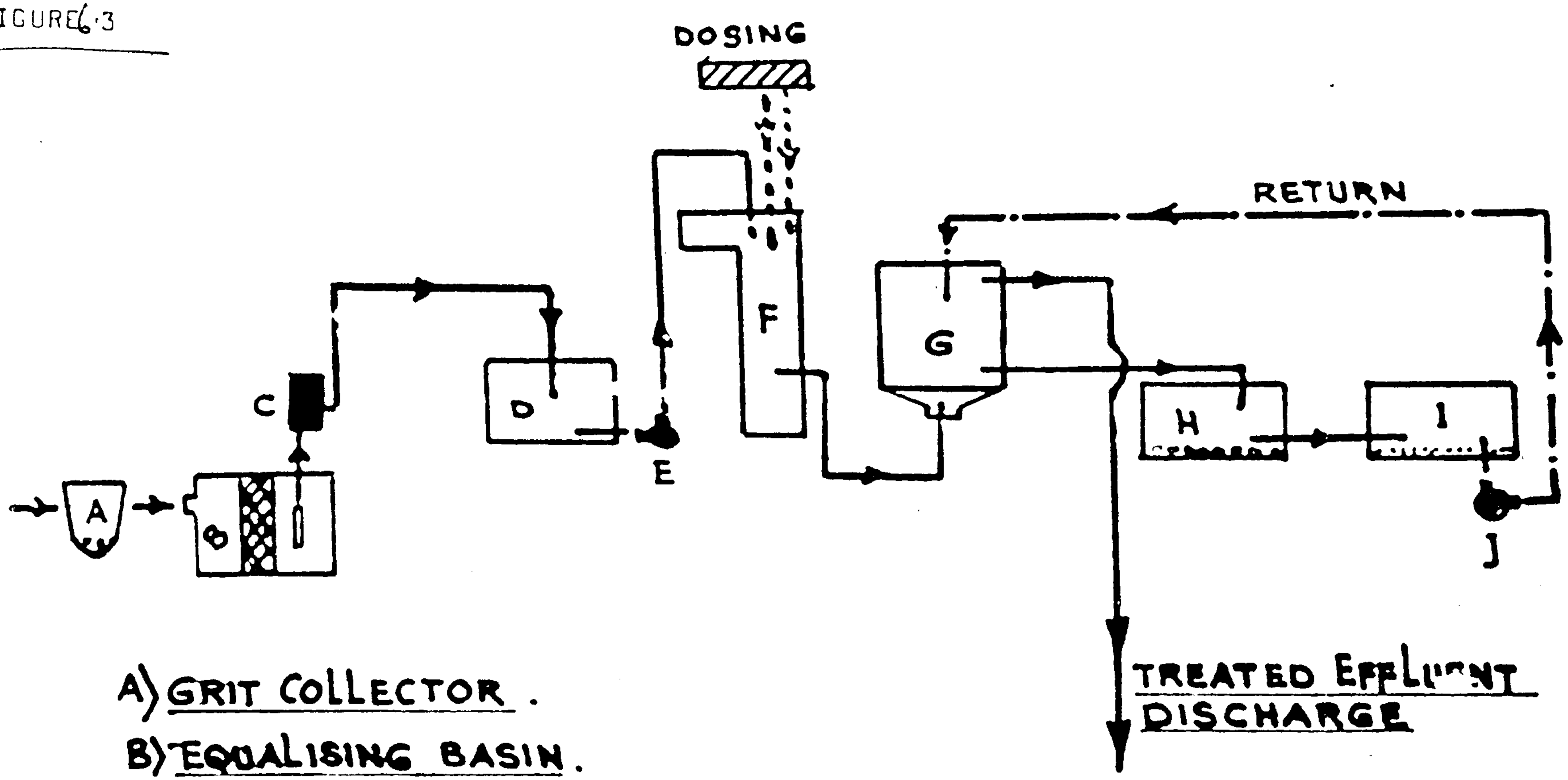


Fig 6.3

A) GRIT COLLECTOR.
B) EQUALISING BASIN.
C) SUB. PUMP.
D) EQUALISING TANK.
E) TRANSFER PUMP.
F) FLASH MIXER.
G) CLARIFLOCCULATOR.
H) SLUDGE PIT.
I) SLUDGE DRYING BED.
J) RETURN PUMP.

CHAPTER VII

FERTILIZER INDUSTRY

7.1 Introduction

Fertilizer industry has grown very fast during last two decades in India. Our country has a total of 47 nitrogenous and 84 phosphatic fertiliser plants. These plants differ in vintage, capacity, and processes, etc. Various pollutants are emanated from fertiliser plants. Their volume and characteristics depend on the choice of technology and quantity and quality of finished products. To take a closer look at the magnitude of pollution generated by fertiliser units and also the complexity of the problem of pollution abatement in fertiliser units, two fertiliser units have been investigated in this study. One of them is Zuari Agro Chemicals Ltd., Goa which has both nitrogenous and phosphatic fertiliser plants and the other is I.E.L. Ltd., Kanpur, U.P. which produces only nitrogenous fertilisers.

Zuari Agro Chemicals Ltd. was set up in 1967. The commercial production started only in the middle of 1973. The present position regarding the capacity of the plant is presented below:

Production Capacity of Zuari Agro Chemicals Ltd.

	Products	Licensed capacity (MT)	Installed capacity (MT)	Utilised capacity (MT) in 1986
1.	Ammonia	2,20,000	2,20,000	106 per cent
2.	Urea	3,40,000	3,40,000	107 per cent
3.	NPK	1,50,409	1,50,409	120 per cent
4.	DAP	1,50,180	1,50,180	119 per cent

In brief, major products of Zuari Agro Chemicals Ltd. are Ammonia, Urea, NPK and DAP. The main raw materials used in the manufacture of the above are naptha, phosphoric acid and muriate of potash.

The I.E.L. Ltd. was incorporated in 1954 at Calcutta. The company subsequently established seven factories at various places in India. The unit situated in Panki Industrial Area of Kanpur is one of them. Urea is the main commodity produced in this unit. Description of production capacity of this unit is as under given below:

Production Capacity of I.E.L. Ltd.

Capacity Per Annum	Licensed capacity in tons	Installed capacity in tons
Upto 1979-80	4,50,000	4,50,000
Since 1980-81	6,75,000	6,75,000

The capacity utilisation has usually been close to 100 per cent except when there are substantial power cuts.

7.2 Description of Manufacturing Process

A brief description of manufacturing process of various products at Zuari Agro Chemicals Ltd. is given below. The flow diagram of various processes is shown in Figure 7.1.

a. Ammonia plant. Ammonia produced at Zuari is consumed by its Urea, NPK and DAP plants. This unit has adopted one of the modern and economical low pressure syntheses process for the production of ammonia. The process is as follows:

In this process, Naptha is desulphurised and reformed with steam to obtain oxides of carbon and hydrogen which is reached into a reformer where air is passed to supply nitrogen required for production of ammonia. In this process, carbon monoxide is formed as a by-product. In order to separate carbon monoxide, it is converted into CO_2 which is absorbed in a solution. The remaining mixture of nitrogen and hydrogen is sent to a compressor in the molar ratio of 1:3 to produce ammonia.

b. Urea plant. The carbon dioxide produced in ammonia plant is regenerated by heating the solution in which it is absorbed for separation. Carbon dioxide and ammonia are compressed and then fed into urea synthesis reacter along with carbonate solution. The urea solution thus obtained is sent for crystallisation. The urea crystals are further dried and melted in a melter. Urea pills are formed while descending through the tower and are further cooled by upcoming air and finally sent for storage.

c. DAP plant. DAP is produced by neutralising phosphoric acid by ammonia. Slurry thus obtained is further ammoniated to convert it in granular forms. The granulated DAP is further dried and screened to separate the required product size while under size and over size granules are crushed into dust which is recycled back for making granules. Dust laden gases and other overhead gases are recycled back to the process.

d. NPK plant. NPK is manufactured in two steps. Step one includes neutralisation of phosphoric acid by ammonia while in step two the slurry produced in step one of the process is ammoniated again to make granules out of it. While doing this potash and urea are added. It is further dried and screened to separate the required size of granules. Gases laden with dust are recycled back to the process.

As mentioned earlier, the main product of I.E.L. Ltd. is Urea. Since ammonia is a major input for production of Urea, this factory has an ammonia plant too. However, information about the process used in the production of both urea and ammonia is not available.

7.3 Consumption of Water by Use and Source

Corporation water is the only source of water for Zuari Agro Chemicals Ltd. Daily consumption of water of this unit is about 22,000 kl. The rates charged by corporation for water supply is Rs 2.50/kl. The water supplied by corporation is further treated for cooling and boiler feed. The quality specifications for above uses in this plant are such that treatment cost of raw water is quite substantial. The treatment of raw water for boiler feed costs Rs 15/kl. while treatment of raw water for cooling purposes costs Rs 8/kl. Chemical analysis of raw water is given in Table 7.1. Tables 7.2 and 7.3 represent the specifications of boiler feed water and cooling water respectively.

In I.E.L. Ltd. total water consumption is 6,30,000 kl. per month. Out of which about 30,000 kl. is drawn from tubewells and the rest is taken from Lower Ganges Canal. The Lower Ganges Canal division charges 2.5 paise/kl. of water drawn from the canal. Besides this, the factory incurs cost in drawing water from canal and tubewell. Quality specifications of water by use are not available for this unit.

7.4 Effluent Generation and Its Treatment

Production of fertilisers leads to release of effluents into the environment in solid, liquid and gaseous forms. The quantity of effluent discharged from fertiliser plant will vary widely from process to process and factory to factory. The effluent may contain a variety of substances depending upon the choice of feedstock, process used, and the product. In general, discharge of fertiliser plant would contain effluents bearing ammonia, urea, oil, chromate, phosphate, floride and arsenic effluents. Various pollutants emanating from fertiliser plants are listed in Table 7.4. The Central Board of Prevention and Control of Water Pollution has laid down Minimal National Standards for the fertiliser industry. The State Boards follow these standards or make the same more stringent if the situation demands but these standards cannot usually be relaxed by them. The Minimum National Standards (hereafter MINAS) for effluent water from various plants are listed in Tables 7.5, 7.6 and 7.7.

Although pollution control in fertiliser industry is a complex problem but if stringent measures are taken 100 per cent recycling of effluent or waste water can be achieved.

The Zuari Agro Chemicals Ltd. having a liquid effluent generation of the magnitude of 550 kl./hr. has implemented a number of measures of pollution abatement. The major schemes implemented are listed in Annexure I of this Chapter. As a result of these measures, it has been possible not only to meet the standards prescribed by the Pollution Control Board but also achieve almost 100 per cent recycling of liquid effluent, i.e., reduce effluent discharge to zero. Technical information on effluent treatment processes is not available. However, flow diagrams of effluent system and effluent recycling system are presented in Annexure II and Annexure III to this Chapter respectively.

Effluents generated in I.E.L. Ltd. fall into two main categories, namely, Nitrogenous effluents and Non-Nitrogenous effluents. While nitrogenous effluents contain ammonia and urea, the non-nitrogenous effluents contain oil, grease and suspended solids. However, the major pollutant released by the factory is ammonical nitrogen, whose outflow is about 600 kg./hour. Effluents discharged by process house are treated through various processes described below. The quantity of waste water finally discharged into the river and sewage is about 6,000 kl./per day. Chemical analysis of which reveals that it meets MINAS.

Though this factory is implementing water pollution control measures since 1968-69, they were found to be insufficient to meet the pollution standards of U.P. Pollution Control Board. In view of this the I.E.L. Ltd. decided to incorporate additional measures in the form of both process changes and end of pipe treatment, to control water pollution. These measures include acquisition of Ebara Pumps, Surface Condensers, Hydrolyser Stripper and treatment of front-end effluents which emanate from ammonia plants. The above measures refer to control and treatment of nitrogenous effluents. Treatment of non-nitrogenous effluents consists of additional measures described later in this Section.

I. Measures for Treatment of Nitrogenous Effluents

a. Ebara pumps. These are multistage centrifugal carbonate pumps. Their induction in the old urea plant has resulted in reduction of effluents by 6 kl. per plant.

b. Surface condensers. Surface condensers system has eliminated the use of crystalliser cooling tower thereby completely eliminating the source of effluents contaminated with ammonia and urea.

c. Hydrolyser stripper. In this plant, the urea present in the effluents undergoes a process of hydrolysis at high pressure and temperature where ammonia is stripped off in a stripping column. Another operation in the plant is oil separation with the help of separators. The residual water from this plant is proposed to be used as cooling water make up.

d. Front end effluent treatment scheme. Effluents emanate from the front ends of three ammonia plants at the rate of about 30 kilolitres per hour. They primarily contain about 1,500 ppm. of ammonia, 4,000 ppm. of CO_2 and 500-1500 ppm. of methanol. Presence of methanol prevents combined treatment of effluents emanating from urea and ammonia plants as methanol interferes in the treatment process of urea done in hydrolyser stripper. Therefore, separate scheme of treatment for ammonia plant effluents has been adopted. In this scheme, first step is fixation of ammonia content by adding hydrochloric acid. Acidified effluent is then led to LDPE lined solar ponds where it is left for evaporation to extinction.

II. Treatment of Non-Nitrogenous Effluents.

This category of effluents essentially consists of oil, grease and suspended solids. To remove them various kinds of separators, filters and settling pits are used. Treated water is discharged into municipal sewage system.

7.5 Estimation of Cost of Supply of Water

The Zuari Agro Chemicals Ltd. takes water from municipal supply which costs Rs 2.50 per kl. while I.E.L. Ltd. uses both tubewell water and canal water. The costs incurred by I.E.L. Ltd. in drawing water from both sources have been estimated. The method of estimation used as well as data requirements for estimation of tubewell water are same as described in Chapter 3. Cost flows of resource cost, commercial cost and social cost of tubewell water are given in Table 7.8. However, to estimate the costs of drawing water from canal, data on the fixed and operation cost of the pump set, etc., is required, which however could not be made available by the factory. We have, therefore, used engineering norms to generate this data. Table 7.9 provides break up of the fixed cost of supplying canal water to the factory. Cost flows of water drawn from canal are presented in Table 7.10. The estimates of all the three types of costs of tubewell and canal water are presented in Tables 7.11 and 7.12 respectively.

7.6 Estimation of Pollution Abatement Cost of Water

The pollution abatement measures adopted by both the units surveyed consist of process changes in production and end of pipe treatment. As mentioned earlier, in Zuari Agro Chemicals

Ltd., quantity of effluents discharged has been brought to nil. Therefore, the cost of pollution abatement is estimated per kl. of water consumed by the factory. Cost flows of pollution abatement are given in Table 7.13, while cost estimates of pollution abatement are presented in Table 7.14. Cost flows of pollution abatement for I.E.L. Ltd. are given in Table 7.15 and cost estimate of pollution abatement are presented in Table 7.16.

7.7 Results

a. For Zuari Agro Chemicals Ltd. the estimates of resource cost, social cost and commercial cost of pollution abatement per kl. of water used are Rs 8.24, Rs 13.73 and Rs 32.57 respectively, while for I.E.L. Ltd. the above costs have worked out to be Rs 1.76, Rs 3.03 and Rs 7.16 respectively. In I.E.L. Ltd. the estimates of above costs per kl. of water released are Rs 6.17, Rs 10.60 and Rs 25.05 respectively for r = 0.10 and t = 30.

b. The estimates of resource cost, social cost and commercial cost of tubewell water per kl. are 20 paise, 27 paise and 43 paise respectively for r and t as 0.10 and 15 respectively.

c. The estimates of resource cost, social cost and commercial cost of river water have worked out to be 9 paise, 12 paise and 10 paise respectively. However, this is only cost of drawing water from the river. It is mentioned earlier that the I.E.L. Ltd. has to pay a price to local authorities at the rate of 2.5 paise kl. of water drawn from the river.

TABLE 7.1

RAW WATER : DATE PF ANALYSIS 13/12/1988
(ZUARI AGRO CHEMICALS LTD.)

pH	6.5
Turbidity, ppm	1.0
Silica, (SiO_2, ppm)	7.9
M-alkalinity (ppm as $CaCO_3$)	24.4
Total hardness (ppm as $CaCO_3$)	25.8
Calcium hardness (ppm as $CaCO_3$)	16.5
Chloride (ppm as $CaCo_3$)	13.6
Sulphate (ppm as $CaCO_3$)	1.2
Iron (Fe, ppm)	0.12
Sodium (ppm as $CaCo_3$)	12.9
Potassium (ppm as $CaCo_3$)	0.4
Conductivity (uv/cm)	114
T.D.S. / ppm	85
C.O.D. (mg/$KMnO_4$/1)	0.4

TABLE 7.2

REQUIRED LIMITS OF BOILER FEED WATER
(ZUARI AGRO CHEMICALS LTD.)

Parameters	Units	Value
p^H	–	Neutral Range
Conductivity	Micro mho/cm	Max. 1 at 25°C
TDS	Mg/Litre	Max. 0.25 as $CaCo_3$
Silica (total)	Mg/Litre	Max. 0.03 as SiO_2
Copper	Mg/Litre	Max. 0.02 as Cu
Iron	Mg/Litre	Max. 0.03 as Fe
Oil	Mg/Litre	0
Total Hardness	Mg/Litre	Nil

TABLE 7.3

COOLING WATER - MONTHLY VARIATIONS
(ZUARI AGRO CHEMICALS LTD.)

	CT_1	CT_2
p^H	6.2 - 7.0	5.6 - 8.0
Phosphate, ppm	9.2 - 17.1	8.6 - 17.7
Total-PO_4,ppm	14.6 - 32.9	16 - 28.5
Chloride, ppm	60.8 - 118	72.1 - 134
Turbidity, ppm	3.7 - 13.8	2.8 - 17
Conductivity (uv/cm)	1240 - 2620	2050 - 4650
T.D.S., ppm	1092 - 1645	1945 - 2979
NH_3-N, ppm	9.0 - 46.0	16.3 - 112
Urea-N, ppm	-	-
Silica, ppm	41 - 112	64.9 - 136
Fe, ppm	0.13 - 0.48	0.53 - 1.2
SO_4,ppm	-	-
Total hardness, ppm as $CaCO_3$	159 - 329	295 - 444
Ca-hardness, ppm as $CaCO_3$	105 - 190	178 - 256
M-alkalinity, ppm	3.0 - 21.7	3.9 - 23.9
Cycle of concn.	3.6 - 12.4	5.4 - 15.9
Corrosion Rate, mils/y	2.6	5.2

TABLE 7.4

FERTILISER INDUSTRY EFFLUENTS AND THEIR SOURCES

	Plants	Solids	Liquid
1.	Ammonia	1. Spent Catalyst	1. Process condensate containing 400-1000 ppm ammonical nitrogen depending on process and catalyst condition.
		2. Arsenic laden sludge from vetrocooke filters generated in the CO_2 removal section	2. MEA, As_2O_3,K_2CO_2 Caustic Soda
		3. Used tower packings especially those contaminated with arsenic arising from CO_2 removal section in Ammonia Plants	3. Blow down of carbon slurry tank in partial oxidation process
		Continous	
		1. Carbon slurry in gas generating section of fuel oil based Ammonia Plants	
		2. Ash slurry in gas generating section of coal based Ammonia Plants	
2.	Urea	Nil	Leakages from pump glands and washings of equipment like CFD and the pneumatic section of the plant
3.	NPK	1. Slurry from draining and washing of equipment 2. Solids arising from spillages	Leakage from pump glands and washing
4.	DAP	1. Slurry from draining and washing of equipment 2. Solids arising from spillage	Leakages from pump and washing
5.	Sulphuric acid and SO_3 oleum	Molten sulphur sludge from filters and from pits	Acidic effluent neutralised with lime
6.	SSP, TSP and Nitrophosphate plants	Nil	Phosphates and fluorides

TABLE 7A (Contd.)

7.	Phosphoric acid plants	Phospho-gypsum about 4.5-5.0 tons/ton of P_2O_5	Acidic effluent neutralised with lime
8.	Ammonium sulphate plant	Chalk($CaCO_3$) slurry 1.0 tons/ton of ammonium sulphate	
9.	Nitric acid plant	Nil	
10.	Power station	Ash slurry in coal fired boilers	oil spillages from fired boilers
11.	Water treatment	1. Used resins 2. Sludge originating from clarifiers in water pre-treatment units 3. Spillages of products in conveying and bagging sections 4. Sludge generated while neutralising alkaline plant effluent with H_2SO_4 acid or whilst neutralising phosphoric acid using lime	Acidic and alkaline liquids arising from ion exchanges after bed regeneration and rising
12.	Effluent treatment	1. Sludge generated whilst neutralising phosphoric acid plant effluent with lime 2. Sludge generated in chromate removal units when chromate treatment is used in cooling towers.	Nil
13.	Cooling water system		Chromates, phosphates biocides depending on the treatment

Source: B.S. Swaminathan, Pollution Control in Fertiliser Industries, in Short-Term course on Pollution Control for Process Industries, I.I.T New Delhi, 1988.

TABLE 7.5

MINAS FOR EFFLUENT WATER
NITROGENOUS (STRAIGHT) FERTILIZER INDUSTRY

PARAMETER	CONCENTRATION NOT TO EXCEED, mg/l (Except pH)
pH	6.5 to 8.0
Ammonical Nitrogen	50
Total Kjeldhl Nitrogen (TKN)	100*
Free ammonia	4
Nitrate Nitrogen	10**
Cyanide (as CN)	0.2
Vanadium (as V)	0.2
Arsenic (as As)	0.2
Hexavalent chromium	0.1***
Total Chromium	2.0***
Suspended solids	100
Oil and Grease	10

Note: * For the plant to be installed, thermal urea hydrolyser stripper should be designed to give effluent of TKN less than 25 mg/l.

** Nitrate nitrogen for calcium ammonium nitrate (CAN) and Ammonium Nitrate (AN) producing plants should not exceed 20 mg/l

*** The limits of hexavalent chromium and total chromium should be conformed at the outlet of chromate removal unit. This implies that in the final treated effluent total and hexavalent chromium shall be lower than prescribed herein.

Source: Same as in Table 4.

TABLE 7.6

MINAS FOR EFFLUENT WATER
PHOSPHATIC (STRAIGHT) FERTILIZER INDUSTRY

PARAMETER	CONCENTRATION NOT TO EXCEED, mg/l (Except pH)
pH	7.0 - 9.0
*Fluorides as F	10
Phosphate as P	5
** Chromium as Cr - Total	2
- Hexavalent	0.1
Oil and Grease	10
Suspended solids	1000

Notes: * The limit for fluoride shall be conformed at the outlet of fluoride removal unit. This implies that in the final treated effluent fluoride concentration shall be lower than prescribed herein which shall not exceed 1.5 mg/l if receiving water requirement so demand.

** The limits for total end hexavalent chromium shall be conformed at the outlet of the chromate removal unit. This implies that in the final treated effluent, total and hexavalent chromium shall be lower than prescribed herein.

Source: Same as in Table 4.

TABLE 7.7

MINAS FOR EFFLUENT WATER
COMPLEX FERTILIZER INDUSTRY

PARMETER	CONCENTRATION NOT TO EXCEED mg/l (EXCEPT p^H)
p^H	6.5 to 8
Ammonical Nitrogen	50
Free Ammonical Nitrogen	4
* Total Kjeldhal Nitrogen (TKN)	100
+ Nitrate Nitrogen	10
Cyanide as CN	0.2
Vanadium as V	0.2
Arsenic as As	0.2
** Chromium as Cr - Total	2.0
- Hexavalent	0.1
++Fluoride as F	10
Phosphate as P	5
Oil and Grease	10
Suspended Solids	100

Notes: * For the plants to be installed, thermal urea hydrolyser stripper shall be designed to produce efluent of less than 25 mg/l shall be designed to produce effluent to less than 25 mg/l TKN.

\+ Nitrate nitrogen for ammonium nitrophosphate, calcium ammonium nitrate (CAN) and ammonium nitrate plants shall not exceed 20 mg/l.

** The limits for total and hexavalent chromium shall be conformed at the outlet of the chromate removal unit. This implies that in the final treated effluent total and hexavalent chromium shall be lower than prescribed herein.

++ The limit of fluoride shall be conformed at the outlet of the fluoride removal unit. This implies that in the final treated effluent fluoride concentration shall be lower than prescribed herein which shall not exceed 1.5 mg/l if receiving water requirement so demands.

Source: Same as in Table 4.

TABLE 7.8

COST FLOWS OF PRODUCTION OF TUBEWELL WATER
(I.E.L. LTD.)

(In Rupees)

	Resource Costs	Social Costs	Commercial cost	
A. Fixed Cost			Fixed Cost	240000
1) Machinery and Equipment			15% of Fixed cost	36000
(a) Pipe	33734	77588	Operating cost	120024
(b) Pump	9804	225425		
(c) Fittings	17016	39137	Total	156024
2) Construction			Quantity of water used over a year	360000
(a) Cement	10267	23614		
(b) Bricks	5253	12082	Per Unit market cost of water	0.43
(c) Steel	11215	25795		
3) Labour	4800	20640		
Total	223496	424281		
B. Operating Cost (Monthly)				
1) Maintenance				
(a) Oil	100	150		
(b) Repair	282	282		
2) Fuel	7500	10298		
3) Labour	2100	903		
Total Operating Cost (Annual)	9982X12 =119784	11633X12 =139596		

TABLE 7.9

BREAK UP OF FIXED COST FOR RIVER WATER (I.E.L. LTD.)

1) Machinery & Equipment		39.75%
a) Pipe	24%	
b) Pump	64%	
c) Fittings	12%	
2) Construction		48.5%
a) Cement	40%	
b) Bricks	20%	
c) Steel	40%	
3) Labour		11.75%
Total		100.00%

TABLE 7.10

COST FLOWS OF PRODUCTION OF RIVER WATER (I.E.L. LTD.)

(In Rupees)

		Resource Cost	Social Cost	Commercial cost	
A.	Fixed Cost				
1)	Machinery & Equipment			Fixed Cost	1361320
	a) Pipe	120000	276000	15% fixed cost	204198
	b) Pump	320000	736000		
	c) Fittings	60000	138000	Operating cost	900000
2)	Construction				
				Total	1104198
	a) Cement	217194	499547	Quantity of water used over a year	7200000
	b) Bricks	111111	255555		
	c) Steel	237239	545650	Per unit market cost of water	0.178
3)	Labour	160000	68800		
	Total	1225544	2519552		
B.	Operating Cost (monthly)				
1)	Maintenance				
	a) Oil	6200	9300		
	b) Repair	17500	17500		
2)	Fuel	42000	57666		
3)	Labour	8000	3440		
	Total Operating Cost (Annual)	73700X12 =884400	87906X12 =1054872		

TABLE 7.11

ESTIMATE OF COST OF PRODUCTION OF TUBEWELL WATER (I.E.L. LTD.)

(In Rupees)

Time (T) in years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.23	0.30	0.19	0.25	0.16	0.21	0.14	0.18	0.43
0.10	0.20	0.27	0.17	0.22	0.14	0.19	0.12	0.16	
0.12	0.19	0.25	0.15	0.20	0.13	0.17	0.11	0.14	

TABLE 7.12

ESTIMATE OF PRODUCTION OF RIVER WATER (I.E.L. LTD.)

(In Rupees).

Time (T) in years->		15		20		25		30	
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social Cost	Commercial cost
0.08	0.100	0.135	0.093	0.115	0.083	0.105	0.076	0.095	
0.10	0.098	0.125	0.086	0.105	0.076	0.095	0.069	0.085	0.170
0.12	0.050	0.115	0.079	0.095	0.070	0.085	0.063	0.075	

TABLE 7.13

COST FLOWS OF POLLUTION
(ZUARI AGRO, GOA)

(In Rupees)

	Resource Cost	Social Cost	Commercial cost	
A. Fixed Cost				
1. Land	1000000	1140000	Fixed Cost	36000000
2. Other Fixed Cost			15% Fixed Cost	5400000
i) Machinery and Equipments and piping	14615050	33614615	Operating Cost	7500000
ii) Civil Work				
a) Bricks	2356902	5420875	Total	12900000
b) Cement	4607158	10596462		
c) Steel	5032350	11574406		
iii) Electrical Equipment	2450000	5635000	Quantity of water used per year (Kl.)	396000
iv) Installation	1750000	4025000		
Total	31811460	72006358	Cost per Kl. of water used	32.57
B. Operating Cost				
1) Labour				
a) Skilled	8000	8000		
b) Unskilled	10750	4622		
2) Maintainence				
a) Oil	2258	3837		
b) Repair	7218	7218		
3) Chemicals	200652	300979		
4) Fuel	357563	490934		
Total	586741X12	808372X12		
Operating Cost (Annual)	7040892	9700464		

TABLE 7.14

ESTIMATES OF COST OF POLLUTION ABATEMENT (ZUARI AGRO, GOA)

(In Rupees)

Time (T) in years->	15		20		25		30		
Social Rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	15.55	26.16	12.73	21.09	10.75	17.65	9.37	15.28	
0.10	14.36	24.53	11.57	19.50	9.68	16.18	8.24	13.73	32.57
0.12	13.41	23.23	10.59	18.15	8.76	14.91	7.43	12.60	

TABLE 7.15

COST FLOWS OF POLLUTION ABATEMENT (I.E.L., KANPUR)

(In Rupees)

	Resource Cost	Social Cost	Commercial cost	
A. Fixed Cost				
1) Land	6000000	6840000	Fixed Cost	176200000
2) Other Fixed Cost			15% of Fixed Cost	26430000
i) Machinery	51575757	118624242	Operating Cost	27675228
ii)Pimping	19340909	44484090		
iii) Civil Work			Total	54105228
a) Bricks	11461279	26360942		
b) Cement	22403949	51529082	Quantity of Water released per year (Kl.)	2160000
c) Steel	24471603	56284687		
iv) Electrical Equipment	11914000	27402200	water used per per year (kl)	7560000
v) Installation	8510000	19573000	Cost per Kl. of water released	25.05
Total	155677497	351098243	Cost per Kl. water used	7.13
B. Operating Cost				
1) Labour				
a) Skilled	40000	40000		
b) Unskilled	28750	12363		
2) Maintainence				
a) Oil	36935	55402		
b) Repair	104248	104248		
3) Chemicals	703230	1054846		
4) Fuel	1253156	1720583		
Total	2152476X12	2971789X12		
Operating Cost (Annual)	=25829712	=35661468		

TABLE 7.16

ESTIMATES OF COST OF POLLUTION ABATEMENT (IEL, KANPUR)

(per KL of Water)

(In Rupees)

Time (T) in Years	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commerical cost
				WATER RELEASED					
0.08	11.66	20.30	9.46	15.21	7.95	13.50	6.90	11.63	
0.10	10.86	19.20	8.68	15.14	7.23	12.51	6.15	10.59	24.96
0.12	10.22	18.32	8.03	14.23	6.61	11.65	5.59	9.83	
				WATER USED					
0.08	3.34	5.81	2.71	4.64	2.28	3.87	1.98	3.33	
0.10	3.11	5.50	2.49	4.34	2.07	3.58	1.76	3.03	7.16
0.12	2.93	5.25	2.30	4.08	1.90	3.34	1.60	2.82	

ANNEXURE I

ZUARI AGRO CHEMICALS LTD.

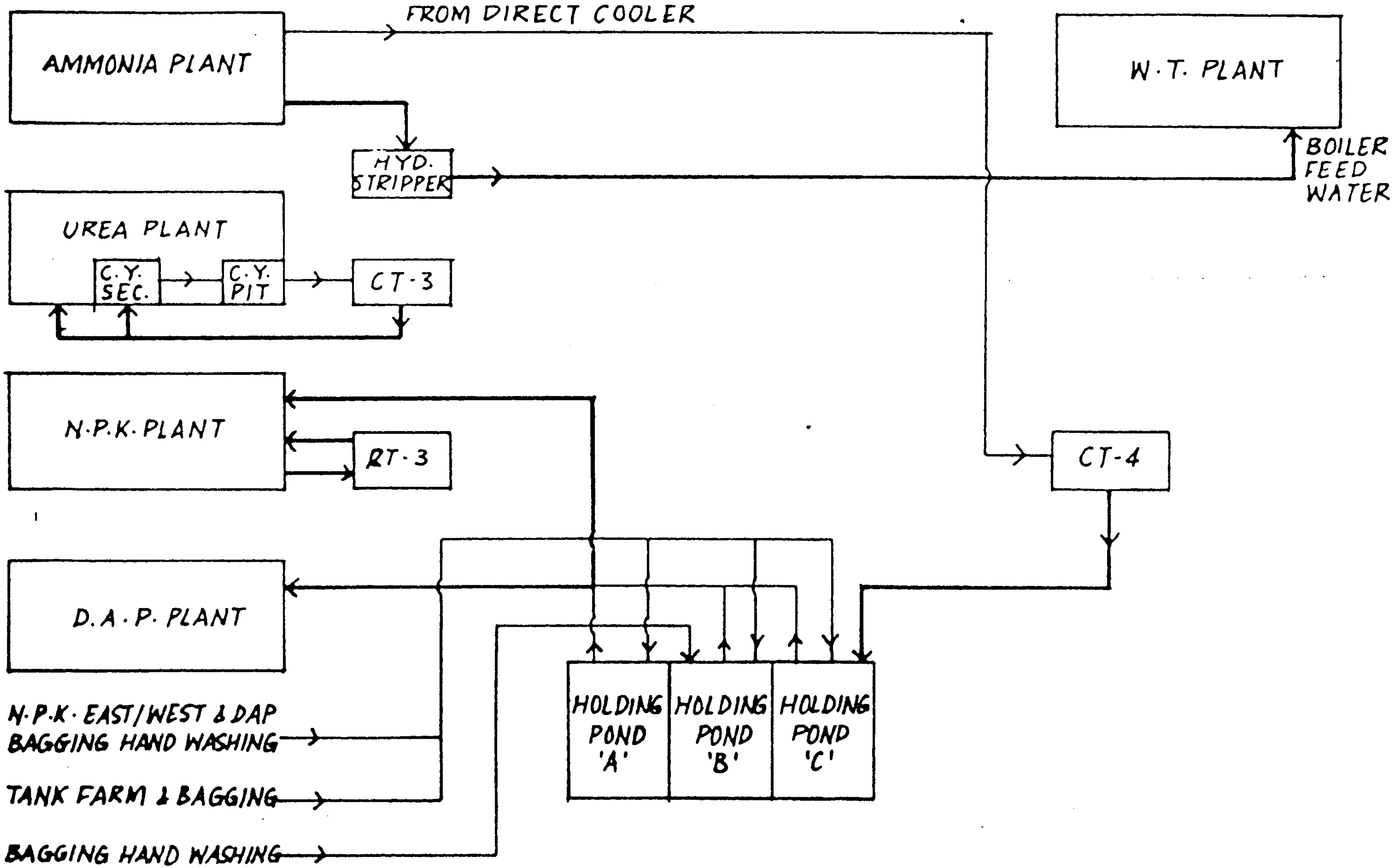
The major schemes implemented are as follows:

- In stallation of separate cooling tower No. 3 for barometric condenser condenser in Urea Plant for the purpose of recycling all the urea plant effluents. (1976) (21.62 lacs).
- Installation of hydrolyser stripper for treating Ammonia Plant process condensate for recycling as Boiler Feed Water. (1977) (1.04 lacs).
- Installation of 4th cooling tower for recycling of CO_2 direct cooler water from Ammonia Plant. (1985) (20.82 lacs).
- Change-over of CO_2 removal system in the Ammonia Plant from the vetrocoke to Benefield System. (1975) (97.77 lacs).
- Recycling of backwash water from the sand filter in Water Treatment Plant.
- Installation of piped headers, lining of various drains with acid proof bricks lining, laying of epoxy painted metal drains to avoid problems of seepage (1977-82) (1.51 lacs).
- Relocation of complete effluent treatment plant with better lining materials (1983) (17.5 lacs).
- A number of schemes for recycling of effluent in various plants such as urea wash water recyling tank in the Urea Plant, recovery tank in NPK Plant and cooling water recyclingg tank in Power Plant. (1979 -1982) (1.15 lacs).
- Installation of three holding ponds for the purpose of storing the effluents incase of upsets. This water is also being recycled to DAP and NPK Plants,. (1985) (15.25 lacs).
- Installation of Guard Pond for hodling of all the effluents in case of total upsets. (1985) (8.0 lacs).
- Installation of diffuser in the final effluent discharge line in the sea for better dispersion and dilution at the discharge point. (1982) (12.55 lacs).

