Technical Manual Series I

From Waste To Profits

Guidelines For Waste Minimisation

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'reface

Pulp and paper production is an important contributor to the national economy. With a production of 2.4 million tons in 1993, it accounted for 3 per cent of the value of output from the manufacturing sector. There are over 300 paper mills in the country using a variety of raw materials ranging from bamboo and forest-based wood to agro residue, bagasse, etc. With dwindling supplies of wood from forests and the increasing availability of agro residues, the trend over the years has clearly indicated a shift towards setting up of agro residue-based pulp and paper mills. While the shift has been satisfying in terms of reduced burden on forest wood, it has had its adverse impacts in terms of pollutant discharges to the environment. The reasons for higher levels of pollution in agro residue-based industries are diverse and many, such as:

- Outdated technology
- Lack of appropriate technology, particularly for chemical recovery
- Poor operational and maintenance practices, etc.

Consequently, the productivity and resource use efficiency of Indian agro residue-based pulp and paper mills has been lower than that of others.

The lack of availability of technical information for improving the material and energy productivity in these industries has been felt for long. It was also realised that the systematic application of the newer concepts of Pollution Prevention/Waste Minimisation (PP/WM) would go a long way in not only improving productivity but also in reducing adverse environmental impacts. Accordingly, in the UNIDO-sponsored Project, 'DESIRE — DEmonstration in Small Industries for Reducing WastE' the agro residue-based pulp and paper sector was taken as a thrust sector. The National Productivity Council conducted the project during 1993-94. The experience gained in identifying and implementing WM measures in the participating units in this project, generated a wealth of technical information. For the benefit of other industries, this information and experience has been compiled in the form of this manual.

The manual has been designed so as to help the industry personnel in implementing a comprehensive WM programme in their respective units. It is expected that this would serve as a useful reference material as well as practical guide for the users. The potential of WM, as estimated at present costs, ranges from Rs 700 to 1,800 per ton. A detailed description of various WM opportunities, as well as their technical, economical and environmental analysis, has been provided to facilitate the decision-maker in identifying and implementing the best suited measures.

I hope and trust that this manual finds wide acceptance in the Indian pulp and paper industry. The National Productivity Council has prepared this manual with the objective of promoting the implementation of cost-effective WM measures so that the pollution generated from the agro residue-based pulp and paper industry is reduced, the industry becomes more competitive and the world becomes a better place to live in.

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Director General

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Contents

ıdustry Profile

KGROUND

The paper industry is one of the oldest industries in India. dating back more than a century. Starting from a moderate volume of 19,000 tons/year at the beginning of the 20th century, Indian paper production had risen to 2.4 million tons/year in 1993. With increasing e¬phasis on literacy and the expansion/mod-emisation of service sectors, the demand is likely to increase much faster in the future. It is expected that the consumption of paper in India would grow from 2.8 million tons in 1993-94 to 4.2 million tons by the turn of the century and to 6.9 mil:ion tons by the year 2010. The growth of the pulp and paper industry during the past four decades is depicted in Figure 1.1.

From the point of view of resources used, the 340 paper mills in the country can be categorised as follows:

- Forest-based industries using wood, bamboo, etc, as raw materials;
- Agro residue-based industries using wheat straw, rice straw, bagasse, etc;

FIGURE 1.1
Growth of Pulp and Paper Industry

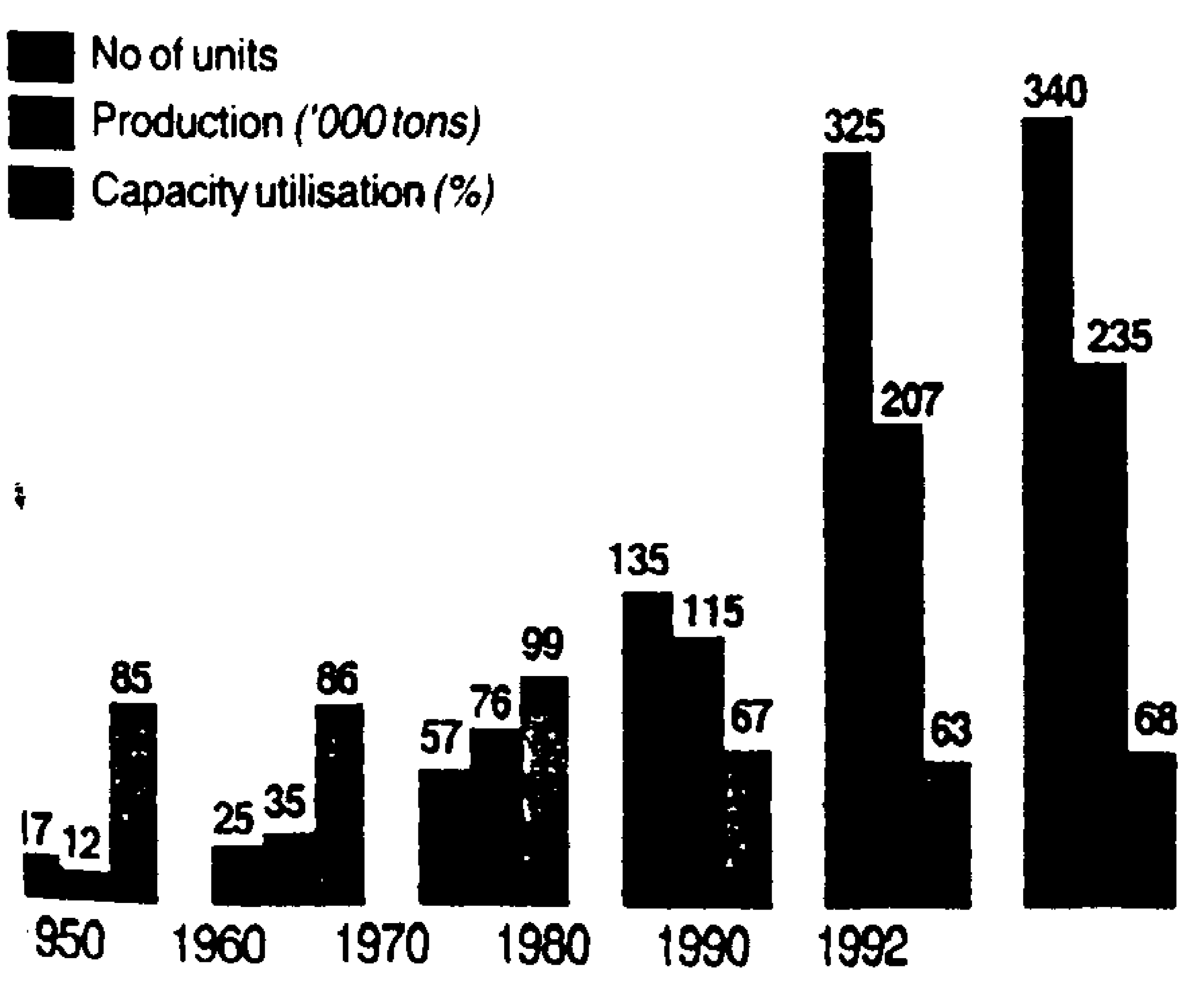
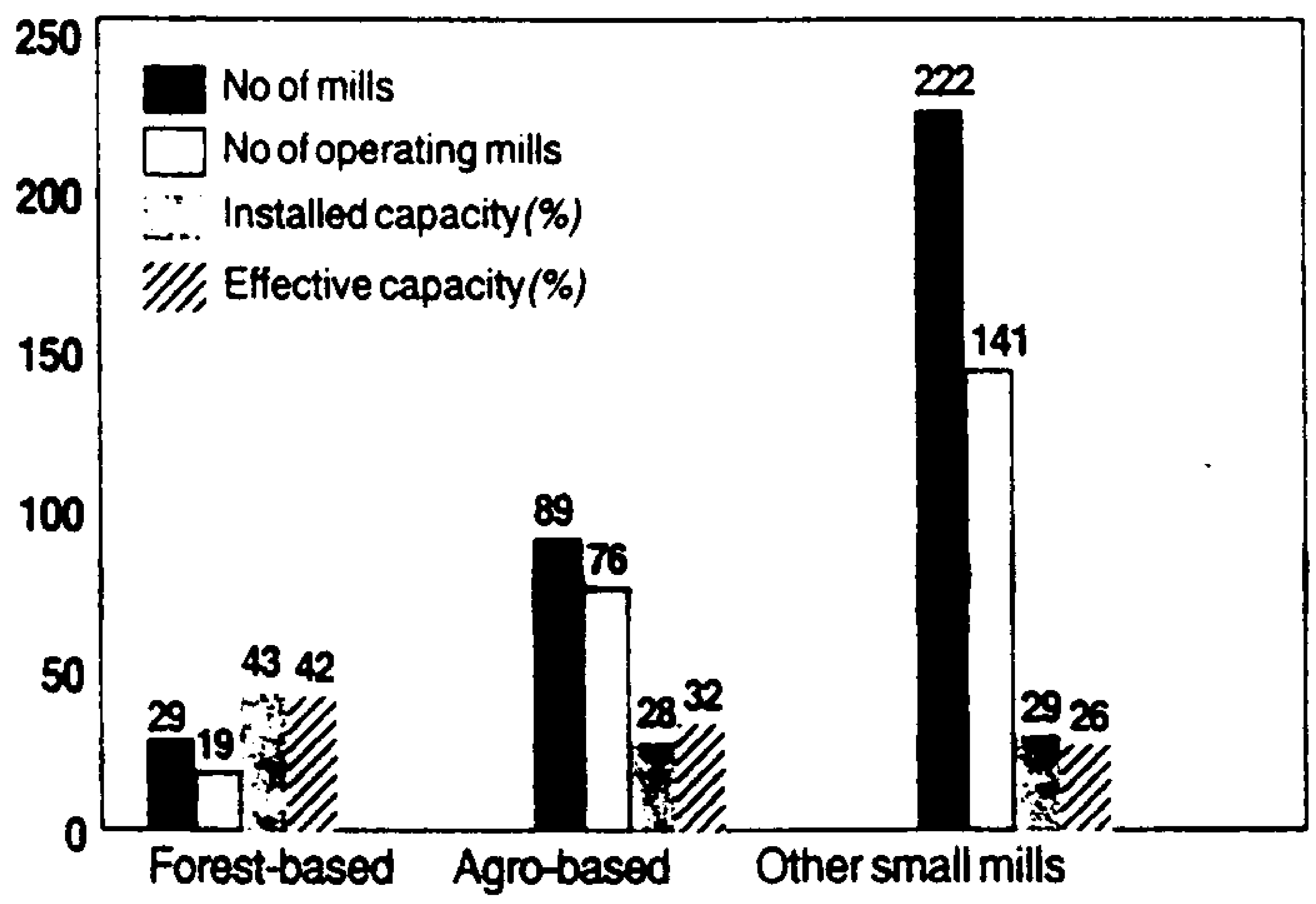


FIGURE 1.2
Installed and Effective Capacity of Different Segments of Mills (1991-92)



- Waste paper-based industry.

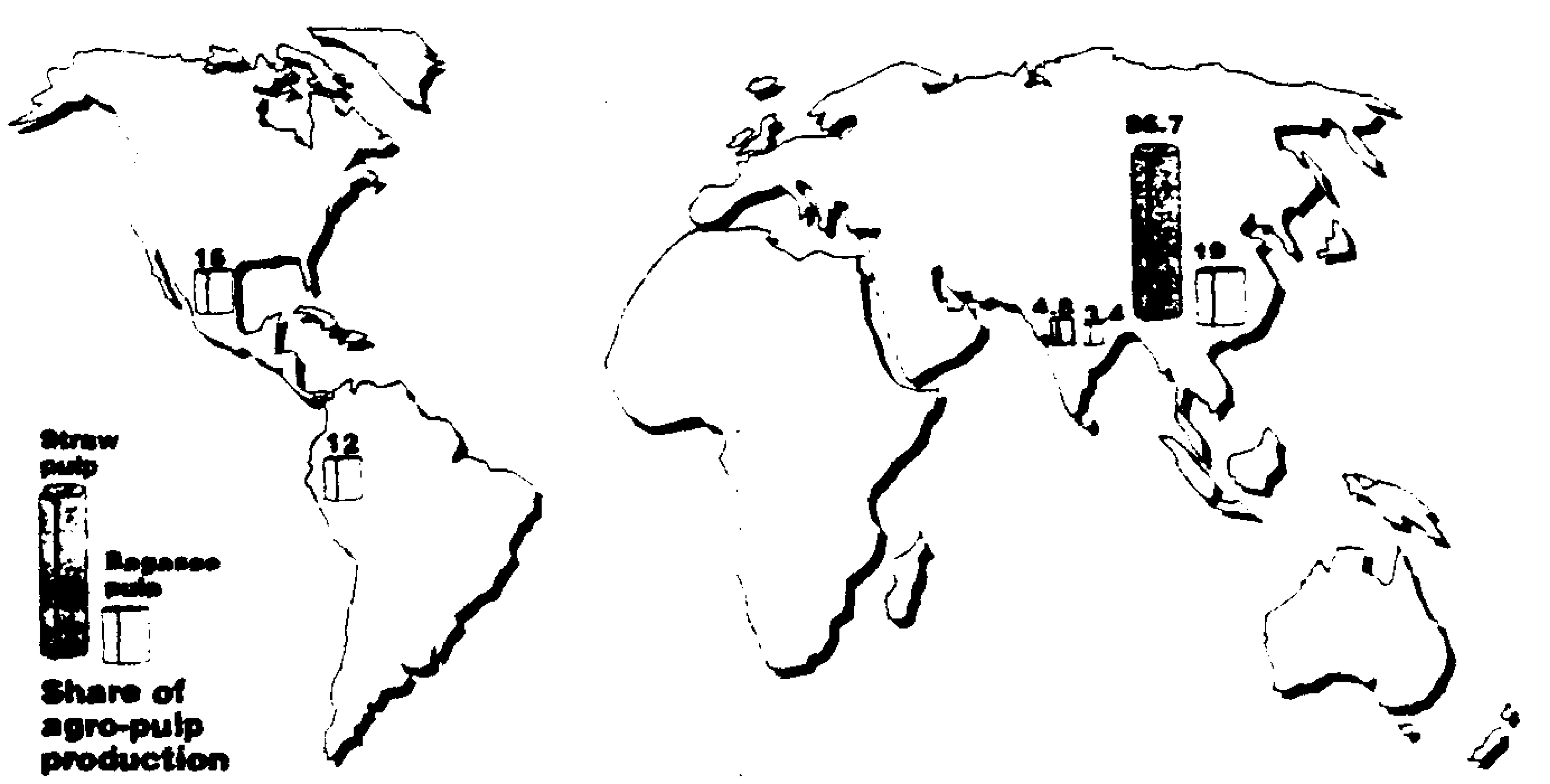
The installed and effective capacity of the paper industry in each of these categories is depicted in Figure 1.2. The last two decades have witnessed a decline in the use of forest-based raw material from 84 per cent in the 1970s to 43 per cent in the 1990s. On the other hand, the use of agro residue-based raw materials has increased during the same period from 10 per cent to 32 per cent and is projected to rise to 60 per cent by the year 2010. Obviously, the focal category in the pulp and paper industry has to be those mills which use agro residue-based raw materials.

Agro residue-based mills are more prevalent in developing countries, which have predominantly agricultural economies. The major agro-pulp producing countries are China, India, Mexico, Brazil, South Africa and Indonesia. China accounts for 86.7 per cent of the world's total availability of straw pulp, followed by India, with a share of just 4.8 per cent. The major producers of bagasse pulp are China, Mexico and Peru, with shares of 19 per cent, 16 per cent and 12 per cent, respectively, of the world's total production. India ranks 13th, producing only 3.4 per cent of the world's bagasse pulp. Global straw and bagasse pulp production stand at 8.5 and 2.7 million tons per annum, respectively.