ANNEXURE II

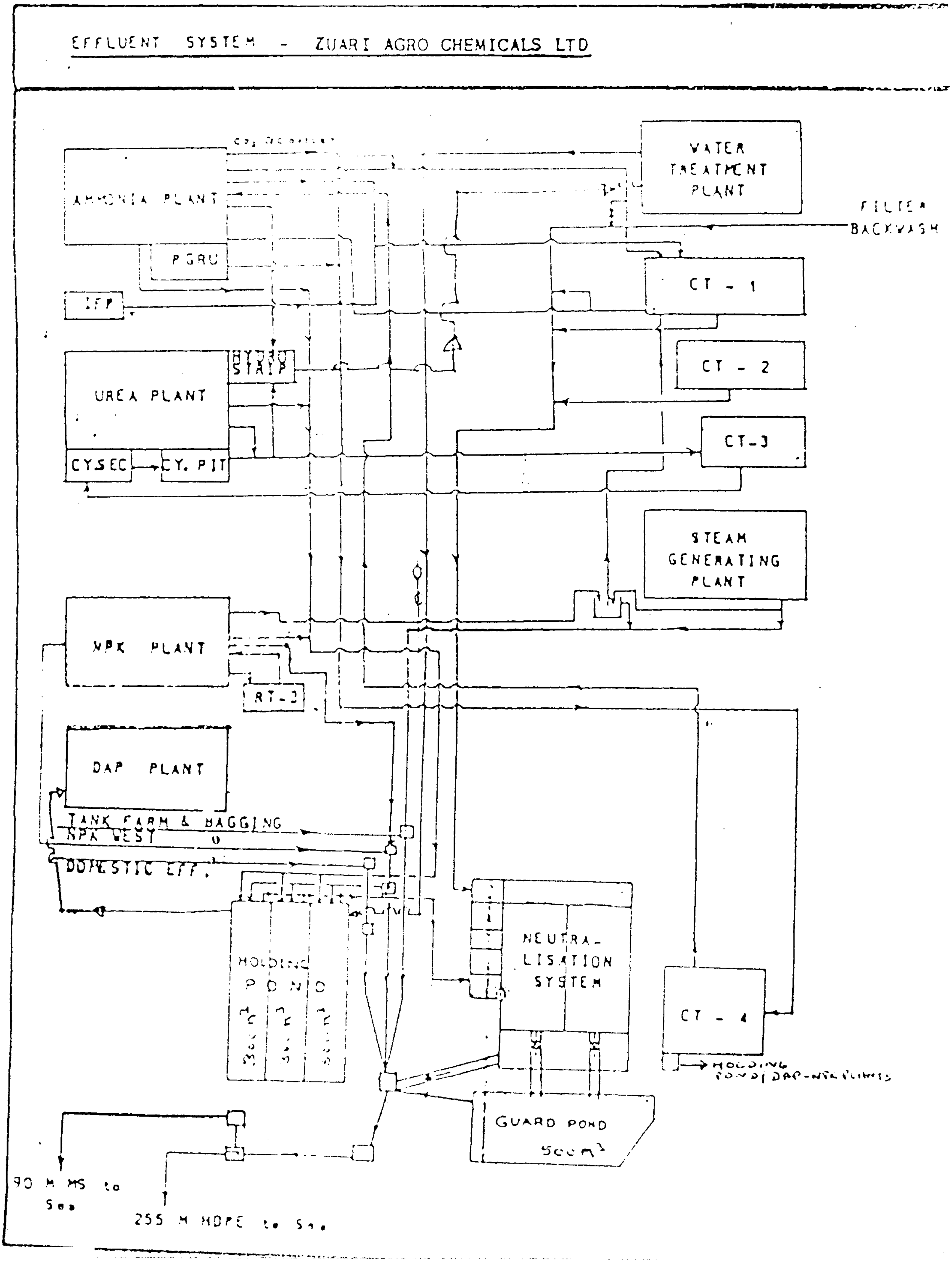
EFFLUENT RECYCLING SYSTEM SCHEMATIC FLOW DIAGRAM

ZACL



ANNEXURE III

EFFLUENT SYSTEM - ZUARI AGRO CHEMICALS LTD



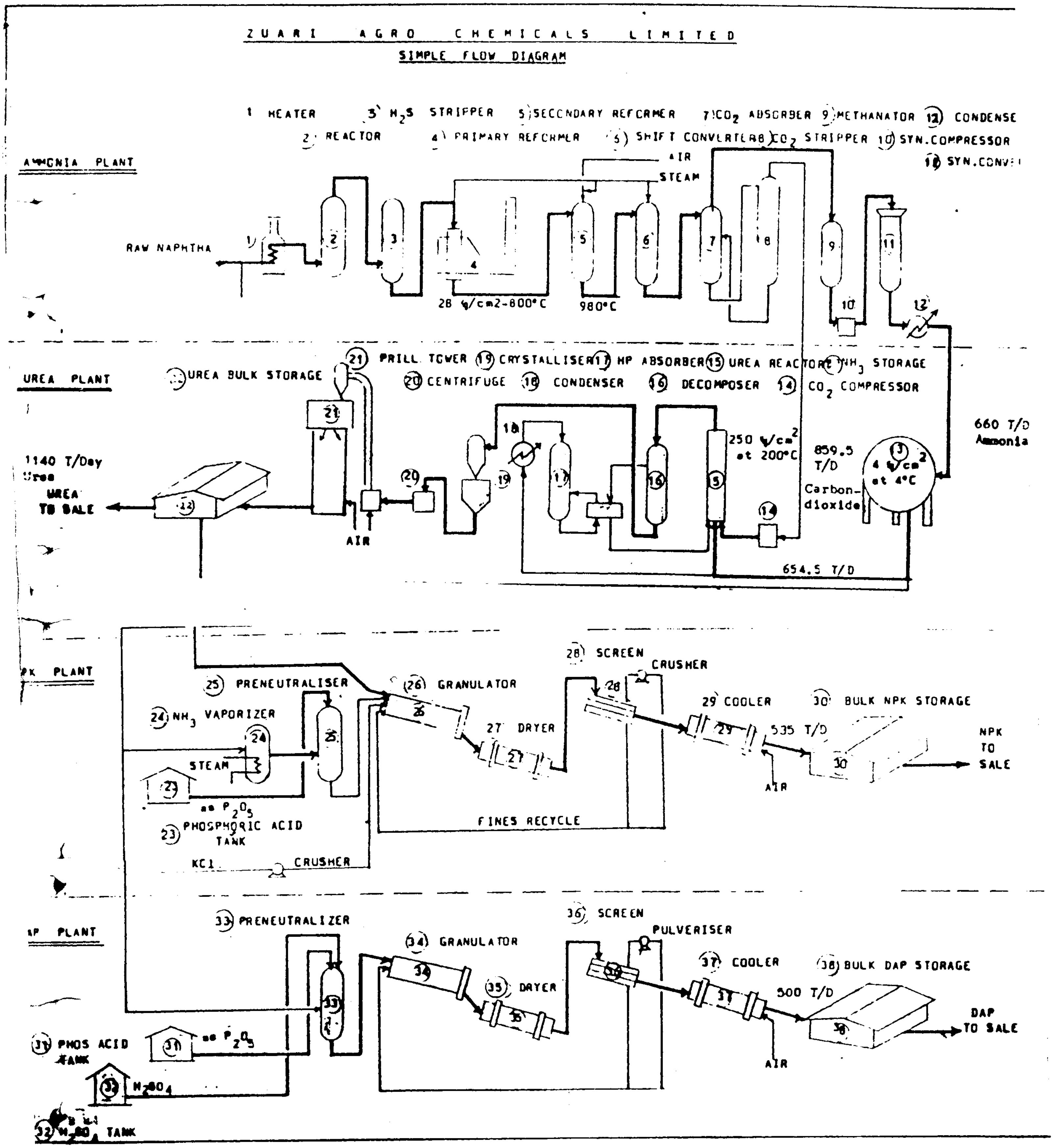

ZUARI AGRO CHEMICALS LIMITED
SIMPLE FLOW DIAGRAM
1 HEATER
2 REACTOR
3 H2S STRIPPER
4 PRIMARY REFORMER
5 SECONDARY REFORMER
6 SHIFT CONVERTER
7 CO2 ABSORBER
8 CO2 STRIPPER
9 METHANATOR
10 SYN.COMPRESSOR
12 CONDENSE
AMMONIA PLANT
RAW NAPHTHA
AIR
STEAM
28 kg/cm2-800°C
980°C
UREA PLANT
UREA BULK STORAGE
21 PRILL TOWER
19 CRYSTALLISER
17 HP ABSORBER
15 UREA REACTOR
NH3 STORAGE
20 CENTRIFUGE
18 CONDENSER
16 DECOMPOSER
14 CO2 COMPRESSOR
660 T/D Ammonia
1140 T/Day Urea
UREA TO SALE
AIR
250 kg/cm2 at 200°C
859.5 T/D Carbon-dioxide
4 kg/cm2 at 4°C
654.5 T/D
NPK PLANT
25 PRENEUTRALISER
24 NH3 VAPORIZER
26 GRANULATOR
27 DRYER
28 SCREEN
CRUSHER
29 COOLER
30 BULK NPK STORAGE
535 T/D
NPK TO SALE
AIR
STEAM
as P2O5
23 PHOSPHORIC ACID TANK
FINES RECYCLE
KCl
CRUSHER
DAP PLANT
33 PRENEUTRALIZER
34 GRANULATOR
35 DRYER
36 SCREEN
PULVERISER
37 COOLER
38 BULK DAP STORAGE
500 T/D
DAP TO SALE
AIR
31 PHOS ACID TANK
as P2O5
H2SO4
32 H2SO4 TANK

Figure 7.1

CHAPTER VIII

VANASPATI INDUSTRY

8.1 Introduction

Vanaspati is an important food products supplying industry in India. The main raw materials used in the manufacture of vanaspati are edible vegetable oils, such as groundnut oil, cotton seed oil, sesame oil, etc.

Like other industries vanaspati industry also consumes a fairly large quantity of water, a part of which is discharged with impurities in the form of BOD, COD, oil and grease, nickel and suspended solids. To identify the water requirements and effluent generation in this industry, it is necessary to further investigate individual units in vanaspati industry. Two units of vanaspati have been investigated for this purpose. Both the units are located in the Gangetic basin. One of them is Motilal Padampat Udyog Ltd. situated in Kanpur while the second is a Vegetable Products producing unit situated in Calcutta. Both the units manufacture vanaspati.

8.2 Manufacturing Process

Vanaspati manufacturing is basically conversion of vegetable oils into hydrogenated fats. Processing of vegetable oil is made up of several stages, namely, refining of raw oil, hydrogenation, re-refining and deodorisation.[1] The quality of final product as well as pollution load would depend on how well and elaborately each of the process is performed. Figure 8.1 gives a flow diagram of the manufacturing process.

(i) Refining of oil. All raw oils contains several impurities, such as free fatty acids, gums, colouring matter, etc. Free fatty acids are the most undesirable elements as they interfere in the process of hydrogenation and also have a disagreeable odour. In refining process free fatty acids are removed. In these units this is done using caustic alkali. To remove the colour content in oil, it is bleached by absorbing it on the surface of bleaching earth or a mixture of bleaching earth and activated carbons. In case some colouring matters are left, further decolourisation is done to remove them during the process of hydrogenation.

(ii) Hydrogenation. After bleaching, the next stage is hydrogenation of oil. In this process hydrogenator is charged with pre-refined oil and catalyst, and the system is heated by steam in coils. Hydrogen gas is introduced into the vessel and the heating is increased to about 160° - 180°C. After the oil charge has been hydrogenated to the desired melting point, it is cooled carefully and then filtered to remove the catalyst.

(iii) Refining of Hydrogenated Oils. As the oil is heated upto a high temperature during the process of hydrogenation this results in slight increase in the percentage of fatty acids.

1. Mathur, M.M., Vanaspati Industry in India, Ph.D. Thesis submitted to University of Agra, 1971.

Further the filtered oil carries with it very small quantities of nickel which is used during the process of hydrogenation. To produce a good quality of Vanaspati it is considered very essential that the filtered hydrogenated oil should be refined again so as to neutralise and bleach it further before the oil is passed on to the next process of production of vanaspati, viz., deodorisation.

(iv)Deodorisation. The process of alkali refining of the vegetable oil and bleaching results in removal of some of the odours contained in the oil. But there are some flavouring substances which are not removed during the process of alkali refining and bleaching. It is for removing these left overs of flavouring substances that the process of deodorisation is required.

Deodorisation is done by distillation in a current of steam in vacuum and at temperatures between 150° to 250°C. In this process even very small quantities of free fatty acids left in oil are removed and very small quantities of leftovers of colouring matters are also removed.

8.3 Water Consumption and the Cost of Production of Water

Source of water for both the units surveyed is own tubewells. Daily consumption of water in Motilal Padampat Udyog Ltd. is about 790 Kl. Out of which 290 Kl. is consumed in industrial use and the rest in domestic use. In Vegetable Products unit of Calcutta, consumption of water in industrial use is 280 Kl. per day. Using this information, we have made estimates of the number of tubewells required and also the fixed and operation cost of tubewells. Cost flows of cost of water are presented in Tables 8.1 and 8.2 for Motilal Padampat Udyog Ltd. and Vegetable Products respectively. The cost of water has to be calculated using methodology mentioned in Chapter 3. Table 8.3 displays the estimates of cost of water for Motilal Padampat Udyog Ltd. The resource cost, social cost and commercial cost estimates of water are Rs 0.260, Rs 0.340 and Rs 0.54 respectively for i = 0.10 and T = 15 years. Table 8.4 presents estimates of cost of water for Vegetable Products, Calcutta. It can be seen from the above table that there is a significant difference in the cost of tubewell water between the two Gangetic regions, viz., Kanpur and Calcutta. The resource cost of production of water for Calcutta unit is Rs 0.44/Kl. while it costs only Rs 0.26 to draw a Kl of water from Kanpur. For given values of r=0.10 and T=10 years the resource cost, social cost and commercial cost of water for vegetable products is 55 paise,, 76 paise and 91 paise respectively.

8.4 Estimation of Cost of Pollution Abatement

The average total quantity of industrial effluent discharged in a day is about 50 KL in Motilal Padampat Udyog Ltd. In the case of Vegetable Products, quantity of industrial effluent is not available separately, however, average total quantity of waste water (including domestic) discharged in a day is about 110 Kl. The pollutants released by both the factories are common. Main pollutants are suspended solids, sulphuric acid which has the effect of increasing BOD and COD, nickel, and some organic constituents of oils.

Both the units have chosen the end of pipe treatment method to control-pollution. In addition to this In-plant control measures have also been taken. It is mentioned earlier that the major by-product of vanaspati industry is soap. Process of removing free fatty acids from raw oils is such that lot of oil content is present in the raw soap. In order to give a quality to soap it is necessary to remove oil content in it. Oil is removed by washing soap with water. This water containing oil used to be discharged as waste water until oil separators were acquired by the units surveyed. Thus with the help of oil separators, these units not only reduce the pollution load but also benefit from oil recovered in this process.

End of pipe treatment technology adopted by these units consist of both primary and secondary treatment process. Primary treatment is a simple physico-chemical process described in earlier chapters while secondary treatment is a biological process where some bacteria are developed which help in cleaning the waste water by eating-up organic matters.

Cost of pollution abatement is estimated using methodology described in the earlier chapters. Tables 8.5 and 8.6 present cost flows of pollution abatement for Motilal Padampat Udyog and Vegetable Products respectively. Cost estimates of pollution abatement for the above units are given in Tables 8.7 and 8.8. Table 8.7 reveals that resource cost of pollution abatement per Kl. of water released is Rs 4.41 while social cost is Rs 8.19 when, r = 0.10 and T = 30 years. For Vegetable Products resource cost of pollution abatement per Kl. of water released worked out to be Rs 1.66 and social cost Rs 2.80, (see Table 8.8), which is much lower compared to the cost of pollution abatement for Motilal Padampat Udyog Ltd.

TABLE 8.1

COST FLOWS OF PRODUCTION OF WATER (MOTILAL PADAMPAT-TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	240000
a. Pipe	33734	77588	15 per cent of Fixed cost	36000
b. Pump	98011	225425	Operating cost	117024
c. Fittings	17016	39137	TOTAL	153024
2. Construction			Per unit market cost of water	0.538
a. Cement	10267	23614		
b. Bricks	5253	12082		
c. Steel	11215	25795		
3. Labour	48000	20640		
TOTAL				
B. OPERATING COST (MONTHLY)				
1. Maintenance				
a. Oil	100	150		
b. Repair	281	281		
2. Fuel	7250	9954		
3. Labour	2100	903		
TOTAL	9731	11288		
TOTAL ANNUAL COST	116772	135459		

TABLE 8.2

COST FLOWS OF PRODUCTION OF WATER
(VEGETABLE PRODUCTS-TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	150000
a. Pipe	21084	48493	15 per cent of Fixed cost	22500
b. Pump	61257	140891	Operating cost	69012
c. Fittings	10635	24460	TOTAL	91512
2. Construction				
a. Cement	6417	14759	Per unit market cost of water	0.91
b. Bricks	3283	7551		
c. Steel				
3. Labour	30000	12900		
TOTAL	139685	265175		
B. OPERATING COST (MONTHLY)				
1. Maintenance				
a. Oil	49	73		
b. Repair				
2. Fuel	4500	6178		
3. Labour	1050	451		
TOTAL	5740	6843		
TOTAL ANNUAL COST	68880	82116		

TABLE 8.3

ESTIMATES OF COST OF PRODUCTION OF WATER (MOTILAL PADAMPAT-TUBEWELL)

(In rupees)

Time (T) in Years ->	15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.287	0.372	0.240	0.307	0.205	0.261	0.180	0.229	
0.10	0.260	0.340	0.213	0.277	0.180	0.233	0.154	0.198	0.538
0.12	0.238	0.315	0.191	0.250	0.159	0.208	0.135	0.177	

TABLE 8.4

ESTIMATES OF COST OF PRODUCTION OF WATER VEGETABLE PRODUCTS-TUBEWELL)

(In rupees)

Time (T) in ->	10		15		20		25		30		
Social Rate of Discount	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Commer-cial cost
0.08	0.596	0.808	0.484	0.642	0.404	0.530	0.345	0.450	0.3030.394		
0.10	0.558	0.764	0.438	0.588	0.359	0.477	0.304	0.401	0.260	0.342	0.910
0.12	0.524	0.723	0.402	0.544	0.322	0.432	0.268	0.359	0.228	0.305	

TABLE 8.5

COST OF POLLUTION ABATEMENT (MOTILAL PADAMPAT)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land			Fixed cost	1825000
2. Other fixed cost	125000	142500	15 per cent of fixed cost	273750
a. Machinery & equipment	508725	1170068	Operating Cost	84996
b. Piping	193182	444319	TOTAL	358746
c. Civil work			Per unit cost of water released	19.93
i. Bricks	114478	263299		
ii. Cement	223776	514685	Per unit cost of water used	1.26
iii. Steel	244428	562184		
d. Electrical equipments	119000	273700		
e. Installation	85000	195500		
TOTAL	1613589	3566255		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	1417	1417		
b. Unskilled	1050	452		
2. Maintenance				
a. Oil	369	554		
b. Repair	1042	1042		
c. Chemicals	1053	1580		
d. Fuels	1877	2577		
TOTAL	6808	7622		
TOTAL ANNUAL COST	81696	91464		

TABLE 8.6

COST OF POLLUTION ABATEMENT (VEGETABLE PRODUCTS)

(In rupees)

	Resource cost	Social cost	Commercial cost		
A. FIXED COST					
1. Land	250000	285000	Fixed cost		800000
2. Other Fixed Cost			15 per cent of fixed cost		120000
a. Machinery & equipment	166666	383332	Operating Cost		250020
b. Piping	62500	143750			
c. Civil work			TOTAL		370020
i. Bricks	37037	85185	Per unit cost of water released	9.34	
ii. Cement	72398	166515			
iii. Steel	79079	181882			
d. Electrical equipments	38500	88550	Per unit cost of water used	3.67	
e. Installation	27500	63250			
TOTAL	733680	1397464			
B. OPERATING COST (MONTHLY)					
1. Labour					
a. Skilled	-	-			
b. Unskilled	3600	1548			
2. Maintenance					
a. Oil	1432	2148			
b. Repair	4043	4043			
2. Chemicals	5050	7575			
3. Fuels	5460	7497			
TOTAL	19585	22811			
TOTAL ANNUAL COST 235020	273732				

TABLE 8.7

ESTIMATES OF COST OF POLLUTION ABATEMENT PER KL. OF WATER (MOTILAL PADAMPAT)

(In rupees)

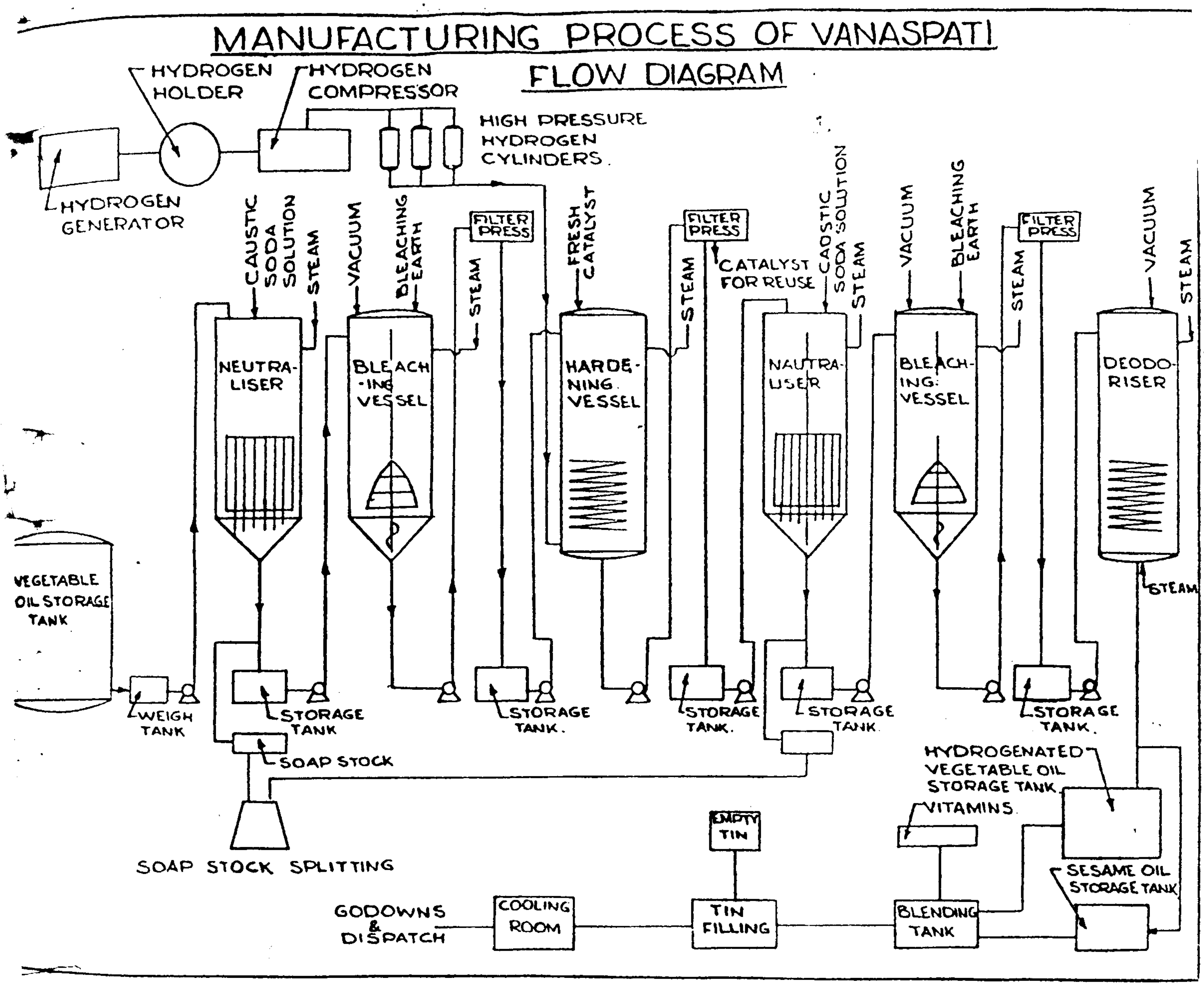
Time (T) in Years ->	15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER RELEASED				
0.80	8.57	16.12	6.70	12.39	5.51	10.07	4.69	8.51	
0.10	8.28	15.78	6.41	12.06	5.23	9.77	4.41	8.19	19.93
0.12	8.03	15.51	6.16	11.78	5.00	9.51	4.20	7.96	
					WATER USED				
0.08	0.54	1.02	0.42	0.78	0.34	0.63	0.29	0.53	
0.10	0.52	0.99	0.40	0.76	0.33	0.61	0.27	0.51	1.26
0.12	0.50	0.98	0.38	0.74	0.31	0.60	0.26	0.50	

TABLE 8.8

ESTIMATES OF COST OF POLLUTION ABATEMENT PER KL. OF WATER (VEGETABLE PRODUCTS)

(In rupees)

Time (T) in ->	10		15		20		25		30		
Social Rate of Discount	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Re-source cost	Social cost	Commer-cial cost
					WATER RELEASED						
0.08	4.64	6.31	3.83	5.15	3.26	4.34	2.85	3.77	2.51	3.31	
0.10	4.24	5.85	3.45	4.70	2.90	3.92	2.48	3.34	2.16	2.90	9.34
0.12	3.92	5.48	3.12	3.32	2.59	3.56	2.20	3.02	1.92	2.62	
					WATER USED						
0.08	1.82	2.48	1.51	2.02	1.28	1.70	1.12	1.48	0.99	1.30	
0.10	1.67	2.30	1.35	1.84	1.14	1.54	0.97	1.31	0.85	1.14	3.67
0.12	1.54	2.15	1.23	1.69	1.02	1.40	0.86	1.18	0.75	1.03	



MANUFACTURING PROCESS OF VANASPATI - A FLOW DIAGRAM.

Figure 8.1

CHAPTER IX

COTTON TEXTILE INDUSTRY

9.1 Introduction

The cotton textile industry is very old in India. There are a number of units manufacturing cotton textile all over the country. Textile industry is a fairly water intensive industry. As practically every manufacturing step is followed by washing. As a result the quantity of water discharged/effluents from process house is likely to be substantial. The total water bill depends on the quantity of water consumed and the cost of effluent treatment to the units depends both on quantum and characteristics of the effluents. A reduction in water consumption would have the effect of lowering water bill as well as the cost of pollution abatement. In order to promote both pollution abatement and pollution control a scheme of incentives/disincentives needs to be designed and implemented. In view of this, estimation of the cost of water supply and the cost of pollution abatement in textile industry is attempted. In order to do this, a survey of five textile units is undertaken, Kanpur city situated in U.P. has a number of textile units of varied nature and capacity. Five of them have been investigated. The names of and products manufactured by these units are indicated in Table 9.1.

Cotton fabric or yarn is made using natural cotton. The total production process of cotton cloth can be divided into two main processes: spinning and weaving and textile processing. A flow sheet of both the processes is presented in Figure 9.1.

It can be seen that some of the units listed in Table 9.1 are manufacturing synthetic cloth in addition to cotton yarn and cloth. These units have recently diversified their production in view of the changes in market demand. Synthetic fibers/cloth also known as Man Made Fibers/cloth is made using natural and synthetic organic polymer.

9.2 Manufacturing Process

The process adopted in general for manufacturing cotton fabric is presented in Figure 9.1. Manufacturing process is almost same in all the units surveyed. Also, the inputs used in production are more or less same, however their quantity and quality varies depending on the capacity and requirements of final products. The process flow diagram presented in Figure 9.1, indicates various stages of production starting from cotton bales to finishing of fabric. However, during the course of discussion with the officials of the units, it was brought out that not often all the processes are carried on simultaneously. Sometimes only grey cloth is produced and sold whereas at other times, depending on the market demand, grey cloth may sometimes be bought from outside and only printing is done in the factory. On account of variation in the quantity of the final product, the quantity of water consumed as well as quantity and characteristics of effluents vary.

9.3 Water Requirements and Cost of Supply of Water

In all the units a major proportion of water requirements is net from water supplied through own tubewells. In general, quantity of raw water consumed per day would be 8 lakh litres for optimally designed cloth production of 80,000 metres per day. On account of variations in final product in the units surveyed, it was found difficult to maintain data on water consumption per unit of yarn or finished cloth. However, data on consumption of water per day/month was made available to us. The cost flows as well as cost estimates of supply of water are made using methodology described in chapter 4. Estimates of cost flows are presented through Tables 9.2, 9.3, 9.4, 9.5 and 9.6, while cost estimates are displayed in Tables 9.7, 9.8, 9.9, 9.10 and 9.11.

9.4. Effluent Generation and Cost of Pollution Abatement

Information regarding effluent generation and pollution load generated by the various units was collected through questionnaires and also through personal discussions. Proportion of effluents released per unit of water consumed varies between 43 per cent to 54 per cent in the case of three units namely; Elgin Mills. In New Victoria Mills it is 78 per cent and for J.K. Cotton Mills it is 30 per cent. The cause for such a large variation in proportion of water released to water consumed seems to be on account of differences in processes as some processes are more water consuming than other.

The other reason for a low discharge could be economical use of water for which there is lot of scope in this industry. For example, cooling water can be recycled for washing and bleaching of both yarn and fabric pollution abatement measures have been taken by 4 units. These are the new victoria Mills, Muir Mills and J.K. Cotton Spinning and Weaving Mills and Elgin

Mills. Remaining one units is also in the process of designing E.T. plant and preparing a feasibility report. All the units have adopted end of pipe treatment method of pollution abatement. Provision for both primary and secondary treatment have been provided. In the primary treatment, process effluent or waste water from the factory is pumped to the equalisation tank where it is retained for about 5 hours to help the effluent coming from various sources in mixing to a uniform quality. The effluent over flowing out of this tank is received in flash mixed tank where alum and slurry of lime is mixed with it. From this tank effluent is pumped into clariflocculator trunk where coagulation of suspended solids takes place. The clear supernatant liquid is sent into aeration tank for secondary treatment. This process consists of biological treatment of effluent received from clariflocculator where micro organisms are added and activated in the presence of oxygen provided by the surface attar. The micro organisms eat up the organic matter thus reducing concentration of pollutants. Aeration process is repeated until desired results are achieved. The contents of aeration tank are taken to secondary clarifier where micro-organisms settle down in the form of suspended solids and the clear supernated liquid overflows out of this tank which is discharged into the sewage.

Presently only in Muir Mill, the E.T. Plant is in full operation . Other three units are either doing primary stage treatment or just equalisation followed by pressure filtration. A flow diagram of effluent treatment plant of Muir Mills is presented in Figure 9.2.

Using the information about investment in E.T.plants, provided by the units surveyed, estimation of the cost of pollution abatement is attempted. The methodology used is, however, same as mentioned in chapter 3. The cost flows of pollution abatement are presented through Tables 9.12, 9.13, 9.14 and 9.15. Estimates of the cost of pollution abatement are displayed through Tables 9.16, 9.17, 9.18 and 9.19. It is apparent from the above tables that there is a big difference between cost estimates of Muir Mills vis-a-vis the other three units. This was expected on account of difference in the treatment levels across factories. The resource cost and social cost of pollution abatement per Kl of water released for Muir Mills is Rs. 2.67, and Rs 4.42, respectively, while the estimates of the above costs per unit of water used are Rs. 1.17, Rs. 1.94, respectively, given that r=0.10 and T = 30 years. The commercial cost per unit of water released is Rs 10.81 and for water used is Rs 4.71.

APPENDIX TO CHAPTER IX

Manufacture of cloth from cotton yarn industry 3 main processes - a) Spinning b) Weaving and c) Dying & Bleaching.

Spinning is mainly done with spidles which not only draw fibres from cloth, but also twist them into yarn. The yarn is then rest to the weaving loom where it is sized and woven. The woven cloth passes through the dying and printing processes.

The variation in spinning techniques machine design are based on fiber length and type of fabric required. The machinery for the assembly of various yarns for weaving for instance, is determined by the tensile strength of the yarn produced and the width and the end use of the product. The printing process calls for highly specialised techniques. The more advanced the technology, the more sophisticated the machinery and equipment is required. Important technological charges in the textile industry have entirely by passed most of the Indian mills. Developments such as semi-high or high production cards, high-speed draw-frames and ring frames, and semi-automatic and automatic looms have been adopted to a limited extent. The technological growth in India has been extremely slow as reflected in the excessive reliance on renovation as opposed to replacement in the modernisation process. Even in more modernised firms in the Indian textile industry, the average level of technology is at the intermediate stage according to international standards. To determine this index, the value of plant and machinery was called out and taken as one of the measures of technological adjustment. As separate figures for plant and machinery were not available for the earlier periods, proportion of investment in plant and machinery for the latest ten years 1964 to 1973 were calculated. These proportions were relatively uniform over the ten year period. Averages were therefore taken as reflective of the normal ratio of investment in plant and machinery to fixed assets. These average percentage were than applied to the figures of fixed assets for the earlier periods to obtain investment in plant and machinery over the three spans. The mills were then ranked.

TABLE 9.1

INDUSTRIAL UNITS AND THEIR PRODUCTS

S.No	Name of Unit	Product
1.	New Victoria Mills, Kanpur	Corey cloth, processed cloth
2.	The Elgin Mills Company Ltd., Kanpur	Cotton Yarn and cloth and Polyester
3.	J.K. Cotton Spinning and Weaving Mills, Kanpur	Cotton and Terry cotton fabrics
4.	Muir Mills, Kanpur	Cotton Yarn and Cloth
5.	Lakshmni Ratan Cotton Mills, Kanpur	Cotton Yarn and fabrics

TABLE 9.2

COST FLOWS OF PRODUCTION OF WATER (MUIR MILLS, TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	120000
a. Pipe	17000	39100	15 per cent of Fixed Cost	18000
(b) Pump	50000	115000	Operating cost	30036
(c) Fittings	7982	18358	Quantity of water used per year (in kl.)	169200
2. Construction				
a. Cement	4936	11352	Cost per kl. of water used	0.28
b. Bricks	2523	5807		
c. Steel	5392	12401		
3. Labour	24000	10320		
TOTAL	111835	212340		
B. OPERATING COST (MONTHLY)				
1. Maintenance Cost				
a. Oil	50	76		
b. Repair	142	142		
2. Fuel	1250	1716		
3. Labour	1050	451		
TOTAL	2492	2385		
TOTAL ANNUAL COST	29909	28624		

TABLE 9.3

COST FLOWS OF PRODUCTION OF WATER (J.K. COTTON - TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	240000
a. Pipe	33734	77588	15 per cent of fixed cost	36000
b. Pump	98011	225425	Operating cost	150024
c. Fittings	17016	39137	TOTAL	186024
2. Construction			Quantity of water used per year (in kl.)	489600
a. Cement	10267	23614		
b. Bricks	5253	12082	Cost per kl. of water used	0.38
c. Steel	11215	25795		
3. Labour	48000	20640		
TOTAL	223496	424281		
B. OPERATING COST (MONTHLY)				
1. Maintenance cost				
a. Oil	100	150		
b. Repair	281	281		
2. Fuel	10000	13730		
3. Labour	2100	903		
TOTAL	12481	15064		
TOTAL ANNUAL COST	149772	180768		

TABLE 9.4

COST FLOWS OF PRODUCTION OF WATER (LAKSHMI RATAN MILLS - TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	240000
a. Pipe	33734	77588	15 per cent of fixed cost	36000
b. Pump	98011	225425	Operating cost	135744
c. Fittings	17016	39137	TOTAL	171744
2. Construction				
a. Cement	10267	23614	Quantity of water used per year (in kl.)	423360
b. Bricks	5253	10282		
c. Steel	11215	25795	Cost per kl. of water used	0.40
3. Labour	48000	20640		
TOTAL	223496	424281		
B. OPERATING COST (MONTHLY)				
1. Maintenance cost				
a. Oil	100	150		
b. Repair	281	281		
2. Fuel	8810	12096		
3. Labour	2100	903		
TOTAL	11291	13430		
TOTAL ANNUAL COST	135492	161160		

TABLE 9.5

COST FLOWS OF PRODUCTION OF WATER (NEW VICTORIA MILLS - TUBEWELL)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	120000
a. Pipe	17000	39100	15 per cent of fixed cost	18000
b. Pump	50000	115000	Operating cost	25032
c. Fittings	7982	18358	TOTAL	43032
2. Construction			Quantity of water used over a year (in kl.)	126000
a. Cement	4936	11352		
b. Bricks	2525	5807	Cost per kl. of water used	0.34
c. Steel	5392	12401		
3. Labour	24000	10320		
TOTAL	11835	212340		
B. OPERATING COST (MONTHLY)				
1. Maintenance Cost				
a. Oil	50	76		
b. Repair	142	142		
2. Fuel	833	1144		
3. Labour	1050	45		
TOTAL	2075	1813		
TOTAL ANNUAL COST	24905	21763		

TABLE 9.6

COST FLOWS OF PRODUCTION OF WATER (ELGIN MILLS - TUBEWELL)

(In Rupees)

			Resource cost	Social cost	Commercial cost		
A.	Fixed Cost				Fixed Cost		480000
(i)	Machinery & Equipment						
(a)	Pipe		67462	155176	15% of Fixed cost		72000
(b)	Pump		196022	450853	Operating cost		585072
(c)	Fittings		34031	78271	Total		657072
(ii)	Construction				Quantity of water used per year (Kl.)		817560
(a)	Cement		20575	47231			
(b)	Bricks		10505	24162	Cost per Kl. of Water used	0.80	
(c)	Steel		22430	51589			
(iii)	Labour	96000	41280				
	TOTAL	446992	848562				
B.	Operating Cost (Monthly)						
(i)	Maintenance						
(a)	Oil		199	299			
(b)	Repair		563	563			
(ii)	Fuel		43752	60071			
(iii)	Labour	4200	1805				
	TOTAL	48714	62739				
Annual Operating Cost		584568	752868				

TABLE 9.7

ESTIMATES OF COST OF PRODUCTION PER KL. OF WATER (MUIR MILLS)

(In Rupees)

Time (T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.145	0.180	0.119	0.145	0.101	0.121	0.088	0.105	
0.10	0.133	0.169	0.108	0.134	0.090	0.111	0.077	0.094	0.28
0.12	0.124	0.160	0.098	0.125	0.081	0.102	0.069	0.087	

TABLE 9.8

ESTIMATES OF COST OF PRODUCTION PER KL. OF WATER (J.K. COTTON MILLS)

(In Rupees)

Time (T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.205	0.269	0.172	0.224	0.147	0.191	0.130	0.167	
0.10	0.185	0.244	0.152	0.200	0.129	0.169	0.111	0.144	0.38
0.12	0.169	0.225	0.136	0.179	0.113	0.149	0.096	0.123	

TABLE 9.9

ESTIMATES OF COST OF PRODUCTION PER KL. OF WATER (LAKSHMI RATAN COTTON MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.218	0.285	0.183	0.236	0.156	0.201	[illegible]	0.176	
0.10	0.200	0.259	0.162	0.211	0.137	0.178	0.117	0.152	0.40
0.12	0.180	0.239	0.144	0.190	0.120	0.158	0.103	0.135	

TABLE 9.10

ESTIMATES OF COST OF PRODUCTION PER KL. OF WATER (NEW VICTORIA MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.172	0.211	0.141	0.168	0.119	0.140	0.104	0.121	
0.10	0.159	0.199	0.128	0.157	0.107	0.130	0.091	0.110	0.34
0.12	0.148	0.190	0.117	0.148	0.097	0.121	0.082	0.102	

TABLE 9.11

ESTIMATES OF COST OF PRODUCTION PER KL. OF WATER (ELGIN MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.44	0.59	0.37	0.50	0.32	0.43	0.28	0.38	
0.10	0.39	0.53	0.33	0.44	0.28	0.37	0.24	0.32	0.93
0.12	0.36	0.48	0.29	0.39	0.24	0.32	0.20	0.28	

TABLE 9.12

COST FLOWS OF POLLUTION ABATEMENT (MUIR MILLS)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost			Fixed Cost	345000
1. Land	125000	142500	15% of fixed cost	517500
2. Other Fixed Cost			Operating Cost	455460
(a) Machinery & Equipments	1007575	2317423		
(b) Piping	377841	869034	Total	972960
(c) Civil work				
(i) Bricks	223905	514982	Per unit cost of water released	10.81
(ii) Cement	437680	1006664		
(iii) Steel	478073	1099568	Per Unit cost of water used	4.74
(d) Electrical equipments	232750	535325		
(e) Installation	166250	71488		
TOTAL	3049074	6556984		
(B) Operating cost (Montlly)				
(a) Labour				
(i) Skilled	2000	2000		
(ii) Unskilled	3000	1290		
(b) Maintenance				
(i) Oil	542	813		
(ii) Repair	1532	1532		
(c) Chemicals	9821	14732		
(d) Fuels	20000	27460		
TOTAL	36895	47827		
Annual Operating Cost	442740	573920		

TABLE 9.13

COST FLOWS OF POLLUTION ABATEMENT
(J.K. COTTON MILLS)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost			Fixed Cost	755000
1. Land	125000	142500	15% of fixed cost	113250
2. Other Fixed Cost			Operating Cost	174348
(a) Machinery & Equipments	190909	439091		
(b) Piping	71591	164659	Total cost	287598
(c) Civil work			Per Kl. cost of water released	1.82
(i) Bricks	42425	97578		
(ii) Cement	82929	190737		
(iii) Steel	90582	208339	Per Kl. cost of water used	0.49
(d) Electrical equipments	44100	101430		
(e) Installation	31500	72450		
TOTAL	679036	1416784		
(B) Operating cost (Montlly)				
(a) Labour				
(i) Skilled	1800	1800		
(ii) Unskilled	2700	1161		
(b) Maintenance				
(i) Oil	183	275		
(ii) Repair	515	515		
(c) Chemicals	3030	4545		
(d) Fuels	5694	7818		
TOTAL	13922	16114		
Annual Operating Cost	167064	193368		

TABLE 9.14

COST FLOWS OF POLLUTION ABATEMENT (NEW VICTORIA MILLS)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost			Fixed Cost	2092000
1. Land	125000	142500	15% of fixed cost	313800
2. Other Fixed Cost			Operating Cost	98352
(a) Machinery & Equipments	596061	1370940		
(b) Piping	223523	514103	Total cost	412152
(c) Civil work				
(i) Bricks	132458	304653	Per Kl. cost of water released	2.86
(ii) Cement	258922	595521		
(iii) Steel	282818	650481	Per Kl. cost of water used	2.28
(d) Electrical equipments	137690	316687		
(e) Installation	98350	226205		
TOTAL	1854822	4121090		
(B) Operating cost (Montlly)				
(a) Labour				
(i) Skilled	1417	1417		
(ii) Unskilled	1050	452		
(b) Maintenance				
(i) Oil	427	640		
(ii) Repair	1205	1205		
(c) Chemicals	1478	2217		
(d) Fuel	2255	3096		
TOTAL	7832	9028		
Annual Operating Cost	93984	108336		

TABLE 9.15

COST FLOWS OF POLLUTION ABATEMENT (ELGIN MILLS)

(In Rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost			Fixed Cost	1885000
1. Land	125000	142500	15% of fixed cost	282750
2. Other Fixed Cost			Operating Cost	94200
(a) Machinery & Equipments	533334	1226668		
(b) Piping	200000	460000	Total cost	376950
(c) Civil work			Per Kl. cost of water released	0.62
(i) Bricks	118518	272591		
(ii) Cement	231674	532850		
(iii) Steel	253055	582027	Per Kl. cost of water used	0.33
(d) Electrical equipments	123200	283360		
(e) Installation	88000	202400		
TOTAL	1672781	3702396		
(B) Operating cost (Montlly)				
(a) Labour				
(i) Skilled	1417	1417		
(ii) Unskilled	1050	451		
(b) Maintenance				
(i) Oil	382	573		
(ii) Repair	1078	1078		
(c) Chemicals	1335	2002		
(d) Fuel	2257	3098		
TOTAL	7519	8621		
Annual Operating Cost	90228	103450		

TABLE 9.16

ESTIMATES OF COST OF POLLUTION ABATEMENT (PER KL. OF WATER RELEASED (MUIR MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	5.08	8.51	4.10	6.76	3.44	[illegible]	2.98	4.83	
0.10	4.75	8.08	3.70	6.35	3.15	[illegible]	2.67	4.43	10.81
0.12	4.49	7.74	3.51	6.00	2.89	[illegible]	2.44	4.13	

WATER USED

0.08	2.23	3.73	1.80	2.96	1.51	2.46	1.31	2.11	
0.10	2.08	3.54	1.66	2.78	1.38	2.29	1.17	1.94	4.74
0.12	1.97	3.36	1.54	2.60	1.27	2.13	1.07	1.79	

TABLE 9.18

ESTIMATES OF COST OF POLLUTION ABATEMENT PER KL. OF WATER RELEASED (NEW VICTORIA MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	1.23	2.33	0.96	1.79	0.79	1.46	0.68	1.23	
0.10	1.19	2.28	0.92	1.75	0.75	1.41	0.63	0.18	2.86
0.12	1.15	2.24	0.89	1.70	0.72	1.37	0.60	1.15	
WATER USED									
0.08	0.99	1.87	0.77	1.43	0.63	1.17	0.54	0.98	
0.10	0.95	1.83	0.74	1.40	0.60	1.13	0.51	0.95	3.27
0.12	0.92	1.79	0.71	1.36	0.57	1.10	0.48	0.92	

TABLE 9.17

ESTIMATES OF COST OF POLLUTIOB ABATEMENT PER KL. OF WATER RELEASED (J.K. COTTON MILLS)

(In Rupees)

Time(T) in Years ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commer-cial cost
0.08	0.89	1.30	0.73	1.05	0.62	0.87	0.54	0.76	
0.10	0.82	1.22	0.67	0.97	0.56	0.80	0.48	0.68	1.82
0.12	0.77	0.15	0.61	0.90	0.50	0.74	0.43	0.62	
WATER USED									
0.08	0.242	0.35	0.20	0.28	0.17	0.23	0.15	0.20	
0.10	0.223	0.32	0.18	0.25	0.15	0.21	0.13	0.18	0.40
0.12	0.21	0.30	0.16	0.23	0.136	0.19	0.115	0.16	

TABLE 9.19

ESTIMATES OF COST OF POLLUION ABATEMENTt PER KL. OF WATER RELEASED (ELGIN MILLS)

(In Rupees)

Time(T) in Years	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.266	0.50	0.208	0.385	0.171	0.313	0.146	0.265	
0.10	0.256	0.488	0.199	0.374	0.162	0.303	0.137	0.254	0.62
0.12	0.249	0.479	0.191	0.365	0.155	0.294	0.130	0.246	
WATER USED									
0.08	0.142	0.267	0.111	0.206	0.091	0.167	0.078	0.141	
0.10	0.137	0.261	0.106	0.200	0.087	0.162	0.073	0.136	0.33
0.12	0.133	0.256	0.102	0.195	0.083	0.157	0.069	0.131	

Cotton bales
↓
Opening & cleaning
↓
Picking
↓
Carding
↓
Combing
↓
Drawing
↓
Ring spinning
↓
Doubling
↓
Yarn bundling
↓
Reeding
↓
Winding
↓
Warping
↓
Sizing
↓
Drawing
↓
Slashing
↓
Weaving
↓
Calendering
↓
Finishing
↓
Grey cloth
↓
To processing

A. Spinning & Weaving

From Weaving Section
→ Grey Cloth
↓
Desizing
↓
Scouring
↓
Bleaching
↓
Mercerising
↓
Dyeing
↓
Printing
↓
Curing
↓
Finishing

B. Textile Processing

Figure 4.1 - Process Flow Diagram of Cotton Textile

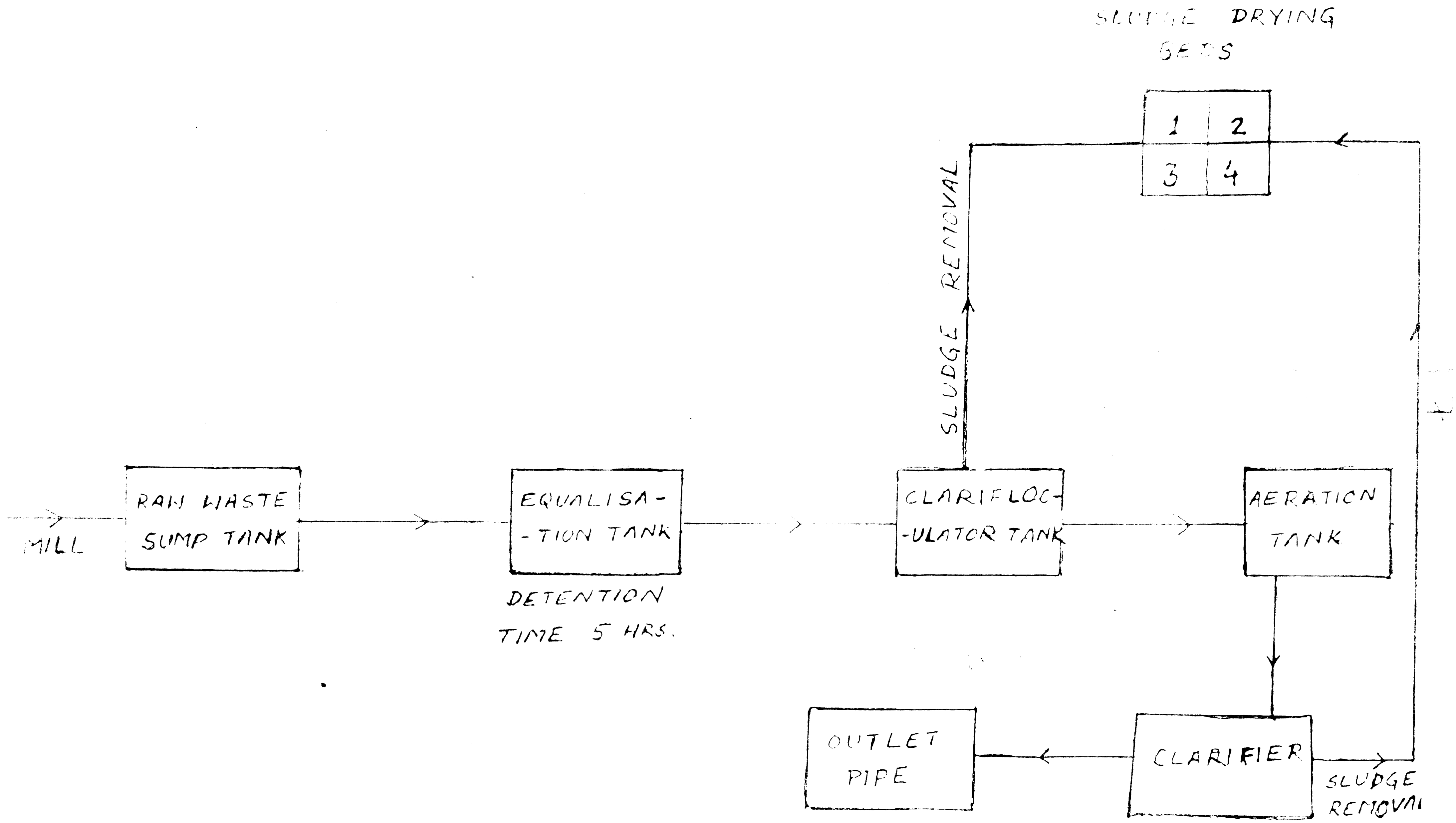


FIGURE 4.2 FLOW DIAGRAM OF EFFLUENT TREATMENT PLANT OF MUIR MILLS

CHAPTER X

CAUSTIC SODA

10.1 Introduction

Caustic soda (sodium hydroxide) is manufactured along with chlorine in an industry generally known as chlor-alkali industry. In 1977, India produced 4.89 lakh tonnes of caustic soda. At that year there were altogether 39 chlor-alkali units consisting of 23 mercury cell chlor-alkali units and 13 diaphragm chlor-alkali units. Although India produces only 2 per cent of world total output still it is an important industry. Many other industries are dependent on it.

In the next section different manufacturing processes are discussed in brief.

10.2 Manufacturing Process

When an electric current is passed between two electrodes, immersed in an electrolyte solution (say, brine) then the electrolyte gets decomposed. The electrodes, solution and containing vessel together is known as electrolytic cell and the process is called electrolysis. Brine, the solution of sodium chloride in water, is described as electrolyte solution. The products of electrolysis are chlorine, sodium hydroxide (caustic soda) and hydrogen.

Mercury Cell Process: The mercury cell has positively charged electrodes (anodes) made from graphite or coated titanium, are fixed to the vessel of the cell. Mercury metal, the negatively charged electrode (cathode), is placed at the bottom of the cell. The vessel is installed at a slight inclination. It is long and has a rectangular cross section. It is made of steel and has arrangement for chlorine outlet, electricity input and for brine and mercury recirculation. Each cell has a secondary cell where mercury flows from the primary cell. In mercury cell when electric current is passed under 3 to 4.5 volt reaction takes place and chlorine gas moves up and is taken out through pipes. The highly reactive sodium liberated at the cathode (mercury) immediately forms sodium-mercury amalgam. It flows to the secondary cell (denuder). It is a small circular chamber packed with loose inert material, through which demineralised water flows. This water reacts sodium-mercury and forms sodium hydroxide (caustic soda) liberating mercury. Mercury is recirculated tothe primary cell to act as cathode again and again. Hydrogen gas is also simultaneously formed. Heat gets generated in secondary cell.

The caustic soda 50 per cent lye which comes out from secondary cell is filtered and sent to the market. It is mercury contaminated. The depleted brine coming out of electrolytic cell also contains some small amount of mercury.

Brine sludge is allowed to settle as filtered. Dried sludge per gram also shows the presence of 2-4 mg. of mercury. The chlorine gas which comes out is cooled by indirect contact of water and then dried by direct contact with concentrated sulphuric acid in towers. Thereafter, it is made free from acid mist, compressed and liquefied by refrigeration. It is substantially free from mercury. Sulphuric acid whose strength falls from 98 per cent to 60 per cent during the chlorine drying operation is discarded. It also contains some mercury. Hydrogen gas which comes out of the secondary cell has high temperature. It is indirectly cooled with water at ambient temperature, then with chilled water. As the gas gets cooled mercury vapour coalesces and forms droplets. These are taped and recovered (See Diagram 10.1).

Diaphragm Cell Process: In this process mercury is not used. The diaphragm is made of asbestos sheet treated with sodium silicate solution. The purpose of the diaphragm is to prevent mixing of chlorine freed at carbon anode and sodium hydroxide at the steel cathode. All diaphragm cells have arrangement of brine entry with overflow arrangement, caustic liquor outflow device and separate ascension pipes for sucking out chlorine and hydrogen. The cell pot is made of mild steel or synthetic material sturdy enough to withstand the operating conditions. Inside the pot a bunch of carbon anodes fixed on a concrete slab is hung. The pot is securely sealed to avoid leakages of chlorine or ingress of air. The cathode is a perforated steel plate around which is fixed the asbestos diaphragm. The liquor leaving the diaphragm cell is weak and has a strength of 11 to 14 per cent sodium hydroxide. it is mixed up with undecomposed salt, chlorate, chlorite and hypochlorite. The liquor is evaporated in triple effect evaporators to a strength of 50 per cent sodium hydroxide containing one per cent salt. Chlorine is dried in the same manner as in mercury cell process. Salt recovered in the evaporators is reused for brine making.

Low electricity consumption and the absence of the hazard of mercury are two advantages of diaphragm cell. The disadvantages are the salt impurity in caustic soda and progressive deterioration of cell efficiency necessitating periodic replacement of carbon and asbestos.

Membrane Cell Process: It replaces the asbestos. The membrane is made of synthetic material from perfluro sulphonic or carboxylic acid. It deflects negatively charged chloride ion. Sodium ions carrying positive charge are allowed to pass through it. it can produce 28 per cent strong caustic soda as compared to 12 per cent in asbestos diaphragm cell.

10.3 Waste Water Generation and Characteristics

The quantity of waste water generated by the mercury cell units in the country is found to vary widely. Mercury bearing waste waters originate from

(i) cell house; (ii) brine plant; (iii) chlorine handling; (iv) hydrochloric acid plant; and (v) hydrogen handling.

The weighted average quantity of mercury bearing waste water is 7 kilolitres per tonne of caustic soda produced. The main concern in the control of water pollution in the industry is the mercury bearing waste water. It has to be segregated and treated for mercury removal before it is allowed to mix with waste water from other sections in the industrial unit. In 1977, average mercury consumption in the industry is calculated at 394 grams per tonne of caustic soda. Large percentage of this gets lost eventually. Table 10.1 gives the mercury loss from a chlor-alkali plant through differerent sources. We can see from the table that the loss of mercury along with the brine purification mud is significant. An immediate measure to be considered is to identify safe dumping place where the mud is disposed of.

Suspended and dissolved substances in the waste water are stable in organic chemicals and do not exert chemical and biological oxygen demand. It is the presence of mercury which is of primary concern. The quality of waste water is subject to temporal variation. In many units caustic soda plant is part of a large industry such as rayon, pulp or textile. In such situations the waste water from the caustic soda unit invariably gets mixed with waste waters from other manufacturing sections, thus providing dilution. As a result, concentration of mercury gets reduced but the mass of mercury remains unchanged. The effect of mercury in the food chain is related to the mass of mercury in the ambient water. Therefore, dilution is no solution to mercury pollution. The characteristics of combined waste water from a mercury cell plant is presented in Table 10.2.

More than one-sixth of chlorine, which remains unutilised is either emitted into the atmosphere or absorbed in lime slurry. In the latter case, bleach liquor containing free chlorine is formed. Its disposal into a stream should not be permitted. Storage of liquor in lagoons may cause ground water pollution. Spillage and leakage of the liquor will introduce suspended and dissolved solids and chlorine in combined waste water emmating from the industry.

The other pollutants that may enter the combined waste water from the mercury cell units are sodium chloride as a result of handling loss in the factory and from brine filter washing, condensed acidic chlorine water containing dissolved mercury and dilute sulphuric acid from chlorine drying unit. Cooling water may carry oil and grease. Overflow from brine purification tank and spillage in the area may also find their way into the effluent. Magnesium chloride from salt washing operation may enter the combined waste stream.

As we have seen inthe foregone discussion that apart from mercury there is no significant pollutant. Correction of pH may be necessary. Many caustic soda units form part of a large complex manufacturing other chemicals based products. In those situations standards for the combined effluent will have to be based on other pollutants but standards herein shall be enforced in regard to mercury at the caustic soda plant limit.

The Minimal National Standard (MINAS) for the caustic soda (mercury cell) unit is presented below:

MINAS for Caustic Soda (Mercury Cell) Industry

Parameter	Concentration, not to exceed, mg./l
pH	5.5 to 9
Total suspended solids (Non-mercuric)	100
Total residual chlorine	1
Mercury in all forms	0.01*

Note: * The concentration should not exceed in the combined effluent from and only from a) Cell house; b) Brine plant; c) Chlorine handling section; d) Hydrochloric acid plant; and e) Hydrogen handling.

The combined effluent from the above cited five sections shall not exced 10 kilolitres/tonne of caustic soda produced.

Based on the limit proposed in MINAS on mercury and mercury bearing waste water flow at 10 kilolitres/tonne of caustic soda, permissible mercury discharge from industrial units of various capacities in the large group are presented below:

Plant Capacity

Tonnes/day	Annual production ('000 tonnes)	Permissible limit on total mercury discharge, gms./day
30	10.0	3
50	16.5	5
100	33.0	10
150	49.5	15
200	66.0	20
250	82.5	25

10.4 Waste Water Treatment Scheme

Inplant control measures to minimise mercury loss in waste water:

(i) The brine in the mercury cell may contain 15 to 50 mg./l of mercury. Therefore, preventive maintenance of fittings vulnerable to leakage and prevention of overflow from brine storage and purification tank is necessary to avoid leakage of brine resulting in mercury reaching the waste water stream.

(ii) Steady supply of electricity should be maintained to ensure non-occurance of mercury-butter phenomenon resulting in high mercury ion in the spent brine.

(iii) Recirculation of cell and end box wash water should be done.

(iv) Prevention of leakage of mercury bearing condensate from the cooled hydrogen line.

(v) Sloping of the cell room floor towards mercury collection pits and rendering the flow smooth with epoxy paint.

(vi) Mercury in waste water emnating from the cell room should be kept in solution by the addition of sodium hypochloride or by any other means.

(vii) Where activated carbon is used, the waste water may be reused for brine preparation.

(viii) Use of metal anodes in cells in place of graphite anodes minimizes the number of times the cells have to be opened and thus reduces mercury loss through vaporisation. It also eliminates the loss of mercury with graphite particles.

Treatment methods available to reduce concentration of mercury in waste water are:

a) reduction process
b) sulphide treatment
c) ferrous chloride treatment

d) magnetic ferrites

e) ion exchange

f) ion exchange followed by chelating resin

a) The Reduction Process consists of reduction of all mercury compounds to the metallic state which may be followed by filtration and is suitable for small volumes of concentrated effluent. It can be accomplished in two different ways:

i) By treating the effluent with a less noble metal such as copper, iron, zinc and aluminium. Mercury is recovered as amalgam or droplets coalescing on the surface of the metal. It can be recovered in a pure state by electrolytic method.

ii) By treating the effluent with reducing chemicals like hydrozine, hydroxylamine, hypophasphorous acid, formaldehyde and sodium borohydride. Mercury is recovered by coalescence and/or filtration.

b) Sulphide treatment consists of treatment of mercury bearing waste water with either sodium hydrosulphide (N_aHS) or sodium sulphide ($N_{a2}S$) and a flocculant. In the reaction that follows metallic mercury remains unaffected but mercurous and mercuric compounds react to form sulphides. They are insoluble and settle down like mercury metal, and can be recovered by filtration or settling or both. The waste water thus treated can be further treated with hydrazine (N_2H_4) to convert the remaining dissolved mercury into finely dispersed metallic form. Further treatment through carbon precoated filter will produce on effluent with mercury content in the range of 0.02 to 0.03 mg./l.

c) In the ferrous chloride treatment mercury salt in waste water is reduced to insoluble compounds. Insoluble ferric hydroxide and mercuric oxide are formed with joint precipitates. The reaction takes place after pH is adjusted between 9 and 9.5 and a 50 mg./l excess alkali is added. Ferrous chloride should be added afterthis alkaline condition is attained by waste water. The precipitate can be settled which takes several days as it can be filtered. The effluent contains 0.005 to 0.006 mg./I of mercury.

d) In the Magnetic Ferris Process for every mole of mercury present in water, 2 moles of ferrous sulphate is added and the wateris neutralized with alkali when dark green complex of hydroxide is formed. Oxidation of the complex with air follows during which a black ferrite is formed. A magnetic separator removes the insoluble ferromagnetic ferrite from the solution. In this treatment mercury content gets reduced from 6 mg./l to 0.005 mg./l in the treated effluent.

In treatment method using Ion-Exchange and Chelating Resin mercury contamination of water, brine mud and slurries can be reduced from 20 mg./l to 0.005 mg./l. It is a two step procedure.

Step 1: Waste water containing 20 mg./l mercury is allowed to settle in large tanks for metallic mercury to sink. Its pH is thereafter adjusted to acidic range to remove free chlorine contamination. It is filtered to remove insolubles and then passed through an ion-exchange resin column which is selective to mercury. The concentration of mercury gets reduced to 0.1 to 0.15 mg./l. The resin gets poisoned by sodium hydroxide and free chlorine. It is regenerated by some inorganic salt solution. During regeneration mercury is removed from resin bed and recovered in the metallic form.

Step 2: If required waste water can be further treated inanother tower containing a patented chelating resin. In this treatment mercury content in the effluent gets reduced to 0.005 mg./l.

10.5 Cost of Waste Water Treatment

After describing different waste water treatment methods we now go on to discuss the cost of waste water treatment for mercury removal for a chlor-alkali plant having an annual capacity of 29,000 tonnes of caustic soda. The capital cost of this plant is Rs 14.88 lakh at 1987-88 prices. The operating (annual) cost of the same treatment turns out to be Rs 1.86 lakh at 1987-88 prices. Table 10.3 and Table 10.4 gives the cost flow and cost estimates of mercury removal respectively.

From the Table 10.4 we can see that the resource and social cost of per kl. of water released is Rs 0.71 and Rs 1.24 respectively for social rate of discount, r at 0.10 and number of years, T = 30 years.

Conclusion

In India, mercury cells constitutes 86.47 per cent of the total annual installed capacity. Therefore mercury removal from effluent stream is important for chlor-alkali industry as a whole. Mercury is not produced in India, it is imported. An

UNESCO study has revealed that in 50 years time mercury will be exhausted. Secondly, mercury poisoning is a notifiable disease but it goes unnoticed. Because of the insidious nature of the poisoning, symptoms develop long after the exposure has ceased. We cannot possibly switch over the entire installed mercury cell capacity to diaphragm process as is done in Japan. Prevention being better than cure, all new units and expansion of capacity of existing plant should be made by the non-mercury cell process. The world trend shows that the membranes will become the standard for chlor-alkali units. Our country cannot lag behind.

TABLE 10.1

MERCURY LOSS FROM CHLOR-ALKALI PLANTS (1977)

Source	gm.Hg./ tonne NaOH	Percentage	Tonne
Water	1	0.3	0.5
Hydrogen	5	1.3	2.1
Products	22	5.6	9.3
Handling loss	50	12.7	21.0
Unknown*	62	15.6	26.1
Brine Mud	254	64.5	107.0
TOTAL	394	100.0	166.0

Note: * Unknown source of loss includes loss of mercury as vapour in the cell room, solid mercury lost in sludge deposited in catch pots, channels and elsewhere.

TABLE 10.2

TYPICAL ANALYSIS OF WASTE WATER AND WATER CONSUMPTION PATTERN IN A MERCURY CELL PLANT

(Units: mg./l Except for p^H and temperature)

Parameter	Minimum	Maximum
p^H	10.4	13.5
Suspended solids	82	216
Temperature, °C	20	30
$Ca(OH)_2$	37	1887
$CaCO_3$	100	1540
Calcium	1040	2920
Magnesium	200	300
Chloride	2942	11670
Sulphate	160	5023
Free chlorine	14.2	195.2
Available chlorine	111	2041
Mercury	2.0	4.8
BOD	--	14.92
COD	43.2	60.5
Dissolved oxygen	6.1	8.5

TABLE 10.2 (Contd.)

<u>Water Consumption Pattern</u>

Consumption point	Qty. kilo-litre/hr.	Pollutants
Salt washing	0.100	NaCL
Brine filter washing	10.000	NaCL
Cell washing	0.600	Hg, NaOH
Purification sludge	0.830	Ca, Mg, Fe, Ba, Hg
Bleach liquor sludge	12.000	Ca Compounds
Chlorine drying unit	0.023	dilute H_2SO_4
Cooling water	24.547	Oil, Acid, Alkali
	48.100	

TABLE 16.3

COST FLOWS FOR CAUSTIC SODA INDUSTRY PER KL OF WATER RELEASED

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	6177	7042	Fixed cost	1488000
2. Other fixed cost			15 per cent of of fixed cost	223200
a. Machinery and equipment	449037	1032785		
			Operating cost	186000
b. Piping	168388	387292		
			TOTAL	409200
c. Civil works				
(i) Bricks	99745	229414	Cost of 1 kl. of water released	0.97
(ii) Cement	194979	448452		
(iii) Steel	212974	489840		
d. Electrical equipment	103726	238570		
e. Installation	74091	170409		
TOTAL	1309117	3003804		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	1082	1082		
b. Unskilled	721	310		
2. Maintenance				
a. Oil	321	369		
b. Repair	908	908		
3. Chemicals	5479	8219		
4. Fuel	5890	8087		
TOTAL ANNUAL COST	172812	227700		

TABLE 10.4

ESTIMATES OF COST OF POLLUTION ABATEMENT OF CAUSTIC SODA (CAPACITY 29 THOUSAND TPA) PER KL. OF WATER RELEASED

(in rupees)

Time (T) in Years ->	10		15		20		25		30		
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
WATER RELEASED											
0.08	1.79	3.29	1.35	2.40	1.09	1.90	0.91	1.57	0.79	1.35	
0.10	1.72	3.20	1 27	2.29	1.01	1.79	0.84	1.47	0.71	1.24	
0.12	1.66	3.11	1.20	2.20	0.94	1.70	0.77	1.39	0.65	1.17	

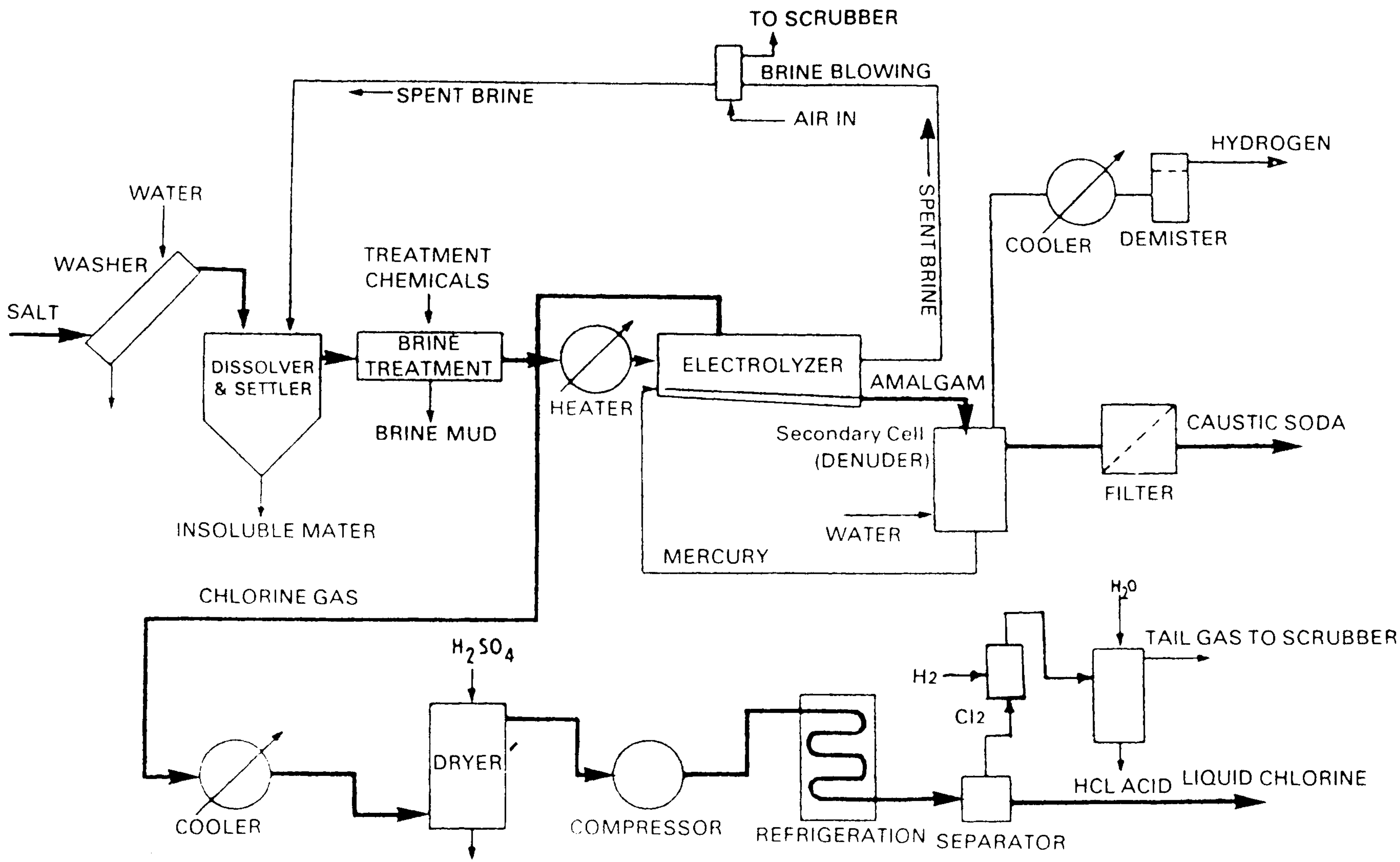


FIGURE [redacted] FLOW DIAGRAM, MERCURY CELL PROCESS

10.1

CHAPTER XI

OIL REFINERIES AND PETRO CHEMICALS

XIA. Oil Refineries

11.1 Introduction

In all there are 11 refineries operating in India and 3 are in advanced stage of commissioning. These refineries are spread out all over the country. They differ in capacities, vintages, type and quantum of crude processed and final product manufactured, manufacturing process, water consumed, type and quantum of waste water generated, system of waste water treatment and disposal of waste waters. In this chapter we use the data pertaining to a) Madras Refineries Limited, Tamil Nadu, b) Indian Oil Corporation, Haldia, West Bengal and c) Indian Oil Corporation, Baroda, Gujarat.