WORLD SCENARIO OF AGRO RESIDUE-BASED PULP AND PAPER INDUSTRY

The capacity of the agro residue-based pulp and paper industry in Asia generally ranges from 15 to 60 tons/day. Constraints imposed due to limitations of availability of raw material within economically transportable areas, frequent operational interruptions causing heavy losses in large capacity machines, and the high cost of transporting low-quality paper producible from agro residues have been responsible for the relatively small size of plants.

World Scenario of Agro Residue-based Pulp and Paper Industry



The agro residue-based industry has not proliferated in developed countries for the following reasons:

- Preferential demand of high-quality paper;
- Cheap and abundant availability of wood;
- Economies of scale in large plants;
- High chemical costs caused by difficulties in chemical recovery.

However, in countries like those mentioned earlier, which would continue to have a significant agricultural economy, the growth of agro residue-based pulp and paper mills is imminent and desirable.

There are over 300 small pulp and paper mills in India, of which about 90 are purely agro residue-based, whereas others utilise a mixed feed of waste paper and/or agro residues. The characteristic features of these mills are summarised below:

- Most of the mills are in the size range of 10 to 40 tons/day capacity.
- Most of the mills follow the soda chemical pulping process and do not have any facility for chemical recovery. Thus, compared with large mills, their chemical consumption — and consequently the pollution load — is very high.
- The mills continue to use old technology, with little emphasis on modern instrumentation and process control.
- The availability of raw material varies from season to season and accordingly the mills have to make frequent adjustments to be able to use the diverse raw material. The product quality also gets affected and the mills are only able to produce low-quality paper. Some of the mills have started using a small proportion of long fibre, thus improving the quality of paper.
- Most of the mills are labour-oriented. The employment in these mills is 12 to 15 persons per ton of installed capacity as compared with 7 to 10 persons for large mills.
- The proliferation of these units has principally been under a protected and artificial fiscal policy regime set by the Government. With such concessions being withdrawn over the last couple of years, the industries have to gear themselves up to be able to meet the competition.

Thus, while the Indian agro residue-based pulp and paper industry faces the challenge of improving its efficiency and cost of production, it also has the opportunity to grow, due to the abundant availability of agro residues.

PROCESS DESCRIPTION

The various production sections and their operations/processes are listed in Table 1.1.

TABLE 1.1
Major Sections and Associated Unit Operations/Processes

Section	Unit Operations/Processes
• Raw material preparation	Dedusting, depithing, leaf removal
• Pulping section	Cooking, beating, pulp washing, refining, bleaching cleaning, and thickening
• Stock preparation	Blending, pulp conditioning
• Paper machine	Refining, centricleaning, dewatering, drying of paper
• Utilities	Steam generation, electricity, raw water supply

A detailled flowsheet of the manufacturing process is presented in Figure 1.3.

Paper manufacturing is an energy and water intensive process. The main sources of energy are fuels (coal, rice husk, bagasse) for boilers, electricity, and diesel for captive power generation. The specific energy consumptions for electrical energy and steam energy are 800 to 1,200 kW/ton of paper and 4 to 6 tons/ton of paper, respectively. The specific water consumption ranges from 180-280m^3/ ton of paper produced.

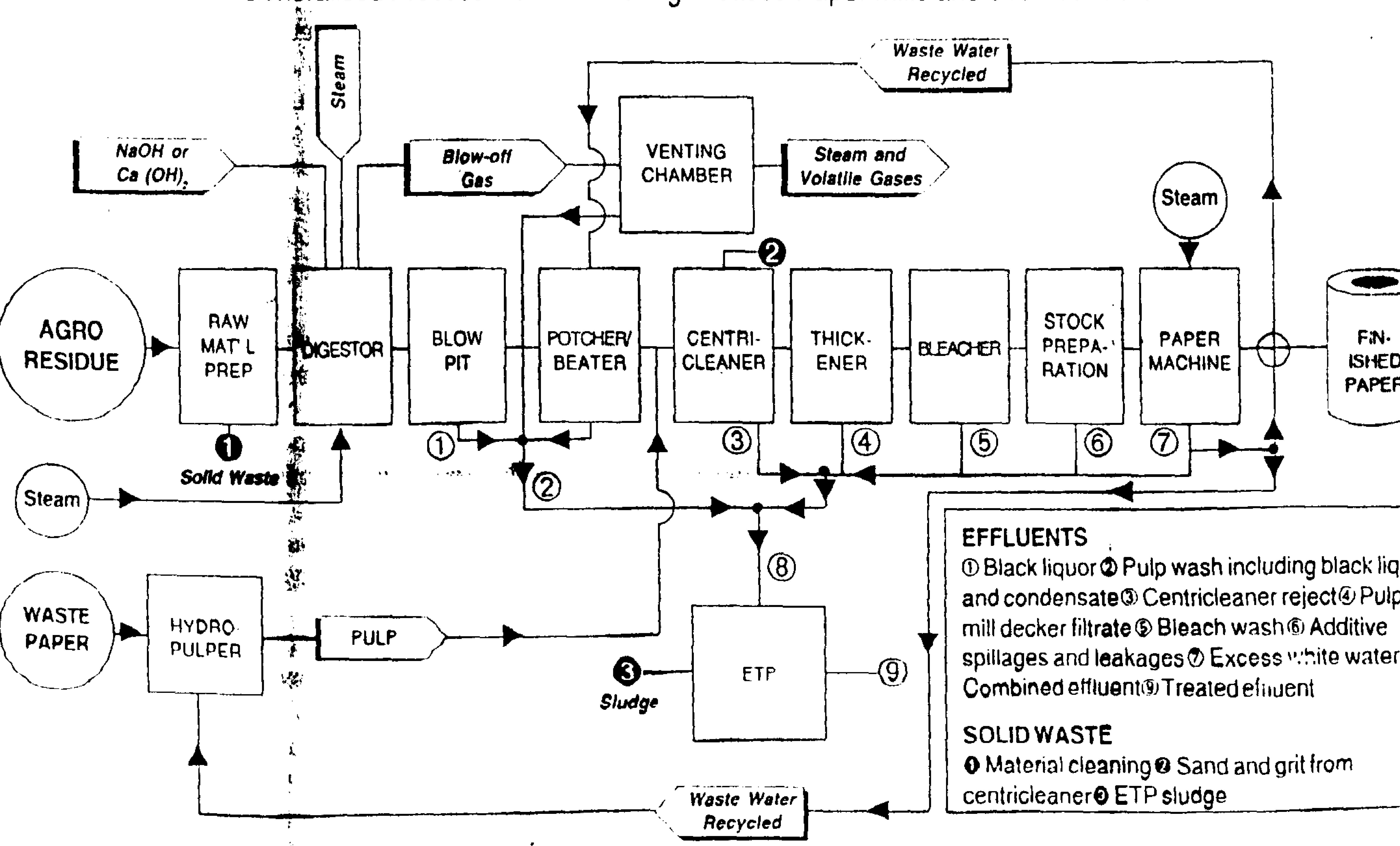
RAW MATERIAL PREPARATION

The agro residue-based raw material (RM) is procured by the mills from nearby farms and in some mills raw material is screened at the site. The dust from the screening section is disposed of as solid waste along with municipal waste. In small mills bagasse is generally not depithed. The prepared agro raw material is then conveyed by a belt conveyer to spherical digestors.

PULPING SECTION

■ *Cooking:* The agro residue is chemically digested in a spherical digestor at 150-160 °C and 6-7 atm pressure for about six hours. Charging and discharging takes another 1.5 hours and 0.5 hours, respectively. The cooking in small agro-based units is done with caustic soda (NaOH) and steam. The quantity

FIGURE 1.3
Generalised Process Flowsheet of Agro-based Paper Mills and Sources of Wastes



Waste wa
rate (m^3/t)
BOD (kg/t
COD (kg/t
TSS (kg/t)
TS (

of NaOH charged, varies from 6 to 14 per cent of RM, depending on the type of agro residue used. For every ton of agro residue, about 1.5-2.0 tons of steam is used, depending on the type of pulp required — hard cooked or soft cooked. During digestion, a solid to liquid (bath ratio) in the range of 1:3 to 1:4 is maintained.

■ *Blow tank:* After cooking, the content of the digestor is discharged, under pressure, either into a blow tank where the pressure is released or directly into potchers. Water is added to reduce the pulp consistency from an inlet value of 12-14 per cent to about 3-4 per cent, so that it can be pumped to the washing and cleaning section.

■ *Washing:* The pulp is then pumped to the washers (potchers) for washing with back water (recycled water from succeeding stages). The washing operation takes about four to six hours. The wash water called black liquor, which has a Total Solids (TS) content of around 1 per cent due to residual alkali and lignin, is discharged into the drains.

■ *Screening:* The washed pulp contains sand and uncooked agro residue as impurities. The impurities are removed through screening and centricleaning. The rejects from screening of writing and printing grade pulp are recycled for kraft grade (unbleached) paper manufacturing, whereas those from unbleached pulp are sold to board manufacturing units. The rejects from the centricleaner are normally drained out. After screening, which is carried out at about 1 per cent consistency, the pulp is thickened to about 4 per cent for the next operation, namely bleaching. The filtrate, called back water, generated during the thickening operation, is collected and used for pulp washing. The pulp for making kraft paper is not bleached and is taken directly for stock preparation.

Paper manufacturing is an energy-intensive process. The main sources of energy are fuels (coal, rice husk, bagasse) for boilers, electricity, and diesel for captive power generation. The specific energy consumption of electrical energy and steam energy are 800 to 1200 kW/ton of paper and 4 to 6 tons/ton of paper, respectively.

■ *Bleaching:* The bleaching in small mills is carried out using calcium hypochlorite (hypo), which is added in two stages in order to provide sufficient retention time for hypo and to minimise the fibre degradation. Fifty per cent of the hypo is added in the screened pulp storage chest and the rest is added in the bleacher. A retention time of about two hours is provided in the storage chest. After bleaching, the pulp is washed, partly with fresh water and partly with white water (recycled from paper machine). The wash water from the bleaching operation contains chlorolignates and residual chlorine and is, as such, not fit for reuse. It is, therefore, mixed with back water and reused for pulp washing.

STOCK PREPARATION

The bleached pulp is mixed with the long fibre pulp, comprising rags and waste paper pulp. The mix depends upon the agro residue being processed and the type of paper to be manufactured. The mixed pulp is blended with additives and fillers in the blending chest. The blending chemicals are rosin, alum, talc, dye (optional), optical whitener and high gum. The blending chemicals are prepared and added manually in every batch.

The agro residue-based pulp and paper mill generates wastes in the form of waste water discharges, air emissions and solid wastes. The most prominent form of waste discharge is the waste water, followed by air emissions and solid wastes.

PAPER MACHINE

The blended pulp is again centricleaned to remove excess additives and impurities and finally fed to the paper machine through a head box. From the dewatering and paper-making angle, the machine has three principal stages:

- The gravitational and vacuum dewatering stage (wire part).
- The mechanical dewatering stage (press rolls part).
- The thermal drying stage (indirect steam dryers).

On the wire part of the paper machine, the dewatering of pulp takes place by gravity and vacuum. The water from the wire mesh is collected in a fan pump pit and is continuously recycled to dilute the pulp fed into the paper machine centricleaner. In some units, the wire is continuously washed with fresh water showers. This water is collected and fibre is recovered from it through diffused air flotation (DAF). The clear water from DAF, called white water, is recycled to various consumption points. Units without DAF either discharge the wire pit cleaning water into the drain or partly recycle it for pulp washing.

After the wire part, the edge cutting operation is carried out to obtain paper of a definite width. The edge cuts of the pulp web falls in the couch pit and are recycled to the machine chest.

Towards the end of the wire part of the machine, the consistency of pulp rises to about 20 per cent. Further dewatering is carried out by press rolls to raise the consistency to about 55 per cent. The paper is finally dried through an indirect steam dryer to about 94 per cent solids and is collected in rolls as the final product.

UTILITY SECTION

The utility section comprises water supply, boiler house, and electrical power supply.

The total requirement of raw water is generally met by the mills' own bore wells; about 200-300 m³ of water per ton of paper is used.

The steam requirement is met by boilers of capacities ranging from 5 to 10 tons of steam per hour. The maximum steam pressure rating is usually [illegible] consumption is about 2 tons per ton of paper at a pressure of 4 kg/cm² in the paper machine and 4 tons per ton of pulp at a pressure of 6 kg/cm² in the pulp mill. The paper machine condensate is partially returned to the boiler. The make-up water requirement for the boiler is met by a softener plant.

The flue gas from the boiler is discharged through an induced draft (ID) fan into a stack. Control systems — multiclones or bag filter are provided to control the particulate emissions.

Some units have diesel generating (DG) sets to meet the electrical power requirement in case of non-availability of power from the grid.

STATUS OF WASTE GENERATI

The agro residue-based pulp and paper mill generates wastes in the form of waste water discharges, air emissions and solid wastes. The most prominent form of waste discharge is the waste water, followed by air emissions and solid wastes.

TABLE 1.2
Sources of Waste Water Generation

Section/Equipment	Sources
• Raw material preparation section	❑ Wet depithing of bagasse ❑ Wet cleaning of straw, elephant grass, etc
• Pulping section	
○ Digestor house	❑ Leaks and spills of black liquor gland cooling water from refiners, etc
○ Pulp washing	❑ Unbleached pulp wash
○ Centricleaners	❑ Rejects containing high concentration of fibres, grit or sand
○ Decker thickener	❑ Filtrate of pulp thickening
○ Hydropulper potcher	❑ Wash water
○ Bleaching	❑ Chlorination stage waste water containing chlorolignin ❑ Hypochlorite waste water
• Stock preparation section	❑ Leaks and spills of chemicals/additives and floor wash
• Paper machine	
○ Centricleaner rejects	❑ Rejects containing fibres, grit or sand
○ Wire pit	❑ Waste water containing fibre
○ Fan pump pit	❑ Fan pump pit overflow
○ Couch decker	❑ Filtrate of couch decker containing fibres, talc and sizing chemicals
• Utilities	
○ Boiler	❑ Boiler blow down
○ Softener plant	❑ Softener regeneration discharges

WASTE WATER

Table 1.2 depicts sources of waste water generation from various sections/equipment.

The section-wise and combined waste water specific pollution load factors of agro residue-based mills is presented in Table 1.3.

TABLE 1.3
Waste Water Pollution Load

Parameters	Pulp mill section	Paper machine	Factory combined
Waste water flow rate *(m^3/t)*	110-168	60-80	162-230
BOD *(kg/t)*	128-210	27-41	161-245
COD *(kg/t)*	705-1140	80-140	865-1215
TSS *(kg/t)*	118-262	61-109	192-362
TS *(kg/t)*	872-1292	205-394	993-1408

AIR POLLUTION

In small paper mills, air pollution occurs mainly from two sources — digestors and steam boilers. A third possible source is the captive power generation facility.

In agro residue-based mills, after the raw material digestion with caustic soda is completed, the pressure in the digestor is released. During this process, about 1.4 tons of steam per ton of pulp escapes into the atmosphere. The escaping gases contain volatile organic compounds. No information is available on the type and nature of these organic compounds. Unlike the conventional sulphate mills (Kraft mills), these mills do not generate hydrogen sulphide and mercaptans (organic sulphides), as sodium sulphide is not used in pulping. The pollution is mostly confined to the surroundings of the mill.