Crude oil is processed to produce a variety of petroleum products. The next section describes the production processes in the refineries.

11.2 Manufacturing Process

The general petroleum refining processes can be broadly classified as -

(i) Storage and Transportation;

(ii) Crude Oil Fractionation - This is the basic refining process for the separation of crude petroleum into intermediate fractions of specified boiling point ranges;

(iii) Reforming - This converts low octane naphtha, heavy gasoline, and napthene - rich stocks, to high - octane gasoline blending stock, aromatics for petrochemical use and isobutane;

(iv) Thermal and Catalytic Cracking - Under thermal cracking process, which also includes misbreaking, heavy oil fractions are broken down into the lower molecular weight fractions, but without the use of a catalyst.

Catalytic cracking breaks heavy fractions, principally gas oils, into lower molecular weight fractions in the presence of catalyst. This is plrobably the key process in the production of large volumes of high - octane gasoline stocks, furnace oils and other useful middle molecular weight distillates are also produced.

(v) Hydrodesulphurization - This process is used mainly for desulphurization of petroleum products containing high concentration of sulphur in the presence of oxygen;

(vi) Solvent Treating Processes for Lube Oil Manufacture, etc. - This process helps to improve the quality of lubricating oil based stocks by way of removing undesirable constituents like, aromatics, asphaltenes, resins, waxes, etc., from lubricating oil cuts and also for the preparation of catalytic cracking feed stock from asphaltic residuals with asphalt as by product; and

(vii) Hydrofinishing - This process is used to remove sulphur and nitrogen compounds, odour and gum - forming materials as well as to saturate olefins by catalytic actions in the presence of hydrogen from either straight - run or cracked petroleum fractions.

Oil refineries are classified on the basis of the principle process of a) misbreaking (Thermal cracking), b) catalytic cracking, c) hydrocracking (Desulphurization), and d) coking unit.

11.3 Pollution Control Methods

The refineries are classified under two categories - a) Those having once-through cooling system and b) Those having cooling water recirculation system.

Treatment of waste water from refineries involves three principal stages - a) Primary, b) Secondary and c) Biological.

a) Primary Oil Separation - The primary oil separator units are essentially gravity oil separators. These separators are normally operated without using any chemicals or coagulents or aids. Oil and grease separated from these units as slop oil are recovered and reused in the refinery.

The gravity separators are essentially rectangular chambers equipped with oil skinning and sludge scraping devices and design of the separation is based on removal of oil globules of 0.015 cm. in diameter and above.

b) Secondary Oil Separation (including sulphide precipitation) - This is necessitated when the amount of emulsified oil present in waste water is significantly high which cannot be removed in gravity oil separator.

An emulsion is a mixture of two immiscible liquids, one of the liquids being dispersed throughout the other in the shape of very fine droplats. Both the oil-in-water and water-in-oil emulsions are present in refinery waste water. The deemulsifying agents which are normally adsorbed on the surface of the emulsified particles rendering the emulsion stable are soaps, sulphates, sulphonic and napthenic acids, quartenery ammonium compounds, organic ethers and esters.

Dissolved air floatation, both with and without flocculation, has been successfully used to obtain a low oil content in a refinery waste water. Under favourable conditions, it is possible to obtain and oil content of as low as 10 mg/l. from a floatation cell using a coagulant and coagulant aid. However, dissolved-air floatation units reguire more skilled and regular supervision and power than gravity oil separators.

Sulphide precipitation - Iron salts are particularly suited to a waste water containing sulphides and mercaptans as the latter are precipitated as iron sulphides. In some refineries which dishcarge significant amount of spend caustic liquor containing very high sulphide concentration, chemical precipitation of sulphides by iron salts has been found to be effective and more economical than by steam or air stripping. By using chlorine with ferrous sulphate, chlorinated cooperas is formed, which becomes more effective in precipitation of sulphide.

c) Biological Treatment - This is primarily meant for removal of pollutants like phenol, residual sulphide and BOD and also the non-recoverable oil present in the secondary effluent. Biological treatment can be effected by various systems like trickling filter, activated sludge process, oxidation ponds, aerated lagoons, etc. Depending on the nature of waste water, a single or a combination of the units is used.

Pollution Standards - Since quantification of pollutants in waste water can be made only by considering the waste water volume and the concentration of the pollutants present in it, any standard for waste water discharge should necessarily include both the quality or concentration standard and emission standard (in quantum of pollutant per unit quantum of raw material processed). Consideration of these two standards in isolation would not lead to any meaningful programme of protection and maintenance of the quality of the receiving water environment.

The pollution standards are given in Table 11.1.

TABLE 11.1

PROPOSED MAXIMUM ALLOWABLE LIMITS OF IMPORTANT POLLUTANTS IN TREATED WASTE WATERS FROM REFINERIES
BASIS: Waste Water Generation - 700 kl./1000 tonnes of Crude Processed

Pollutants	Concentration mg./l.	Quantum, kg./1000T crude processed
Oil and Grease	10.0	7.0
Phenol	1.0	0.7
Sulphide	0.5	0.35
BOD	15.0	10.0
Suspended solids	20.0	14.0
pH	6.0 - 8.5	—

Source: Comprehensive Industry Document Oil Refineries, Central Board for the Prevention and Control of Water Pollution, New Delhi.

The Haldia Refinery processes about 6,850 tonnes of crude per day. It uses about 10,500 kl. of water per day and discharges 5,000 kl. of effluents per day. It has a cooling water recirculation system. It has two waste water treatment facilities, one for complete treatment of the process oily waste waters containing organic pollutants and the other for treatment of the inorganic waste water from water demineralization plant. See Figure 11.1.

The waste water treatment plant has all the three stages of treatment, i.e., primary, secondary and biological (trickling filter). The emergency pond for storing raw waste waters is also used from time to time as primary oil separator. The final guard pond is also similarly used as a secondary oil separator. The pollution standards achieved are given in Table 11.2.

TABLE 11.2

CHARACTERISTICS OF WASTE WATERS OF HALDIA REFINERY AT VARIOUS STAGE OF TREATMENT

Characteristics		A	B	C	D
pH		7.2	7.2	7.0	7.3
Oil and Grease	mg./l	600	120	62	2
Phenol	mg./l	15	15	11	1
Sulphide	mg./l	80	78	10	Traces
BOD (20° C, 5 day)	mg./l	100	90	55	15

Notes: A: Inlet to API separator
B: Outlet from API separator (Inlet to Chemical Treatment Unit)
C: Effluent from Chemical Treatment Unit (Inlet to Trickling filter)
D: Final Effluent.

The Gujarat Refinery Expansion Project (GREP), Baroda, processes about 8,200 tonnes of crude per day. It uses 8,000 kl. of water per day and discharges 3,940 kl. of waste water per day. The refinery has a cooling water recirculation system. The waste water treatment plant has only two stages of treatment - primary and biological. However, the spent caustic waste which contains unusually high concentration of sulphide is segregated from other wastes and given separate chemical treatment for removal of the sulphide before mixing with other waste waters and further treatment in a common biological treatment unit. A schematic diagram of the waste water treatment facility is shown in Figure 11.2. Besides the API oil separators, the equalization pond is also used as primary oil separator. The oil removed from these units is reused in the refinery. A final guard pond after biological treatment also helps in arresting oils. The oil, if any, recovered from the guard pond is reused in the refinery. The biological treatment unit is a two-stage one, the first stage featuring a trickling filter and the second stage an activated sludge process. The pollution standards achieved are given in Table 11.3.

In the Madras refinery, three types of waste water are generated. They are

(i) Oily effluent from process area;

(ii) Chemical effluent from water treatment plant; and

(iii) Sanitary sewage.

TABLE 11.3

CHARACTERISTICS OF WASTE WATERS OF GREP, BARODA AT VARIOUS STAGES OF TREATMENT

Characteristics		A	B	C	D
PH		7.4	7.2	7.3	7.0
Oil and Grease	mg./I	486	73	39.5	4
Phenol	mg./I	--	2.1	9	1
Sulphide	mg./l	47.7	42.0	10	0.02
BOD(20°C, 5 days)	mg./l	120.0	--	78	12

Notes: A: Inlet to API separator.
B: Outlet from API separator.
C: Outlet of Equalization Pond.
D: Final Effluent.

In the Madras refinery, three types of waste water are generated. They are

(i) Oily effluent from process area;
(ii) Chemical effluent from water treatment plant; and
(iii) Sanitary sewage.

As shown in Figure 11.3. Oily effluent is pumped from the process area to the sewer basin. In this basin oil is also separated from the effluent and pumped to the slop oil tank. Separated effluent is pumped to the inlet of the API oil separator. Sulphuric acid is added to the inlet of the API oil separator to maintain the p_H around 6-6.5. From this API oil separator water overflows to the retention pond. Oil separated in this separator is collected in the oil sump which is pumped to the slop oil tanks. The pollution standards achieved are shown in Table 11.4.

In the retention tanks settleable solids also get settled and clear effluent enters into the oxidation pond for final polishing. At the outlet of retention pond and oxidation pond skimmers are provided to collect the free oil present in the waste water, and collected oil is pumped back to the slop oil tanks for reprocessing in the plants. The overflow from the oxidation pond joins the canal for discharge into the sea.

TABLE 11.4

CHARACTERISTICS OF WASTE WATERS OF MADRAS REFINERY LIMITED, MADRAS AT VARIOUS STAGES OF TREATMENT

Characteristics		Sources				
		I	II	III	IV	V
PH	8.3	8.3	6.7	6.8	6.8	
Oil & Grease	mg./l	5900	3601	9.6	6.4	3.8
Sulphide	mg./l	2.1	1.75	1 75	1.18	0.7
Phenol	mg./l	2.2	2.1	2.0	1.8	1.2
COD	mg./l	2797	1766	483	258	34.0
BOD	mg./I	390	280	152	82	33.0
Chromium:						
i. Total	mg./I	1.5	1.5	Traces	Traces	Traces
ii. Hexavalent	mg./l	1.0	0.8	Traces	Traces	Traces
Zinc	mg./l	1.2	0.9	Traces	Traces	Traces

Source I: Inflow to sewer basin.

Source II: Inlet to API separator.

Source III: Outlet of API separator.

Source IV: Outlet of retention pond

Source V: Outlet of oxidation pond.

Chemical effluent from the water treatment plant and sanitary sewage from the refinery are discharged into a large lagoon where it is kept open for evaporation and percolation through the soil.

11.4 Costs of Pollution Abatement

From the information on fixed cost and operation cost supplied by the refineries surveyed, various cost flows were calculated for water used and water treated. It was found that for r = 0.10 and T = 30 years, for the Haldia Refinery the resource cost of water used and water released was Rs 0.13 and Rs 0.29 per kl. respectively, the social cost was Rs 0.24 and Rs 0.51 per kl. respectively. Cost flows are given in Table 11.5. Cost estimates are given in Table 11.8.

For the Gujarat refinery (GREP), the resource cost was Rs.0.24 and Rs.0.48 per kl. of water used and water released respectively, for r = 0.10 and T = 30 years. The social cost was Rs 0.42 and Rs 0.85 per kl. respectively. Table 11.6 gives the cost flows and Table 11.9 gives the cost estimates.

For the Madras refinery the resource cost of water used and water released was Rs.0.28 and Rs 0.61 per kl. respectively, for r = 0.10 and T = 30 years. The social cost was Rs 0.52 and Rs 1.14 per kl. respectively. Table 11.7 gives the cost flows and Table 11.10 gives the cost estimates.

Gravity oil separation of waste waters in oil separators and guard pond is an integral part of an oil refinery for recovery and reuse of the valuable hydrocarbons. In the context of the present-day shortage and high cost of hydrocarbon oil, recovery of more hydrocarbon from waste waters would go a long way in not only economising on the cost of waste water treatment but also in conserving one of the most valuable natural resources of the country. Primary treatment recovers over 80 per cent of the oil.

Secondary treatment recovers 50 to 80 per cent of the residual oil in the primary effluent.

Haldia and GREP have complete waste water treatment systems. The oil removed in biological treatment is entirely lost.

Total recovery of oil in the combined waste water is around 92 per cent and the remaining 8 per cent oil is lost in biological treatment.

11.5 Conclusion

From the foregoing analysis it can be concluded that the technology presently available for effluent treatment is capable of removing the various pollutants from refinery effluent to a high degree and that the cost of effluent treatment is compatible with the cost realised from the oil that can be recovered in the system.

Since quantification of pollutants in waste water could be made only by considering the waste water volume and the concentration of the pollutants present in it, any standard for waste water discharge should necessarily include both the quality or concentration standard (in mg./l) and emission standard (in quantum of pollutant per unit quantum of raw material processed). Consideration of these two standards in isolation would not lead to any meaningful programme of protection and maintenance of the quality of the receiving water environment.

From the foregoing discussions it can be concluded that by installing and properly operating a well designed effluent treatment plant, it would be possible for a refinery not only to recover valuable hydrocarbons to a significant extent but also to conform to the Minimal National Standards for the residual pollutants.

COST FLOWS OF HALDIA REFINERY
(1987-88 PRICES)

(In rupees)

	Resource cost	Social cost
A. FIXED COST		
1. Land	12355	14085
2. Other fixed cost		
a. Machinery and equipment	2884893	6635254
b. Piping	1081833	2488221
c. Civil works		
(i) Bricks	641087	1474500
(ii) Cement	1253166	288228
(iii) Steel	1368821	3148288
d. Electrical equipment	666410	1532743
e. Installation	476007	1094816
TOTAL	8384574	16676135
B. OPERATING COST (MONTHLY)		
1. Labour		
a. Skilled	3693	6164
b. Unskilled	2466	1060
2. Maintenance		
a. Oil	2066	3749
b. Repair	5831	5831
3. Chemicals	25622	45659
4. Fuel	27540	37812
TOTAL	67223	100275
TOTAL ANNUAL COST	806676	1203300

Commercial cost	
Fixed cost	9532500
15 per cent of fixed cost	1429875
Operating cost	869676
TOTAL	2299551
Quantity of water used per year (in kl.)	3832500
Quantity of water released per year (in kl.)	1825000
Cost of 1 kl. of water used	0.60
Cost of 1 kl. of water released	1.26

TABLE 11.6

COST FLOWS FOR GREP REFINERY
(1987-88 PRICES)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	12370	14102	Fixed cost	13485000
2. Other fixed cost			15 per cent of fixed cost	2022750
a. Machinery and equipment	4082615	9390015	Operating cost	1063152
b. Piping	1530981	3521256	TOTAL	3085902
c. Civil works			Quantity of water used per year (in kl.)	2920000
(i) Bricks	907247	2086663	Quantity of water released per yearin (in kl.)	1438100
(ii) Cement	1773443	4078919		
(iii) Steel	1937115	4455365	Cost per kl. of water used	1.05
d. Electrical equipment	943084	2169093	Cost per kl. of water released	2.15
e. Installation	673631	1549351		
TOTAL	11860486	27264769		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	3559	3559		
b. Unskilled	2372	949		
2. Maintenance				
a. Oil	2924	4386		
b. Repair	8252	8252		
3. Chemicals	31322	46983		
4. Fuel	33666	46223		
TOTAL	82095	110352		
TOTAL ANNUAL COST	985140	1324224		

TABLE 11.7

COST FLOWS OF MADRAS REFINERY (1987-88 PRICES)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	12370	14102	Fixed cost	11383200
2. Other fixed cost			15 per cent of fixed cost	1707480
a. Machinery and equipment	3445706	7925124	Operating cost	972180
b. Piping	1292140	2971922	TOTAL	2679660
c. Civil works			Quantity of water used in a year (in kl.)	2190000
(i) Bricks	765712	1761138		
(ii) Cement	1496777	3442587	Quantity of water released in a year (in kl.)	1003750
(iii) Steel	1634915	3760305	Cost per kl. of water used	1.19
d. Electrical equipment	795959	1830703	Cost per kl. of water released	2.61
e. Installation	568541	1307644		
TOTAL	10012119	23613525		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	3752	3752		
b. Unskilled	2502	1001		
2. Maintenance				
a. Oil	2468	3702		
b. Repair	6964	6964		
3. Chemicals	28641	42962		
4. Fuel	30786	42269		
TOTAL	75113	100650		
TOTAL ANNUAL COST	901336	1207800		

TABLE 11.8

ESTIMATES OF COST OF POLLUTION ABATEMENT (FOR HALDIA OIL REFINERIES)

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Soical cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.35	0.65	0.26	0.47	0.21	0.37	0.18	0.31	0.15	0.26	
0.10	0.34	0.63	0.25	0.45	0.20	0.35	0.16	0.29	0.13	0.24	0.60
0.12	0.33	0.61	0.24	0.43	0.19	0.33	0.15	0.27	0.12	0.22	
					WATER RELEASED						
0.08	0.75	1.35	0.55	0.98	0.45	0.77	0.37	0.65	0.32	0.55	
0.10	0.73	1.31	0.53	0.94	0.42	0.73	0.34	0.60	0.29	0.51	1.26
0.12	0.71	1.29	0.51	0.91	0.39	0.70	0.32	0.57	0.27	0.48	

TABLE 11.9

COST ESTIMATES FOR POLLUTION ABATEMENT IN GREP

(In rupees)

Time (T) in Years →	10		15		20		25		30		
Social rate of Discount	Resource cost	Soical cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.63	1.24	0.46	0.88	0.37	0.69	0.31	0.57	0.26	0.48	
0.10	0.61	1.21	0.44	0.85	0.34	0.66	0.28	0.54	0.24	0.45	1.05
0.12	0.59	1.19	0.42	0.83	0.33	0.63	0.26	0.51	0.22	0.43	
					WATER RELEASED						
0.08	1.28	2.52	0.94	1.79	0.75	1.40	0.62	1.16	0.53	0.97	
0.10	1.25	2.46	0.89	1.73	0.70	1.34	0.57	1.10	0.48	0.91	2.15
0.12	1.21	2.42	0.86	1.69	0.67	1.28	0.54	1.04	0.45	0.87	

TABLE 11.10

COST ESTIMATES FOR POLLUTION ABATEMENT IN MADRAS REFINERY

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Soical cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
WATER USED											
0.08	0.73	1.42	0.54	1.04	0.43	0.81	0.36	0.67	0.31	0.57	
0.10	0.71	1.41	0.51	1.00	0.40	0.77	0.33	0.63	0.28	0.53	1.19
0.12	0.69	1.39	0.49	0.97	0.38	0.74	0.31	0.60	0.26	0.51	
WATER RELEASED											
0.08	1.60	3.16	1.18	2.26	0.94	1.77	0.78	1.45	0.67	1.24	
0.10	1.53	3.09	1.12	2.18	0.88	1.69	0.73	1.37	0.61	1.16	2.61
0.12	1.50	3.03	1.07	2.11	0.83	1.62	0.68	1.31	0.57	1.11	

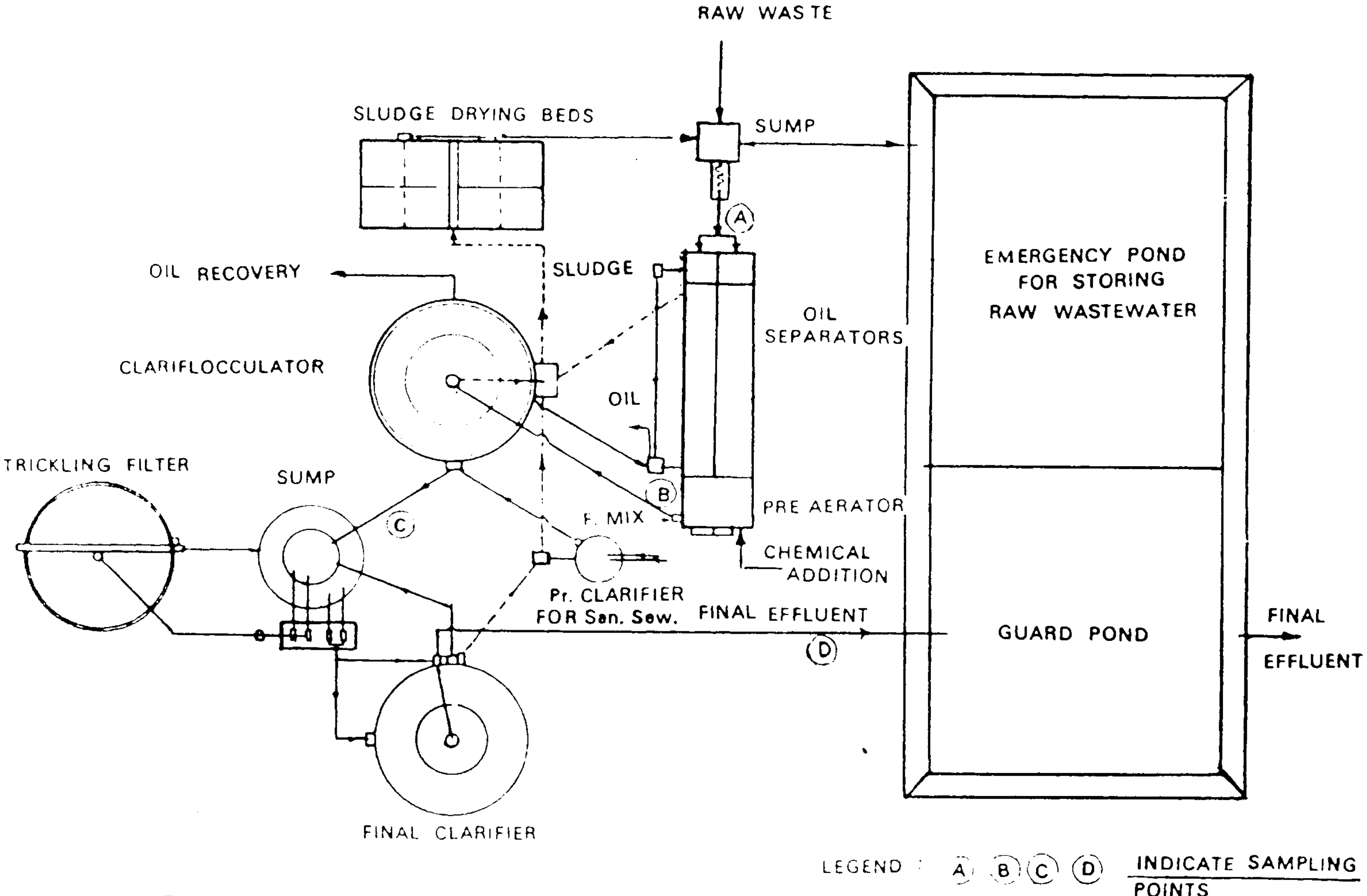


FIGURE 5 FLOW SHEET FOR WASTEWATER TREATMENT IN HALDIA REFINERY

11:1

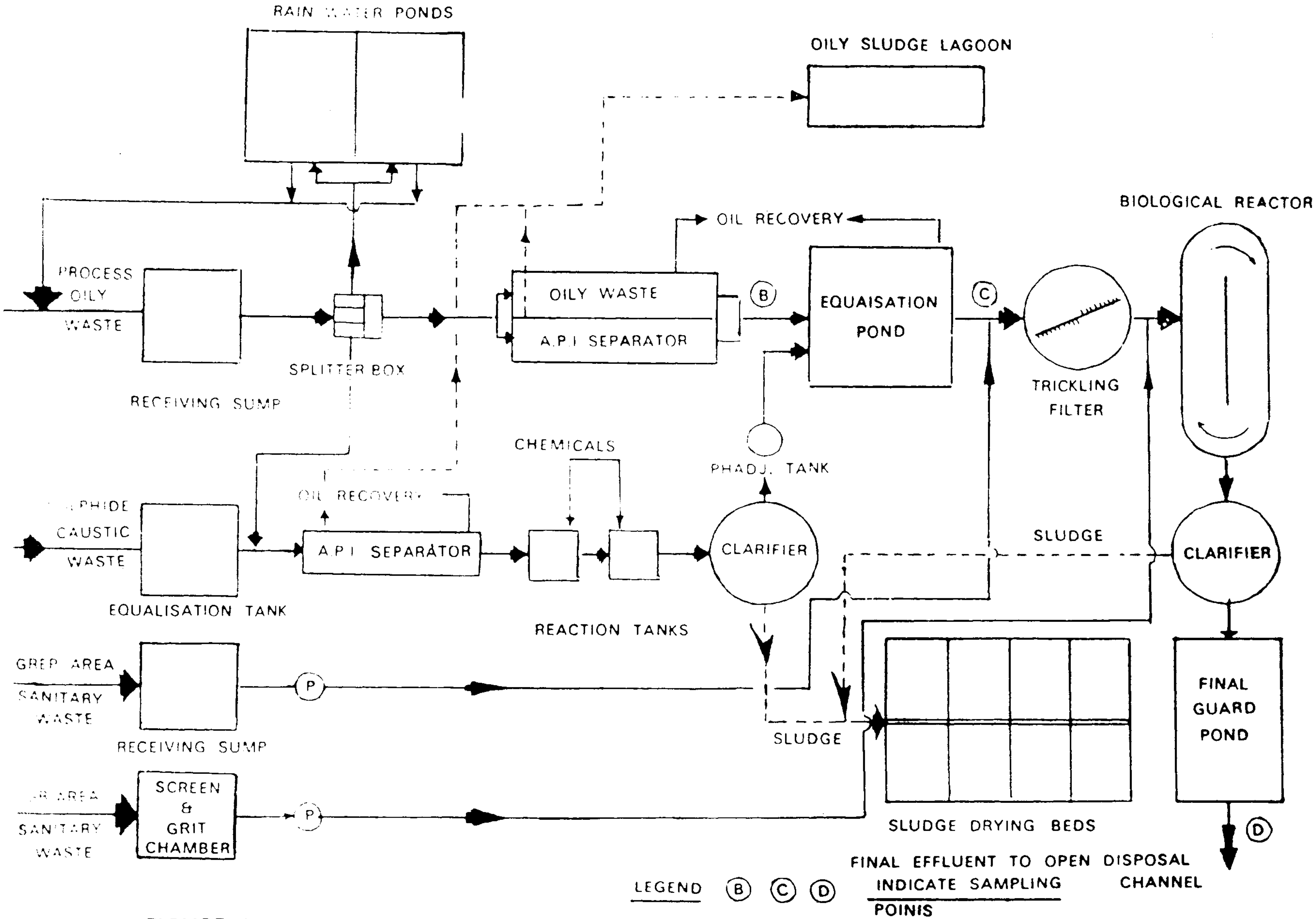


FIGURE 6 FLOW SHEET FOR WASTEWATER TREATMENT PLANT IN G R E P REFINERY

11-2

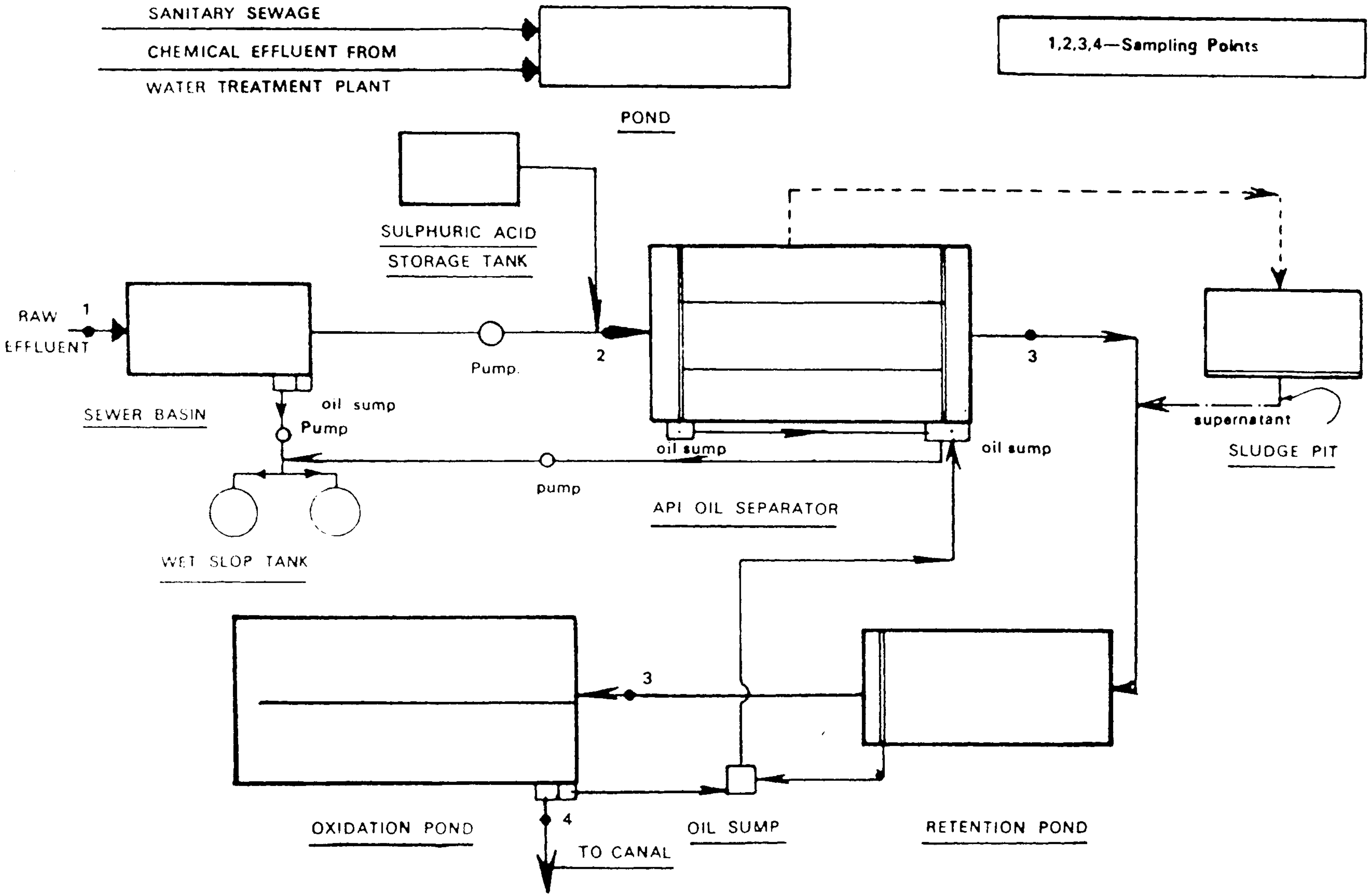


FIGURE 11·3 SCHEMATIC FLOW OF EFFLUENT TREATMENT SCHEME OF MADRAS REFINERY LIMITED MADRAS

CHAPTER XIB

TAMIL NADU PETROPRODUCTS LIMITED, MADRAS

11.1 Introduction

Tamil Nadu Petroproducts Limited manufactures Linear Alkyl Benzene, a petroleum product. It has a technology licence from Universal Oil Products, U.S.A. It has a production capacity of 60,000 million tonnes per annum. It consumes 1670 kl of water per day and releases 820 kl of effluents per day.

Linear Alkyl Benzene (LAB) is produced by reacting Benzene with Olefine having a Carbon Number range of C_{10}-C_{13} or C_{11}-C_{14}. The Olefin in turn is prepared from Kerosene which is the feedstock for the process.

The process plant can be broadly classified into Five major sections. The first three sections known as a) Prefractionation b) Hydrotreating and c) Molex or Molecular Sieve separation, are involved in separating normal paraffine of carbon number range C_{10}-C_{13} or C_{11}-C_{14} from the foodstock kerosene. The fourth section namely Pacol Dehydrogenation converts the normal paraffine to the corresponding mono-olefins which are the more active forms of the alkyl group. In the final Detergent Alkylation section, the mono-olefins are reacted with Benzene to form the product LAB.

11.2 Manufacturing Process

(i) Prefractionation Section

The feedstock kerosene chiefly contains various paraffins in the carbon number range of say C_{6-18} alongwith Aromations. The function of the Prefractionation section is to separate out the heart out with carbon number range of C_{10}-C_{13} or C_{11-14}. This is achieved in Two Stripper columns.

(ii) Hydrotreating or Hydrobon Section

The function of this section is to remove the sulphur and nitrogen present in the product from the previous section as otherwise these would harm the catalysts in the subsequent sections. The incoming stream is mixed with hydrogen, the sulphur and nitrogen compounds are converted to hydrogen sulphide and ammonia.

(iii) Molex or Molecular Sieve Separation

In addition to the desired normal paraffin, certain co-boiling non-normal paraffins and aromatics are present in the feed stream to this unit. The function of this section is to separate the co-boiling fractions through selective absorption of the normal paraffin on molecular sieves.

(iv) Pacol or Dehydrogenation Section

The extracted normal paraffins with the carbon number range of C_{10}-C_{13} or C_{11}-C_{14} is dehydrogenated in this section. The feed stream to this section is first mixed with recycled hydrogen and in the presence of platinum based catalyst, the paraffins are converted to corresponding olefins and hydrogen, hydrogen is separated from the hydrocarbons. The hydrocarbons are further stripped in a stripping column to remove light ends and balance hydrogen. The bottom product is sent to the next section.

(v) Detergent Alkylation Section

The final reaction between benzene and olefin is achieved in this section in the presence of liquid Hydrogen Fluoride (HF) Catalyst. The reactants and catalysts are initially mixed and reacted in two stages in tray columns. The HF acid is then separated from the product stream by settling and recycled for further reaction. In a further step, the product stream is stripped in a HF stripper to remove the balance HF which is recycled. This is followed by separation of the unreacted benzene in the product stream by sending the same to Benzene Column from the top of which benzene is separated and recycled to the reaction section. The bottom product from the Benzene Column is sent to a Paraffin Stripper where the normal paraffins which were not converted in the Pacol section is removed from the top of the column and returned to Pacol section while the product stream emerges from the bottom. In the final step, the product stream which contains a compound called Heavy Alkylate formed through side reactions and due to the presence of small quantities of heavy non-normals, is removed from the LAB with the use of a Rerun Column and a Recovery Column.

11.3 Pollution Abatement Methods

The cooling Tower blow down is sent to reduction precipitation sums in series where H_2SO_4, $FeSO_4$ and lime solutions are added and the trivalent chromium is precipitated and subsequently settled in a clarified. The sludge from this clarified goes to drying beds while the overflow is mixed with the acidic effluent from water treatment plant and neutralised and sent for disposal. V Notch is provided to measure the flow.

The process effluents are deoiled in a tilted plate oil separator and the slp oil is pumped to tanks. The deoiled effluent is mixed with domestic sewage and treated for BOD using low rate Bio filter.

The mixed effluent is circulated through a low rate Bio filter packed with plastic rings down to a recycle sump by pumps. The recycle sump overflows to a secondary clarified where the settled sludge is drained to sludge drying beds. The clarified overflow goes for final disposal. V Notch is provided to measure the flow.

Table 11.1 shows characteristics of the effluents before treatment. Table 11.2 gives the quality of effluent as per IS2490 standards. Figure 11.1 gives the flow diagram of effluent treatment plant.

TABLE 11.1

Influent to Effluent Treatment Plant

Sl.	Description	Quantity in kl/day	Quality
1.	Chromate Effluent from Cooling Tower Blow Down	720	CrO_4-30 ppm
2.	Water Treatment Plant Regeneration waste and Boiler Blow Down	324	Acidic TDS 5500 ppm
3.	Oily Effluent From Process	120	Oil-2000 ppm Traces-NH_3 & H_2S
4.	Domestic Effluent	9	High BOD

TABLE 11.2

Quality of the Final Effluent As Per IS 2490

SI.No.	Characteristics	Unit	Tolerance Limit
1.	PH	No.	5.5 to 9
2.	Temperature	^oC	40 at the point of discharge
3.	Particle size of suspended solids	mm/ micron	Shall pass IS 850 microne sieve
4.	Total suspended solids	mg/1	100
5.	Total dissolved solids (inorganic)	mg/1	2100
6.	Chlorides as (cl)	mg/1	1000
7.	Fluoride as (F)	mg/1	2
8.	Sulphide as (S)	mg/1	2
9.	Oils and grease	mg/1	10
10.	BOD 5 days @ 20°C	mg/1	30
11.	COD	mg/	250
12.	Total residual chlorine	mg/1	1
13.	Chromium as blexavalent cr.	mg/1	0.1
14.	Total Chromium	mg/1	2
15.	Free Ammonia (as NH_3)	mg/1	5

1. All the hydrocarbon waste from the plant which may occur during any pump out of the equipment are connected to a Slop Oil header which runs all through the plant and pumped to the slop oil tank from where it is used for burning.

   This reduces the load to the ESTP whenever there is a problem in the plant.

2. All the condensable hydrocarbon vapours are knocked off and directly pumped to slop oil system so that the oil load on the Effluent Treatment Plant is minimised.