Agro residue such as paddy husk and baggase are the most commonly used fuel for generating steam. Besides agro residue, coal and diesel oil, etc, are also used as fuel in some mills. The air pollutants of concern are:

- Suspended particulate matter (SPM);
- Sulphur dioxide; and
- Oxides of nitrogen.

Mills with new boilers generally employ particulate removal devices, such as a multiclone or bag filter. The gaseous emissions from boilers as well as from DG sets are usually taken care of by dispersion through stacks of the appropriate height.

SOLID WASTE

Solid waste is basically generated from the process, and from pollution control facilities. The sources and quantities of solid waste generated are given in Table 1.4. The amount of waste (rejects) from centricleaner and screenings is very small, and is just a small fraction of the total waste generated during raw material handling.

It can be seen that small paper mills have to handle 0.3 to 0.4 tons of organic solid waste and 0.7 to 1.1 tons of boiler ash per ton of paper produced. At present, the solid wastes, particularly boiler ash, are disposed of in lowlying areas. After natural solar drying, the organic solid waste is either disposed of by burning, or sold to secondary users, such as brick kilns.

The waste generation in pulp and paper is quite significant. It not only represents a loss of resources, but also demands high treatment and disposal costs. Waste Minimisation efforts are, therefore, likely to yield the dual benefits of better resource utilisation and reduced pollution control costs.

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TABLE 1.4
Sources and Quantities of Solid Waste

[illegible]	[illegible]
■ ***PRODUCTION PROCESS***	
● Raw material cleaning	70-100
● Johnson screen	20-60
● Centricleaner rejects (from trap and riffler)	
❍ Pulp mill	10-20
❍ Paper machine	8-15
■ ***TREATMENT FACILITY***	
● Effluent treatment sludge	
❍ Primary clarifier	60-90
❍ Secondary clarifier	100-150
● Dust control system in boiler	500-750
■ ***UTILITIES***	
● Boiler bottom ash	175-350

aste Minimisation

ciple, Need And Potential

In order to be able to tap the available potential of Waste Minimisation in the pulp and paper industry, let us first get familiar with the concept of Waste Minimisation.

WHAT IS WASTE SATION?

The answer to the question 'what is Waste Minimisation?' could be as varied and diverse as one could perceive it to be. One of the definitions states:

"Waste Minimisation is a new and creative way of thinking about products and the processes which make them. It is achieved by continuous application of strategies to minimise the generation of wastes and emissions."

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Waste Minimisation is best practised by reducing the generation of waste at the source itself. After exhausting the source reduction opportunities, attempts should be made to recycle the waste within the unit. The type of techniques which are available in the two areas along with a few illustrative examples are given below.

OF

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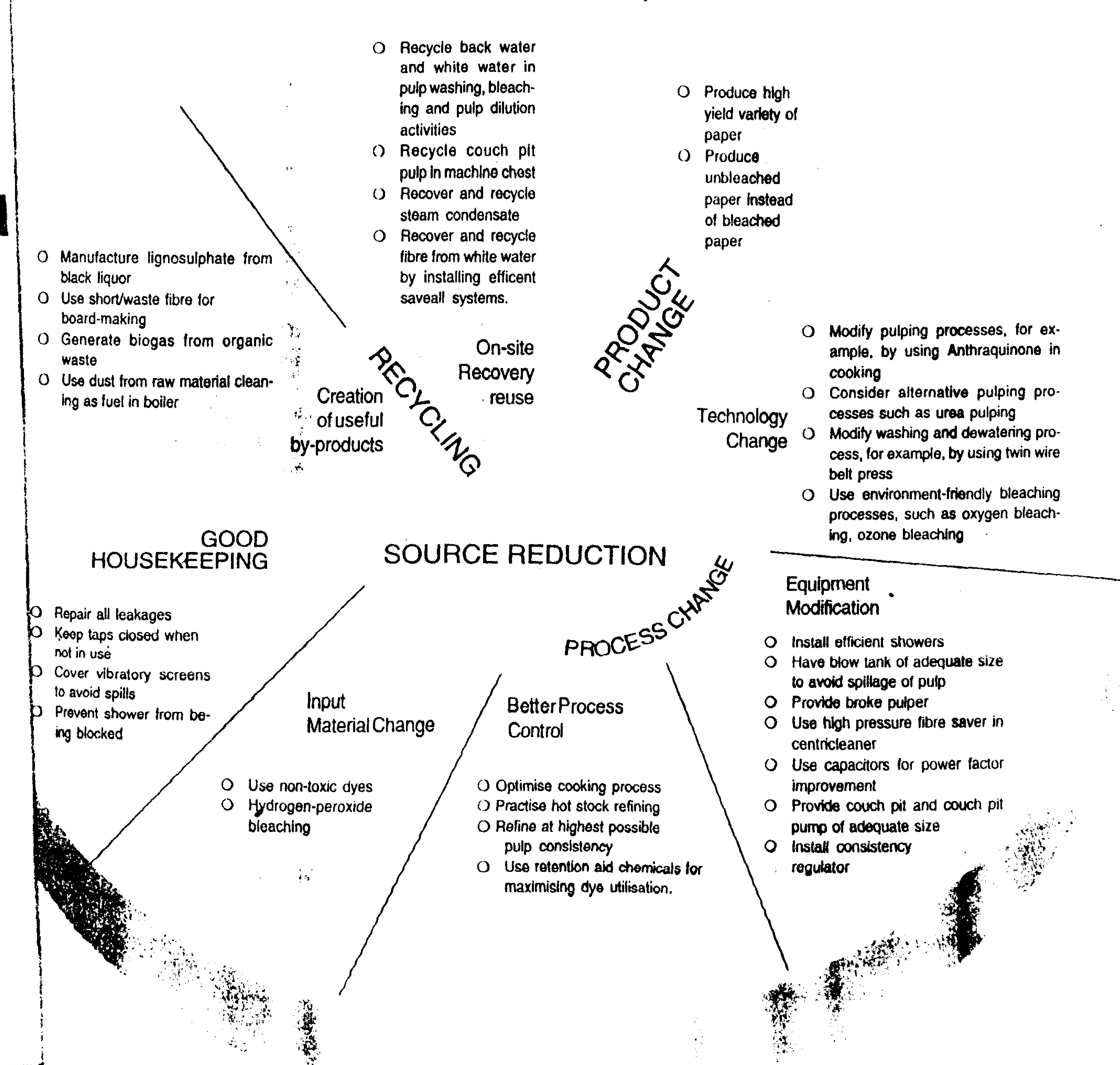
Waste Minimisation Techniques



NEED FOR WASTE MINIMISATION

The conventional end-of-pipe pollution control in small scale agro residue-based pulp and paper mills is very expensive. It has been estimated that the investment cost of effluent treatment alone could be as high as 20 per cent of the plant and machinery cost. The annualised operating cost could be up to 10 per cent of the turnover. A better approach would be to first exploit the opportunities of Waste Minimisation and control only the residual pollution. This approach not only leads to resource savings and hence lower production cost, but also, reduces the effluent treatment cost. Waste Minimisation is necessary from other aspects also, as described below.

NEED FROM REGULATORY POINT OF VIEW

Meeting progressively more stringent discharge standards has been a major problem faced by the pulp and paper industry. As discussed earlier, conventional effluent treatment is highly expensive. Additionally, it is very difficult to achieve the prescribed standards with such treatment facilities, unless one goes in for advanced treatment methods which could be beyond the technical and financial capabilities of this sector. The adoption of Waste Minimisation techniques renders the residual effluents relatively easier, simpler and cheaper to treat and would enable mills to approach the prescribed standards.

NEED FROM THE POINT OF VIEW OF RAW MATERIAL CONSERVATION

Given the increasing cost of input materials — raw material, chemicals and energy — no industry can afford to lose these resources in the form of wastes. The specific consumption of these raw materials can be considerably reduced by adopting waste minimisation measures, for example, by recycling some waste streams during the manufacturing process.

NEED FROM THE POINT OF VIEW OF WATER CONSERVATION

Water has increasingly become a scarce commodity, and several industries are experiencing acute water shortages, specially during lean periods. Most small scale agro residue-based pulp and paper mills are not located close to water bodies with abundant water supplies, and therefore have to depend on ground water. The continuous lowering of the ground water table leads to water shortage, increasing pumping costs. Instances have been reported where the industries had to curtail their production levels for want of adequate amounts of water. Efforts made towards conserving water not only get paid back through reduced costs, they also ensure continuous availability of water, thus sustaining desired production levels.

NEED FROM THE POINT OF VIEW OF ENERGY CONSERVATION

The pulp and paper manufacturing is an energy intensive industry with energy accounting for more than 25 per cent of production costs. As per published literature (ref *Report on Specific Energy Consumption Norms in Indian Pulp and Paper Industry,* published by the Confederation of Indian Industries), there is a potential for saving energy to the tune of 20 per cent by simple, low-cost measures. For the industry to retain its competitiveness and also to reduce its energy intensiveness, it is essential that it take steps to reduce energy consumption, which can be achieved through a concerted Waste Minimisation effort.

NEED FROM THE POINT OF VIEW OF OPERATING COST OF ETP

As mentioned earlier, unlike large scale plants, small scale plants can hardly afford to install capital intensive waste water treatment plants which require heavy investments and entail high recurring operational costs. Waste Minimisation techniques help in reducing the overall pollution load and hence the cost of effluent treatment.

NEED FROM THE POINT OF VIEW OF ENVIRONMENTAL PRESSURE GROUPS AND WORKERS' AWARENESS

The public awareness in the field of environment protection is growing day by day. Over the last few years, several non-governmental environmental protection organisations have come up, not only to create awareness in this field but to also act as watchdogs against polluters. The industry can no longer keep itself isolated from such pressure groups and has to take positive steps to mitigate environmental pollution. Waste Minimisation could be one such positive step. In addition, today's industrial workers are far more aware of their right to a clean work environment. A sizable number of skilled workmen, who are not available plentifully, now consider the environment as an important factor in an organisation. Ensuring a clean environment through Waste Minimisation could be a definite way of attracting, retaining and even motivating good workmen. It also inculcates, among the workers, a mentality of controlling waste, which is of prime importance in getting the competitive edge.

It could thus be concluded that the implementation of Waste Minimisation measures serves the dual objectives of reducing raw material, energy and chemical losses as well as bringing down the investment and operating costs of pollution control systems.

DTENTIAL IR WASTE MISATION

Small pulp and paper mills in India operate under constraints, such as obsolete and inefficient technology, a small scale of operation, poor grades of raw material which changes from season to season, low profit margins and untrained manpower. Further, the technology for chemical recovery from black liquor is still not developed for this sector, resulting in higher chemical consumption as well as higher pollution load. This leads to high levels of waste generation and decreased profitability. The potential of Waste Minimisation in this sector is, therefore, very high. Table 2.1 illustrates the potential of Waste Minimisation in quantitative and monetary terms.

Small pulp and paper mills in India operate under constraints such as obsolete and inefficient technology, small scale of operation, poor grades of raw material which changes from season to season, low profit margins and untrained manpower.

The overall potential of Waste Minimisation and subsequently enhancing profit margin in the pulp and paper sector is about Rs 730 to 1,800 per ton of paper produced. In addition, waste water treatment costs get reduced from a level of Rs 1,000 -1,250 per ton to Rs 500-700 per ton of paper made.

Tapping the above potential does not necessarily require huge investments/expenditure. In fact, significant waste reduction and consequently significant monetary benefits can be achieved even with minimal inputs. Categorising Waste Minimisation measures as 'Minor' (requiring investment up to Rs 20,000,

TABLE 2.1
Potential of Waste Minimisation in Small Agro Residue-based Pulp and Paper Mills*

Area	*Unit*	General [illegible] Consumption range	[illegible] Quantity	[illegible]
Fibre	*yield %*	40-44	40-100 kg/T	250-600 Rs/T
Caustic	*kg/T*	60-120	10-15 kg/T	100-150 Rs/T
Additives	*kg/T*	11-15	1-2 kg/T	5-10 Rs/T
Steam	*ton/T*	4.5-6.5	0.5-1.5 T/T	125-400 Rs/T
Electrical energy	*kW/T*	850-980	60-120 kW/T	150-300 Rs/T
Overall capacity	*per cent*	5-20	75-300 kg/T	75-300 Rs/T
Water consumption	*m^3/T*	180-280	60-120 m^3/T	25-50 Rs/T
TOTAL POTENTIAL [illegible]				[illegible]800 Rs/T

**These figures are an indication of the magnitude of WM in average agro-based pulp and paper mills of 30 TPD.*

and production stoppage of less than two hours), 'Moderate' (requiring investment between Rs 20,000 and Rs 75,000, and production stoppage of about eight hours) and 'Major' (requiring investment of more than Rs 75,000, and production stoppage of more than eight hours), it

Significant waste reduction and consequently significant monetary benefits can be achieved even with minimal inputs.

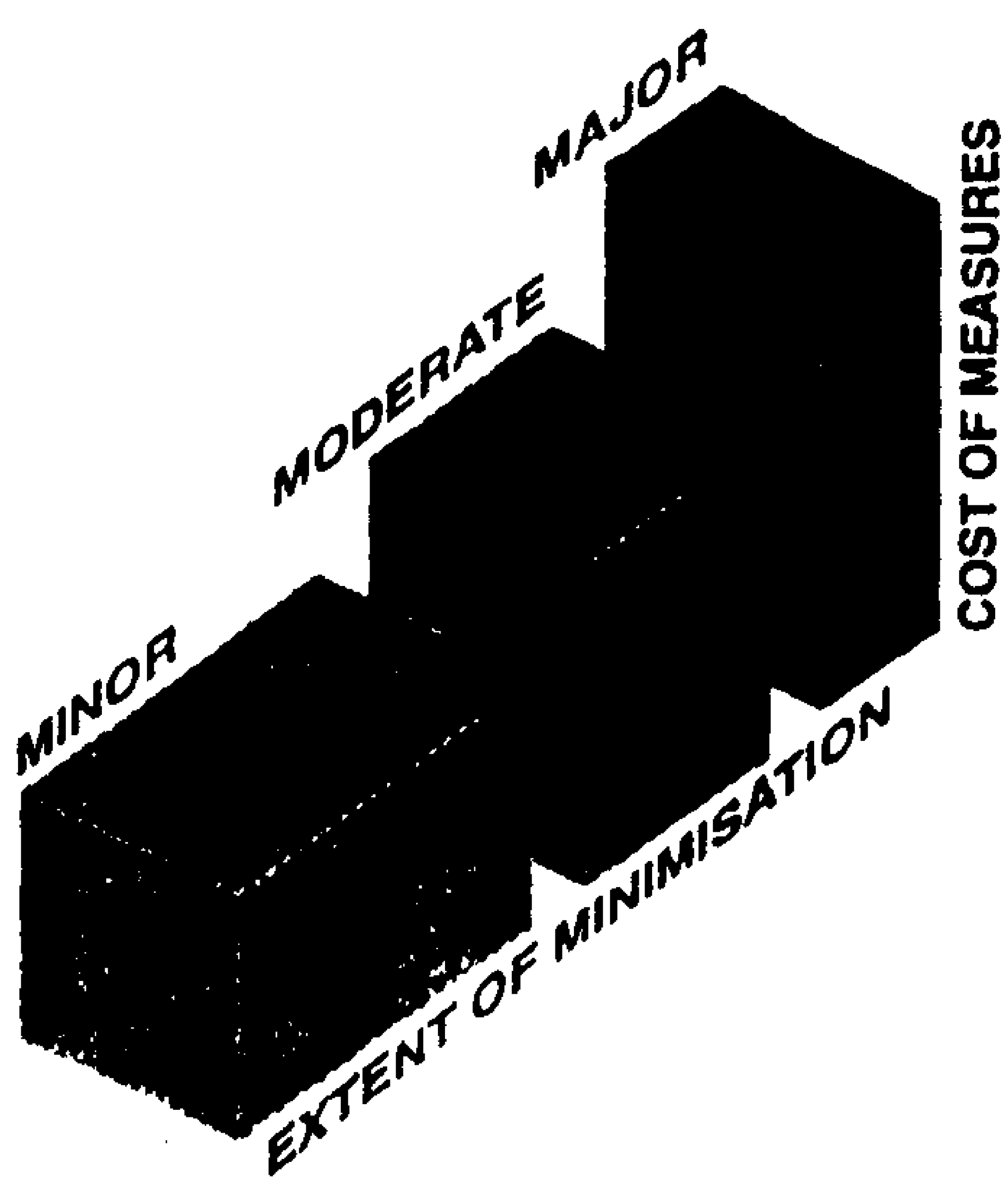


TABLE 2.2
WM Potential of Minor, Moderate and Major Mea

[illegible]	[illegible]	[illegible]	[illegible]
Fibre recovery	kg/T	16-40	10-25
Caustic saving	kg/T	5-7	5-7
Additives saving	kg/T	0.5-1.0	0.5-0.8
Steam conservation	T/T	0.2-0.6	0.1-0.3
Electricity saving	kW/T	18-35	18-35
Capacity increase	kg/T	15-60	22-90
Water conservation	m^3/T	30-60	15-30

can be seen from Table 2.2 that about 40 per cent of Waste Minimisation potential can be tapped by implementing just the Minor ones.

Let us now have a look at the various Waste Minimisation opportunities in greater detail.

aste Minimisation Opportunities

DUCTION

The experience of a number of agro residue-based pulp and paper mills show that there are several proven Waste Minimisation techniques which could be implemented to tap the WM potential discussed in Chapter II. The impact of WM measures often extends beyond the point of application and has a cascading effect on other sections/operations as well. Better raw material preparation has its beneficial effect on pulping, washing, paper-making and even on paper quality. Most importantly, these measures enable reduction in environmental costs due to reduced end-of-pipe pollution control requirements.

In this chapter, various Waste Minimisation measures have been described. For the sake of clarity, the WM opportunities have been grouped under the four major production sections — the Raw Material Preparation section, Pulping section, Stock Preparation section and Paper-making section. The technical requirements, economic viability, environmental aspects and anticipated benefits for each measure are also discussed.

ATERIAL
ARATION

The fibrous raw material used by the industry contains 8 to 10 per cent dust and fines and up to 25 per cent pith in the case of bagasse. These fines (impurities) do not contribute to the pulp value. Instead, they consume costly cooking chemicals and steam. In addition, they end up as pollution load in terms of COD and TS. The impurities adversely affect the washing efficiency and overload the centricleaner. Those impurities which escape the centricleaner cause specks (black spots) on the finished paper. They also increase the wear and tear (maintenance) of mechanical equipment (refiner, pumps, etc). Most importantly, the drainability of pulp in the machine wire part is adversely affected, resulting in reduced paper machine speed and consequent loss of production.

The appropriate preparation of raw material is therefore not only important from the economic standpoint, but also from the environmental, equipment efficiency and product quality points of view. Proper raw material preparation can result in savings.

The raw material preparation section of a typical pulp and paper mill.

Benefits Of Proper Raw Material Preparation

Potential area	Savings/improvement quantity	Potential value/ton of paper
Chemical saving — caustic	12-18 kg/T paper	Rs 120-180
Steam requirement for cooking	0.1-0.2 T/T paper	Rs 25-50
Increased pulping capacity	6-8%	Rs 25-100
Total		**Rs 170-330**
Reduction in pollution load	8-10%	Rs 95-120
TOTAL		**Rs 265-450**

Unfortunately, in most agro residue-based pulp and paper mills, the raw material preparation section is conspicuous by its absence. A myopic view might indicate that there is, therefore, no waste generated. However, as discussed earlier, this has a serious deleterious effect in all downstream sections. The raw material preparation techniques discussed in Table 3.1 emerge as important Waste Minimisation measures due to their impact on waste reduction in downstream sections.

TABLE 3.1
Waste Minimisation Measures In The Raw Material Preparation Section

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic* viability	Environmental impact	Remarks
1. Dry dedusting of straw for removal of fines and dust	❍ Reduction in consmn of: Steam 7-10%, Caustic 7-10%, Electrical (marginal) ❍ Reduction in screening rejects by 10-15% ❍ Increased pulping capacity ❍ Fines and dust can be used as fuel ❍ Enables reuse of black liquor due to reduced silica content ❍ Better runability of paper machine ❍ Reduced wear and tear of pumps and refiners	*Equipment:* ❑ Vibratory/rotary screen ❑ Conveyor ❑ Dust handling system *Manpower:* ❑ No additional skilled manpower reqmt *Process:* ❑ Applicable for RM having moisture < 15%	I = Rs 2-3.5 lakh P = < 1 year	Reduction in TS by 6-8% and in COD by 5-10%	All equipment/technology available indigenously. The measure is easily implementable
2. Wet cleaning for removal of fines and dust	❍ Reduction in consmn of Steam 7-10%, Caustic 8-12% ❍ Reduction in screening rejects by 10-15% ❍ Enables reuse of black liquor due to reduced silica content ❍ Increased pulping capacity ❍ Better pulp quality ❍ Better runability of paper machine ❍ Reduced wear and tear of pumps and refiners	*Equipment:* ❑ Cleaning pond ❑ Screw conveyor ❑ Showers ❑ Dewatering equipment *Process:* ❑ Additional space reqmt of about 5,000 sq mt *Manpower:* ❑ No additional skilled manpower reqmt *Technology:* ❑ Indigenous dewatering equipment not found to be successful	I = Rs 15-20 lakh S = Rs 3-4 lakh P = > 5 years	Reduction in TS by 8-10% and COD by 8-12%	The measure, though environmentally attractive, requires high capital investment and needs additional space. Additional quantities of waste water are generated
3. Installation of disk cutter for revomal of fines dust and non-cellulosic material	❍ Reduction in consmn of: Steam 15-20%, Caustic 15-20% ❍ Reduction in screening	*Equipment:* ❑ Air blower ❑ Screw conveyor ❑ Disk mill ❑ Cyclone	I = Rs 10-15 lakh S = Rs 2-3.5 lakh P = > 4 years	15-20% reduction in TS and 8-15% in COD	Recommended mainly for rice straw. For other agro residues, the fibrous RM loss could be high (up to 35%)

* *The assumed capacity of paper mill for all listed options is 30 TPD.*
I: Investment; S: Savings; P: Payback period.
Note: The following abbreviations mean: RM: Raw material; reqmt: requirement, consmn: consumption

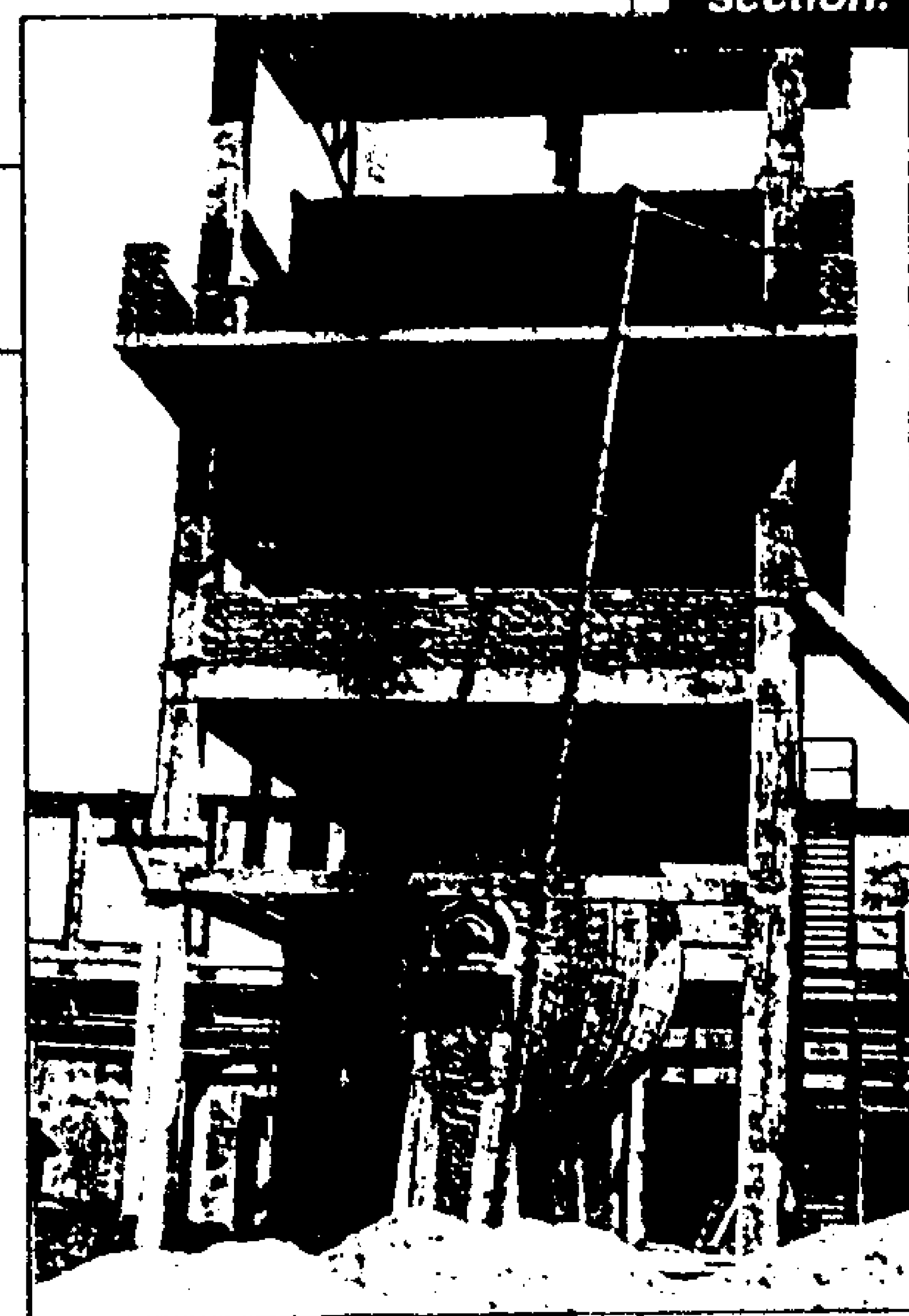
Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental impact	Remarks
	rejects by 15-20% ❍ Enables reuse of black liquor due to reduced silica content ❍ Increased pulping capacity ❍ Fines and dust can be used as fuel ❍ Better pulp quality ❍ Better runability of paper machine ❍ Reduced wear and tear of pumps and refiners	❑ Collection chutes *Process:* ❑ The measure is flexible to suit different raw materials, provided moisture is <15% *Technology:* ❑ Disk mill not available indigenously *Manpower:* ❑ Skilled manpower required	 **A disc mill.**		Additional fuel
4. Using 25% top cut elephant grass (the top 25% is mainly leaves and doesn't contribute to fibre value)	❍ Improved packing density ❍ Increased pulping capacity ❍ Better pulp quality ❍ Reduced caustic reqmt by 3-7% ❍ Reduced steam reqmt ❍ Easy RM transportation ❍ Better runability of paper machine ❍ Dried out leaves can be used as fuel	*Equipment:* ❑ Cutter ❑ Conveyor *Technology:* ❑ Indigenous cutters are not effective and require additional unskilled manpower	I = Rs 1-2 lakh S = Rs 2-3 lakh P = < 0.5 years	Reduction in TS load by 8-10% and in COD load by 10-12%	A good technology, yet to be demonstrated
5. Baling of wheat and rice straw	❍ Reduced storage area ❍ Reduced fibre degradation ❍ Better housekeeping ❍ Reduced loss due to entrainment in air ❍ Easy handling ❍ Only feasible with mechanical harvesting	*Equipment:* ❑ Baling machine ❑ Bale breaker *Process:* ❑ Yet to be demonstrated *Manpower:* ❑ Additional unskilled manpower required *Technology:* ❑ Not indigenously available	I - Not available S - Not yet quantifiable	Reduced air-borne particulate. Reduced pollution load due to degraded raw material	The measure is feasible only if mechanical harvesting is practised
6. Depithing of bagasse	❍ Reduced consmn of: Steam 10-15% Caustic 15-20% Electricity (marginal) ❍ Enables the use of BL due to reduced viscosity ❍ Improved pulp yield ❍ Increased pulping capacity ❍ Removed pith can be used as fuel ❍ Better runability of paper machine	*Equipment:* ❑ Depither ❑ Allied equipment *Technology:* ❑ Indigenously available *Manpower:* ❑ No additional manpower is required	I = Rs 4-6 lakh S - Rs 5-6 lakh P - 1 year	20-25% reduction in TS and 15-30% in COD	The measure is easily implementable

PULP MILL SECTION

This section is the single largest polluting section in a pulp and paper mill, accounting for about 80 per cent of the total pollution load. At the same time, it also has scope for the largest number of WM interventions, ranging from raw material substitution to technology modifications, and recycling.

The overall potential of benefits accruing from Waste Minimisation in the pulp mill section is given in the following table.

The pulp mill section.