3. All the acid containing streams including rain water and wash water are neutralised in the plant and are sent to the Effluent plant in an acid free level. This reduces the load on the water handling system.

4. In the cooling tower to make up for the blow down, we have a provision to add demineralised water instead of raw water. This reduces the impurity level in the cooling water system to such an extent that the blow down reduces to about 720 M^3/day maximum.

   (Though this is costly, it is being done to reduce the Effluent Treatment Load.)

5. All the Benzene containing streams are not routed to Effluent Treatment Plant. They are collected and stored in tanks from where they are recycled back into the unit. This reduces the toxic level of influent

water to ETP.

11.4 Cost Estimates of Pollution Abatement

The investment on the Effluent Treatment Plant is to the tune of Rs 305 lakh. Its operation cost is Rs 6.5 lakh. The water used is 1670 kl per day while the water treated is 820 kl per day. From these, the resource cost and social cost of one kl of water used works out to Rs 1.61 and Rs 3.39, respectively for r=0.10 and T=30 years. The commercial cost of one kl. of water used is Rs 8.61. The resource cost and social cost of one kl of water released is Rs 3.28 and Rs 6.90, respectively for r=0.10 and T=30 years. The commercial cost per one kl. of water released is Rs 17.53. The cost flows are given in Table 11.3 and the cost estimates are given in Table 11.4.

11.5. Conclusion

From the above analysis, it can be seen that the cost of pollution abatement per kl of water released is slightly high with the commercial cost of water released being Rs 17.53.

TABLE 11.3

Cost of Pollution Abatement (TN Petroproducts Limited)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. Fixed Cost				
1. Land	1500000	171250	fixed cost	30650000
2. Other fixed cost				
i) Machinery & equipment	9242424	21257575	15% of social cost	4597500
ii) Piping	345280	794143	Operation cost	651540
iii) Civil work				
a) Bricks	20553872	4723905	Total	5249040
b) Cement	4014808	9234060		
c) Steel	4385334	10086268		
iv) Electrical equipment	2135000	4910500	Quantity of water used per year	609550
v) Installation	1525000	3507500		
Total	23851718	54685701	Quantity of water released per year	299300
B. Operating Cost (Monthly)				
1. Labour			Cost per kl of water used	8.61
a) Skilled				
b) Unskilled	50000	2150		
2. Maintenance			Cost per kl of water released	17.53
a) Oil	2206	3310		
b) Repair	6226	6226		
3. Chemicals	23906	35858		
4. Fuel	12000	16476		
TOTAL ANNUAL	592056	768240		

TABLE 11.4
Estimates of Cost of Pollution Abatement
per kl of water
(TN Petrochemicals Limited)

(In rupees)

Time (T) ->	15		20		25		30		
Social rate of discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
WATER USED									
0.08	3.17	6.70	2.43	5.10	1.98	4.12	1.67	3.47	
0.10	3.10	6.61	2.37	5.02	1.92	4.05	1.61	3.39	8.61
0.12	3.05	6.59	2.32	4.95	1.87	3.98	1.56	3.33	
WATER RELEASED									
0.08	6.46	13.65	4.95	10.39	4.03	8.39	3.40	7.07	
0.10	6.31	13.46	4.83	10.22	3.91	8.25	3.28	6.90	17.53
0.12	6.21	13.34	4.72	10.08	3.81	8.11	3.18	6.78	

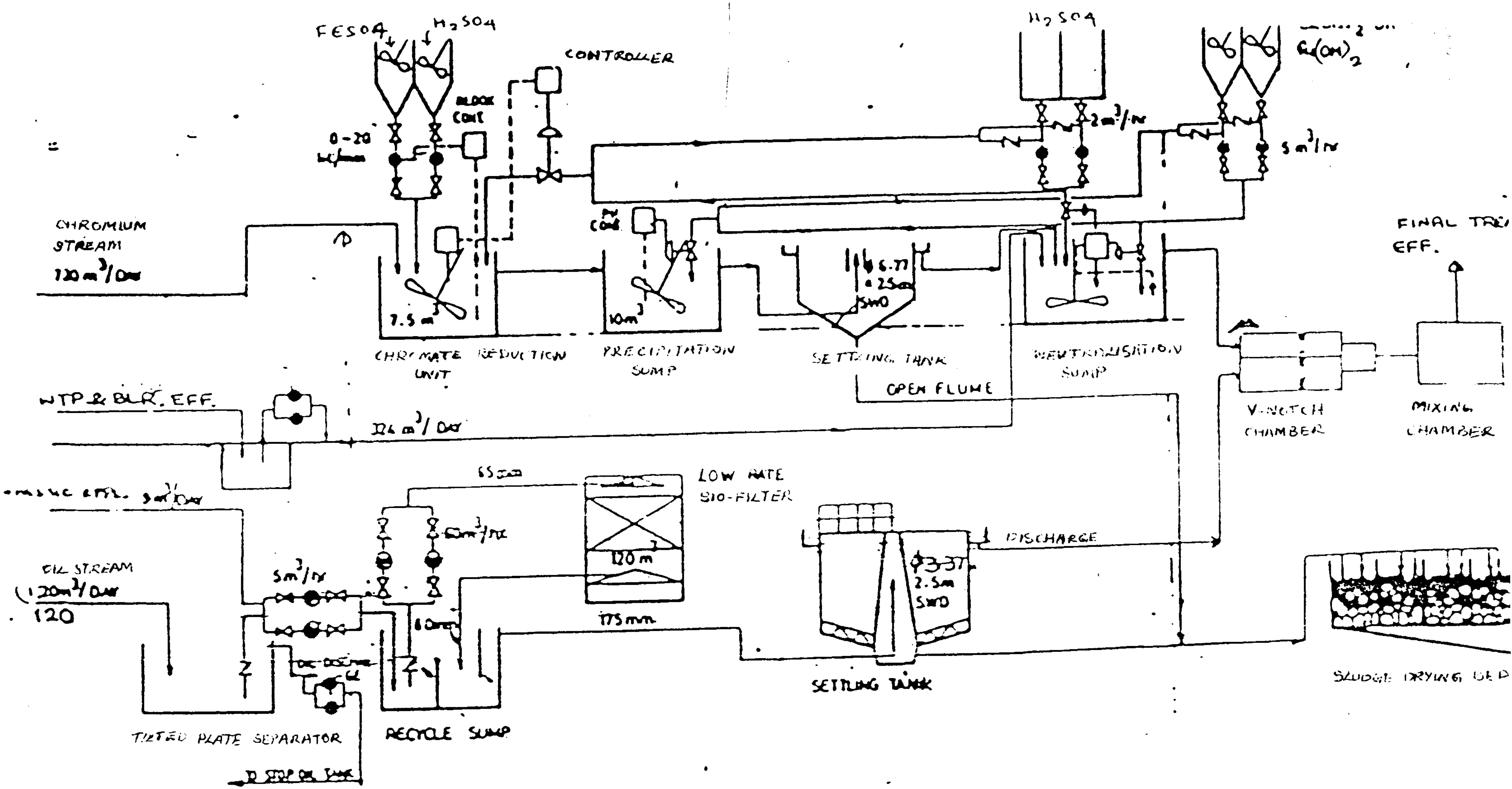


FIGURE 11.1 FLOW DIAGRAM OF EFFLUENT TREATMENT PLANT

CHAPTER XII

GUN & SHELL FACTORY

12.1 Introduction

Gun and Shell Factory is an Engineering factory under the Government of India, Ministry of Defence which produces empty components of Arms and Ammunition. Along with guns, shells and fuses, it also undertakes production of heavy engineering and precision engineering components. It functions on the basis of one shift per day, working for about 330 days in a year.

12.2 Water Consumption and the Cost of Production of Water

The factory utilizes water for electroplating of the components produced and for domestic consumption. It uses approximately 2537 kl. of water per day, the sources being deep tubewell and Calcutta Municipal Corporation for filtered water and river Hooghly for unfiltered water. Its domestic consumption comes to 162 kl. per day while industrial consumption is 2100 kl. per day.

The cost of production of water from tubewells is calculated using methodology described in Chapter III, and given the requisite information about operation and investment cost of the tubewells. The cost flows of production of water is presented in Table 12.1 while Table 12.2 gives the estimates of cost of production of water per kl. The resource cost and social cost estimates per kl. of water are Rs 0.25 and Rs 0.34 for $r = 0.10$ and $T = 30$ years. The commercial cost of water is Rs 0.82. The high resource cost of production of water in this Calcutta unit (as with all other Calcutta units vis-a-vis Kanpur units) is explained by the sandy nature of the soil and the existence of the water table at a greater depth. This factor is also responsible for the shorter life span of a tubewell, on the average, in and around Calcutta.

12.3 Waste Water : Generation and Treatment

It is interesting to note that the factory was till very recently discharging 2262 kl. (Domestic – 162 kl. per day and Industrial – 2100 kl. per day) of untreated effluent water into the river Hooghly, without being penalised. It is due to recent notices issued by the Ministry of Environment and Forests that the factory has commissioned a Primary Effluent Treatment Plant in 1988-89 while the secondary plant is under commissioning. The effluent treatment plant under operation undertakes a treatment process that is complete. A look at the water pollution contributing inputs used in the production process may be helpful (Table 12.3) to get an idea of the toxicity of effluents released. Table 12.4 summarizes the discharge of effluents by composition. The effluent treatment process comprises of,

(a) effluent water treatment at fuze section, and
(b) treatment at EDS section.

The process of pollution abatement is given in Annexure 12.1 and Annexure 12.2.

Apart from setting up the effluent treatment plants, quality changes in output have been incorporated in the production process as additional water pollution abatement measures.

The cost of pollution abatement is worked out using methodology described earlier. Table 12.5 gives the cost flows of pollution abatement while the estimates of costs of pollution abatement are given separate them in Table 12.6. Table 12.5 reveals that the resource cost of pollution abatement per kl. of water released is Rs 0.25 while social cost is Rs 0.36 for r = 0.10 and t = 30 years. The commercial cost per unit of water released works out to be Rs 0.93.

12.4 Conclusion

It is seen that fixed cost of effluent treatment plant is low while the operating cost is quite high due to the heavy expenditure on chemicals required. The pollution standards stipulated are not achieved in practice.

Annexure 12.1

PROCESS LAY OUT OF EFFLUENT WATER TREATMENT AT FUZE

Process water of Fuze Section will be collected in equalising Tank and then water will be pumped off to the second Tank where water will be treated chemically. The treating tank will be separated in three chambers. In the Ist Chamber a solution of Hydro-Chem R for treating hexavalent chromium to trivalant chromium will be mixed in the chamber which will be brought in the 2nd Chamber by over flowing where water will be given a stirring effect. Chemically treated water will be brought in the 3rd Chamber where a solution of sodium carbonate will be mixed in the water with a stirring arrangement to make water alkaline. Now entire water will pass through a settling Tank - 'A' where trivalant chromium salt and other heavy metal-salts will be precipated. Finally water will pass through another settling Tank 'B' where water will be free from any residue. Now the water will be allowed to go into the drain.

From time to time the settling Tanks will be cleared and residual substances will be stored in polythene containers which will be stored in a secured place to avoid contamination.

Diagram 12.1 gives the flow chart of this process.

Annexure 12.2

EFFLUENT TREATMENT PLANT AT EDS - 2 NOS.

1. Plant to Treat Hexavalant Chromium

a. Procedure and Layout

Effluent arising from different pockets of EDS will be collected in tanks of total capacity of 19000 litres which are called Equalising Tank and then water will be pumped off to the next set of tanks where water will be treated chemically in two stages. In the first Treating Tank of 2800 litres capacity a solution of Hydro-Chem R will be added to the water with a stirring action to convert hexavalant chromium and then water will pass through a small tank of 2000 litres capacity (approx.) where it will get some time gap before going to the second Treating Tank of 2800 litres capacity. In the second Treating Tank a solution of sodium carbonate will be added to the water with a stirring action to make water alkaline. The p_H value of water will be kept at 8.5 to 9 and that will be controlled by a p_H meter. After Treating Tanks there will be a series of 4 tanks which will be used as Settling Tanks. Each tank will be 8000 litres capacity approximately. Due to the massive capacity of Settling Tanks (near about 32000 litres) treated water will get sufficient time to be retained. In the period of retainment entire undissolved trivalent chromium will settle at the bottom of tanks.

From time to time the settling tanks will be cleaned and residuals will be stored in small polythene containers. This will be stored in a secured place to avoid contamination.

2. Plant to Treat Copper Cadmium and Cyanide Contamination

a. Procedure and Layout

Process Layout of Treating Effluent Containing Copper Cadmium and Cyanide Contaminants arising from the Electroplating Shop of EDS.

The plant consists of 3 units. First unit is called treating unit where copper and cadmium will be treated by adding sodium carbonate solution (maintaining a range of p_H value 8.5 to 9 by a p_H controller) with a stirring effect. Second unit consists of two settling tanks where insoluble carbonate and hydroxides of copper and cadmium will settle with the help of coagulating aid. Eight hours retention time will be required. Settling tanks will be used alternately. After eight hours water free from copper and cadmium contamination will be released to pass through the third unit where cyanide will be treated in a alkaline media (maintaining a range of p_H value 11 to 12 by a p_H controller) by adding bleaching powder with a stirring effect. Finally sulphuric acid drip will be given to the treated water for neutralising its alkalinity before releasing it into the drain.

Diagram 12.2 provides flow chart of the process.

TABLE 12.1

COST FLOWS OF PRODUCTION OF WATER PER KL.
(GUN & SHELL - TUBEWELL)

(in rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery Equipment				
a. Pipe	42167	96984	Fixed Cost	300000
b. Pump	122514	281782	15 per cent of fixed cost	45000
c. Fittings	21269	48918	Operating cost	560424
2. Construction			Total	605424
a. Cement	12891	29649	Per unit market cost of water	0.82
b. Bricks	6565	15099		
c. Steel	14018	32241		
3. Labour	60000	25800		
TOTAL	279424	530473		
B. OPERATING COST (MONTHLY)				
1. Maintenance				
a. Oil	290	435		
b. Repair	151	151		
2. Fuel	44100	60549		
3. Labour	2100	903		
TOTAL	46641	62038		
ANNUAL OPERATING COST	559692	744456		

TABLE 12.2

ESTIMATES OF COST OF PRODUCTION OF WATER PER KL.
(GUN & SHELL - TUBEWELL)

(in rupees)

Time (T) in Years ->	15		20		25		30		
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.46	0.62	0.39	0.53	0.33	0.45	0.30	0.40	
0.10	0.40	0.56	0.34	0.46	0.29	0.39	0.25	0.34	0.82
0.12	0.37	0.50	0.30	0.41	0.25	0.34	0.21	0.29	

TABLE 12.3

CHEMICAL COMPONENTS USED IN EDS PRODUCTION PROCESS

(KG./PER DAY)

Hydrochloric Acid	30
Nitric Acid	8
Sulphuric Acid	16
Chromic Acid	8
Sodium Dichlorate	8
Cadmium Metal Anode	2
Cadmium Cynide	1
Caustic Soda	8
Sodium Cyanide	3

CHEMICAL COMPONENTS USED IN FUZE PRODUCTION PROCESS

(KG./PER DAY)

Hydrochloric Acid	25
Sulphuric Acid	35
Nitric Acid	40
Chloric Acid	15

TABLE 12.4

INDUSTRIAL EFFLUENT DISCHARGE

Sl. No.	Item	Standard required	Actual (average of C+D)	Sample A	Sample B	Sample C	Sample D
1.	pH value	9.0	7.6	6.5	2.0	7.8	7.4
2.	Temperature oC		29.2	30	28	29	29.4
3.	Colour		Whitist	Yellow	Yellow	Whitist hazy	Whitist
4.	TSS mg./l	100	138	98	78	144	132
5.	TDS mg./l (Inorganic)		1900	1140	1050	1930	1870
6.	Total volatile solid mg./l		476.5	410	388	458	495
7.	BOD mg./l	30	42.5	40	40	45	40
8.	COD mg./l	250	382	375.5	397.8	408.8	355
9.	Oils & Greases mg./l	10	5.5	8.4	2.6	7.6	3.5
10.	Chloride (as Cl) mg./l	1000	117.8	212.5	638.8	180.6	54.9
11.	Sulphate (SO4) mg./l		29.5	32	28	30	29
12.	Sodium (per cent)		82.5	105	76	118	47
13.	Lead (as Pb) mg./l	0.1	0.44	2.5	1.6	0.88	nil
14.	Chromium (as Cr) mg./l	0.5	nil	1.3	1.4	nil	nil
15.	Zinc (as Zn) mg./l	5	0.65	nil	nil	1.3	nil

Notes: Sample A - EDS Section

Sample B - Fuze Section

Sample C - Discharge in river Ganges

Sample D - Sewerage settling tank.

TABLE 12.5

COST FLOWS OF POLLUTION ABATEMENT

(in rupees)

	Resource cost	Social cost	Commercial Cost	
A. FIXED COST				
1. Land	250000	285000	Fixed cost	432000
2. Other fixed cost			15 per cent of fixed cost	64800
a. Machinery equipment	55152	126849	Operating cost	639588
b. Piping	20682	47569	Total	704388
c. Civil work			Per unit market cost of water released	0.93
(i) Bricks	12255	28186		
			Per unit market cost of water used	0.77
(ii) Cement	23957	55101		
(iii) Steel	26168	60186		
d. Electrical equipment	12740	29302		
e. Installation	9100	20930		
TOTAL	410054	653123		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	6250	6250		
b. Unskilled				
2. Maintenance				
a. Oil	39	59		
b. Repair	111	111		
3. Chemicals	37879	56818		
4. Fuel	1890	2595		
TOTAL	46169	65833		
ANNUAL OPERATING COST	554028	789996		

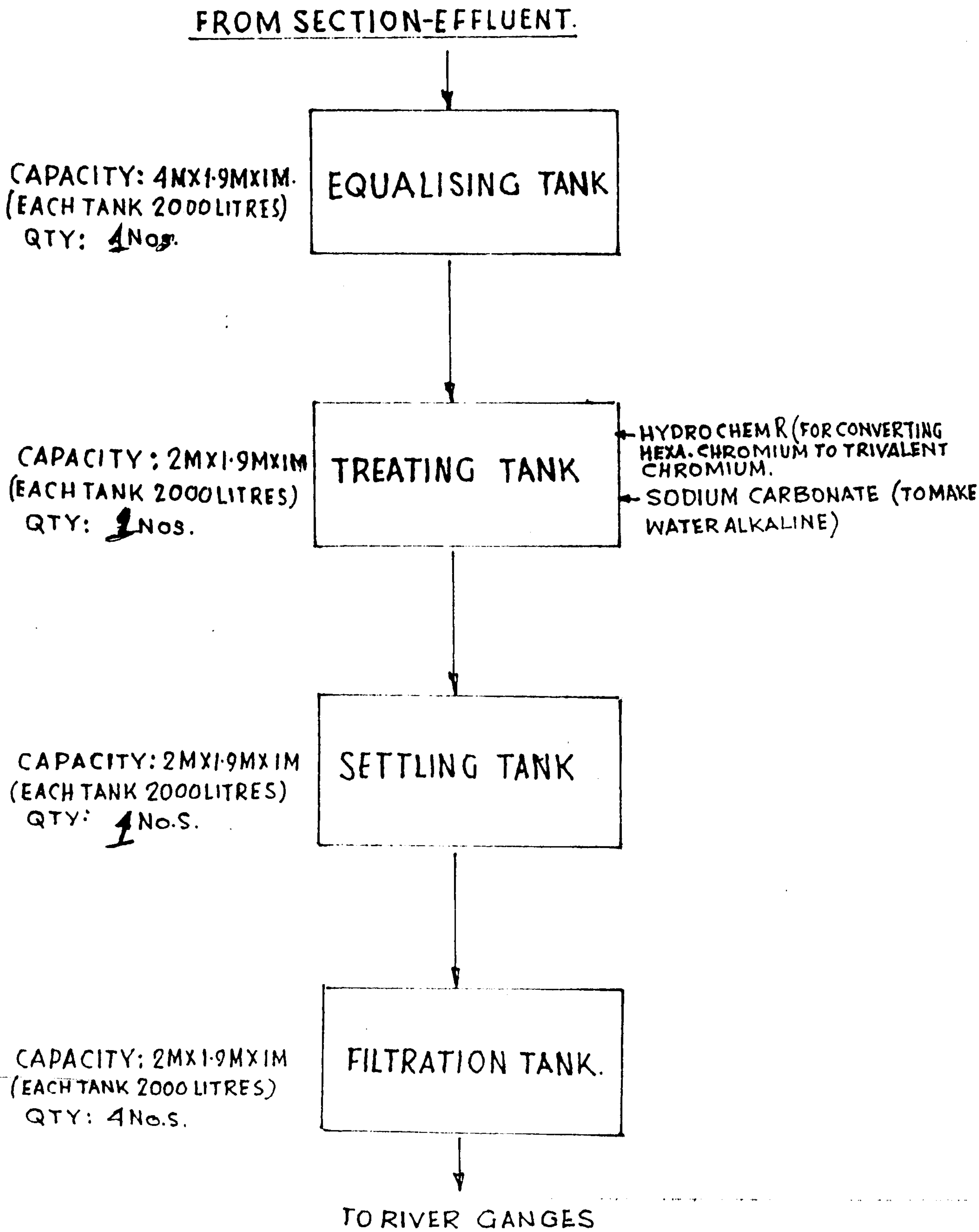
TABLE 12.6

ESTIMATES OF COST OF POLLUTION ABATEMENT PER KL. OF WATER

(In rupees)

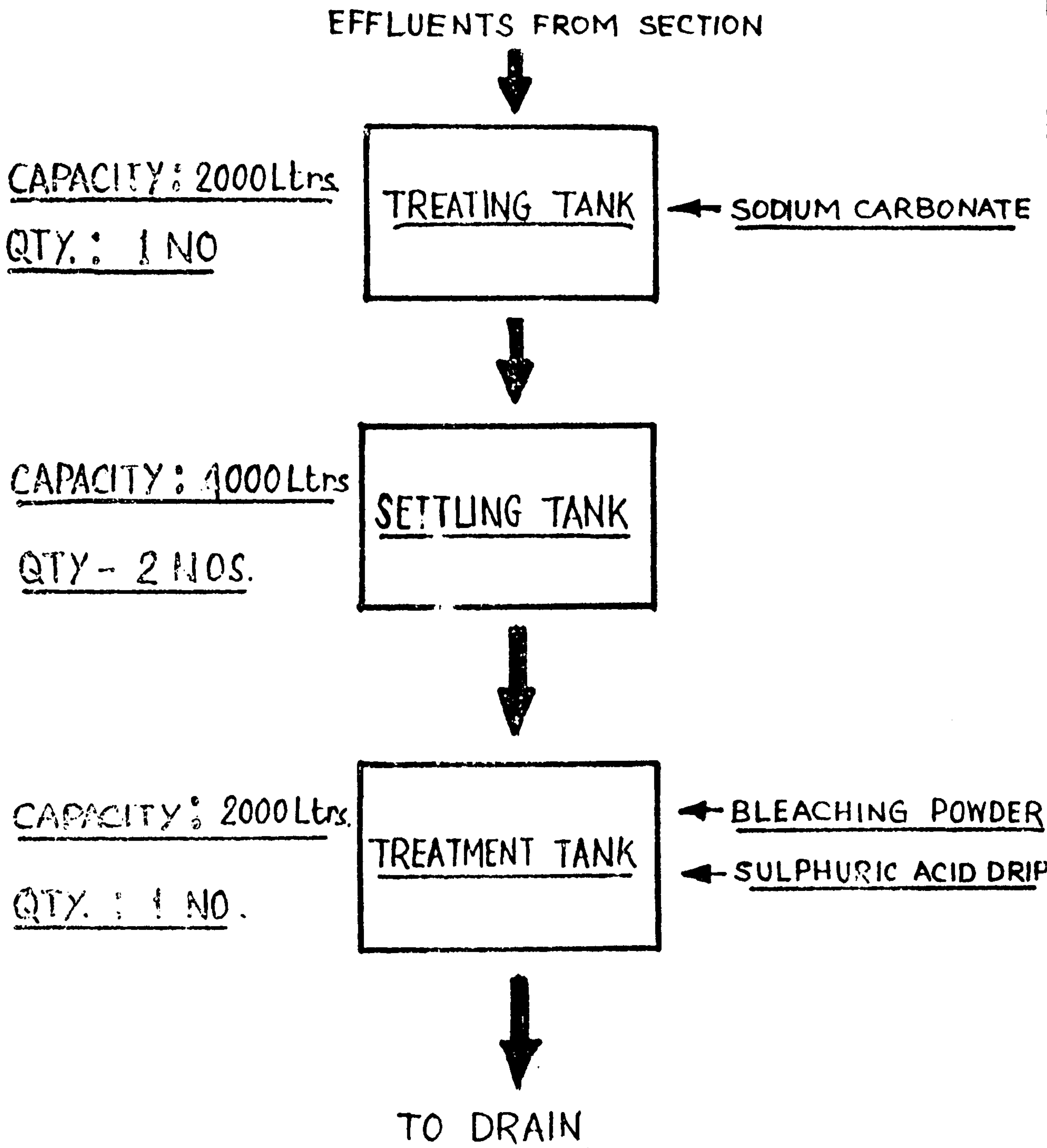
Time (T) in Years ->	15		20		25		30	
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost
				WATER RELEASED				
0.08	0.46	0.66	0.39	0.55	0.33	0.48	0.29	0.42
0.10	0.41	0.59	0.34	0.49	0.29	0.41	0.25	0.36
0.12	0.37	0.53	0.30	0.43	0.25	0.36	0.21	0.31
				WATER USED				
0.08	0.38	0.54	0.32	0.46	0.27	0.39	0.24	0.35
0.10	0.34	0.48	0.28	0.40	0.24	0.34	0.20	0.29
0.12	0.30	0.44	0.25	0.35	0.21	0.30	0.18	0.25

PROCESS LAYOUT - FUZE SECTION



PROCESS LAYOUT – EDS. SECTION

CYANIDE & COPPER TREATMENT PLANT



CHAPTER 13

SMALL PAPER AND PULP MILLS

13.1 Introduction

The rise and growth of small paper and pulp mill is comparatively a recent phenomenon in India. They require less initial investment and can base themselves on agricultural residues, besides wastepaper which are found in abundance in several parts of the country. Their capacity varies from 3 to 30 tonne per day (TPD). As on 31 March, 1983 they numbered 170 with an installed capacity 7.12 lakh tonnes per annum (TPA) constituting 35 per cent of total installed capacity of paper and boards in the country. Three states namely Gujarat, Uttar Pradesh and Maharashtra account for 43 per cent of total installed capacity of the country.

In the next section we describe in brief the manufacturing process.

13.2 Manufacturing Process

The raw materials for small paper mill is constituted of rice and wheat straw, bagasse, jute, cotton rags, different types of grasses, waste paper, purchased pulp etc.

Main pluping processes which are normally employed in paper industry are (i) chemical process (ii) chemo-mechanical process (iii)_ mechanical process (hydro-pulping).

Chemical Process Agrigultural residues like gunny, jute etc. are put into the rotary digesters along with chemicals like sodium hydroxide and/or lime and are heated at high temparature (150° C). Steam pressure is maintained between 5 and 6 kg/sq. cm. Digestion time is of 2.5 to 5 hours. Ratio of raw material to water is maintained at 1:3.3-4.0 before digestion starts.

Chemo-mechanical pulping: This process use both chemical and mechanical process in series. The raw material is soaked in 3-5 per cent caustic soda solution at 90°C for 15-30 minutes. The soaked material is then subjected to drastic mechanical treatment to seperate fibres.

Mechnical Process: Used for waste paper and recycled paper. Hydro pulping unit comprises of a high speed rotating dire which chops the paper to fibre in presence of steam and moisture. The pulp yield is estimated to be 70-80 per cent.

Pulp Processing

<u>Pulp Washing</u>: Chemically digested pulp is discharged in a blow pit or on a perforated floor where part of Black liquor drains out. Some mills take cooked material directly taken for washing in pouchers. The pulp wash is one of the major sources of wastwater besides black liquor.

<u>Beater, centri - cleaner, thickener:</u> Pulp from poucher is dumped to beater for beating to separate fibers and remove adhering dirt, chemicals and colour. From beater, the pulp is sereened and then taken to centre-cleaner for removal of heavy inorganic materials (mostly sand). It is then pumped to thickener where water is sucked by rotary drums and discharged as wastewater.

Bleaching: It is adopted for bleach paper production. After thickening the pulp is subjected to chlorination, alkati extraction and calcium hypochlorite treatment in that order. In small mills only calcium hypochlorite or bleaching powder is used.

Paper Making

Blending, conditioning and stock preparation: Blending provides the required pulp to water ratio. conditioning is done by chemicals like alum, rosin, talc & acid to suit requirement of final paper quality.

Paper Machine: This consists of a moving wire mesh and rotary driers. Steam is used is driers to drive away moisture from the sheet of paper formed on the wire mesh and picked up by the driers. The wastewater generated in this section is known as white water and is recycled upto 80 per cent for pulp washing in pouchers. Finished product is cut to size and ready for marketing (See Diagram 13.1).

Water requirement in agricultural residue mills ranges from 200-350 cubic metre per tonne of paper and that in wastepaper based mills ranges from 100-150 cubic metre per tonne of paper.

13.3 Waste Water Generation and Cheracteristics

As we have seen in manufacturing process wastewater is released from (i) Black liquor from cooking section (ii) Pulp wash water from pouchers (iii) Beater section (iv) Bleaching section (v) Thickener and (vi) paper machine.

In agricultural residue based mills black water is not segregated and it ends up in pulp washing wastewater. Black liquor is the most pulluting among different streams. Pulp washing section contributes rearly 80 per cent of toal pullution load. Flow and composition of pulp wash water varies since operations are carried out in batches. Paper machine wastewater is least polluting but it contributes appreciable amount of suspended solids.

The wastewater is brown in colour due to lignin content and has a pH of 6.0-8.5. (See table 13.1). The 90 percentile value for flow works out to 335 cubic metre per tonne of paper.

Wastepaper based mills generate wastewater only from bleaching, thickener and paper machine since no chemical pulping is adopted.

The 90 percentile value for flow is 149 cu.m. per tonne of paper. The soluble BOD fraction is 35-40 per cent (See table 13.2).

Based on the weighted average cheracteristics of wastewater, the pollution loads for mills using agricultural residues (20 TPD) and waste paper (15 TPD) has ben presented in Table 13.3. It is useful to work out the treatment system and their costs.

The Minimum National Standard (MINAS) for pulp and paper industry is as follows:

MINAS for Small Pulp and Paper Industry

Parameter	Concentration
pH	6.0 - 9.0
Suspended Solids	100 mg/l
Bio-chemical Oxygen Demand (BOD)	50 mg/l

13.4 Pollution Abatement Methods

The unit process ivolved in the treatment of waste water from agricultural residue based mills are:

i. Equalisation of flow from pulp washing section;

ii. primary clrification for combined waste water;

iii. secondary bological treatment;

iv. sludge drying beds or lagoons for primary sludge.

Equalisation for pulp washwater: pulp washing section accounts for 20-25 per cent of total waste water and contributes around 70-80 per cent of pollution load. These waste waters are discharged intermittently. The first wash water is more concentrated than the second wash water.

Alternative 1: It envisages flow equalisation for the first pulp wash water.

Alternative 2: It envisages flow equalisation for the entire pulp wash water.

Primary clarifier and sludge drying; Five alternatives are suggested for agricultural residue based mills.

Treatment Alternative I: After proper seeding and acclimatisation, primary clarified effluent will be treated in an anaerobic lagoon with a detention time of 20 days. Subsequently, it will be treated in aerated lagoon with a detention time of 4 days. The effluent leaving aeratead lagoon will pass through a polishing pond with a detention time of 2-3 days before discharge or use on land for agriculture.

Treatment alternative II: Effluent from primary clarifier will be treated in an aerated lagoon with a detention time of 6 days. Then it will be taken to a polishing pond with 3-5 days detention time before final discharge.

Treatment alternative III: Oxidation ditch on extended aeration principle with high MLSS (4,500-5,000 mg/l) can be used followed by a secondary clarification.

Treatment alternative IV: Combined effluent without equalisation and primary settling will be treated in anaerobic lagoon after proper seeding and acclamatisation with a detention time of 25 days. It will be subsequently treated in aerated lagoon with a detention time of 4 days followed by polishing pond with 4 days detention time.

Treatment alternative V: Same as alternative II except polishing pond is replaced by settling tank.

After any one of the treatments, waste water will be practically devoid of nitrogen and phosphorous, hence nutrients will have to be supplemented to biological treatment process.

For mills using waste paper and purchased pulp as raw material the treatment is carried out in the following process:

i. Recycling of recovered fibre and water to the maximum possible extent;

ii. primary clarification of the combined waste water before or after fibre recovery;

iii. drying of primary sludge or sludge drying bed or lagoon;

iv. the effluent from primary clarifier needs to be further treated either in a stabilisation pond or in an aerated lagoon.

Design criteria of five alternative treatments is given in **diagram 13.2.** The effluent quality at each stage of treatment for agricultural residue based mills and waste paper and purchased pulp mill is given in **Table 13.4 and 13.5.** 10 cu m of black liquor is generatead for one tonne of paper made. If 50 per cent of this liquor can be squeezed out by some means the pollution load and cost of waste water treatment would get reduced proportionately.

13.5 Cost Estimates

The cost flows of alternative treatments for 30 TPD agricultural residue based mill are given in tables 13.6 to 13.10. The corresponding cost estimates are given in Table 13.11 to 13.15. These cost flow tables reveal that the resource cost of pollution abatement per Kl. of water used ranges from Rs 0.29 to Rs 0.41 while social cost ranges from Rs 0.37 to Rs 0.69 taking rate of discount r=0.10 and time period, T=30 years. Similarly resource cost of pollution abatement per KL of water released lie between Rs 0.48 and Rs 0.81 when social cost lie between Rs 0.76 and Rs 1.43 for the same r and T, respectively.

13.6 Conclusions:

In this study we have restricted ourselves to small paper mills only. Like small paper mills, large ones also have environmental problems associated with it. Water requirement per tonne of paper produced in small mills are significantly higher than that of large mills. Also there is significant differences in the characteristics of waste water discharged by small and large paper mills.

The capital and operating cost of pollution abatement methods per tonne of paper produced is higher in small mills. This also gets reflected in resource and social cost of pollution abatement which turns out to be larger for small mills. The reason being that small mills do not practice chemical recovery and reuse of water while it is economical for large mills. In addition, small mills are located in isolated areas and they cannot take advantage of significant economies of scale in the pollution abatement measures.

TABLE 13.1

RANGE AND AVERAGE CHARACTERISTICS OF COMBINED WASTE WATER AND POLLUTION LOADS FROM MILLS BASED ON AGRICULTURAL RESIDUE

Parameters	Based on Data for 7 Mills (7-30 TPD)		
	Actual Values*		Average** (weighted)
	Minimum	Maximum	
Valume Cu m/T	187	383	252 ± 57.4
pH	6.0	8.5	--
Suspended solids, kg/T	88	239	155 ± 46.8
BOD Kg/T	85	267	176 ± 55
COD Kg/T	497	1,087	741 ± 154.7
Lignin Kg/T	93	197	142 ± 30

Notes: * Eleven values are taken for working out min and max values.

** Waste water volume and production are taken for weighted average calculations.

TABLE 13.2

RANGE AND AVERAGE CHARACTERISTICS OF COMBINED WASTE WATER AND POLLUTION LOADS FROM MILLS BASED ON WASTE PAPER AND/OR PERCHASED PULP

Parameters	Based on Data for 4 Mills (2-25 TDP)		
	Actual Values*		Average (Weighted)**
	Minimum	Maximum	
Volume Cu m/T	72	159	107 ± 28.4
Volume Cu m/T(90 percentile value)	–	–	149
pH	7.1	7.7	
Suspended Solids, Kg/T	47	78	58 ± 10.7
BOD Kg/T	9	38	20 ± 10.5
COD Kg/T	49	91	70 ± 15.2

Notes: * Seven values are taken for working out minimum and maximum values.