Benefits Of Proper Pulping Operation

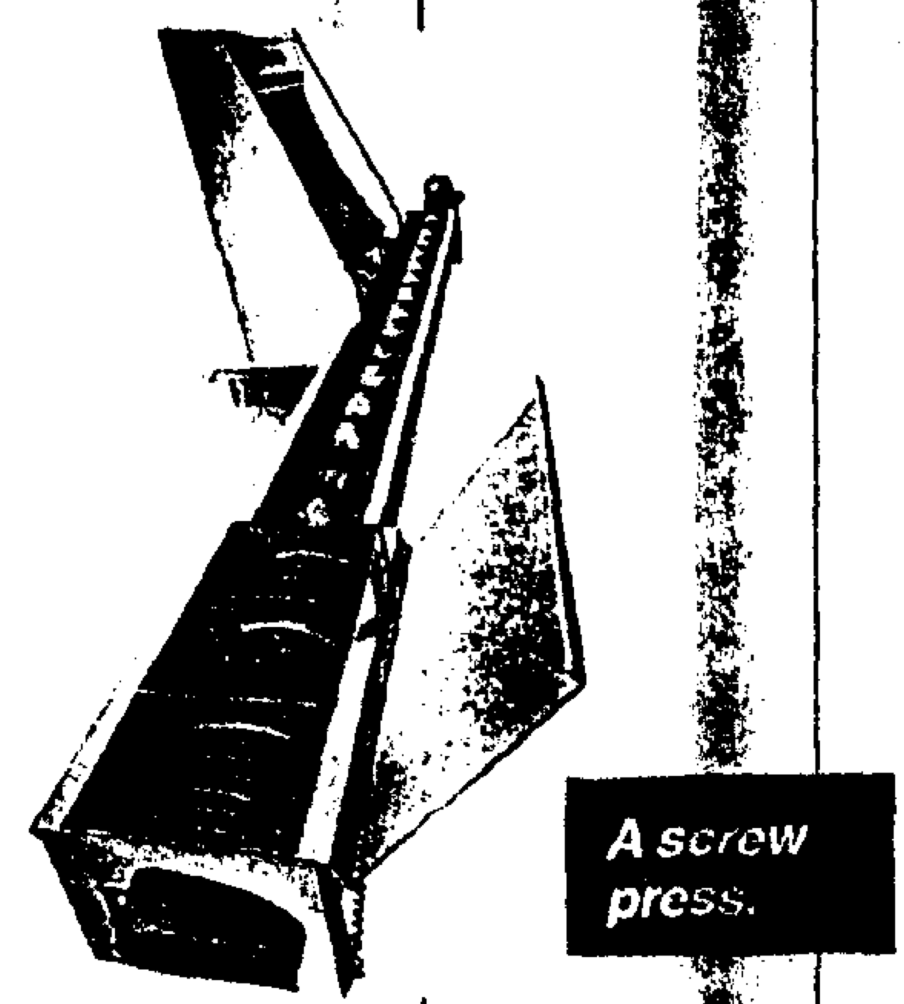
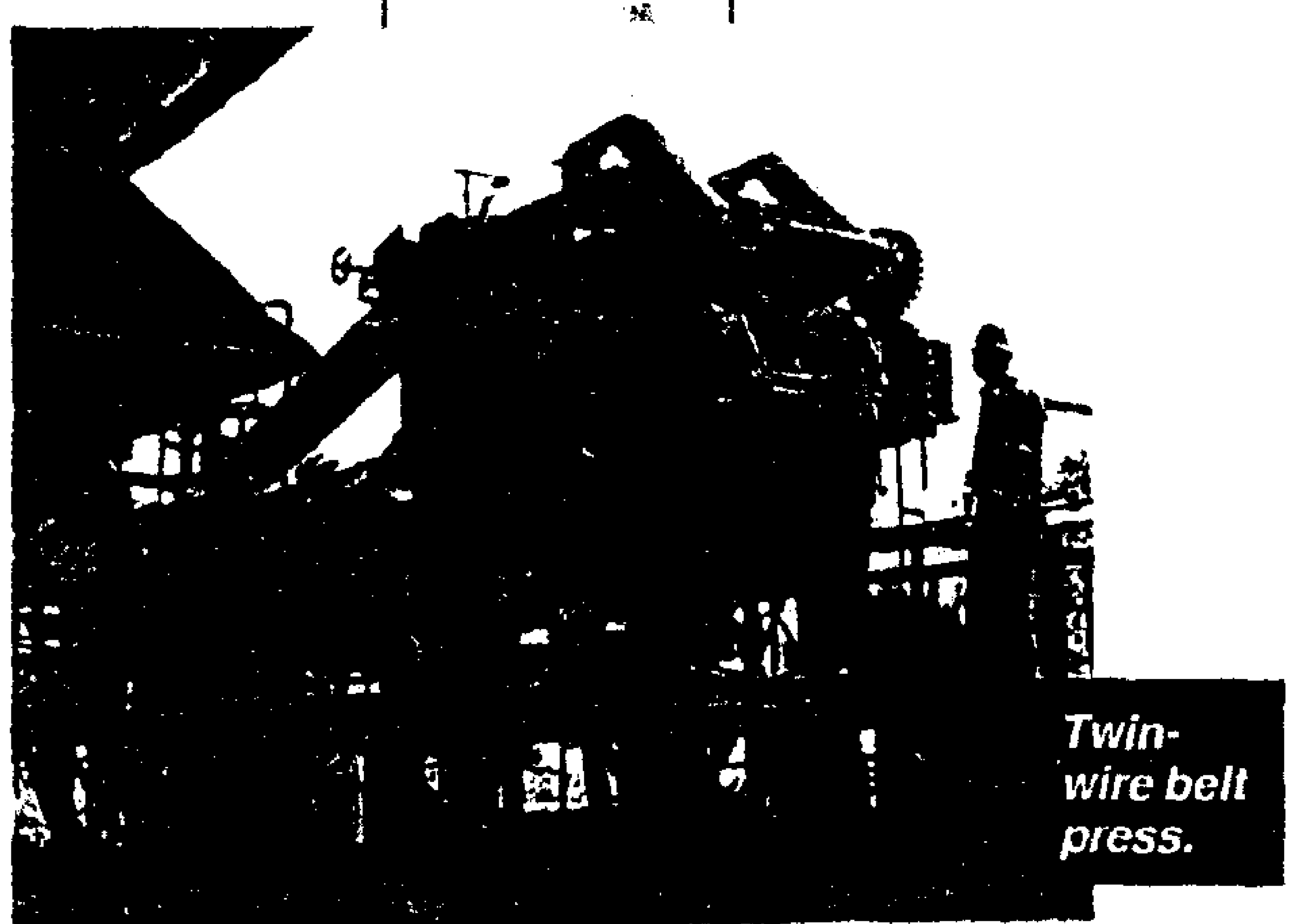
Potential area	Savings/improvement quantity	Potential value/ton paper
• Chemical saving — caustic	3-12 kg/T paper	Rs 30-120
• Fibre recovery	20-45 kg/T paper	Rs 120-240
• Water conservation	30-60 m³/T paper	Rs 12-25
• Reduced steam requirement	0.2-0.6 T/T paper	Rs 50-150
• Reduced electrical energy	20-50 kWh/T paper	Rs 50-125
• Increased pulping capacity	5-7%	Rs 20-75
Total		**Rs 282-735**
• Reduction in pollution load	25-30%	Rs 300-360
• Extra fuel value	25-40 kg/T paper	Rs 15-25
TOTAL		**Rs 597-1,120**

The various Waste Minimisation measures which would enable tapping of this potential are discussed in Table 3.2.

TABLE 3.2
Waste Minimisation Measures In The Pulping Section

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
1a. RM impregnation with recycled liquor	○ Improved packing density (7-10%) ○ Increased pulping capacity by 7-10% ○ Reduced cooking time by 5-7% ○ Reduced caustic ○ Reduced steam reqmt ○ Enables low bath ratio ○ Uniform pulp quality	*Equipment:* ❑ Belt conveyor ❑ Liquid feed tank ❑ Showers ❑ Black liquor feed tank ❑ Paddle mixer *Process:* ❑ Suitable for all agro residues *Manpower:* ❑ No additional manpower is required	I = Rs 1-1.5 lakh S = Rs 0.5-1 lakh P = < 2 years unquantifiable	Reduction in pollution load	The measure is easily implementable black
1b. RM impregnation with caustic	○ Improved packing density ○ Increased pulping capacity ○ Reduced cooking time	*Equipment:* ❑ Belt conveyor ❑ Showers ❑ Liquor feed tank	I = Rs 5-8 lakh S = Rs 3-4 lakh P = < 2 years	Marginal reduction in pollution load	The measure is easily implementable

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
	○ Reduced caustic consmn by 3-7% ○ Reduced steam consmn ○ Enables low bath ratio ○ Uniform pulp quality	❑ Paddle mixer ❑ Caustic collection tank *Process:* ❑ Suitable for all agro residues *Manpower:* ❑ No additional manpower is required			
2. Multiple loading of digestor	○ Increased digestor capacity by 10-15% ○ Reduced steam consmn ○ Increased pulp yield	Nil	Savings due to reduced steam consmn to be quantified on case-to-case basis. Other savings difficult to quantify	10-15% reduction in digestor vent gases	The extra time required for double loading will be more than offset by the reduction in number of batches for same pulp production
3. Reduction in bath ratio	○ Reduced consmn of: Steam by 5-10% Cooking time	Nil	I = Nil S = Rs 3-6 lakh	No direct impact	No financial involvement. Measure is easily implementable
4. Using anthraquinone or anthraquinone-plus-molasses as cooking aid	○ Higher pulp yield ○ Improved delignification ○ Reduced washing reqmt ○ Reduced water consmn ○ Improved bleachability ○ Better pulp quality ○ Better runability of paper machine	*Technology:* ❑ Availability of good quality anthraquinone in domestic market is uncertain	S = Unquantifiable	Reduction in TS and COD load in effluent	Increase in chemical cost will be compensated by high yield and better quality of pulp
5. N[illegible]utral ammonium sulphite cooking	○ Enables use of black liquor as fertiliser ○ Reduced bleaching chemical reqmt	*Process:* ❑ Not yet successfully demonstrated	S = Not yet quantified	80% reduction in pollution load, as BL can be used for agricultural applications	Due to the disadvantages such as corrosion of digestor, higher cooking temperature and time, and emission of ammonia gas, this measure needs further investigation
6. Alkaline sodium sulphite cooking	○ Reduced washing reqmt ○ Reuced water consmn ○ Improved bleachability ○ Reduced bleaching chemical reqmt ○ Higher paper strength	Nil	S = Unquantifiable	Reduction in colour intensity of effluent	If proper pH conditions are not maintained, it could lead to corrosion of digestor
7. High yield pulping, that is, mechano-chemical pulping for unbleached paper	○ High pulp yield 8-15% ○ Reduced cooking chemicals	*Equipment:* ❑ Mechano-chemical digestors *Technology:* ❑ Available indigenously	I = Rs 10-15 lakh S = Unquantifiable	Reduction in TS and COD by 10-15%	Increase in steam and electrical energy consmn

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental impact	Remarks
8. Optimisation of cooking process (that is, operating at required steam pressure, temperature, chemical dosing)	○ Better pulp quality ○ Reduced uncooked and screening rejects ○ Reduced refining reqmt ○ Reduced chemical consmn ○ Reduced steam reqmt ○ Better pulp yield	*Equipment:* ❑ Temperature indicator ❑ Pressure indicator ❑ Control panel *Manpower:* ❑ Skilled operator required	I = Rs 1-1.5 lakh S = Unquantifiable	Reduced overall pollution load	Strongly recommended for all mills
9. Screw press for removal of concentrated black liquor from pulp	○ Easy handling and treatment of black liquor ○ Enables recycling of BL for using residual caustic ○ Hot BL recycle reduces steam reqmt ○ Enables better impregnation of RM with BL ○ Reduced washing time by 50-60% ○ Water conservation in washing by 50% ○ Reduced energy reqmt in effluent treatment ○ Enables solar drying of black liquor ○ Reduced fibre loss at washing stage	*Equipment:* ❑ Recirculation tank ❑ Blow tank ❑ High consistency pump ❑ Dilution pump ❑ Screw press ❑ Piping *Process:* ❑ Unwashed pulp conveying system to be modified *Technology:* ❑ Indigenously available but needs modification *Manpower:* ❑ Additional skilled manpower required	I = Rs 1.2-3 lakh S = Rs 1.5-3 lakh P = < 1 year  *A screw press.*	Reduction in effluent volume by 40-50%	The measure is at pilot scale and is being implemented in some mills
10. Twin-wire belt press for pulp dewatering	○ Easy handling and treatment of black liquor ○ Enables recycling of BL for using residual caustic ○ Hot BL recycle reduces steam reqmt ○ Enables better impregnation of RM with BL ○ Elimination of separate batch washing ○ Water conservation in washing by 80% ○ Reduced energy reqmt in effluent treatment ○ Enables solar drying of black liquor ○ Reduced fibre loss at washing stage ○ Low power consmn	*Equipment:* ❑ Twin-wire belt press and circulation pumps ❑ Blow tank ❑ High consistency pump ❑ High density tower *Process:* ❑ Washing system almost eliminated *Technology:* ❑ Available but expensive *Manpower:* ❑ Skilled manpower is required	I = Rs 10-15 lakh S = Rs 6-10 lakh P = < 2 years  *Twin-wire belt press.*	Reduction in effluent volume by 60-70%	Versatile piece of equipment, usable for any agro residue raw material
11. Vacuum washers for washing of pulp: ■ with barometric leg	○ Easy handling and treatment of black liquor ○ Enables recycling of BL for using residual caustic	*Equipment:* ❑ Tall civil structure ❑ High density tower ❑ High consistency pump	I = Rs 60-80 lakh S = Rs 6-10 lakh P = 8-10 years	Reduced effluent volume	This option recommended for medium-sized mills (35 TPD and above) The measure would be

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental Impact	Remarks
■ with vacuum pump	○ Hot BL recycle reduces steam reqmt ○ Enables better impregnation of RM with BL ○ Reduced washing time due to continuous wash ○ Water conservation in washing by 50% ○ Reduced energy reqmt in effluent treatment ○ Enables solar drying of black liquor ○ Reduced fibre loss at washing stage	❑ Barometric leg or vacuum pump ❑ Vacuum washers *Process:* ❑ Counter-current multi-stage washing to be incorporated *Technology:* ❑ Indigenously available but expensive *Manpower:* ❑ Skilled manpower required			attractive when taken up in conjunction with solar evaporation measure *(see below)*
12. Segregation of initial thick black liquor from potchers and its recirculation to the extent possible	○ Easy handling and treatment of remaining BL ○ Reuse of residual caustic due to BL recycle ○ Hot black liquor will reduce steam reqmt ○ Enables better impregnation of RM with BL	*Equipment:* ❑ Collection sump ❑ Pumps and pipes *Process:* ❑ Separation drains required for thick and weak black liquor	I = Rs 0.5-0.8 lakh S = Rs 1.5-2.5 lakh P = < 1 year	Reduction in sodium load in effluent	The measure is simple and easy to implement
13. Solar evaporation of concentrated black liquor generated by implementation of any of the four preceding measures	○ Use of BL cake as fuel ○ Reduced treatment cost ○ Reduced colour of effluent ○ Improves achievability of discharge standards ○ BL cake can be briquetted with RM dust and both to be used as fuel	*Equipment:* ❑ Briquetting machine ❑ Civil work for solar evaporation ponds with appropriate lining, etc *Process:* ❑ Space reqmt of about 50,000 sq mt for solar ponds	I = Rs 15-40 lakh S = Rs 20-40 lakh P = < 1 year (Investment mainly for land cost)	30-40% reduction in overall pollution load	Availability of land in nearby areas is a must
14. Anaerobic treatment of black liquor	○ Biogas generated can be used as fuel ○ Reduced treatment cost ○ Reduced colour of effluent	*Equipment:* ❑ Digestor (anaerobic) ❑ Gas holder ❑ Burners ❑ Pressure piping *Technology:* ❑ Proven and available but expensive *Manpower:* ❑ Skilled and trained manpower required	I = Rs 125-175 lakh S = Rs 20-45 lakh P= > 5 years	30-40% reduction in overall pollution load	The measure is economically not attrac[tive] for a typical small mill
15. Chemical recovery from black liquor	○ Caustic recovery 60-80% ○ Reduced pollution load	*Equipment:* ❑ Recovery boiler and associated system ❑ Pumps ❑ Multi-stage evaporator ❑ Causticising plant	I = Rs 300-600 lakh S = Rs 15-30 lakh P= > 20 years	Up to 50% reduction in COD load	Technological problem[s] of high silica content, high viscosity (due to high % of fines) and low solids and lignin content in raw BL (thus

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
		❑ Lime sludge recovery or disposal system *Technology:* ❑ Not yet proven *Manpower:* ❑ Skilled manpower required			lesser heat generation in boiler) yet to be overcome. The measure is not economically viable
16. Hot stock refining	○ Reduced electrical energy consmn ○ Reduced fibre degradation ○ Better pulp quality ○ Reduced screening rejects ○ Improved runability on wire	*Equipment:* ❑ Refiner *Process:* ❑ Sequence of washing and refining to be modified	I = Rs 1-2 lakh S = Difficult to quantify	Reduced solid waste	Well-proven technology. Can be easily implemented
17. Use of screening rejects for unbleached paper-making	○ RM saving ○ Cooking chemical saving	None	I = Nil S = Rs 1-2 lakh	Reduced solid waste	The measure is valid only for mills making both bleached and unbleached paper
18. Conversion of lignin in black liquor to lignosulphonate	○ Reduced pollution load and effluent colour ○ Additional by-product which is an import substitute	*Equipment:* ❑ Plant and equipment for manufacture of lignosulphonate *Technology:* ❑ Not proven for agro residue-based black liquor	I = Rs 300-400 lakh S = Rs 15-20 lakh P = 20 years	Up to 50% reduction in COD load	It is a very expensive measure and virtually amounts to setting up another industry. Trial samples of product not accepted by market
19. Recovery of lignin for land application	○ Reduced pollution load and effluent colour ○ Additional by-product ○ Increased crop yield	*Equipment:* ❑ Plant and equipment for lignin recovery ❑ Sulphuric acid and other chemicals *Process:* ❑ Sophisticated layer separation required	I = Rs 8-10 lakh S = Yet to be established due to undev-eloped market	Up to 50% reduction in COD load	Market of lignin as a soil conditioner and fertiliser yet to be developed. Impact of sodium on soil not established
20. Buffering with caustic soda before bleaching	○ Reduced fibre degradation and thus higher pulp yield ○ Reduced bleaching time ○ Better bleaching and hence brighter pulp ○ Better paper machine runability	*Process:* ❑ Precise pH control (at least 8.5) required	Difficult to quantify	Not yet established	Suggested only for mills making high quality paper
21. Vacuum bleacher for pulp bleaching:	○ Reduced water reqmt ○ Enables bleaching at higher consistency	*Equipment:* ❑ Barometric leg or vacuum pump	I = Rs 60-80 lakh S = Rs 10-15 lakh (estimated)	Reduced AOX formation.	The measure is highly cost intensive.

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental impact	Remarks
■ with barometric leg ■ with vacuum pump	○ Enables multi-stage counter-current washing, thus improving washing efficiency and reducing fibre loss ○ Increased bleaching capacity ○ Reduced chemical consmn	❑ Tall civil structure ❑ High density tower ❑ High consistency pump ❑ Vacuum bleachers *Process:* ❑ Clear high vertical space required for installing equipment	P = 5-6 years	Reduced COD load. Enables total recycle of bleach wash water	Applicable only for mills making high quality bleached paper
22. Bleaching with sodium hypochloride	○ Better pulp quality ○ Less sludge generation from bleaching chemical preparation section ○ Smaller chemical preparation area reqmt due to higher content of chlorine in bleach liquor	*Equipment:* ❑ NaOCl storage tank	The measure is not economically viable due to the high cost of NaOCl	Handling and disposal of solid waste is reduced	The measure can be implemented if market price parity between NaOCl and $CaOCl_2$ is brought about
23. Bleaching with hydrogen peroxide (H_2O_2)	○ Better pulp quality ○ Significant environmental benefits due to: No chlorine in shop air No chlorine in effluent No AOX generation ○ No sludge generation in bleaching chemical preparation section ○ Chemical preparation area is smaller ○ Elimination of hazard in chlorine handling	*Equipment:* ❑ H_2O_2 handling and dosing equipment *Process:* ❑ Care and safety reqmt for handling	I = Rs 0.5 lakh	Chlorine-free shop air. No chlorine in effluent. No AOX generation. Elimination of sludge in bleach liquor preparation	The measure yet to be demonstrated in agro residue-based mills
24. Oxygen-assisted bleaching (OCEoP)	○ Better pulp quality ○ Significant environmental benefits due to: Less chlorine in shop air Less chlorine in effluent Less AOX generation ○ No sludge generation in bleaching chemical preparation section ○ Chemical preparation area is smaller ○ Reduction of hazard in chlorine handling	*Equipment:* ❑ Oxygen preparation equipment *Process:* ❑ Safety reqmt in oxygen handling	Not yet quantified	Less chlorine in shop air and in effluent. Less AOX generation	The measure is yet to be demonstrated in agro residue-based mills. Apparently, it is not economically viable
25. Bleaching with ozone	○ Better pulp quality ○ Significant environmental benefits due to: No chlorine in shop air No chlorine in effluent	*Equipment:* ❑ Ozonation plant *Process:* ❑ Safety reqmts	Not yet quantified Ozonation plants are very	Chlorine-free shop air. No chlorine in effluent.	The measure is yet to be demonstrated in agro residue-based mills. Import of ozonation

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
	No AOX generation ○ No sludge generation in bleaching chemical preparation section ○ Chemical preparation area is smaller ○ Elimination of hazard in chlorine handling	for ozone preparation and handling *Technology:* ❑ Not available indigenously ❑ Yet to be proven for agro residue mills	expensive	No AOX generation. Elimination of sludge in bleach liquor	plant required preparation
26. Provision of hot water for maintaining bath ratio in digestor, recovered from DG set waste heat	○ Reduction in cooking time 30-45 minutes ○ Reduction in steam reqmt 0.2-0.5 tons per ton paper	*Equipment:* ❑ Piping and pumps ❑ Waste heat recovery unit *Technology:* ○ Indigenously available	I = Rs 8-10 lakh S = Rs 10-12 lakh P = < 1 year	No direct impact	Option is valid for units having captive DG set and operating it for at least 40% of time
27. Insulation of digestor	○ Reduced steam reqmt	*Equipment:* ❑ Insulation material P = < 1 year	I = Rs 1-1.5 lakh S = Rs 2-3 lakh	Nil	Care needs to be taken to avoid sagging and deterioration due to the spillage of BL

STOCK PREPARATION SECTION

The major operation in the stock preparation section is the blending of pulp to make it suitable for making paper. Additives such as sizing chemicals, fillers, dyes, etc, are blended with the pulp. As such, there is no significant waste generation from this section. Waste Minimisation opportunities, as discussed in Table 3.3, predominantly relate to chemical substitution and process optimisation which would have an impact on waste in the paper making section.

The stock preparation section.

TABLE 3.3

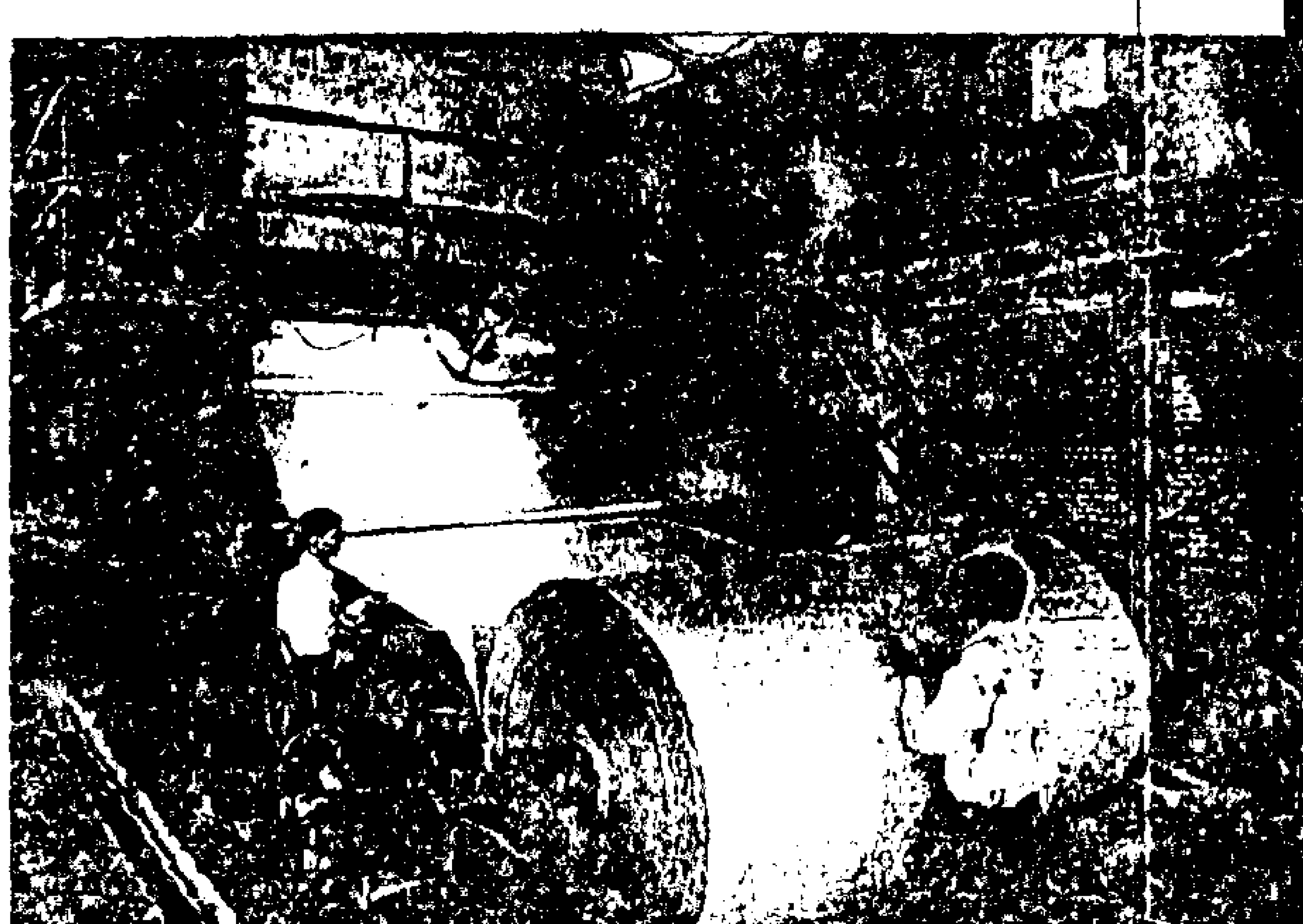
Waste Minimisation Measures In The Stock Preparation Section

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
1. Using Poly-Aluminium Silicate-Sulphate (PASS) as sizing chemical, instead of alum	○ Improved drainability ○ Increased filler retention ○ Enables manufacture of high grammage paper	Nil	I = Not quantified S = Not quantified	Reduced TS in effluent	The option not yet tried in agro-based mills. The effectiveness of size is increased when PASS is used with cationic starch

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
2. Adoption of alkaline neutral sizing to enable making high ash content paper	○ Lower pulp consmn per ton of paper ○ Lower production cost and higher profitability ○ Reduced pollution load due to lower pulp reqmts	*Technology:* ❑ Yet to be demonstrated in agro-based mills *Process:* ❑ The process is applicable only when pulp temperature in blending chest is <38°C	I = Negligible S = Yet to be quantified	No direct impact	Applicable only for mills making writing and printing paper
3. Consistency indicator	○ Consistency regulation becomes easy ○ Variation in grammage avoided ○ Reduction in paper breakage ○ Enables uniform paper drying	*Equipment:* ❑ Consistency indicator	I = Rs 1-2 lakh S = Rs 1.2-2.5 lakh P = <1 year	Marginal reduction in TS load	Reduces dependence on human judgement
4. Consistency regulator	○ Automatic consistency regulation ○ Variation in grammage avoided ○ Reduction in paper breakage ○ Enables uniform paper drying	*Equipment:* ❑ Consistency regulator *Technology:* ❑ Indigenously not available ❑ Experience of some large mills not satisfactory	I = Rs 15-20 lakh S = Rs 2-4 lakh P = > 7 years	Marginal reduction in TS load	More suitable for continuous pulp-making. The measure is very expensive and not economically viable
5. Substituting existing dyes with less toxic or non-toxic dyes	○ Reduced toxicity of effluent ○ Reduced toxic content in product ○ Environment-friendly operation	❑ Toxicity of existing dyes and development of non-toxic dyes yet to be studied. Chemical names of existing dyes are trade secrets	Not yet quantified since cost of substitute dyes not known	Marginal impact on effluent toxicity	The measure requires further basic studies on toxicity of existing dyes and development of less toxic dyes
6. Use of dye fixing agents	○ Reduced dye consmn ○ Reduced toxicity in effluent	❑ Some of the indigenously available dye fixing agents are: SARSOLAN TAMOL MNOX	I = Nil S = Cost of dye fixing agents and possible savings yet to be quantified	Reduces toxicity in effluent	The measure is easily implementable. Attractive only for units having substantial dye reqmts

PAPER-MAKING SECTION

The paper-making section is the largest consumer of fresh water in the entire mill, accounting for more than 60 per cent of total water consumption. The total amount of water in circulation is still higher, as large quantities are recycled as tray water. Consequently, the waste water generation is also the largest in this section. As a general rule, the pulp enters the section at 4 per cent consistency, which improves up to 20 per cent after mechanical dewatering, resulting in the generation of 20 m^3 of waste water per ton of paper. Loss of fibre along with waste water is a serious loss,



but most fibre loss minimisation measures are economically viable. Enhancing the productivity of the paper machine also simultaneously affects the generation of waste.

The paper machine is highly energy-intensive, in terms of both electrical energy and steam energy, and substantial savings can be obtained by cutting down energy waste. The Waste Minimisation measures are based upon water recycling, fibre recovery, energy conservation and improvements in paper machine productivity. The various WM measures in this section are discussed in Table 3.4.

TABLE 3.4

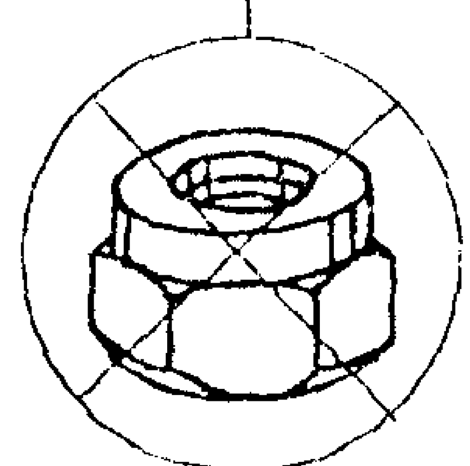
Waste Minimisation Measures In The Paper-making Section

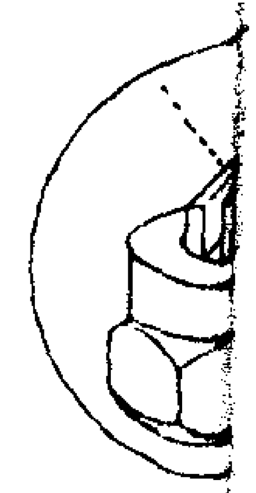
Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental impact	Remarks
1. Fine-tuned dilution control at fan pump	❍ Enables uniform pulp consistency ❍ Enables easy switchover from one grammage to other ❍ Reduces paper breakage	*Equipment:* ❑ Additional pipeline (of smaller diameter) with a valve to fine control the water feed for dilution	I = Rs 0.1-0.2 lakh S = Rs 0.6-1 lakh P = < 1 year	No significant impact	Simple and easy to implement
2. Provision of high consistency pump in couch pit	❍ Reduced fibre loss due to couch pit overflow during paper breakage ❍ Reduced consmn of water in couch pit ❍ Reduced load on couch decker ❍ Reduced fibre loss in couch decker filtrate	*Equipment:* ❑ High consistency pump	I = Rs 1-1.5 lakh S = Rs 1-5 lakh P = < 1 year	Significant reduction in TS and COD	Saving and environmental impact depends on the extent of couch pit overflow
3. Controlled water pressure for edge cutting nozzle	❍ Reduced paper breakage	*Equipment:* ❑ Separate water tank ❑ High pressure pump	I = Rs 0.2-0.3 lakh S = Rs 0.4-0.6 lakh P = < 1 year	Marginal reduction in TS & COD	Measure is easily implementable
4. Double felting to reduce press picking	❍ Reduced paper breakage ❍ Higher fines allowable in pulp ❍ Increased production capacity due to higher machine speeds ❍ Reduced kerosene oil consmn ❍ Reduced alum consmn at paper machine ❍ Reduced steam reqmt in dryer because of better mechanical dewatering ❍ Reduction of VOC in waste water	*Equipment:* ❑ Additional felt rolls	I = Rs 3.5-4 lakh S = Rs 4-6 lakh P = < 1 year	Reduced kerosene contamination in effluent	Will increase drying capacity of paper machine
5. Recycling couch decker filtrate in pulp washing	❍ Fibre recovery ❍ Reduced water consmn ❍ Reduced pollution load	*Equipment:* ❑ Pipelines and pump	I = Rs 0.5-1 lakh S = Rs 1.0-2 lakh P = < 1 year	Reduction in TS and COD load by 2-5%	The measure is easy to implement

Double felting helps reduce paper picking.