** Waste water volume and production are taken for weighted average calculations.

TABLE 13.3

WASTE WATER VOLUME AND POLLUTION LOAD FOR MILLS EMPLOYING AGRICULTURAL RESIDUE (20 TPD) AND WASTE PAPER AND/OR PULP (15 TPD)

Parameters	Capacity (TPD)	
	20	15
Volume cum/d(average)	5040	1605
pH	6.0-8.5	7.1-7.7
Suspended solids kg./d	3,100	1,350
BOD kg./d	3,518	300
COD kg./d	14,818	1,050

TABLE 13.4

EFFLUENT QUALITY AT EACH STAGE OF TREATMET PROPOSED IN DIFFERENT ALTERNATIVE METHODS (AGRICULTURAL RESIDUE BASED SPM)

Parameters	Raw waste water	Primary clari-fier	Alternative I			Alternative II		Alternative III	Alternative IV			Alternative V	
			Anaerobic lagoons (20d DT)	Aerated lagoons (4d DT)	Polishing pond (3d DT)	Aerated lagoons (6d DT)	Polishing pond (4d DT)	Oxidation ditch or activated sludge followed by secondary setting	Anaerobic lagoons (25d DT)	Aerated lagoon (4d DT)	Polishing pond (4d DT)	Aerated lagoon (6d DT)	Secondary settling
Flow Cu m/T	252	335*											
pH	6.0-8.5	6.0-8.0	6.6-7.3	7.0-8.0	7.0-8.0	7.5-8.0	7.0-8.0	7.5-8.3	6.6-7.3	7.5-8.0	7.0-8.0	7.5-8.0	7.0-8.0
SS, mg./l	615	185 (70)	95 (70)	40-60 (70)	30 (85)	100-250	50-60 (75)	20-30 (80)	95 (81)	40-60 (70)	30 (85)	100-250	50-60 (75)
BOD, mg./l	700	525 (25)	290 (45)	70-80 (85)	40-50 (90)	80 (35)	30-50 (90)	290 (50)	70-80 (85)	40-50 (90)	80 (85)	30-50 (90)	
COD, mg./l	2,940	1,765 (40)	1,250 (30)	1,000*	1,000*	1,000*	1,000*	1,000*	1,250	1,000*	1,000*	1,000*	1,000*
Sludge volume % v/v average flow and at 0.75 per cent solids concentration		6.5											

Notes: * 90 percentile value.

DT-Detention time; figures in brackets represents expected percentage reduction.

TABLE 13.5

EFFLUENT QUALITY AT EACH STAGE OF TREATMENT PROPOSED (WASTE PAPER AND PURCHASED PULP BASED SPM)

Parameters	Raw waste water	Primary clarifier	Alternative I stabilisation pond	Alternative II aerated lagoon followed by polishing pond
pH	7.1-7.7	7.0-7.5	7.5-8.3	7.0-8.0
SS, mg./l	540	110	30-50 (40)	30-50 (64)
BOD, mg./l	190	80	20-30 (70)	15-20 (80)
COD, mg./l	655	165	80-100 (45)	50 (70)
Sludge volume at 0.75 per cent solids consistency (% v/v)		6.5		

Note: Figures in brackets represents percentage reduction.

TABLE 13.6

COST FLOWS FOR PULP AND PAPER INDUSTRY (AGRICULTURAL RESIDUE BASED, CAPACITY 20 TPD) AT 1987-88 PRICES (TREATMENT ALTERNATIVE A)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	1207000	1375980	Fixed cost	8215740
2. Other fixed cost			15 per cent of fixed cost	1232361
a. Machinery and equipment	2097365	4823940	Operating cost	721872
b. Piping	787221	1810610	TOTAL	1954233
c. Civil works				
(i) Bricks	464260	1067797	Quantity of water released per year	748880
(ii) Cement	903286	2077558	Quantity of watr used per year kl.	1548000
(iii) Steel	1001184	2302723		
d. Electrical equipment	490612	1128408	Cost of 1 kl. of water released	2.61
e. Installation	350437	806005	Cost of 1 kl. of water used	1.26
TOTAL	7301365	15393021		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	3540	3540		
b. Unskilled	2360	1015		
2. Maintenance				
a. Oil	1490	2235		
b. Repair	4292	4292		
3. Chemicals	20919	31379		
4. Fuel	22859	31385		
TOTAL ANNUAL COST	665520	886152		

TABLE 13.7

COST FLOWS FOR PULP AND PAPER INDUSTRY (AGRICULTURAL RESIDUE BASED, CAPACITY 20 TPD) AT 1987-88 PRICES (TREATMENT ALTERNATIVE B)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	552270	629588	Fixed cost	6474284
2. Other fixed cost			15 per cent of fixed cost	971143
a. Machinery and equipment	1772163	4075974	Operating cost	1023804
b. Piping	665161	1529870	TOTAL	1994947
c. Civil works				
(i) Bricks	392274	902230	Quantity of water released per year kl.	748800
(ii) Cement	763229	1755426	Quantity of water used per year kl.	1548000
(iii) Steel	845948	1945680	Cost of 1 kl. of water released	2.66
d. Electrical equipment	414541	953444		
e. Installation	296101	681032	Cost of 1 kl. of water used	1.28
TOTAL	5701687	12473244		
B. OPERATING COSST (MONTHLY)				
1. Labour				
a. Skilled	7129	7129		
b. Unskilled	4752	2043		
2. Maintenance				
a. Oil	1259	1888		
b. Repair	3627	3627		
3. Chemicals	29670	44505		
4. Fuel	32420	44512		
TOTAL ANNUAL COST	946284	1244448		

TABLE 13.8

COST FLOWS FOR PULP AND PAPER INDUSTRY (AGRICULTURAL RESIDUE BASED, CAPACITY 20 TPD) AT 1987-88 PRICES (TREATMENT ALTERNATIVE C)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	1919967	2188762	Fixed cost	10701528
2. Other fixed cost			15 per cent of fixed cost	1605230
a. Machinery and equipment	2627882	6044128		
b. Piping	986345	2268593	Operating cost	1094016
c. Civil works			TOTAL	2699246
(i) Bricks •	581691	1337890	Quantity of water released per year kl.	748800
(ii) Cement	1131768	2603066	Quantity of water used per year kl.	1548000
(iii) Steel	1254429	2885186		
d. Electrical equipment	614709	1413831	Cost of 1 kl. of water released	3.60
e. Installation	439078	1009879	Cost of 1 kl. of water used	1.74
TOTAL	9555869	19751335		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	6330	6330		
b. Unskilled	4220	1815		
2. Maintenance				
a. Oil	1866	2799		
b. Repair	5379	5379		
3. Chemicals	31704	47556		
4. Fuel	34644	47566		
TOTAL ANNUAL COST	1009716	1337340		

TABLE 13.9

COST FLOWS FOR PULP AND PAPER INDUSTRY (AGRICULTURAL RESIDUE BASED, CAPACITY 20 TPD) AT 1987-88 PRICES (TREATMENT ALTERNATIVE B)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	938980	1070437	Fixed cost	4760917
2. Other fixed cost			15 per cent of fixed cost	714138
a. Machinery and equipment	1143715	2630544	Operating cost	723264
b. Piping	429280	987344	TOTAL	1437402
c. Civil works				
(i) Bricks	253165	582280	Quantity of water released per year kl.	748800
(ii) Cement	492571	1132914	Quantity of water used per year kl.	1548000
(iii) Steel	545956	1255700		
d. Electrical Equipment	267535	615330	Cost per kl. of water released	1.91
e. Installation	191097	439523	Cost per kl. of water used	0.92
TOTAL	4262299	8714072		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	5226	5226		
b. Unskilled	3485	1498		
2. Maintenance				
a. Oil	812	1218		
b. Repair	2341	2341		
3. Chemicals	20960	31440		
4. Fuel	22903	31446		
TOTAL ANNUAL COST	668724	878028		

TABLE 13.10

COST FLOWS FOR PULP AND PAPER INDUSTRY (AGRICULTURAL RESIDUE BASED, CAPACITY 20 TPD) AT 1987-88 PRICES (TREATMENT ALTERNATIVE E)

(In rupees)

	Resource cost	Social cost
A. FIXED COST		
1. Land	494200	563388
2. Other fixed cost		
a. Machinery and equipment	2236704	5144419
b. Piping	839520	1930897
c. Civil works		
(i) Bricks	495102	1138734
(ii) Cement	963296	2215580
(iii) Steel	1067698	2455705
d. Electrical equipment	523205	1203371
e. Installation	373718	859551
TOTAL	6993443	15511645
B. OPERATING COST (MONTHLY)		
1. Labour		
a. Skilled	6455	6455
b. Unskilled	4304	1850
2. Maintenance		
a. Oil	1588	2382
b. Repair	4578	4578
3. Chemicals	30076	45114
4. Fuel	32865	45124
TOTAL ANNUAL COST	958392	1266036

Commercial cost	
Fixed cost	7968563
15 per cent of fixed cost	1195284
Operating cost	1037856
TOTAL	2233140
Quantity of water used per year kl.	1548000
Quantity of water released per year kl.	748800
Cost per kl. of water used	1.44
Cost per kl. of water released	2.98

TABLE 13.11

ESTIMATES OF COST OF POLLUTION ABATEMENT (PAPER AND PULP) PER KL. OF WATER USED AND RELEASED

ALTERNATIVE A

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.76	1.37	0.56	0.99	0.45	0.78	0.37	0.64	0.32	0.55	
0.10	0.74	1.35	0.53	0.95	0.42	0.74	0.35	0.60	0.29	0.51	1.26
0.12	0.71	1.32	0.51	0.92	0.39	0.71	0.32	0.58	0.27	0.48	
					WATER RELEASED						
0.08	1.57	2.85	1.16	2.05	0.92	1.61	0.76	1.32	0.66	1.13	
0.10	1.52	2.78	1.10	1.97	0.87	1.53	0.71	1.25	0.60	1.05	2.61
0.12	1.48	2.72	1.05	1.91	0.82	1.47	0.67	1.19	0.56	1.00	

TABLE 13.12

ESTIMATES OF COST OF POLLUTION ABATEMENT (PAPER AND PULP) PER KL. OF WATER USED AND RELEASED

ALTERNATIVE B

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.78	1.34	0.60	1.00	0.48	0.80	0.41	0.66	0.35	0.57	
0.10	0.74	1.30	0.56	0.94	0.44	0.74	0.37	0.61	0.31	0.52	1.28
0.12	0.71	1.26	0.52	0.90	0.41	0.70	0.33	0.57	0.27	0.48	
					WATER RELEASED						
0.08	1.61	2.78	1.23	2.06	1.00	1.64	0.84	1.37	0.72	1.18	
0.10	1.54	2.69	1.15	1.95	0.92	1.54	0.76	1.27	0.64	1.07	2.66
0.12	1.48	2.60	1.08	1.86	0.85	1.45	0.70	1.18	0.59	1.00	

TABLE 13.13

ESTIMATES OF COST OF POLLUTION ABATEMENT (PAPER AND PULP) PER KL. OF WATER USED AND RELEASED

ALTERNATIVE C

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	1.05	1.85	0.76	1.34	0.63	1.06	0.52	0.87	0.45	0.75	
0.10	1.02	1.80	0.74	1.28	0.58	1.01	0.48	0.82	0.41	0.69	1.74
0.12	0.99	1.76	0.70	1.24	0.55	0.95	0.45	0.77	0.38	0.65	
					WATER RELEASED						
0.08	2.17	3.83	1.58	2.78	1.29	2.19	1.08	1.81	0.93	1.55	
0.10	2.10	3.73	1.53	2.66	1.21	2.07	1.00	1.71	0.84	1.43	3.60
0.12	2.03	3.64	1.46	2.57	1.14	1.98	0.93	1.61	0.79	1.35	

TABLE 13.14

ESTIMATES OF COST OF POLLUTION ABATEMENT (PAPER AND PULP) PER KL. OF WATER USED AND RELEASED

ALTERNATIVE D

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.56	0.94	0.43	0.70	0.35	0.56	0.29	0.47	0.25	0.40	
0.10	0.54	0.91	0.40	0.66	0.32	0.52	0.27	0.43	0.23	0.37	0.92
0.12	0.52	0.88	0.38	0.63	0.30	0.49	0.24	0.40	0.21	0.34	
					WATER RELEASED						
0.08	1.16	1.94	0.89	1.45	0.72	1.16	0.60	0.97	0.52	0.83	
0.10	1.12	1.88	0.83	1.36	0.66	1.08	0.56	0.89	0.48	0.76	1.91
0.12	1.08	1.82	0.79	1.30	0.62	1.01	0.50	0.83	0.43	0.70	

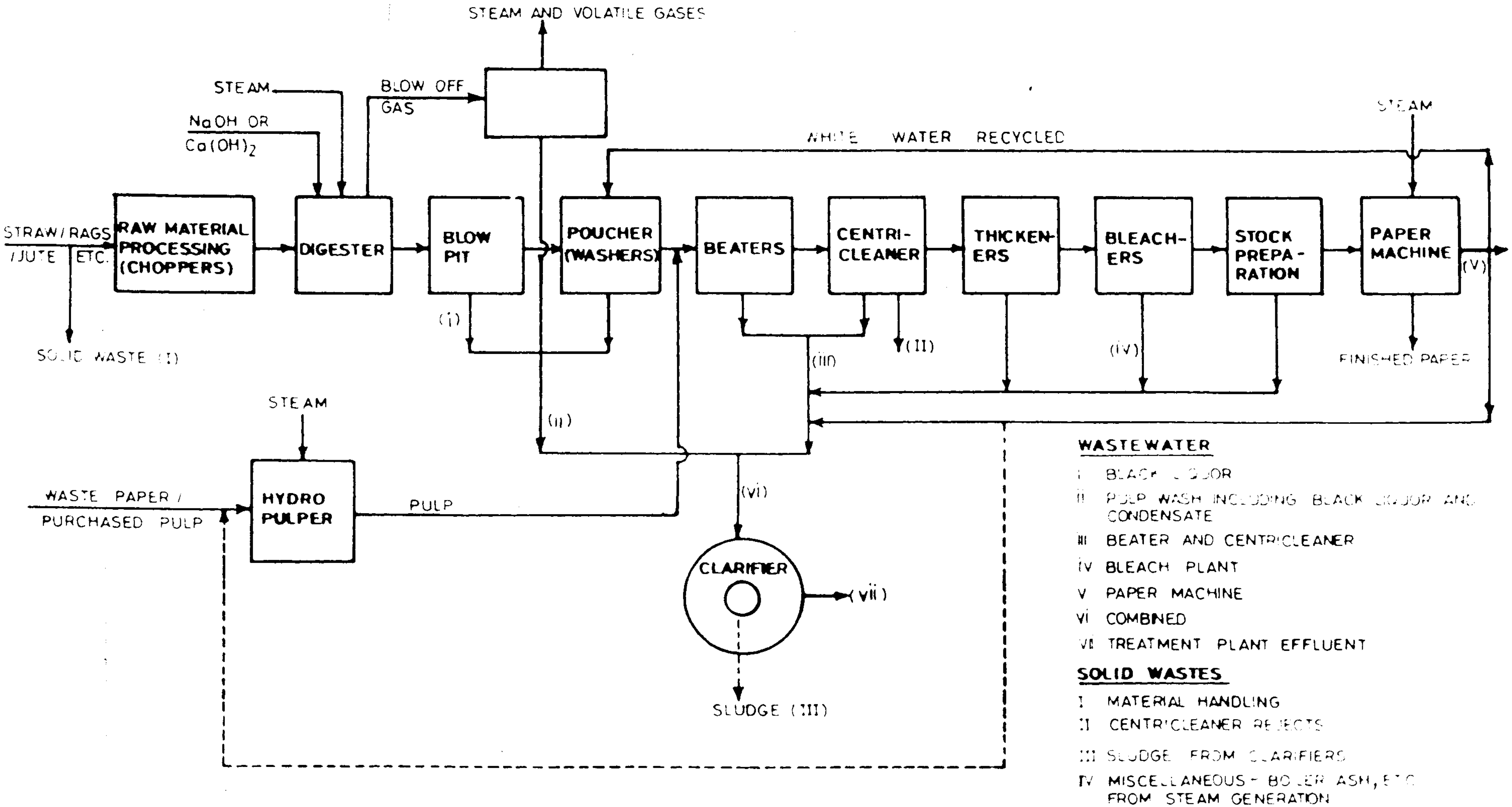
TABLE 13.15

ESTIMATES OF COST OF POLLUTION ABATEMENT (PAPER AND PULP) PER KL. OF WATER USED AND RELEASED

ALTERNATIVE E

(In rupees)

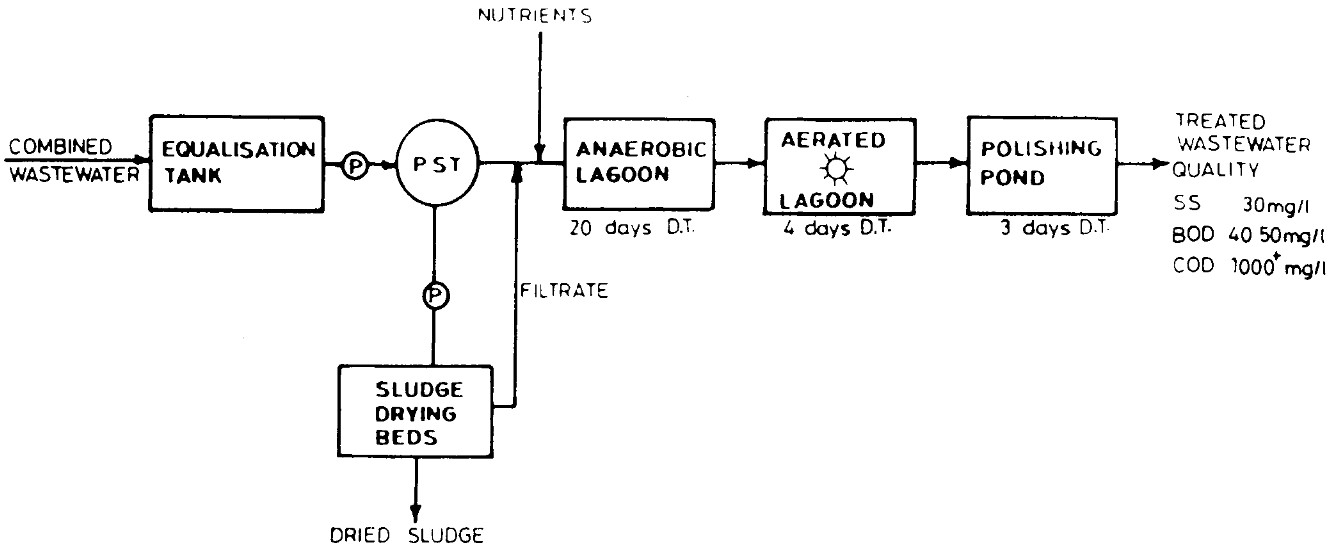
Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
					WATER USED						
0.08	0.87	1.55	0.65	1.14	0.53	0.90	0.44	0.75	0.38	0.64	
0.10	0.83	1.51	0.61	1.08	0.49	0.85	0.41	0.70	0.34	0.59	1.44
0.12	0.80	1.46	0.58	1.04	0.45	0.80	0.37	0.66	0.31	0.55	
					WATER RELEASED						
0.08	1.80	3.20	1.34	2.36	1.10	1.86	0.91	1.55	0.79	1.32	
0.10	1.72	3.12	1.26	2.23	1.01	1.73	0.85	1.45	0.70	1.22	2.98
0.12	1.65	3.02	1.20	2.15	0.93	1.65	0.76	1.36	0.64	1.14	



255

FIGURE 13.1 GENERALISED PROCESS FLOW SHEET OF SMALL PAPER MILLS AND SOURCES OF WASTES

A: TREATMENT ALTERNATIVE I



B: TREATMENT ALTERNATIVE II

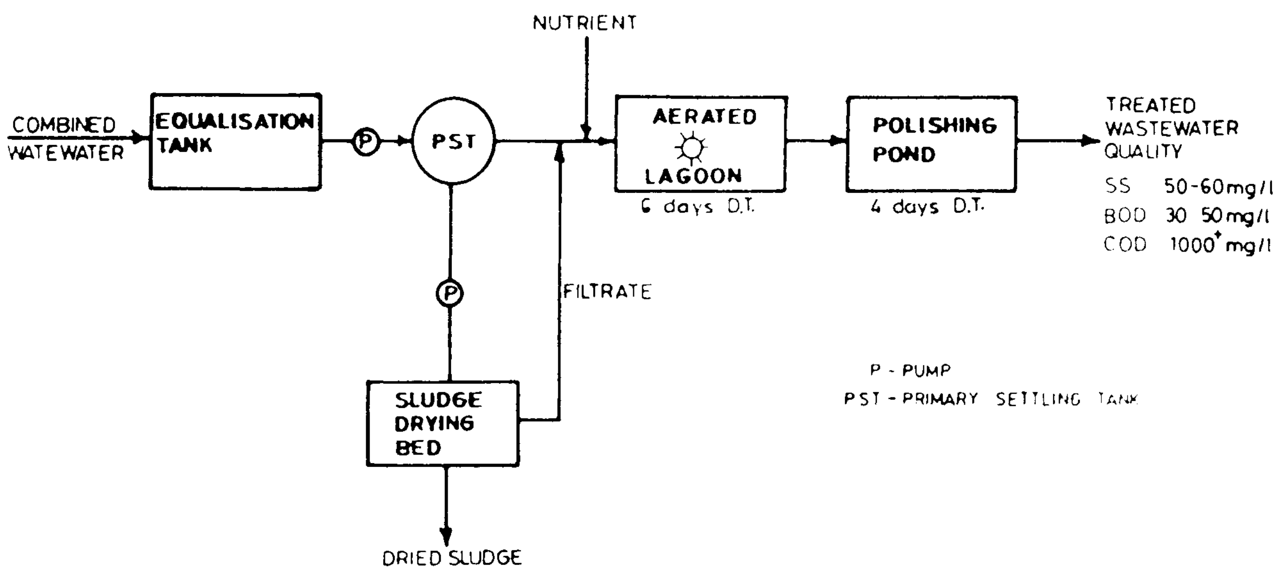
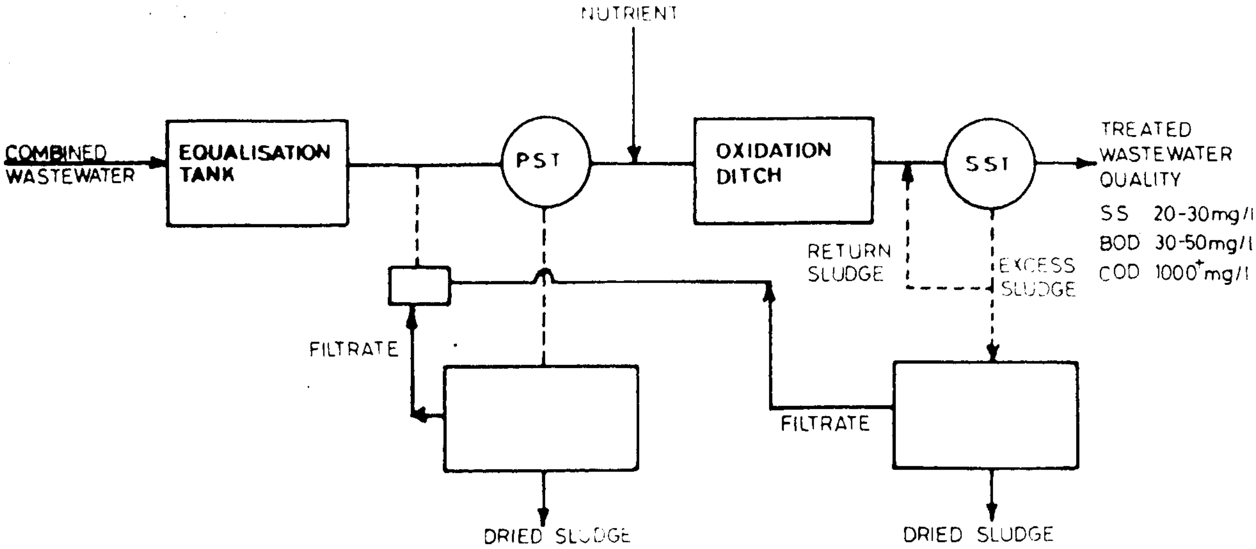
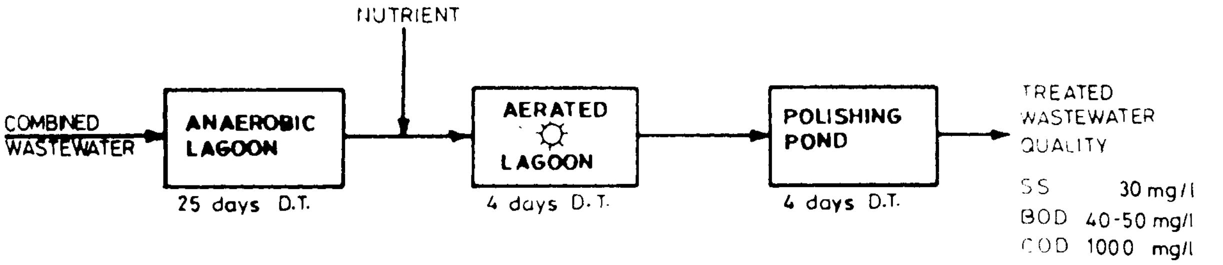


FIGURE 13·2 WASTEWATER TREATMENT ALTERNATIVES FOR AGRICULTURAL RESIDUE-BASED PAPER MILLS

[redacted] C: TREATMENT ALTERNATIVE III



[redacted] D: TREATMENT ALTERNATIVE IV



[redacted] E: TREATMENT ALTERNATIVE V

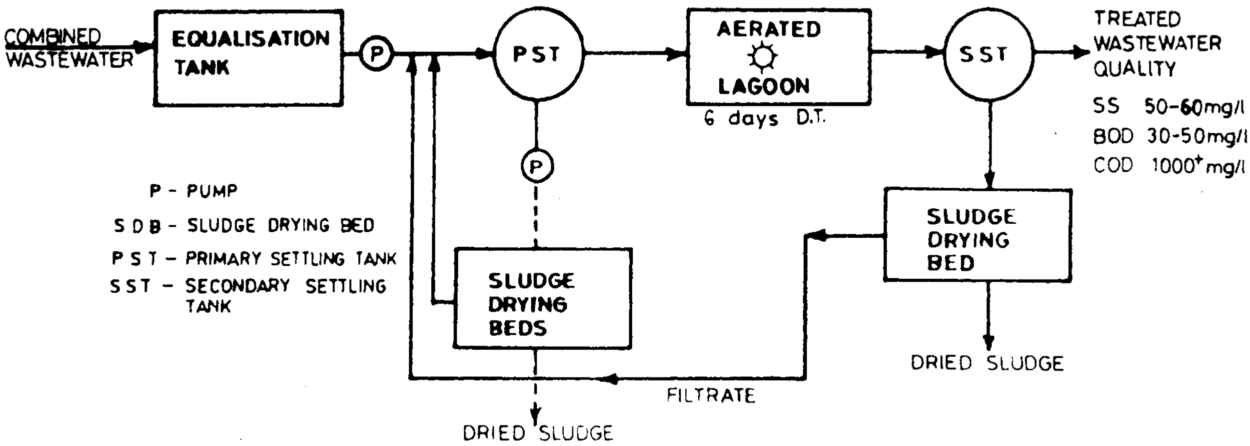


FIGURE [redacted] 13.2 WASTEWATER TREATMENT ALTERNATIVES FOR AGRICULTURAL RESIDUE-BASED PAPER MILLS

CHAPTER XIV

SUGAR INDUSTRY

14.1 Introduction

Sugar is one of the significant agricultural products and the industries processing sugar are, therefore, vital for India's economy. Even on the scale of world's sugar production, India ranks the fourth.

The water consumption in the sugar factories is comparatively high. The impurities from cane sugar remaining after the extraction of the sugar which flow down the drain are mainly carbohydrate and hence easily biodegradable. The wastes from sugar industry are highly putriscible and therefore tend to deplete dissolved oxygen from receiving water bodies when discharged into them. The sugar industry is a seasonal industry and the waste flow is mainly during a crushing season. This causes difficulty in employing biological pollutional abatement systems which would otherwise remain very suitable for treating such wastes.

The unit produces 1250 tonnes per day. It uses 2500 kl. of water per day and releases 400 kl. of effluents per day.

14.2 Manufacturing Process

The two main processes of manufacture of sugar are a) double sulphitation and b) double carbonation with double sulphitation. Figure 14.1 gives a simplified flow diagram of sugar manufacture and generation of waste.

In western countries, approximately 300 kl. of water is required per tonne of cane crushed per day due to mechanicical harvesting where a lot of dirt, soil, grit, etc., is included which has to be washed away. In India, due to manual cutting, water requirement is as low as 2 kl. to 3.3 kl. per tonne of cane crushed per day.

Double Sulphitation Process : Juice is treated with lime and sulphur dioxide (SO_2). The juice is adjusted to neutral pH and passed to the heat exchanger to raise its temperature to the boiling point.

It is then sent for clarification where the juice is clarified and then sent to multiple effect evaporators and the sediment from the clarifier is sent to vacuum filters or pressure filters. In vacuum filter or pressure filter, the juice mud is taken as solid waste and the extracted juice is mixed with raw juice before clarification. The clarified juice is concentrated to about 65 per cent solids from about 15 per cent solids before entering the first multiple effect evaporator sending steam in the first evaporator. Vapours from the first evaporation are fed to the second evaporator and so on. Spent steam from the first evaporator is returned to the boiler for reuse as water for steam. Spent steam from the second and third evaporators and the vapours from the last evaporator are condensed through condensers. The concentrated syrup from the evaporator is again bleached by passing sulphurdioxide through it, and the pH of the syrup drops down to about 5.4. It is then sent to the vacuum pan, where the thickned syrup is boiled three to four times as per purity in order to extract the sucrose content. It is sent to crystallizers to deposit any additional sucrose content on the crystals. After this, the commercial sugar and molasses are separated in the centrifuges.

Double Carbonation - Double Sulphitation - Juice is heated to 50°C to 55°C and the hot juice is mixed with lime and concentrated simultaneously such that the pH of the system remains at 10.5. During the process, a thick precipitate of calcium carbonate is obtained. By the process of absorption, it removes inorganic and organic impurities of the juice. Then the juice is filtered through large filter presses or vacuum filters. The treated juice, which has a pH of 9.8, is carbonated again with carbondioxide till the pH falls down to 8.2 to 8.5.

During this process also, a thin precipitate is obtained which is filtered off. The clear juice at pH of 8.2 to 8.5 is heated to about 70°C and sulphitation is done after which it is sent to evaporators for further process.

The amount of sugar recovery, molasses and bagasse production are given below in Table 14.1.

TABLE 14.1
SUGAR INDUSTRY - STATISTICS OF OPERATION

Particulars	Range* (Per cent)	Average*
Sugar recovery	7.5 - 12.3	9.5
Bagasse	26.2 - 45.7	34.0
Molasses	3.2 - 7.8	4.5
Press mud		
a. Double sulphitation	2.3 - 5.0	3.4
b. Double carbonation	8.1 - 10.0	9.3

Note: * Expressed as percentage of cane crushed.

The water used in sugar industry is of two types a) cold water, and b) condensate hot water. The cold water is used as make-up water, injection water to condensers, cooling water for various accessories such as engines, crystallizers, etc., cold maceration, juice dilution, lime preparation, laboratory testing and factory equipment cleaning.

The condensate water is hot and it is used as boiler feedback water, maceration, juice dilution, lime and sulphate preparation, oliver wash, dilution, pan boiling, molasses conditioning, centrifugals, magma making, massecuite dilution, etc. Sugarcane contains about 70 per cent water and during the manufacturing of sugar, water is added from outside for extraction and dilution. All the water is to be removed through the process of evaporation to get the sugar, for which steam is to be used as a media of heat.

14.3 <u>Effluent Treatment Methods</u>

<u>Soda and Acid Wastes</u> - The heat exchangers and evaporators are cleaned with caustic soda and hydrochloric acid in order to remove the formation of the deposits of scales on the surface of the tubings. The washings should be stored and reused, but usually factories release it into the drains, thereby involving a lot of wastage and expenditure. After the equipment is boiled with caustic soda and rinsed with fresh water, it is cleaned with diluted hydrochloric acid using an inhibitor. The waste water is discharged into the drains as the recovery of the chemicals may not prove to be economical in this case.

Excess Condensate – The condensate does not normally contain any pollutant and is used as boiler feed water and in the washing operations. It may so happen sometimes that it gets contaminated with juice due to entrainment or carry over of solids with the vapours being condensed, in which case it goes into waste water drain. The treatment required in this case is almost negligible and water can directly be used for irrigation.

Condensor cooling Water – Condensor cooling water is recirculated unless it gets contaminated with juice. The best way is to avoid entrainment and keep up p^H of the water to 7.0 or 7.2 by adding lime and fresh water regularly, and the surplus overflow can be used for land irrigation.

Sulphur and Lime Houses – The washings of sulphur and lime house contain a considerable amount of inorganic solids which include carbonates and sulphates. The effluents from these two units, when combined, give neutral p^H value of waste. This can be characterized as inorganic waste and does not contribute to organic pollution.

Rotary Filter Washings – The rotary filter is washed periodically and this would contain considerable amount of suspended solids. The waste contains both inorganic and organic matter.

Molasses – The concentrated boiled juice is converted into the consistency of syrup. Sugar is separated by crystallization and centrifuging and the bottom liquor is molasses or mather liquor. As such, it contains a significant concentration of uncrystallized sugar and other organic compounds. The quantity of molasses averages about 4.45 per cent of the cane crushed.

Molasses is the basic raw material for the production of alcohol and many other organic compounds. Even though molasses is fully utilisable for getting valuable by - products, it is usually stored in unlined kutcha pits, leading to serious ground water contamination as it contains a high BOD.

Bagasse - Bagasse forms 33 per cent residue of the total cane crushed. It is used mainly as a fuel in boilers for steam generation. About 95 per cent is consumed as fuel. The remaining 5 per cent is sold to paper mills or cardboard manufacturing units.

Press Mud - Press mud of double - sulphitation process contains valuable nutrients like nitrogen, phosphorus, potassium, etc. This is used mainly as organic manure, and does not pose any problem of disposal. The press mud from double carbonation process is used for land filling, and is not used as manure.

Air pollution leads to problems of cleaning, reduction in property value, effect on vegatation , etc.

Characteristics of waste steams are given in Table 14.2 while Table 14.3 gives characteristics of combined waste.

This if followed by biological treatment of effluents in goons, on the principle of anaerobic and aerobic action.

This is shown in Figure 14.2 and Figure 14.3.

The MINAS standards for sugar industry are given in Table 14.4.

14.4 Cost Estimates of Pollution Abatement

The total investment on pollution abatement plant for treating 400 kl. of waste water per day is Rs 9.6 lakh at 1987-88 prices. The operating cost is Rs 93,000 per annum. The resource cost and social cost per kl. of water released is Re 0.38 and Re 0.69 given r = 0.10 and t = 30 years.

TABLE 14.2

CHARACTERISTICS OF WASTE STREAMS

	Plant/House	Tempera-ture (°C)	p^{H}	Dissolved solids mg./l	Suspended solids mg./l	Oil and grease mg./l	COD mg./l	BOD mg./l
1.	Milling plant	25-30	5-5.5	350-400	500-550	30-50	1000-1500	700-1000
2.	Pump cooling at milling plant and at boiler house	30-50	6-6.5	400-500	30-50	-	200-300	50-80
3.	Boiler blow-down	85-90	5.8-6	450-500	50-100	-	500-550	30-40
4.	Boiling house	40-60	4.5-5	400-450	400-600	5-10	2000-3000	1500-2000
5.	Excess condensate	60-70	6-6.2	80-1000	5-10	-	250-300	100-150
6.	Sulphur house	30-35	-	-	-	-	-	-
7.	Lime house	25-30	9-10	1400-1500	3500-4000	4.6	200-250	100-150

Ref. M.E. Desertation on "Sugar Waste Treatment" by Mr. A. K. Mhaskar.

TABLE 14.3

CHARACTERISTICS OF COMBINED WASTE

Temperature in °C	30-40
pH	4.6-6.0
Dissolved solid mg./l	1000-1200
Suspended solids mg./l	250-300
Oil and Grease mg./l	5-10
COD mg./l	2000-3000
BOD mg./l	1000-1500

Ref. M. E. Desertation on "Sugar Waste Treatment" of Mr. A. K. Mhaskar.

TABLE 14.4

MINAS STANDARDS FOR SUGAR INDUSTRY

Characteristics	Parameters
pH	6.5 to 8
BOD	100 mg./l
TSS	100 mg./l
Oil and Grease	10 mg./l

Here the costs of treatment of water are quite low as the quantity of water used is quite large.

The commercial cost of one kl. of water released works out to Rs 1.64.