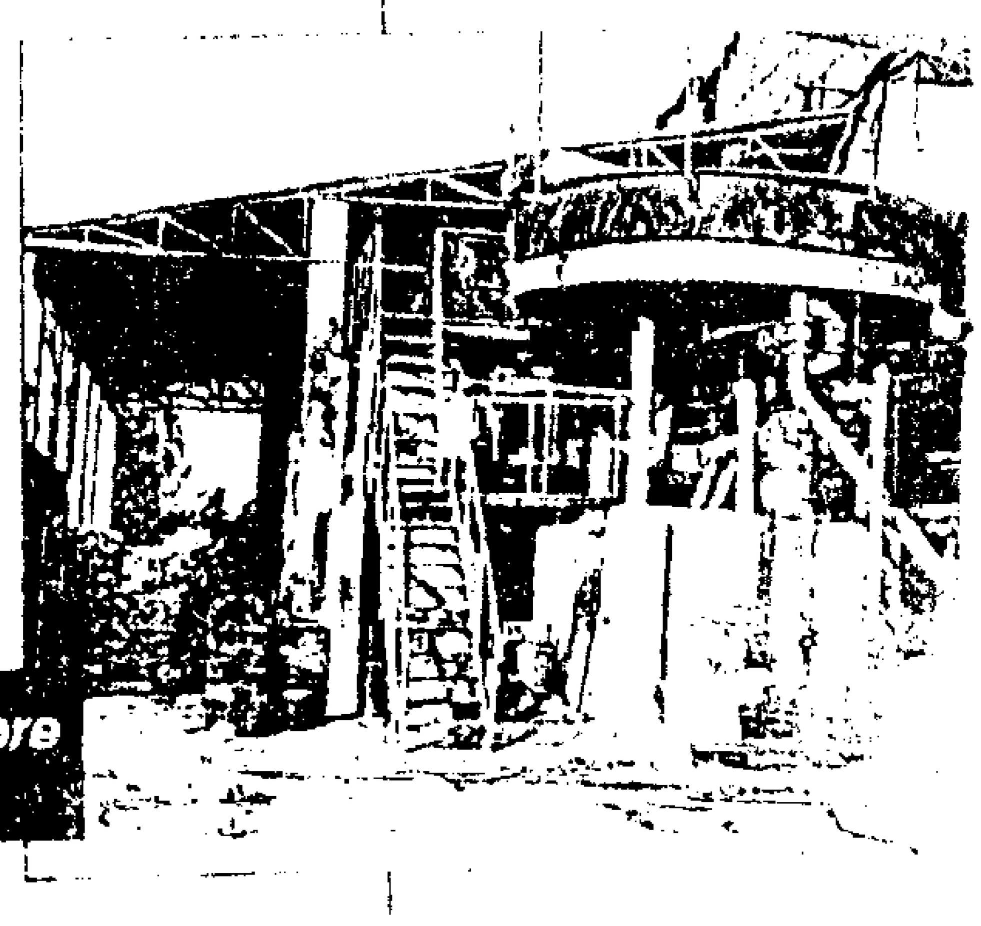
Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
6. Avoiding fan pump pit overflow by: ■ Providing level control in fan pump pit or ■ Recycling it to couch pit	○ Reduced fibre loss ○ Reduced dilution reqmt in couch pit	*Equipment:* ❑ A small pipeline. The flow takes place by gravity *Process:* ❑ The level controller should actuate and control the fresh water supply	I = Negligible S = Difficult to quantify	Reduction in TS and COD load but difficult to quantify	The measure simple and ea implement
7. Recycling wire pit water in showers	○ Reduced fresh water consmn in showers ○ Reduced effluent volume	*Equipment:* ❑ Multiplex filter unit ❑ High pressure pump ❑ Water collection sump	I = Rs 4-6 lakh S = Rs 1-1.5 lakh P = 4 years	Reduction in effluent volume	The measur y aimed at red fresh water. the filter cak used for boa
8. Removal of sand and inerts from centricleaner waste water	○ Prevention of sand and inert loading in ETP ○ Reduced wear and tear of pumps in ETP and hence reduced maintenance ○ Prevention of choking of drains	*Equipment:* ❑ Rifflers	I = Rs 0.1-0.2 lakh S = Nil	Nil	Frequent cle drains is avo
9. Recovery of fibre from centricleaner reject	○ Reduced fibre loss ○ Reduced dependence on operators ○ Reduced pollution load	*Equipment:* ❑ Fibre savers with high pressure pump or ❑ Hill screen with low pressure pump	I = Rs 0.2-0.3 lakh S = Rs 2-4 lakh P = < 1 year	Reduction in TS and COD load by 2%	An HP pum system ca supply HP
10. Provision of better nozzles in cleaning showers	○ Reduced water consmn ○ Better cleaning efficiency resulting in better machine runability	*Equipment:* ❑ Fan flat type or other suitable nozzle in place of existing perforated pipe of simple nozzles ❑ High pressure pump *Technology:* ❑ Nozzles and pump indigenously available	I = Rs 1-1.5 lakh S = Rs 0.5-0.7 lakh P = 2 years	Reduced effluent volume	Measure is implement
11. Adjustment of paper width by edge cutting nozzles	○ Reduced paper trimming loss ○ Reduced reprocessing of paper trimmings ○ Marginal reduction in dryer steam consmn	Nil	I = Nil S = Would depend on market demand for paper of different widths	Nil	The width governed demand. practice paper to Instead, be reduc the pulp


Sand and inerts being removed in a riffler.





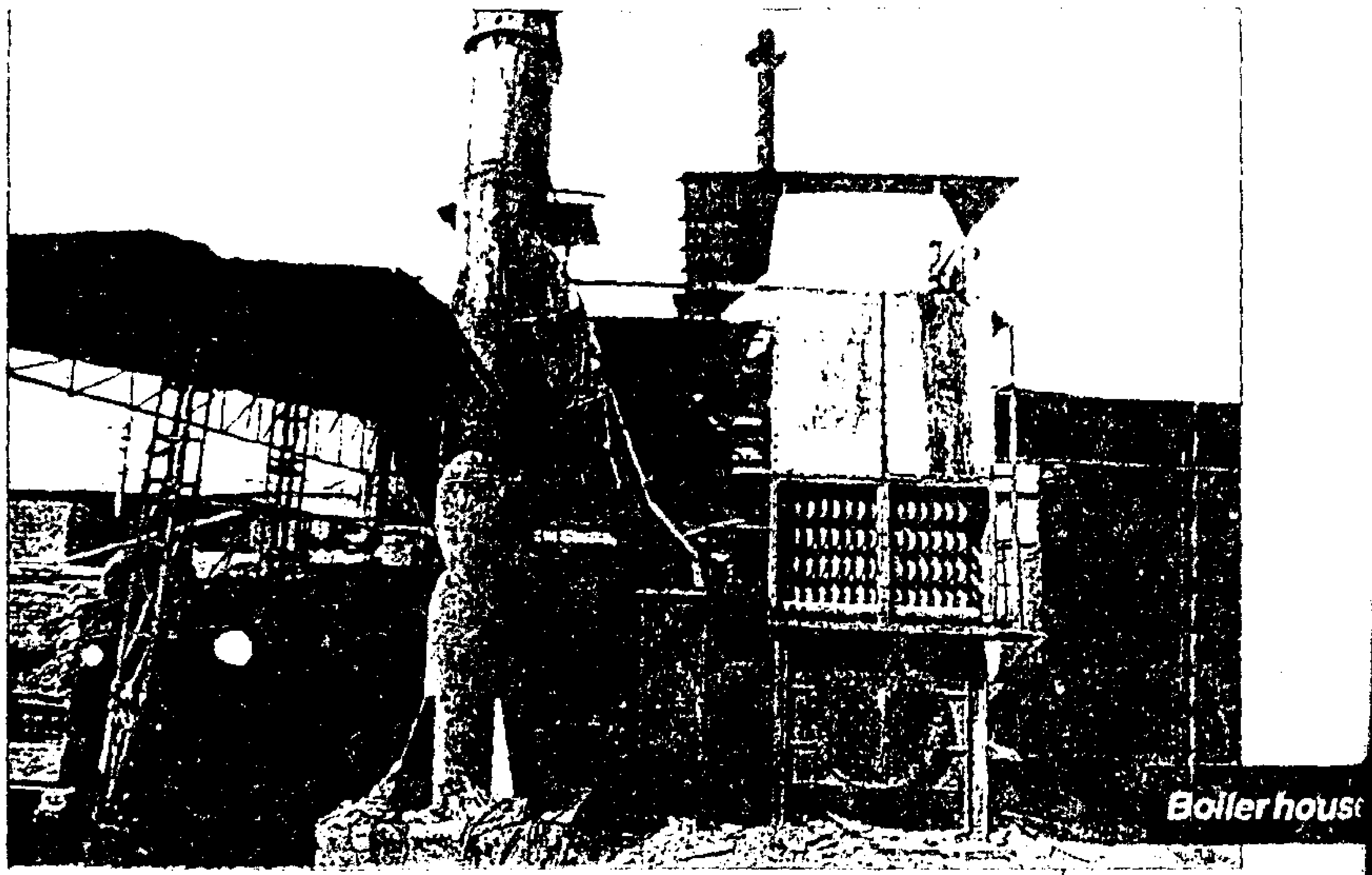
Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental impact	Remarks
12. Installation of broke pulper in paper machine section	○ Reduced reprocessing reqmt ○ Reduced filler and chemical consmn ○ Reduced handling reqmt due to proximity of pulper to trimming generation point ○ Reduced pollution load	*Equipment:* ❑ Broke pulper ❑ Pulp conveying pipes ❑ Pump *Process:* ❑ 10 sq m space is required in the paper machine section	I = Rs 5-10 lakh S = Rs 2-3 lakh P = 3-4 years	Reduced TS and COD load	The savings would be higher in the manufacture of writing paper due to retention of fillers and other chemicals
13. Installation of additional press roll set	○ Increased mechanical dewatering ○ Reduced steam consmn in drying ○ Increased speed of paper machine and hence increased capacity	*Equipment:* ❑ Press roll set *Process:* ❑ Space availability between existing press roll and dryers is a must	I = Rs 8-12 lakh S = Rs 6-8 lakh P = < 2 years	Reduced air pollution due to lower steam reqmt	The measure is usually applicable in cases where adequate space is already available. Shifting the dryer is quite cumbersome and expensive
14. Timely replace-ment of upper press roll to reduce press picking	○ Reduced paper breakage ○ Reduced consmn of kerosene and anti-picking agents ○ Increase in capacity by 3-4% ○ Reduced pollution load	*Equipment:* ○ Chilled SS rolls and MS rolls are reported to give a better performance than conventional rolls	I* = Rs 2 lakh S = Rs 5-8 lakh P = < 1 year **based on average life of roll as six months*	Reduced TS and COD load. Reduced air pollution due to less steam reqmt	This measure requires close monitoring of the press roll to replace it as soon as press picking shows a rising trend
15. Provision of high velocity hood in steam dryer	○ Increase in paper production capacity by 15% ○ Marginal improvement in drying efficiency	*Equipment:* ❑ High velocity hood *Process:* ❑ The measure is recommended for final drying stages *Technology:* ❑ Indigenously available	I = Rs 17-20 lakh S = Rs 18-20 lakh P = < 1 year	Marginal reduction in air pollution	The measure is cost-intensive; however, the payback period is very attractive. Major shutdown required to install the system
16. Saveall for fibre recovery	○ Increased fibre recovery ○ Reduced pollution load ○ Reduced effluent volume ○ Filtrate can substitute fresh water consmn in pulping section	*Technology:* ❑ Two types of saveall systems are available: Dissolved Air Flotation (DAF) Sedimentation *Equipment:* ❑ Saveall system pump *Process:* ❑ Additional energy consmn ❑ Additional polyelectro-lyte consmn *Manpower:* ❑ Skilled manpower required for DAF	For DAF system I = Rs 10-15 lakh S = Rs 5-8 lakh P = > 2 years For sedimentation system I = Rs 3-5 lakh S = Rs 3-5 lakh P = 1 year	Reduction in TS and COD load by 4%	The DAF system is more energy- and chemical intensive but gives higher fibre recovery. It also requires meticulous care to run the system



DAF system for fibre recovery.

UTILITIES

In the utilities section, the steam boiler is the major source of waste generation. It generates solid, liquid and gaseous wastes. Quite often, the role of the boiler department is limited to supplying steam at the desired pressure and in desired quantities. The efficiency of steam generation is rarely taken seriously, resulting in increased waste generation and higher energy losses. The Waste Minimisation measures discussed in Table 3.5 pertain mainly to boiler efficiency improvement.



Boiler house

TABLE 3.5

Waste Minimisation Measures In The Utilities Section

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environmental impact	Remarks
1. Use of soft water water as boiler feed water	❍ Reduced scaling of boiler tubes and thus lower tube failures ❍ Increased boiler efficiency and capacity ❍ Reduced blow-down heat loss ❍ Reduced boiler maintenance ❍ Reduced blow-down reqmt	*Equipment:* ❑ Water softening plant *Technology:* ❑ Indigenously available *Manpower:* ❑ Skilled manpower is required	I = Rs 1-2 lakh S = Rs 2-3 lakh P = < 1 year	Reduced air pollution by 3-5%	The additional cost of regeneration chemicals and manpower reqmt is very low as compared to savings. The use of soft water has a beneficial effect on boiler life
2. Insulation of feed water tank [illegible] condensate [illegible]very tank	❍ Increased steam generating capacity ❍ Reduced fuel reqmt	*Equipment:* ❑ Insulation material	I = Rs 0.3-0.5 lakh S = Rs 1-2 lakh P = < 1 year	Reduced air pollution	The measure is easily implementable
3. Proper insulation of steam pipelines	❍ Reduced steam pressure and temperature drop ❍ Reduced heat loss from steam pipelines ❍ Better cooking due to availability of higher steam pressure	*Equipment:* ❑ Insulation material	I = Rs 0.5-1 lakh S = Rs 0.3-0.5 lakh P = 1-2 years	Marginal reduction in air pollution	The measure is easily implementable
[illegible]gular maintenance of DG set	❍ Reduction in specific fuel consmn by 5-10%	*Process:* ❑ Preventive maintenance	I = Rs 1-2 lakh S = Rs 2-3 lakh P = < 1 year	Reduced air pollution from DG set	Preventive maintenance plan has to be prepared and adhered to