The cost flows are given in Table 14.5 and the cost estimates are given in Table 14.6.

14.5 Conclusion

From the above discussion it can be seen that pollution control measures are simple and cheap. But if the pollution control standards are not adhered to, the water pollution will cause extensive damage to land, air, etc., and thus reduces the condition and value of land and property. Pollution of sea-water is dangerous for marine life and leads to contamination or death of fishes, algae, and other organisms.

TABLE 14.5

COST FLOWS FOR SUGAR INDUSTRY (AT 1987-88 PRICES)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	2470	2816	Fixed cost	959496
2. Other fixed cost			15 per cent of fixed cost	143924
a. Machinery and equipment	290007	667016	Operating cost	93000
b. Piping	108752	250130	Total	236924
c. Civil works			Quantity of water used per year (kl.)	900000
(i) Bricks	64449	148233		
(ii) Cement	125975	289743	Quantity of water released per year (kl.)	144000
(iii) Steel	137602	316485	Cost of 1 kl. of water used	0.26
d. Electrical equipment	66992	154082	Cost of 1 kl. of water released	1.64
e. Installation	47853	110062		
TOTAL	844100	1938567		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	567	567		
b. Unskilled	380	163		
2. Maintenance				
a. Oil	207	311		
b. Repair	586	586		
3. Chemicals	2739	4109		
4. Fuels	2712	3724		
TOTAL				
TOTAL (ANNUAL)	[illegible]	[illegible]		

TABLE 14.6

COST ESTIMATES OF SUGAR INDUSTRY PER KL. OF WATER

(In rupees)

Time (T) in Years ->15			20		25		30		
Social rate of Discount	Reosurce cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
				WATER USED					
0.08	0.12	0.21	0.09	0.16	0.08	0.14	0.07	0.12	
0.10	0.11	0.20	0.08	0.16	0.07	0.13	0.06	0.11	0.26
0.12	0.10	0.20	0.08	0.15	0.06	0.12	0.05	0.10	
				WATER RELEASED					
0.08	0.73	1.34	0.59	1.05	0.49	0.87	0.42	0.74	
0.10	0.69	1.29	0.55	1.00	0.45	0.82	0.38	0.69	1.64
0.12	0.66	1.25	0.51	0.96	0.42	0.78	0.35	0.66	

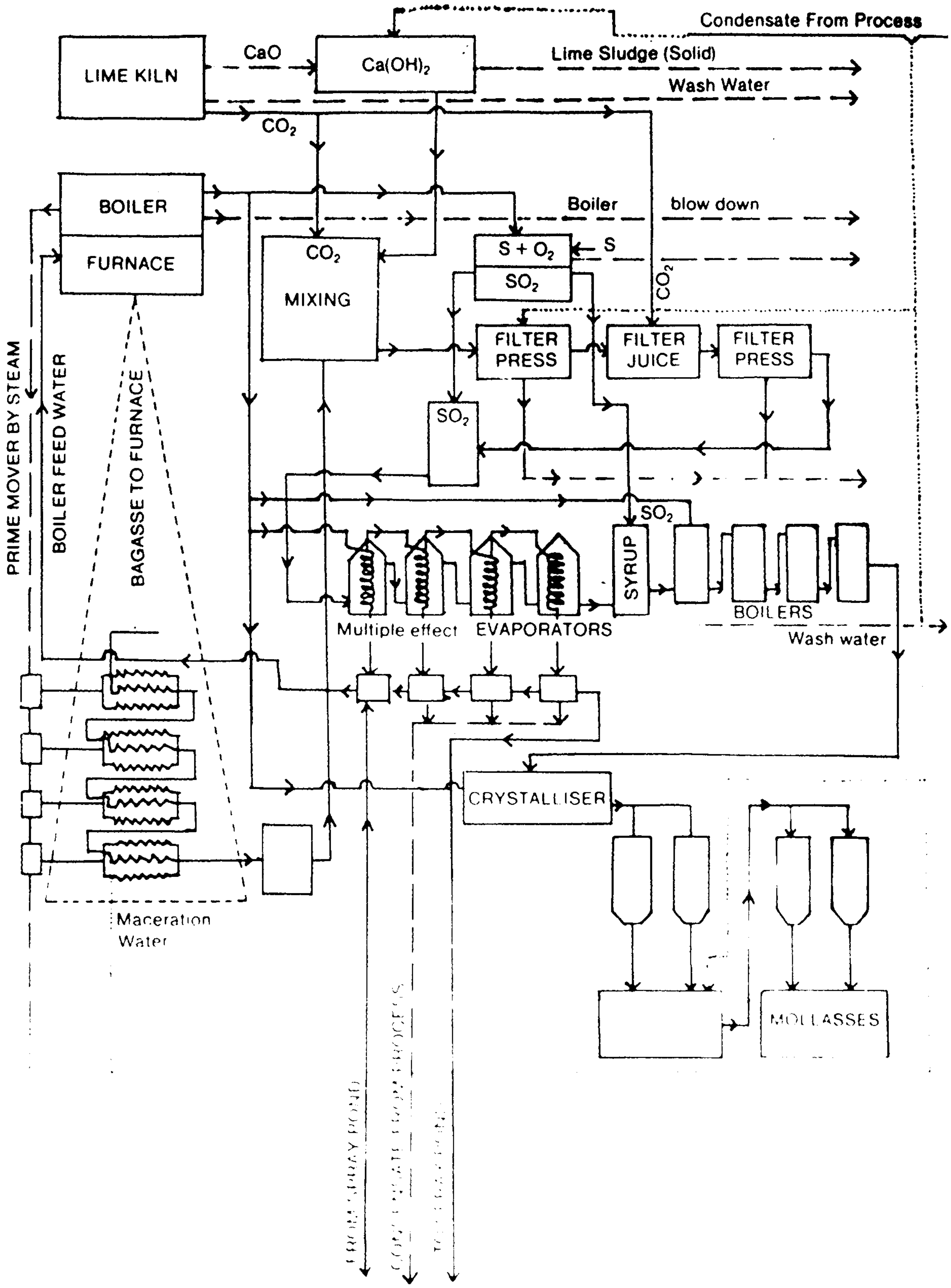


FIG. 41 SIMPLIFIED FLOW DIAGRAM OF SUGAR MANUFACTURE AND GENERATION OF WASTE

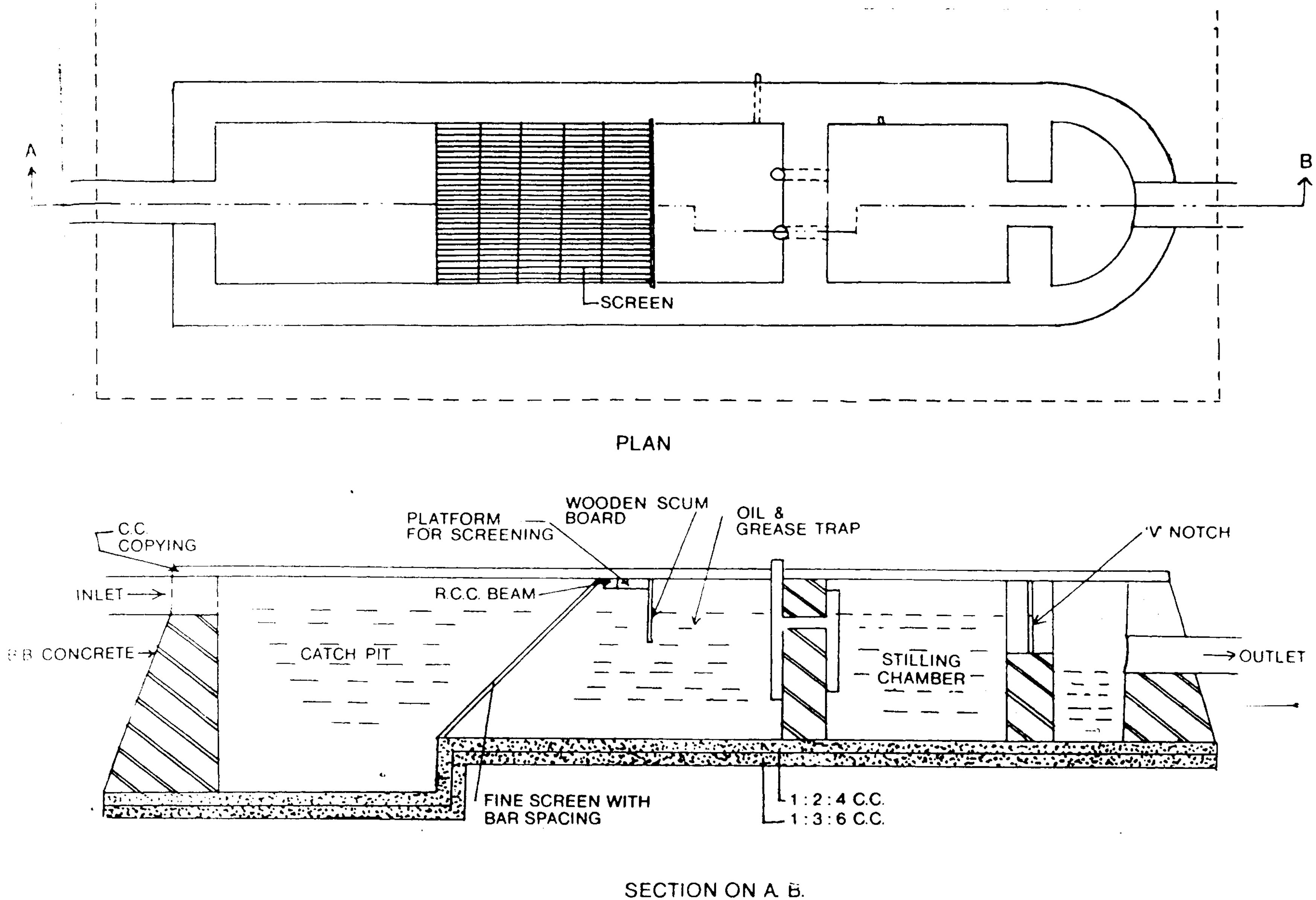


FIG 14.1 SCHEMATIC STANDARD DESIGN FOR PRELIMINARY TREATMENT OF SUGAR FACTORY EFFLUENT

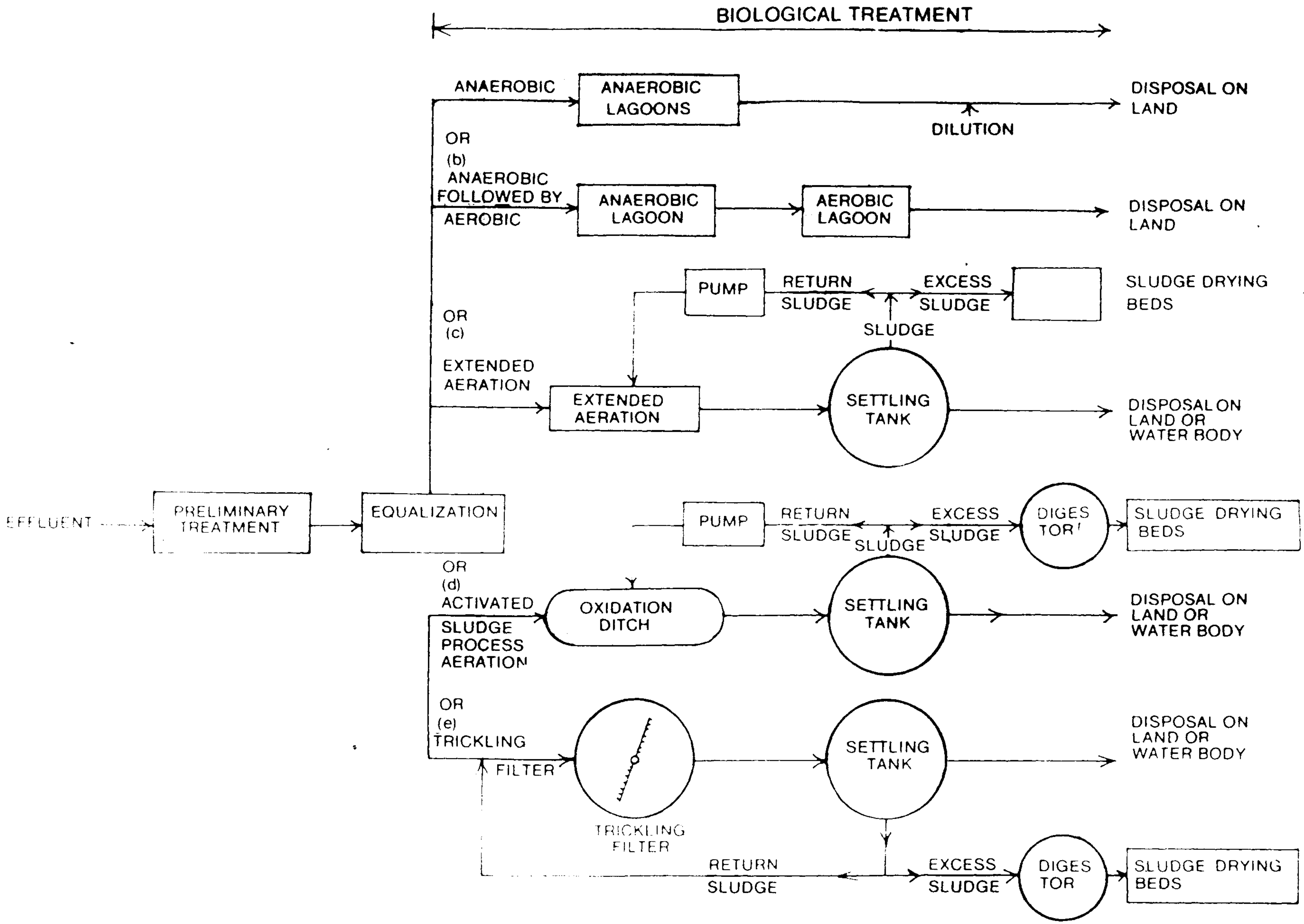


FIG. 13 TREATMENT PROCESSES

CHAPTER XV

MAN-MADE FIBRE INDUSTRY

Man-made fibre industry consists of both synthetic and semi-synthetic type. Synthetics are made from synthesised organic polymers and semi-synthetics from natural polymer (i.e., of vegetable origin) cellulose. There are 29 manufacturing units of man-made fibre which are mainly concentrated in Gujarat, Maharashtra and Tamil Nadu.

These units differ in the manufacturing process undertaken, raw materials used, finished product produced and type and amount of effluent generated.

Now we proceed to discuss the manufacturing process in brief.

Manufacturing Process

The manufacturing process of synthetic product like polymide (nylon 6) and polyester and semi-synthetic product like viscose rayon and cellulose acetate rayon are enumerated below:

Polymide (Nylon 6)

Polymerisation: Main raw material is caprolactum, a white flaky solid soluble in water, which has a melting point at 68°C. Polymerisation of caprolactum is carried out in stainless steel cylinders at 240-270°C in the presence of acetic acid, water and a dulling agent, normally T_iO_2. Polymerisation takes place in the cylinder and at the bottom of the cylinder, highly viscose molten polymer consisting of 89-92 per cent of the polymer and 11-8 per cent of the unconverted caprolactum gets collected. Molten material is turned into ribbons by extrusion that passes through cold water in cooler. The ribbon is then cut in chips by cutter. Chips are washed with demineralised water at 80°C to remove unconverted caprolactum. It is centrifuged to remove the excess water and dried under reduced pressure at maximum 80°C in tumble drier. The whole process is carried out in an inert atmosphere of nitrogen to prevent oxidation. The dry polymer chips are then sent to melt spinning section.

The water used in cooling the ribons from extruder normally goes to waste constituting major volume of effluent.

Melt Spinning: The dry polymer chips are melted by electrically heating to 250-260°C. The molten polymer is then fed to a spinning pump and filtered before entering spinnerette which is a special alloy steel disc with a number of fine holes in it. The molten polymer coming out of spinnerette solidifies while falling through a counter-current of cold air. The yarn thus formed is subjected to stretching, application of an antistatic agent, etc., to make it suitable as textile yarn. The different steps in the manufacturing of filament nylon 6 are shown is flow chart (See Diagram 15.1).

Polyster

The basic raw materials are dimethyl terephethalate (DMT) and ethylene glycol.

Polymerisation: DMT is condensed with ethylene glycol in reactor by heating it where methyl alcohol is eliminated. Rest of the process is similar to polymide fibre.

Spinning and Drawing: It is done in similar manner as in polymide fibre.

Viscose Rayon (Cellulose)

Rayon grade pulp is the basic raw material for production of rayon. The manufacturing process consists of steeping and ageing, xanthation or sulphidation, ripening and filtration and spinning.

Steeping and Ageing: Pulp sheets are conditioned in a room at a fixed temperature and humidity and then steeped in sodium hydroxide at a temperature of 18-22°C for 30 to 90 minutes. The steeped pulp is squeezed in hydraulic press to remove excess alkali. Then it is subjected successively to breaking, shredding and kneading operations to convert them in small bits called 'crumb'. The shedding operation is carried out in water cooled tanks at 22-27°C temperature for about one hour. These crumbs are subsequently aged by contact with air at 20-35°C for 6 to 35 hours.

Xanthation: The aged crumbs are put in huge, rotating churn where carbon disulphide is added and it is churned for 3 hours. As xanthation reaction proceeds, the crumb changes colour from yellow to orange and sodium cellulose xanthate in the form of small balls is collected. It is emptied into a dissolver containing caustic soda solution at 10°C. Titaniun dioxide is added to the solution to obtain viscose solution.

Ripening and Filtration: Viscose solution is ripened for 2-3 days at 19°C in blender. Ripened solution is filtered in plate and it is deareated by keeping in tanks for 18-20 hours under vacuum.

Spinning: The ripened viscose solution is pumped to the spinning machine containing large number of spinning heads. Viscose emerges from the orifices of the spinning nozzle into the spinning bath to allow it to solidify into filament yarn. Substantial amount of waste water is generated in this section. Then it is centrifuged in hydro extractors to remove moisture, dried in tunnel drier and rehumidated in humidifier at 65 per cent relative humidity. The viscose yarn is then classified into grades and mounted into coning machine for delivery to weaving mills (See Diagram 15.2).

Cellulose Acetate Rayon

Main raw materials are cotton linters and wood pulp. Unlike in viscose rayon case, cellulose acetate is manufactured by converting cellulose into chemical compound of cellulose which is then dissolved in a suitable solvent and spun by evaporating the solvent.

Waste Water Generation and Characteristic

The quantity of waste water discharged varies depending on the size of the unit, its production, availability of water and its uses. In synthetic fibre section, the unit which discharged lowest volume of effluent economises on the cooling water required to solidity the ribbons from extruder by practicising closed circular cooling. Among the rayon units, those which produce their rayon pulp in integrated plant contribute a larger volume of effluent. The average waste water discharged by nylon polyester plants and viscose rayon plants are 37,400 gallons/tonne and 2,64,000 gallon/tonne respectively.

The waste water characteristics of nylon and polyester plants are given in Table 1.51.

TABLE 15.1

WASTE WATER CHARACTERISTICS

Parameters	Effluent from	
	Nylon plant	Polyester plant
Temperature °C	30	32
pH	7.25	8.55
Total solids, mg./l	1388	1736
Total dissolved solids, mg./l	1352	1542
BOD, 5 days, 20°C, mg./l	619	580
Volatile solids, mg./l	384	632
COD, mg./l	1459	1680
Alkalinity (C_aC_{O3})mg./l	350	730

The viscose plants' waste are much larger in volume and have grater pollution load than other fibre units. The sources of waste are alkaline waste from viscose production process, acid waste from spinning machine, neutral wastes from further washing of fibres, and cooling water from acid evaporators. 80 per cent of total quantity of concentrated effluent is generated during fibre spinning and finishing process and is discharged principally from washers. The wastes contain mainly waste fibre, zinc sulphate, sulphuric acid and several sodium chemicals. Among the pollutants, zinc ranks highest because of its toxicity to acquatic life. Around 55 per cent of the input zinc is discharged with the effluent (See Table 15.2 for waste water characteristics).

TABLE 15.2

WASTE WATER CHARACTERISTICS OF A VISCOSE RAYON PLANT (NOT INTEGRATED)

Parameter	Viscose product
pH	3-5
BOD	100 mg./l
COD	175 mg./l
TSS	100 mg./l
Zinc (Zn)	20 mg./l

A major portion of pollution from integrated rayon mill originates in the pulping process. These originate from grinding, digester, cooking, washing, bleaching, thickening and defibering. They contain sulphate liquor, fine pulp, bleaching chemicals, waxes, grease, oil, etc. Average waste discharged and waste water characteristics from pulp making process is given in Table 15.3.

TABLE 15.3

AVERAGE WASTE WATER DISCHARGE AND CHARACTERISTICS IN PULP MILL

Type of Process	Gallon/ tonne	BOD (mg./l)	Suspended solids (mg./l)
Sulphate (Kraft)	59,000	123	—
Sulphite	55,000	443	—
Soda	77,000	100	1720

Effluent Standard

Minimum national standards (MINAS) for Synthetic Fibre Industry are

Synthetic Fibre Industry

Parameters	Concentration, mg./l not to exceed
pH	5.5 to 9
Suspended solid	100
Biochemical Oxygen Demand (BOD) (20°C, 5 day)	30

Semi-Synthetic Fibre Industry

Parameters	Concentration, mg./l not to exceed
p^H	5.5 to 9
Suspended solids	100
Biochemical Oxygen Demand (20°C, 5 day)	30
Zinc	1

Pollution Abatement Measures

The effluents generated from nylon 6 and polyester plants do not contain much pollutants since most of the chemicals are recovered. The normal methods of treatment based on extended aeration are found to be quite effective in treatig these effluents. The various parameters in the effluents are brought to acceptable limits by secondary treatment only. The method of extended aeration by'oxidation pond removes nearly 85-90 per cent of the BOD and COD content of the effluent.

As mentioned earlier in viscose rayon mill the presence of zinc poses a serious threat to aquatic life. There are different methods of removing zinc from effluents. The most common method is chemical precipitation by the adjustment of p^H. It is described in brief.

It is a two-stage precipitation. In the first stage sufficient lime is added to the mixed stream of acid and alkali waste to raise the p^H to 6.0. No zinc hydroxide precipitates and the clear overflow from a clarifier contains the dissolved zinc. This dissolved zinc is contacted with a circulating stream of previously precipitated zinc hydroxide sludge. The bulk of zinc precipitates on to the existing crystals in the circular slurry, and is collected.

In several, cases effluent treatment in a rayon plant without recovery of zinc is done in the following process. Acidic and alkaline streams are neutralised. In the next a single stage precipitation with lime is done followed by biological treatment in oxidation ditch. In the end the sludge is disposed in the land.

Cost Estimates

Cost of pollution abatement is estimated using methodology described in earlier Chapters. Table 15.4 and Table 15.5 gives the cost flow of pollution abatement for two man-made fibre plants with 22 TPD and 7.2 TPD capacity respectively.

Table 15.4 (22 TPD) shows that resource cost and social cost of pollution abatement per kl. of water released is Rs 0.062 and Rs 0.095 respectively when rate of discount, r = 0.10 and time period, T = 30 years.

Table 15.5 (7.2 TPD) reveals that resource cost and social cost of pollution abatement per kl. of water released is Rs 0.14 and Rs 0.21 respectively for the same r and T which is larger than that of the plant with higher TPD capacity.

Conclusion

In the foregoing discussion we have seen that most of the plants in man-made fibre industry employ some kind of chemical recovery method. To reach required effluent treatment standard they have to only upgrade and add some capital equipments. The technologies required are already available. A matter of concern among semi-synthetic units is that they allow zinc to be passed on to rivers along with waste water. It is literally throwing hard-earned foreign-exchange, since zinc is mostly imported; down the river. Different estiates show that zinc recovery treatment from effluents in itself is a profitable proposition for the semi-synthetic plants. Lower cost of pollution abatement measures for man-made fibre also gets reflected in lower resource and social cost of per kl. of water as compared to other industries.

TABLE 15.4

COST FLOW OF MAN-MADE FIBRE (22 TPD)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	350000	399000	Fixed cost	2845800
2. Other fixed cost	2201324	5063046	15 per cent of fixed cost	426870
a. Machinery equipment	756303	1739497		
b. Piping	283614	652312	Operating cost	995100
c. Civil works			Total	1421970
(i) Bricks	174532	401424	Quantity of water released per year kl.	10201750
(ii) Cement	328529	755617	Cost of 1 kl. of water released	0.139
(iii) Steel	358850	825355		
d. Electrical equipment	174706	401824		
e. Installation	124790	287017		
TOTAL	2551324	5462046		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	8640	8640		
b. Unskilled	5760	2477		
2. Maintenance				
a. Oil	541	812		
b. Repair	1529	1529		
3. Chemicals	29317	43976		
4. Fuel	31512	43266		
TOTAL ANNUAL COST	927588	1208400		

TABLE 15.5

COST FLOW OF MAN-MADE FIBRE (CAPACITY 7.2 T/DAY)

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Land	250000	285000	Fixed cost	2139000
2. Other fixed cost			15 per cent of fixed cost	320850
a. Machinery equipment	572425	1316578	Operating cost	744000
b. Piping	214659	493716	Total	1064850
c. Civil works				
(i) Bricks	127205	292572	Quantity of water released per year kl.	3339750
(ii) Cement	248653	571907	Cost of 1 kl. of water released	0.31
(iii) Steel	271603	624687		
d. Electrical equipment	132230	304129		
e. Installation	94450	217235		
TOTAL	1911227	4103824		
B. OPERATING COST (MONTHLY)				
1. Labour				
a. Skilled	6448	6448		
b. Unskilled	4299	1849		
2. Maintenance				
a. Oil	410	615		
b. Repair	1157	1157		
3. Chemicals	21919	32879		
4. Fuel	23560	32348		
TOTAL ANNUAL COST	693516	903552		

TABLE 15.6

ESTIMATES OF COST OF POLLUTION ABATEMENT OF MAN-MADE FIBRE (AT 1987-88 PRICES)
(22 TPD CAPACITY)

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.086	0.133	0.069	0.104	0.057	0.085	0.049	0.072	0.043	0.062	
0.10	0.081	0.126	0.063	0.096	0.051	0.077	0.043	0.065	0.037	0.055	0.14
0.12	0.076	0.120	0.057	0.089	0.046	0.071	0.038	0.058	0.033	0.050	

TABLE 15.7

ESTIMATES OF COST OF POLLUTION ABATEMENT OF MAN-MADE FIBRE (AT 1977-88 PRICES)
(7.2 TPD CAPACITY)

(In rupees)

Time (T) in Years ->	10		15		20		25		30		
Social rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	0.196	0.304	0.157	0.237	0.130	0.194	0.111	0.164	0.097	0.143	
0.10	0.185	0.289	0.143	0.219	0.117	0.176	0.098	0.148	0.084	0.124	0.31
0.12	0.175	0.276	0.132	0.205	0.105	0.162	0.088	0.134	0.075	0.113	

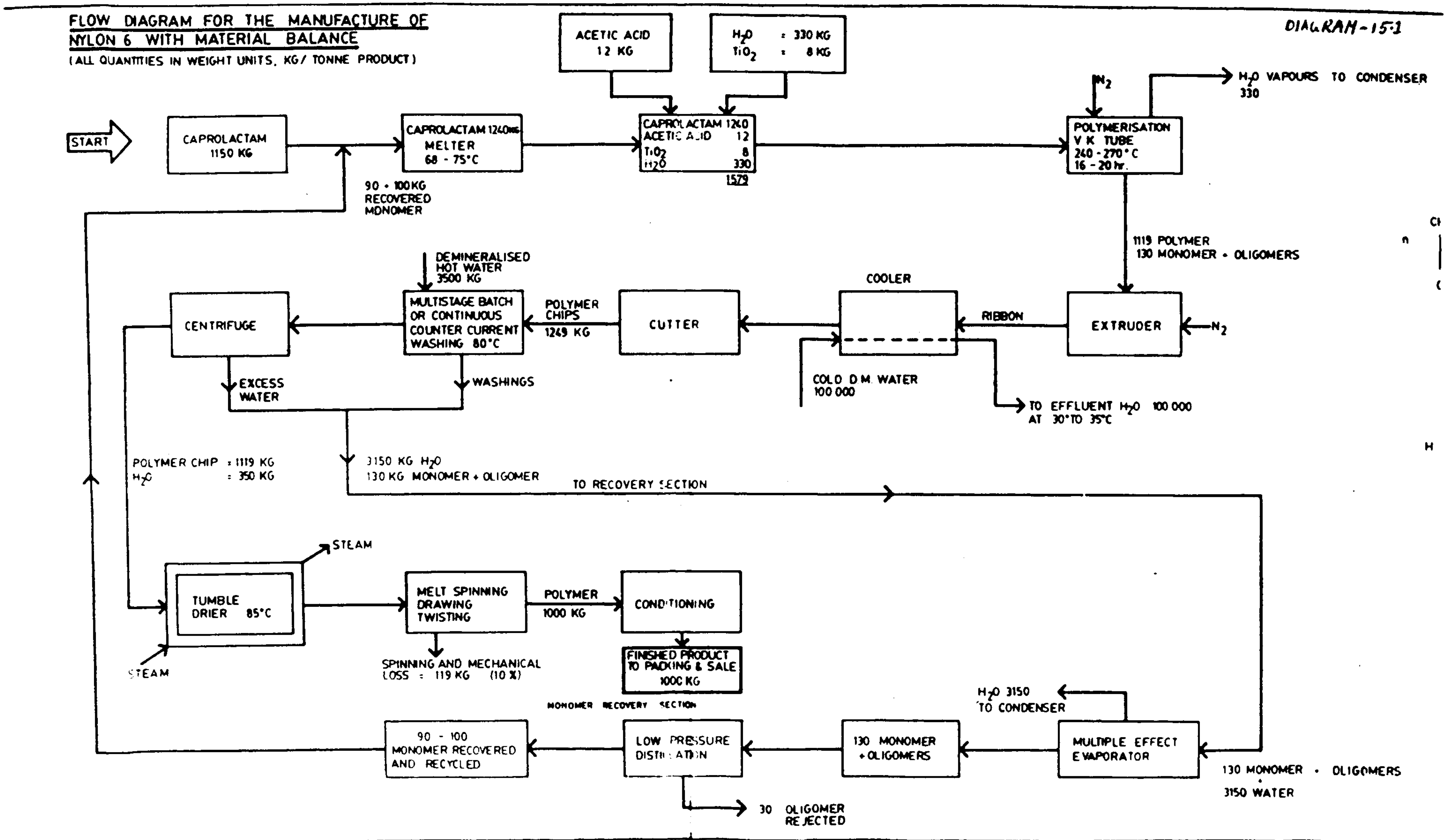
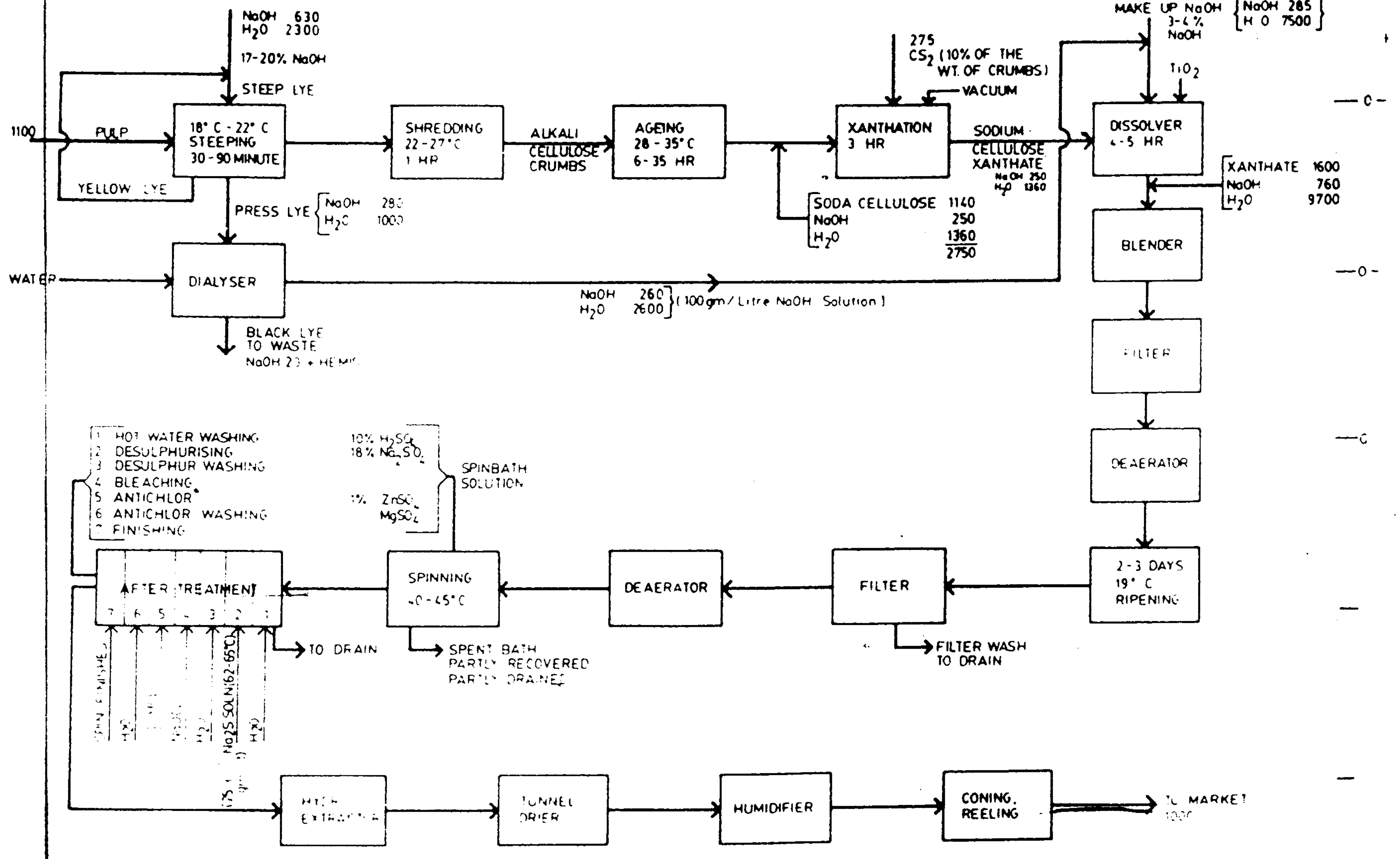

FLOW DIAGRAM FOR THE MANUFACTURE OF NYLON 6 WITH MATERIAL BALANCE
(ALL QUANTITIES IN WEIGHT UNITS, KG/ TONNE PRODUCT)
DIAGRAM - 15.1
ACETIC ACID 12 KG
H2O : 330 KG
TiO2 : 8 KG
START
CAPROLACTAM 1150 KG
CAPROLACTAM 1240 KG MELTER 68 - 75°C
CAPROLACTAM 1240
ACETIC ACID 12
TiO2 8
H2O 330
1579
N2
H2O VAPOURS TO CONDENSER 330
POLYMERISATION V K TUBE 240 - 270°C 16 - 20 hr.
90 - 100 KG RECOVERED MONOMER
1119 POLYMER
130 MONOMER + OLIGOMERS
DEMINERALISED HOT WATER 3500 KG
CENTRIFUGE
MULTISTAGE BATCH OR CONTINUOUS COUNTER CURRENT WASHING 80°C
POLYMER CHIPS 1249 KG
CUTTER
COOLER
RIBBON
EXTRUDER
N2
EXCESS WATER
WASHINGS
COLD D.M. WATER 100 000
TO EFFLUENT H2O 100 000 AT 30°TO 35°C
POLYMER CHIP : 1119 KG
H2O : 350 KG
3150 KG H2O
130 KG MONOMER + OLIGOMER
TO RECOVERY SECTION
STEAM
TUMBLE DRIER 85°C
MELT SPINNING DRAWING TWISTING
POLYMER 1000 KG
CONDITIONING
STEAM
SPINNING AND MECHANICAL LOSS : 119 KG (10 %)
FINISHED PRODUCT TO PACKING & SALE 1000 KG
MONOMER RECOVERY SECTION
H2O 3150 TO CONDENSER
90 - 100 MONOMER RECOVERED AND RECYCLED
LOW PRESSURE DISTILLATION
130 MONOMER + OLIGOMERS
MULTIPLE EFFECT EVAPORATOR
130 MONOMER + OLIGOMERS
3150 WATER
30 OLIGOMER REJECTED

DIAGRAM 15.2 FLOW SHEET FOR THE MANUFACTURE OF VISCOSE RAYO

(ALL QUANTITIES IN WEIGHT UNITS, KG/TONNE FINISHED PRODUCT)



287

CHAPTER XVI

MUNICIPAL WATER SUPPLY : TWO CASE STUDIES

XVIA. KANPUR JAL SANSTHAN, KANPUR

16.1 Introduction[1]

Kanpur Jal Sansthan is the biggest water supplying system of Uttar Pradesh. The water works was established in the year 1892 with a designed capacity of 15.14 million litres per day to serve a population of about 2 lakhs. The source of water was river Ganga and the Ganga water was pumped from Bhaironghat raw water pumping station, about two kilometers away from Benajhabar treatment works. The pumping plants were steam engine driven. Electrification of Kanpur water works was done in the year 1927.

Augmentation of water supply by Jal Sansthan was done on a piecemeal basis. Major re-organisation programmes were carried out during 1937-42, 1951-56, 1977-81. The first two re-organisation programmes mainly included installation of zonal pumping stations and mechanical filter plants of increased capacity. During 1977-81 major achievement of re-organisation scheme was installation of tubewells to supplement surface water supply and expansion in number as well capacity of zonal pumping stations.

---

1. This Section draws heavily from a paper presented by Kanpur Jal Sansthan, titled "A Case Study for Prevention of Wastage of Drinking Water".

At present daily water supply by Jal Sansthan, Kanpur is about 300 million litres per day (mld). Surface water is treated and supplied to 26 zonal pumping stations from a central plant at Benajhabar. To supplement this water supply, 46 tubewells are working. While a few of them are directly connected to the distribution system, the remaining supply water either to the elevated tanks or semi-sunk reservoirs. Each zonal pumping station has a separate distribution system. Details about distribution system are as follows:

1.	Length of distribution mains	900 Kms.
2.	Number of metered connections upto 31-8-88	44,193
3.	Number of unmetered connections	8,328
4.	Number of public stand-posts	2,803
5.	Number of properties billed for water and sewerage tax	70,000
6.	Number of fire hydrants	689

Population assessed in 1988 in Kanpur is 2.250 million. Considering 270 litres of water as per capita per day demand, the daily water demand works out to be 607.5 mld. against current supply of 300 mld. The Uttar Pradesh Urban Development Project (U.P.U.D.P.) which is under progress, stipulates for increasing water supply by only 110 mld. Even if growth in population in Kanpur remains unchanged increase in water supply by 110 mld. will not be a significant contribution. Another factor which affects the effective water supply is wastage of water due to leakage in the distribution system. Annual balance sheets of Kanpur Jal Sansthan have shown unaccounted amounts of water in different years as given below:

Year	Unaccounted water as per cent of total water supply.
1986-87	39.31
1987-88	43.95
1988-89	39.67

Leakage of water not only affects effective water supply and revenue of Jal Sansthan but also causes contamination of water.

16.2 Cost of Production and Supply of Water

It is mentioned earlier that Kanpur Jal Sansthan has a raw water treatment plant at Benajhabar and 26 pumping stations at various places in Kanpur. Besides this, it also has a supply network through which water is supplied to households. To estimate the cost of production and supply of water, data on fixed and operating expenditure of Jal Sansthan was required. The data is made available by Jal Sansthan in a reply to questionnaire. When we approached them, the data on fixed assets was available only upto 1986-87. The value of net fixed assets on 31st March 1987 has been taken as fixed investment made upto 1986-87. It is assumed that fixed assets available to Jal Sansthan on 31.3.1987 have a life time of minimum 15 years. The method followed for estimation of cost of water is the same as mentioned in Chapter 4. The cost estimates are presented in Table 16.1. For Jal Sansthan, the resource cost of water worked out to be 20 paise while commercial cost of water is higher than resource cost by 2 paise, when r=0.10 and T=15 years. The social cost of production and supply of water is about 29 paise.

16.3 Sewage Treatment

With the increase in population of Kanpur water is becoming increasingly polluted. Both domestic and industrial effluents contribute to this. However, contribution of domestic effluents is 70 per cent while industrial effluents contribute only 30 per cent.

In Kanpur, sewage services are supplied by Kanpur Municipal Corporation but the operation and maintenance of sewage services is looked after by Jal Sansthan.

Domestic effluent is usually discharged into sewage wherever this service is available. In addition to this, a major portion of industrial liquid effluent is also discharged into sewage which is finally dumped into the environment. Besides this, there are a large number of industrial units which discharge their untreated effluents directly into the river Ganga. As yet Kanpur does not have a sewage treatment plant.

The Central Ganga Authority has undertaken a programme of pollution control of the river Ganga.[2] The project comprises of a number of programmes related to environment. Some of them are integration of sewage and storm water drainage, treatment of domestic and industrial waste water and management of solid waste. Kanpur is one of the cities where this project is in progress. In Kanpur the project has, so far, concentrated its activities in the Jajmani area, which includes an industrial zone with tanneries and

---

2. See Mass, J.A.W., Indo-Duch Environmental and Sanitary Engineering Project, Civic Affairs, August, 1988.

glue factories. The tanneries use large amount of water for washing of hides and processing of leather. The waste water is discharged outside the factory, mostly without any treatment and it eventually meets the river Ganga. Besides this, living conditions in the area are poor with inadequate sanitary facilities and overcrowding. Domestic effluent is discharged into Kutcha open drains which eventually meets the Ganges.

Therefore, in this project besides sewage and other low cost sanitation facilities, sewage treatment plant is also envisaged. It is planned to treat 25 mld of sewage by an upflow Anacrobic Sludge Blanket (UASB) treatment system. The first phase of the project includes construction and operation of an UASB module for treatment of the domestic sewage in Kanpur. This module will treat 5000 Kl/day of sewage. The work on this scheme is in progress. Another scheme on which the work is going on is a plant for chromium recovery from tannery waste product and a pilot UASB reactor for the treatment of tannery effluent. It is envisaged that all the waste water is Jajmau area will ultimately be treated in UASB type plants. Estimated cost of UASB (25 mld) sewage treatment plant including 5 mld. pilot plant is Rs 262.47 lakhs. During the year 1988-89, Rs. 54.66 lakhs have been invested. The executing agency of this project is Jal Nigam. Other two projects, namely, UASB pilot plant for tannery waste water treatment and chromium recovery pilot plant are also executed by Jal Nigam. Their estimated costs are Rs 11.63 lakhs and Rs 5.31 lakhs respectively. Due to unavailability of data on operation costs of the above plants and also on quantity of effluents proposed to be treated in both tannery waste water treatment plant and chromium recovery plant it is not possible to estimate the cost of treatment per unit of effluent.

TABLE 16·1

Estimats of Resource Cost, Social Cost and Commercial Cost of Pollution Abatement Per Unit of Water Used (J.K. Cotton Mills)

(In Rupees)

Time(T) in Years ->		15			20			25			30		
Social Discount Rate	Resource cost	Social cost	Commercial cost	Resource cost	Social cost	Commercial cost	Resource cost	Social cost	Commercial cost	Resource cost	Social cost	Commercial cost	Commercial cost II
0.08	0.242	0.35	0.258	0.20	0.28	0.21	0.17	0.23	0.18	0.15	0.20	0.16	
0.10	0.223	0.32	0.238	0.18	0.25	0.19	0.15	0.21	0.16	0.13	0.18	0.14	
0.12	0.21	0.30	0.22	0.16	0.23	0.17	0.136	0.19	0.145	0.115	0.16	0.123	

XVIB. MADRAS METRO WATER SUPPLY

16.1 Introduction

The Madras Metropolitan Water Supply and Sewerage Board (Metrowater) caters to the water requirements of Madras city and surrounding areas. It has six area offices and three regional offices. It supplies a total of 301 million litres of water per day to the city.

Metrowater uses surface storage lakes and ground water (deep tubewells) as raw water which is chemically treated before being supplied to the consumers.

16.2 Production of Water

Metrowater supplies a total of 301 million litres of water per day (mld). Of this 230 mld is supplied for domestic use, 17 mld is supplied for non-domestic use and 54 mld is supplied for industrial use.

Metrowater has assets worth Rs 9780 lakhs which includes contributions from the government and the public. The maintenance cost is Rs 1740 lakhs. It also operates a sewerage treatment plant which has a fixed cost of Rs 1970 lakhs and annual operation cost of Rs 190 lakhs.

The water rates charged for different categories on a monthly basis are given in Table 16.2.

TABLE 16.2

WATER TARIFF FOR DIFFERENT CATEGORIES (METROWATER)

Category	Quantity (in kl.) (per month)	Rate (Rs)
1. Domestic	0 - 50	1.00
	above 50	2.00
2. Non-domestic	0 - 50	3.00
	50 - 100	4.00
	above 100	5.00
3. Industrial	Per kl.	7.00

A uniform rate of 20 per cent is charged as sewerage surcharge for all categories. Metrowater gives a free allowance upto 30 kl. But at present, due to the recent drought, it is charging a flat rate of Rs 12.00 per connection. Table 16.3 gives the income of metrowater from various sources while Table 16.4 gives income from taxes. From this, we can conclude that remuneration from industrial connections form bulk of the income of metrowater at 56 per cent. This is followed by income from public authorities at 16 per cent.

TABLE 16.3

SCHEDULE SHOWING INCOME OF METROWATER FROM VARIOUS SOURCES (1986-87)

(In rupees)

Source	Income (in percentage)
Metered - domestic	6.3
Metered - commercial	4.9
Metered - industrial	56.1
Metered - public authorities	16.1
Metered - supply through public fountains	7.1
Metered - non-residential	4.5
Metered - other than domestic	1.2
Mobile water supply to private customers	1.7
Mobile water supply to slums	1.9
Miscellaneous water supply	0.2
TOTAL	100.0

TABLE 16.4

INCOME FROM TAX IN 1986-87
METROWATER

Source	Income (in percentage)
Water tax	21.5
Sewerage tax	78.5
TOTAL	100.00

The resource cost and social cost of one kl. of water produced is Rs 0.77 and Rs 1.13, respectively for r = 0.10 and t = 30 years. The commercial cost of one kl of water produced is Rs 2.50.

16.3 Conclusion

From the above analysis, it is seen that 56 per cent of the sale proceeds of metrowater are obtained from industries.

TABLE 16.5

COST FLOWS OF MADRAS METROWATER

(In rupees)

	Resource cost	Social cost	Commercial cost	
A. FIXED COST				
1. Machinery and equipment			Fixed cost	668526000
a. Pipe	140250210	322575483	15 per cent of fixed cost	100278900
b. Pump	407482514	937209782	Operating cost	174200000
c. Fittings	70743491	162710029	TOTAL	274478900
2. Construction				
a. Cement	44901215	103272795	Quantity of water used per year kl.	109865000
b. Bricks	21837374	50225960		
c. Steel	46626168	107240186	Cost of per kl. of water used	2.50
3. Labour	199560000	85810800		
TOTAL	931400972	1683234235		
B. OPERATING COST (MONTHLY)				
1. Maintenance cost				
a. Oil	8234127	12351190		
b. Repair	23240000	23240000		
2. Fuel	127000000	174371000		
3. Labour	14000000	6020000		
TOTAL	172474127	215982190		

TABLE 16.6

ESTIMATES OF COST OF POLLUTION ABATEMENT OF MADRAS METROWATER PER KL OF WATER USED

Time (T) in Years ->	15		20		25		30		
Social Rate of Discount	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Resource cost	Social cost	Commercial cost
0.08	1.47	2.15	1.19	1.73	1.00	1.45	0.87	1.25	
0.10	1.36	2.01	1.09	1.60	0.91	1.33	0.77	1.13	2.50
0.12	1.28	1.91	1.00	1.49	0.83	1.23	0.70	1.04	

CHAPTER XVII

RECOMMENDATIONS AND CONCLUSIONS

17.1 Differential Pollution Taxes on Industries

The detailed studies of different industries in Chapters V – X suggest that the cost of treatment of a Kl. of polluted water varies across the industries, given the MINAS. Table 17.1 provides the estimates of resource cost of treating a Kl. of residual water for distilleries, tanneries, textiles, fertilizers, vegetable oils, man-made fibres, refineries, chemicals and paper and pulp. As expected, these estimates differ significantly across the industries, mainly because of the fact that the quantity and nature of pollutants in a Kl. of residual water vary from industry to industry. Therefore, recovery of full cost of providing the services for treatment of residual water by the pollution control boards would imply a differential schedule of pollution taxes on industries.

Alternatively, it may be possible to express pollution loads in the residual waters of different industries in the homogenous units. There are attempts to express industrial pollution in population equivalent units. For example, defining population equivalent unit as the pollution load in the waste waters from domestic use of water by a person or a group of persons, we may be in the position to convert pollution loads in the residual waters of different industries into population equivalent units. Given the estimates of marginal cost of pollution abatement per population equivalent unit of water pollution, a uniform pollution tax per population equivalent unit on the industries may be required to achieve MINAS. With the

TABLE 17.1

ESTIMATES OF POLLUTION ABATEMENT COSTS FOR VARIOUS INDUSTRIES (Rs.)

Name of the Industry	Resource Cost	Social Cost	Commercial Cost
1. Distilleries	5.55	12.12	25.18
2. Cotton textiles	2.67	4.42	--
3. Fertilizers	6.15	10.59	--
4. Vegetable oils	4.41	8.19	19.93
5. Man-made fabrics	0.036	0.054	1.39
6. Oil refineries	0.61	1.14	2.61
7. Chemicals	0.74	1.24	2.21
8. Sugar	0.38	0.69	1.64
9. Paper and pulp	0.41	0.69	3.60
10. Gun and shell products	0.41	0.59	0.93
11. Tanneries	0.98	1.63	--

* Pertains only to the situation of primary treatment of effluents

assumption of increasing marginal cost of pollution abatement, a tax based on marginal cost will induce the industries to spend on pollution abatement to achieve MINAS. However, it may not be possible to express unambiguously the pollution loads of different industries in population equivalent units. It is because many water borne pollutants are not common to residual waters from domestic and industrial uses of water. The population equivalent units may be defined for the water borne pollutants like suspended solids, BOD, COD, etc., which are common for domestic and industrial waste waters. However, water borne industrial waters may consist of toxic chemicals, like chromium, mercury, lignin etc. which may not be expressible in population equivalent units.

The Taxes-Standards approach described in Chapter II requires that pollution taxes should be based on the marginal pollution abatement costs of the industries or the marginal damages to receiving industries, the estimation of which requires the estimates of cost functions of pollution abatement for different industries. Due to paucity of data for the industrial units surveyed, we have not attempted the estimation of these functions in this study. However, our estimates of resource cost of pollution abatement reported in Table 17.1 may be regarded as costs per KL. of residual water for the cost minimising industrial units to obtain the environmental standards. It may be assumed that given the taxes-standards approach, a rational firm may be minimising the pollution abatement cost to achieve the standards. Given the properties of cost functions, the minimised average cost (cost per KL. of residual water) is equal to marginal cost of pollution abatement. Thus by levying pollution taxes on the basis of minimum average cost of pollution control, we are in fact levying taxes on the basis of marginal abatement costs as required by the taxes-standards approach.

The estimates of pollution abatement cost per KL of residual water for different industries given in Table 17.1 provide guidance as to what can be the pollution taxes on the respective industries so that they are induced to spend on pollution abatement to realise the MINAS.

17.2 What should be the Price of Water for Industrial Uses

The price of water for industrial uses should cover both the private as well as social cost of water, the methods of estimation of which are described in Chapter III. The private cost is cost to the user (production cost of water) while the social cost is cost to the society (damages from water pollution to the society). The price that government charges for industrial uses of water depends upon the source of water. If the factory uses municipal water, the price charged by the municipality should include production cost as well as pollution abatement cost of using water. On the other hand, if the factory uses its own tube well, the price that the municipality/government charges should consist only of pollution abatement cost. In both the situations, the pollution abatement costs can be recovered by the government through the pollution taxes that are designed to realise the prespecified environmental standards. If the pollution taxes are collected by the municipality as part of the price of water, they have to be fixed on the basis of per KL of water used. However, for practical purposes, it may be useful to separate the problem of charging cost of supply of water from the problem of fixing the pollution taxes. The pollution taxes may be based on pollution loads of different industries and pollution standards and they have to be fixed on the basis of per KL of residual water or per population equivalent unit. The Central and State pollution control boards have the responsibility of designing and collecting these taxes.

In the dry regions, water conservation by the industries may be promoted through pricing policy of water. The recycling and reuse of water by the industries may involve relatively higher cost of treatment than the pollution abatement cost to meet environmental standards. Therefore, the pollution taxes to induce factories to observe water conservation may be higher than the taxes needed to achieve environmental standards. As an illustration let us consider two case studies of fertilizer plants made in Chapter VII: IEL Limited, Kanpur and Zuari Agro-Chemicals, Goa. Table 17.2 gives the estimates of commercial and resource costs of treating a KL of residual water for the two factories. For IEL Limited and Zuari Agro the commercial costs are respectively Rs.7.16 per KL while the resource costs are

Rs.1.76 and Rs.8.24. IEL Limited being a factory located in water abundant Gangetic basin, does not observe water conservation and it treats residual water to meet only pollution standards. On the other hand, due to limited availability of potable water, Zuari Agro Chemicals incurs considerably higher cost in the treatment of residual water so that it is recycled in the factory.

TABLE 17.2

ESTIMATES OF COMMERCIAL AND RESOURCE COSTS FOR TREATING A KL OF RESIDUAL WATER WITH AND WITHOUT WATER CONSERVATION

Factory	Commercial Cost (Rs.)	Resource Cost (Rs.)
IEL LTD	7.16	1.76
Zuari Agro	32.57	8.24

17.3 Water Conservation by the Factories

The conservation of water by the industrial units depends upon the supply price of water. If the production cost of water is very high, the factories have the incentive to recycle the water in various production processes so that intake and discharge of water can be significantly reduced. Thus the water conservation through the recycling of water may enable the factory to save on the production cost of water. However, as explained above the factory may have to incur relatively higher cost for making residual water fit for reuse than the cost it has to incur to meet the pollution standards. In this case, the factory's decision about the conservation of water depends upon the net savings in the cost of water use (gain due to fall in the production cost of water - Loss due to increase in the cost of treatment of polluted water).

None of the units surveyed in the Gangetic basin has been practicing water conservation methods. This is expected because, the cost of production of water in this region is very low. Table 17.3 shows that the social cost of producing water for various factories in this region varies between Rs 0.16 to Rs 0.61. However, in the dry regions, where the demand for water far exceeds it supply, there are economic gains from water conservation. We have good examples of water conservation from some of the factories we have visited. (Tamil Nadu Petro Chemicals, Madras and Zuari Agro Chemicals, Goa). The Madras Metro Water Supply can barely meet one-third of industrial demand for water. Given the limited potable ground water resources, there are governmental regulations on the industries to tap ground water in Madras industrial areas. The Tamil Nadu Petro Chemicals spends around Rs.47 per KL to conserve water for cooling purposes. The Zuari Agro Chemicals, Goa has adopted water conservation methods due to very limited supply of water from municipality. In this factory, 90 per cent of residual water is recycled in the various production processes and as it is already prointed out it spends around Rs.32.57 per KL of water on conservation.

There are significant economic gains from water conservation by the municipalities and industries. These are in the form of generation of energy, production of manure, alga, fish, biogas apart from the pollution control. For example, the benefits from waste waters of 27 class I cities of Ganga basin (which amount to 902 million litres per day) are estimated to be Rs.37.00 per capita (Tyagi, Sengupta and Chakrabarty, 1989).

TABLE 17.3

COST OF WATER SUPPLY - PER KL.

Name of the Units		Tubewell		River Water	
		Resource cost	Total cost	Resource cost	Social cost
1.	Karam Chand & Bros., Unnao	0.127	0.164	-	-
2.	TAFCO, Kanpur	0.139	0.180	-	-
3.	Bata India, Calcutta	-	-	0.270	0.423
4.	Muir Mills, Kanpur	0.133	0.169	-	-
5.	J.K. Cotton Mills, Kanpur	0.185	0.244	-	-
6.	Lakshmi Rattan Cotton Mills, Kanpur	0.197	0.259	-	-
7.	New Victoria Mills,Kanpur	0.159	0.199	-	-
8.	Elgin Mills (Unit-1),	0.69	0.53	-	-
9.	I.E.L. Ltd., Kanpur	0.20	0.27	0.073	0.10
10.	Hindustan Vegetables Corpn. Ltd. Kanpur	0.159	0.205	-	-
11.	Motilal Padampat Udyog Ltd	0.260	0.340	-	-
12.	Vegetable Oil, Calcutta	0.441	0.591	-	-
13.	Kanpur Jal Sansthan, Kanpur	0.21	0.29	-	-

Note: Cost has been calculated taking the rate of discount as 10 and the life of the tubewell equal to 15 years.

* Zuari is taking water from Goa Municipal Corporation. It is paying Rs 2.50 per Kl. of water used.

17.4 Pollution Taxes Based on the Method of Public Utility Pricing

The alternative method of levying pollution taxes which is described in Chapter III, Section 4 regards a municipal sewage treatment plant as a public utility supplying jointly services for treating different water borne industrial pollutants. This method requires uniform taxes on each pollutant across the industries. For example, there may be a uniform tax per unit of BOD or COD on the industries. The tax on each pollutant is based on the full cost of its treatment. Thus there will be differential taxes by pollutants and uniform taxes across the industries.

The problem of fixing pollution taxes by this method is similar to the problem of fixing prices for the services jointly supplied by a public utility. As it is normally the case of a public utility, there may be economies of scale in the joint treatment of different water borne residuals by a municipal sewage treatment plant. Thus there are joint costs and attributable cost of the plant. The full cost of treating each pollutant can be estimated by following a method described in Chapter III, Section 3.

For example, if the Central Ganga Authority wants to invest on ET plants at different places (say Hardwar, Kanpur, Banaras and Howrah) it may recover the full cost of pollution treatment by following the public utility pricing approach. It may not be difficult for this authority to estimate the full cost of treatment of each pollutant since it possesses the full information about joint and attributable costs of each ET plant.

17.5 Environmental Standards.

The first best pollution taxes that are discussed in Chapter II requires the estimation of damages from environmental pollution. Since pollution is an external diseconomy of industrial development, its damages accrue to a large number of economic activities. The cost of collecting data for the estimation of these damages can be prohibitively high. The taxes - standards approach, the second best solution for the pollution control that is adopted in this study avoids the difficult problem of estimating damages. It requires that the pollution standards have to be determined through a political process that involves receivers as well as generators of pollution. Any pollution standards that are fixed without ascertaining the views of pollutees cannot be regarded as national standards. The minimum national standards (MINAS) for environmental pollution developed by Central Pollution Control Board (CPCB) in India suffer from this limitation.

The MINAS have been developed by CPCB for effluents from about 15 specific industrial categories and work is in progress for other industries as well. The pollution standards are developed by CPCB on the basis of costs of various technological options for effluent treatment. Typically MINAS were selected so as to keep the cost of pollution control to a fraction of one per cent of the annual turnover of the individual firm. That means the interests of industry (polluter) are accounted for while neglecting the damages receive by the polluters in determining MINAS by CPCB.

The problem of fixing effluent standards may be tackled satisfactorily by setting them in two stages. In the first stage national level standards can be set. These standards are based on technological and economic considerations alone and apply to industries in disregard to their location. In the second stage, mole stringent standards can further be imposed on the industries depending upon the local or regional water quality requirements. The MINAS developed by CPCB correspond to first stage standards described above which actually take care of interests of industry alone. It is only standards developed in the second stage to suit the local environmental conditions, which may be directly related to damages received by the polluters.

17.6 Scale Economies in Pollution Treatment and the Methods of Pollution Control

Studies in water pollution control in India and abroad (Dasgupta and Murty, 1985) show that there are scale economies in the treatment of polluted water. That means it is economical to treat higher volume of residual water in relation to lower volumes. Thus the resource cost of treating a Kl. of residual water is lower for a big industrial unit than that for a smaller unit. For example, a detailed study on the social cost of water pollution control in big and small paper mills in India show that the social cost of water pollution control per tonne of paper produced is Rs 145 for a mill of 10 tonnes per day capacity while it is Rs 30 for a mill producing 115 tonnes of paper per day. Table 17.1 provides estimates of social cost of water pollution control per tonne of paper produced by small and big paper mills in India.

TABLE 17.4

SOCIAL COST OF WATER POLLUTION CONTROL PER TONNE OF PAPER PRODUCED BY BIG AND SMALL PAPER MILLS IN INDIA

Capacity (tonnes per day)	10	15	20	30	115
Cost (Rs)	145	125	116	106	30

Source: Dasgupta and Murty (1985)

The presence of scale economies in the water pollution control suggests that it is not economical for the government to ask smaller units to have their own effluent treatment (ET) plants. Instead, the resource cost minimisation requires the treatment of combined effluents of a number of smaller units by the end-of-pipe treatment methods. Therefore, water pollution control boards or local administration can have sewage treatment plants to treat the collected residual water from smaller units and the cost of such plants may be realised through pollution taxes on the smaller industrial units. In the case of bigger industrial units they may be provided with the option of either paying the pollution tax (price for the services rendered by the government for treating effluents) or having their own ET plants. The pollution taxes for smaller and bigger units may be fixed by following the standards - taxes approach described in chapters II and III.

17.7 Pollution Taxes Based on the Method of Public Utility Pricing

The alternative method of levying pollution taxes which is described in Chapter III, Section 4 regards a municipal sewage treatment plant as a public utility supplying jointly services for treating different water borne industrial pollutants. This method requires uniform taxes on each pollutant across the industries. For example, there may be a uniform tax per unit of BOD or COD on the industries. The tax on each pollutant is based on the full cost of its treatment. Thus there will be differential taxes by pollutants and uniform taxes across the industries.

The problem of fixing pollution taxes by this method is similar to the problem of fixing prices for the services jointly supplied by a public utility. As it is normally the case of a public utility, there may be economies of scale in the joint treatment of different water borne residuals by a municipal sewage treatment plant. Thus there are joint costs and attributable cost of the plant. The full cost of treating each pollutant can be estimated by following a method described in Chapter III, Section 3.

For example, if the Central Ganga Authority wants to invest on ET plants at different places (say Hardwar, Kanpur Banaras and Howrah) it may recover the full cost of pollution treatment by following the public utility pricing approach. It may not be difficult for this authority to estimate the full cost of treatment of each pollutant since it possesses the full information about joint and attributable costs of each ET plant.

The treatment of combined effluent of industries may be having some limitations. The joint effect of water borne chemicals from different industries may make the residual waters more toxic and increase the cost of treatment in comparison to a situation where they are treated/recovered at individual factory level. Therefore, the above prescribed method of pricing of pollutants may be more suitable for an effluent treatment plant set up for treating the collected effluents of various factories in a given industry. As pointed out already, there are scale economies of effluent treatment in a given industry and it may be economical to have a common effluent treatment plant for effluents of different firms of an industry, especially when the firms are small and located in clusters. Therefore, the public utility pricing approach described in Chapter III for fixing pollution taxes may be described as an appropriate method in this type of situations.

17.8 Pollution Subsidies for an Isolated Small Factory

The presence of economies of scale in the water pollution treatment makes the treatment of combined effluents of a cluster of small industrial units economical. However, if the small units are scattered geographically it is not economical to have effluent treatment plant for each unit. Especially, if there are scale diseconomies in the output production (as in paper and pulp industry in India), a pollution subsidy may have to be given to a geographically isolated smaller unit for having its own effluent treatment plant.

17.9 Some Problems Associated with Effluent Charges on an Industry

In conclusion, we would like to indicate some of the problems arising out of the imposition of effluent charge on an industry. To begin with such a step would have the consequence of raising the cost of production as effluent charge is like any other cost to the industry. The burden of this charge/tax may be shifted to the consumer, the extent of which will however depend upon the elasticities of supply and demand for the goods in question. This is likely to adversely affect the competitive power of the industry and may eventually retard the pace of industrial development. The relative weights that can be assigded to the competing objectives of development and environment preservation would however depend largely on the pecepation of the policy makers. Before levying effluent charge one must also ascertain the likely costs that an industry may have to incur to instal effluent treatment plant in order to meet the MINAS. It should however be pointed out that in fixing the MINAS, consideration is given to the commercial viability of the industry. In prescribing levels of effluent discharges the location of the industry should also be taken into account. In the context of location, water conservation practices assume particular significance in dry or water scarce regions. In such situations pollution abatement taxes will have to be levied in such a way as to induce the industries to practice recycling and reuse of water. In the wet regions like the gangetic basin where water is abundant concern for water conservation is less acute, and effluent charges would be so designed as to compel the industries to merely meet the prescribed standards. Clearly as already mentioned the effluent charges in the dry regions would necessarily be higher than those in wet regions.

Another important issue relates to the question of how to recover the costs incurred in treating the water residuals in the discharge for the prescribed pollution standards relevant to the ultimate recovering media. Clearly the pollution taxes would differ with respect to the recieving media of the effluent. If the effluents are received by the municipal sewers, there will be a sewer tax to induce the industry to treat the residual water as per the standards relevant for public sewers. Further, there should be pollution tax by the local authorities to meet the cost of treatment of effluent in public sewers as per the standards relevant for the ultimate receiving media (reivers, marine coastal water etc.) The possibility of the reuse of treated sewer water by industries should also be explored more seriously, especially in the water scarcity regions. We should like to conclude by stating that in general effluent charges are to be preferred to effluent standards, not merely because effluent charges provide revenues but also requires less information base to implement pollution control and water conservation.

BIBLIOGRAPHY

1. Baumol, W.J. (1972), "On Taxation and Control of Externalities", **American Economic Review**, Vol. 42, No. 3, June, pp. 307-322.

2. Baumol and Oates (1975), "The Theory of Environmental Policy: Externalities, Public Outlays and the Quality of Life", Prentice Hall, INC, Englewood Cliffs, New Jersey.

3. Baumol, W.J. and W.E. Oates (1979), "Economics, Environmental Policy and the Quality of Life", Englewood Cliffs, N.J., Prentice Hall.

4. Chopra, K., Kadekodi, G.K. and Murty, M.N. (1988), "Participatory Development; An Approach for the Management of Common Property Resources", **SAGE.**

5. Clawson, M. and Knetsch (1966), "Economics of Outdoor Recreation", John Hopkins University Press for Resources for the Future, Baltimore.

6. Das Gupta, A.K. and Murty M.N. (1985), "Economic Evaluation of Water Pollution Abatement: A Case Study of Paper and Pulp Industry in India", **Indian Economic Review**, Vol. 20, No. 2, December, pp. 231-267.

7. Das Gupta, Ajit and Murty M.N. (1988), "Economic Evaluation of Environmental Pollution Abatement; A Review of Methods", Working Paper, Department of Economics, University of Otago, Newzealand.

8. Das Gupta, P., Sen, A.K. and Marglin, S.A. (1972), "Guide Lines for Project Evaluation", New York, U.N.

9. Dorfman Nancy S. Assisted by Arthur Snow (1975), "Who Will Pay Pollution Control? The Distribution by Income of the Burdon of the National Environmental Protection Program, 1973-1980", **National Tax Journal**, Vol. 28, No. 1, March, pp. 101-115.

10. Dorfman, R. (1977), "Incidence of the Benefits and Costs of Environmental Programs", **American Economic Review**, Vol. 67, No. 1, February, pp. 341-350.

11. Dwyer, J.F. and Bowes, M.D. (1978), "Concepts of Value for Marine Recreational Fishing", **American Journal of Agricultural Economics**, Vol. 60, No. 5, December, pp. 1008-1112.

12. Federal Water Pollution Control Administration, Delaware Estuary, Estuary Comprehensive Study: Preliminary Report and Findings, Philadelphia: U.S. Department of the Interior, Philadelphia, 1966.

13. Fisher, A.C. and John V. Krutilla (1975), "Valuing Long Run Ecological Consequences and Irreversibilities" in Peskin H.M. and E.P. Saskin (eds); Cost Benefit Analysis and Water Pollution Policy, The Urban Institute, Washington, D.C.

14. Fisher, A.C., Krutilla, J. V. and Cichethi, C.J. (1972), "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis", **American Economic Review**, Vol. 62, No.4, August, pp. 605-619.

15. Freeman, A.M. (1979), "The Benefits of Environmental Improvements", **John Hopkins Press**, for Resources for the Future, Baltimore.

16. Freeman, A.M. (1982), "Air and Water Pollution Control: A Benefit Cost Assessment, John Wiley, New York.

17. Freeman, A.M. - III Haveman R.H. and Kneese, A.V. (1973), "The Economics of Environmental Policy", John Wiley, New York, London, Sydney and Toronto.

18. Government of India, Planning Commission (1989), A Preliminary Report , "Guide Lines for Evaluation of Transport Projects".

19. Greenley, D.A., Walsh, R.G. and Young, R.A (1981), "Option Value: Empirical Evidence from a Case Study of Recreation and Water Quality", **Quarterly Journal of Economics**, Vol. 96, No. 4, November, pp. 657-673.

20. Guni, R. and Martin, W. (1975), "Problem and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation", **American Journal of Agricultural Economics**, 57, pp. 558-566.

21. Henry, C. (1974), "Option Values in the Economics of Irreplaceable Assets", Review of Economic Studies: Symposium on The Economics of Exhaustible Resources, pp. 89, 1, 4.

22. Jha, R., Murty, M.N., and Paul Satya (1988), "On Fixing Postal Tariffs in India", Mimeographed, National Institute of Public Finance and Policy, New Delhi.

23. Kesarwani, S., Sinnarkar, S.N. and Bhat, S.G. (1982), "Management of Environmental Problems in the Pulp and Paper Industry: A Bibliographical Review of Indian Literature, National Environmental Engineering Research Institute", Nagpur.

24. Kneese, A.V. and Bower B.T. (eds.) (1972), "Environmental Quality Analysis", **Johns Hopkins Press**, Baltimore and London.

25. Krutilla, John V. (ed.) (1972), "National Environments", **The Johns Hopkins University Press**, Baltimore and London.

26. Krutilla, J.V. (1967), "Conservation Reconsidered", **American Economic Review**, Vol. 57, No. 4, September, pp. 777-786.

27. Krutilla, J.V. and Fisher, A. (1975), "The Economics of Natural Environments", **The Johns Hopkins Press**, For Resources for the Future; Baltimore.

28. Lin, S.A.Y. (ed.) (1974), "Theory and Measurement of Economic Externalities", **Academic Press**, New York, San Francisco,, London.

29. Marchand, J. K. and Russell, K. P. (1973), "Externality Liability, Separability and Resource Allocation", **American Economic Review**, Vol. 63, pp. 611.20.

30. Mc Millan John (1979), "The Free - Rider Problem, A Survey", **The Economic Record**, June, pp. 95-107.

31. Mishan, E.J. (1971), "The Postwar Literature on Externalities: An Interpretive Essay", **Journal of Economic Literature**, Vol. 0, No. 1, March, pp. 1-28.

32. Murty, M.N. (1987), "Efficiency and Distributional Equity and Pricing of Public Electricity Supply in India, **Economic and Political Weekly**, October 19, 1987.

33. Murty, M.N. (1988), "Economic Evaluation of Environmental Management Programmes", **Commonwealth Publishers**, New Delhi.

34. Murty, M.N. and Nayak, P.B. (1982), "Externality Abatement Technologies, Pigovian Taxes and Property Rights", **Indian Economic Review**, Vol. 17, No. 1, January, pp. 1-26.

35. Pearson, C. and Pryol, A. (1973), "Environment North and South: An Economic Interpretation", John Wiley and Sons, New York.

36. Pigou, A.C. (1932), "The Economics of Welfare", 4th Edition, London.

37. Ramanathan, N.L. (ed.) (1982), "Pulp and Paper Industry in India - Progress, Problems and Pollution Abatement - A National Overview".

38. Samuelson, P.A. (1954), "The Pure Theory of Public Expenditures", **Review of Economics and Statistics**, Vol. 36, No. 6, November, pp. 387-389.

39. Saxena, P. and Saidullah, S.: Central Board for Prevention and Control of Water Pollution : A Review mimeographed, June, 1989, **People's Science Institute**, Dehradun, U.P.

40. Subrahmanyan, P.V.R. and Hanumanulu, V. (1976), "Economics of Waste Water Treatment in Small Paper Mills", Paper Presented at the 12th Annual Meeting at Seminar on Environmental Engineering, New Delhi, March.

41. Weisbrod, B.A. (1964), "Collective Consumption Services of Individualized Consumption Goods", Quarterly Journal of Economics, Vol. 79, No. 3, August, pp. 471-477.

42. Whitcomb, D.K. (1972), "Externalities and Welfare", **Columbia University Press**, New York.