Waste Minimisation measure	Anticipated benefits	Technical requirements	Economic viability	Environ-mental Impact	Remarks
5. Installation of maximum demand controller	○ Enables avoidance of penalties levied due to exceeding the contracted power demand	*Equipment:* ❑ MD controller *Technology:* ❑ Indigenously available	I = Rs 1.5-3 lakh S = Difficult to quantify	No direct impact	The option is applicable to units with lower contract demand limits. The savings would depend on the number of times the MD exceeds contract demand
6. Provision of fuel (rice husk) feed control mechanism in boiler	○ Enables boiler operation at maximum capacity and efficiency by ensuring uniform fuel firing	*Equipment:* ❑ Feed controller *Technology:* ❑ Available indigenously	I = Rs 1-2 lakh S = Difficult to quantify	Reduced air pollution. Reduced ash generation	Simple and easy to implement
7. Supply of make-up water in condensate tank	○ Reduces steam locking of condensate feed pump ○ Reduces flash steam loss from condensate tank	*Equipment:* ❑ Pipings	I = Rs 0.05-0.1 lakh S = Rs 1-1.5 lakh P = < 1 year	Marginal impact	Simple and easy to implement
8. Combustion optimisation in boilers	○ Reduced fuel reqmt due to reduced stack and unburnt loss in ash	*Manpower:* ❑ Requires training of boiler operators to optimise combustion	I = Nil	Reduced air pollution	The measure requires improvement in operational practices
9. Use of fluidised bed boiler	○ Improvement in boiler efficiency by 10-15% over that of fixed grate boilers ○ Better steam pressure control	*Equipment:* ❑ Fluidised bed boiler *Technology:* ❑ Indigenously available *Manpower:* ❑ Skilled operator required	I = Rs 50-60 lakh S = Rs 15-20 lakh P = 3-4 years	Reduced air pollution. Reduced ash generation	The measure is more attractive for new mills and mills going in for expansion and requiring additional steam generation capacity
10. Insulation of condensate return line	○ Reduced heat loss ○ Higher feed water temperature and hence faster load response	*Equipment:* ❑ Insulation material	I = Rs 0.2-0.3 lakh S = Rs 0.2-0.3 lakh P = 1 year	No significant impact	The measure is simple and easy to implement
11. Avoidance of condensate and steam leakages	○ Reduced heat loss ○ Reduced make-up water reqmt	Nil	I = Negligible S = Difficult to quantify	No significant impact	The measure requires timely repair and maintenance
12. Rationalisation of steam and condensate lines	○ Reduced temperature and pressure drop	*Equipment:* ❑ Pipelines	Difficult to quantify. Would vary from case to case	No significant impact	Special care needs to be taken to avoid unnecessary bends and submergence of condensate line in water

HOUSEKEEPING MEASURES

The general housekeeping in most of the small agro residue-based pulp and paper mills is far from satisfactory. Good housekeeping is, in fact, the first step in any Waste Minimisation programme. The expenditure is small and the savings are immediate, with very attractive pay-back period — usually less than a year. A well kept mill has tremendous psychological impact on the employees and helps in building the right attitude for Waste Minimisation. Other side benefits such as better working conditions, reduced risks and hazards, etc, further motivate the employees. Housekeeping-related Waste Minimisation measures are mostly unit specific and can be easily identified through a careful inspection of the production sections. A range of such measures found in some mills, albeit to varying degrees, is given below. The technical requirements are usually minimal and have therefore not been discussed in detail. The economics (expenditure and savings) is mill-dependent and it is difficult to give a general range. The measures given below should be taken as guidelines, and specific measures should then be evolved from case to case.

SUGGESTED HOUSEKEEPING MEASURES

- Installation of appropriate chutes, to collect screening rejects. The collected rejects should be handled and disposed with minimum spillage.
- Repair of raw material conveyor, to prevent spillage of raw material and contamination of cooked pulp.
- Modification of the digestor loading chute, to prevent the spillage of raw material.
- Covering of all vibratory screens and chemical dosing tanks by proper lids to prevent spills.
- Provision of dykes in rag pulp dumping area, to contain and channelise the flow of black liquor into the drain.
- Installation of spring-actuated self-closing valves in all water hose pipes, to minimise water wastage.
- Avoidance of spillage of lime sludge in the Hypo section, by proper containment, handling and disposal.
- Proper collection and storage system for dedusting rejects, to contain their spillage.
- Provision of an appropriate discharge system for unloading cooked pulp in potchers (in cases where the pulp is directly discharged in potcher), to avoid spillage of pulp and black liquor.
- Control of leakages and spillages in the handling and preparation of chemicals and additives.
- Avoidance of pump gland leakages through proper pump maintenance.
- Timely repair/sealing of water and steam leakages from pipes, valves, flanges.

Notes

Let's Do It

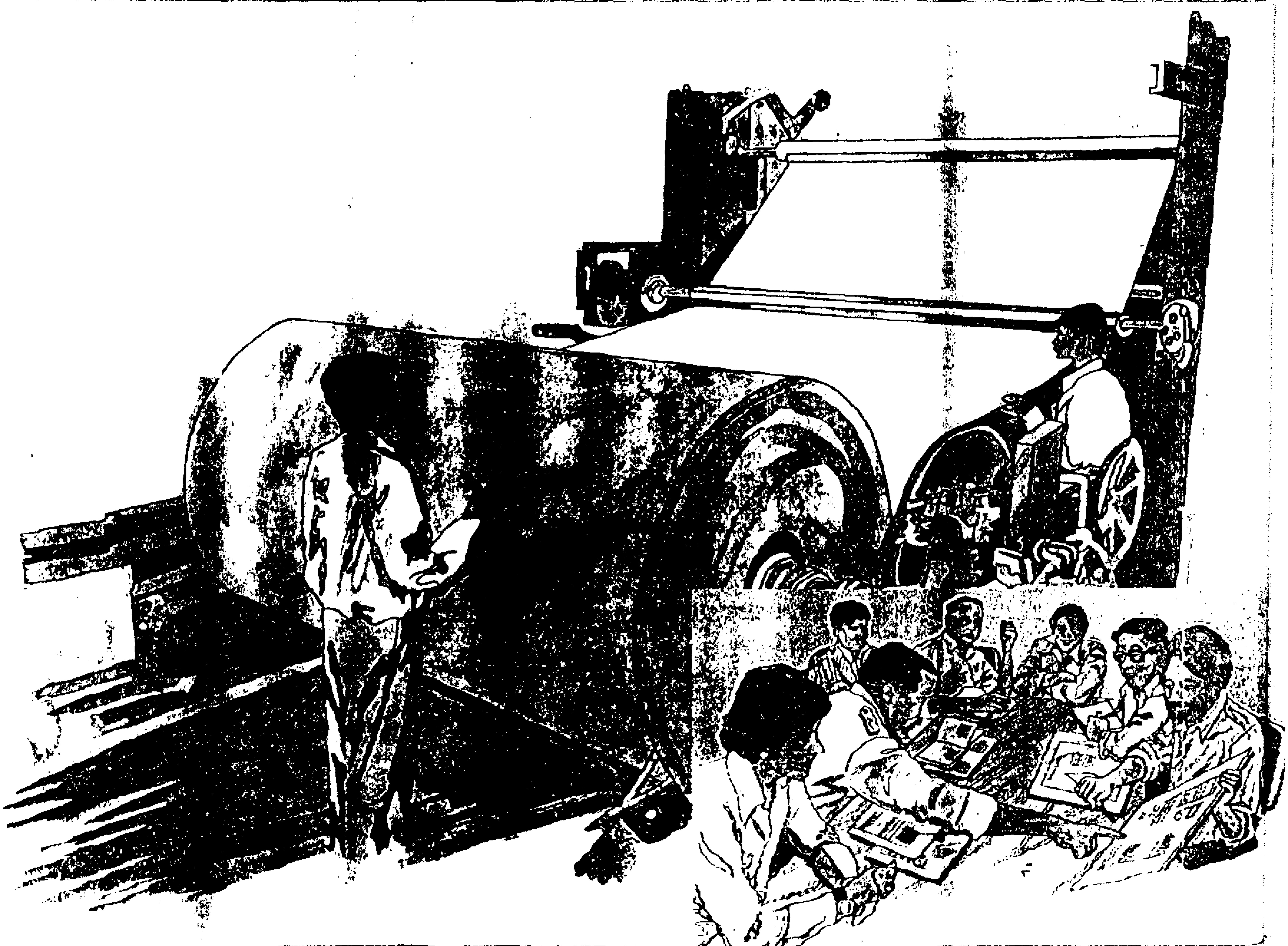
A Six-step Approach To Waste Minimisation

Waste Minimisation (WM) in a pulp and paper mill needs to involve all the production sections as mentioned in Chapter I, since the potential of reducing waste exists in all these sections. In addition, the WM measures of one section will have repercussions and linkages with other sections as well. It is essential that a methodical step-by-step approach is adopted to bring the various groups together and ensure the implementation of Waste Minimisation. The approach should be flexible enough to adapt itself to unexpected circumstances. Such an approach also ensures the exploitation of the maximum WM opportunities. A typical approach which has been tried and tested in several units is discussed in this chapter.

STEP I: GETTING STARTED

FORM A WASTE MINIMISATION TEAM

A WM team is essential for coordinating the programme, to get the various measures implemented and to bear overall responsibility. The team should comprise personnel from sections such as the pulp mill, stock preparation, paper machine, maintenance, electrical and utilities departments, as well as persons from shop-floor level to the top management. Depending on the need, external experts can also be included. For a typical agro residue-based mill, the team should have four to six persons. It should first collect general information regarding the unit, and record it in Worksheet 1.



WORKSHEET 1
General Information

Name of the Company:
Waste Minimisation Team

	Name	Designation
1.		
2.		
3....		

A. Major Raw Materials Consumption

i) ***Fibrous Material***

a) Wheat straw	7131 T/yr
b) Elephant grass (Sarkanda)	7131 T/yr
c) Bagasse	1578 T/yr
d) Others	
Rags	1914 T/yr
Waste paper	778 T/yr

ii) ***Chemical***

a) Caustic soda	1210 T/yr
b) Hypo	651 T/yr
c) Others	28 T/yr
High gum	186 T/yr

B. Energy Consumption

a) Electrical energy	8712 MWh/yr
b) Fuel for boilers (Rice husk)	12994 T/yr
c) Others	..... T/yr

C. Water Consumption 1960200 m³
5940 m³/day

D. Production

Installed Capacity		
Pulp-making	Hydro — 10TPD Chem — 25TPD	35 TPD
Paper-making		30 TPD
Actual Production		
Pulp		30 TPD
Paper		--
Bleached		Nil
Unbleached		30 TPD

E. Type Of Effluent Treatment

✓ Primary
✓ Secondary
No treatment

F. Any Other Relevant Information

Waste Minimisation activities would require several documents and information. If these are not available, they will have to be generated and updated. The checklist given in Worksheet 2 would help in assessing the level of information availability.

WORKSHEET 2
Available Information

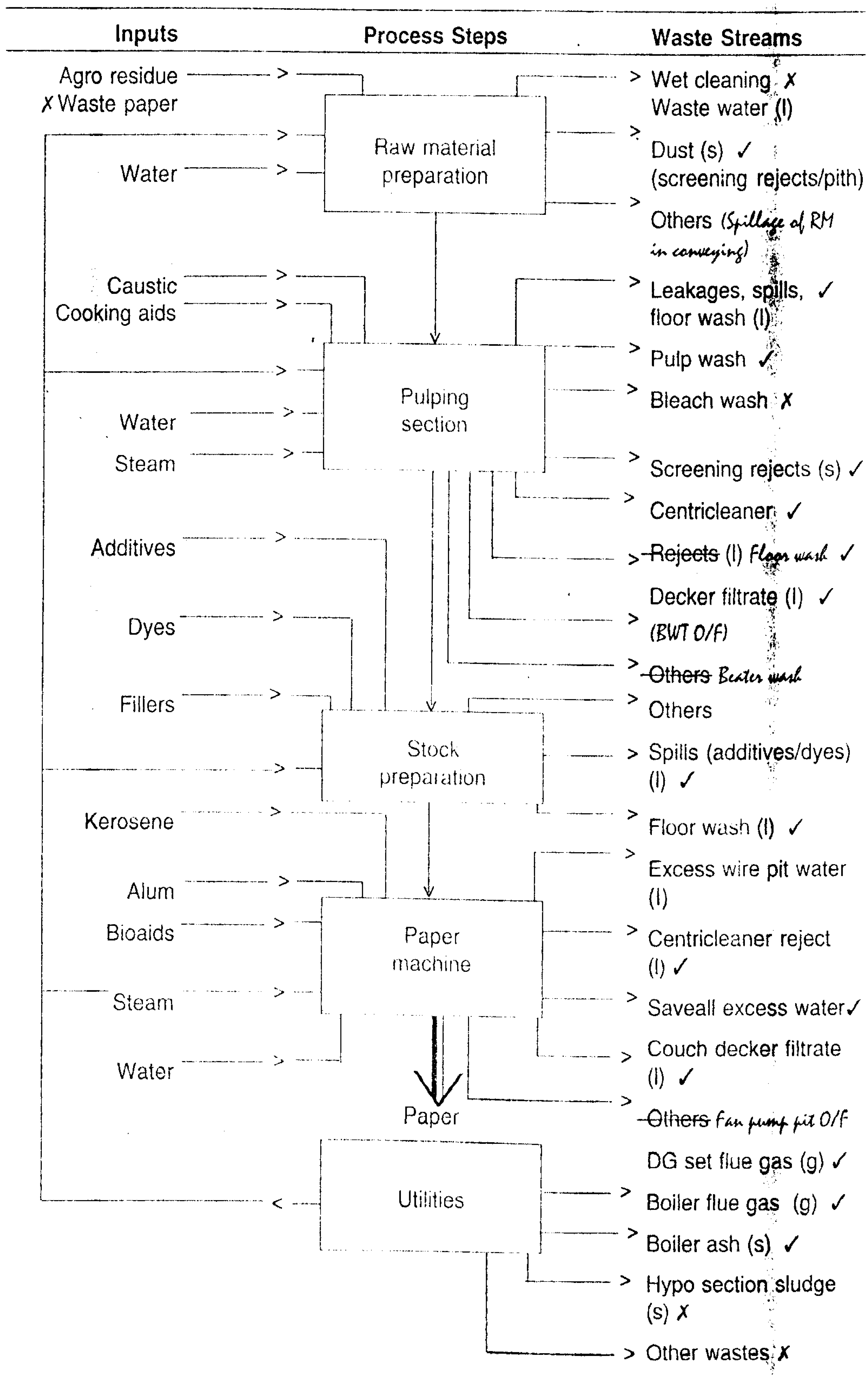
Information	Availability	Remarks
Process flow diagram	No	–
Material balance	No	–
Energy balance	No	–
Water balance	No	–
Plant layout	Yes	Helpful for studies
Waste analysis	No	–
Emission records	No	–
Production log sheets	Yes	Was helpful for audit
Maintenance log sheets	No	–
Any other information	No other information was available	

LIST PROCESS STEPS AND IDENTIFY WASTEFUL STREAMS

During the first shop-floor study, the team should identify input and output streams. Major and obvious waste generating areas should be marked as shown in Worksheet 3. Labelling the waste streams with respect to their physical state (solid, liquid or gaseous) would be of help subsequently at the waste quantification stage. If possible, the reasons for the generation of wastes should also be identified and recorded.

WORKSHEET 3

Process Flow Diagram Indicating Waste Streams



In a pulp and paper mill, poor housekeeping alone contributes to a significant amount of waste generation. This often neglected area can be the simplest and most attractive starting step to effect Waste Minimisation. While conducting the first shop-floor study, the Waste Minimisation team should pay special attention to areas with poor housekeeping.

Worksheet 4 could be used to record the housekeeping status in each section. Some commonly encountered housekeeping lapses are indicated in it. Many more should be elaborated under 'others'.

WORKSHEET 4
Housekeeping Status

Sections	Lapses In Housekeeping
Raw material preparation	RM spillage from conveyor/screens ✓ Dust spillage from ~~screens~~ cutter ✓ Others
Pulp mill section	RM/pulp spillage during digestor loading/unloading ✓ ❑ Leakage/spillage of caustic/hypo, etc ✗ ❑ Spillage of screen rejects and its interference with product stream ✓ ❑ Loss of fibre due to defective wire mesh of potcher drums/bleacher drums/pulp deckers, etc ✓ Others Leakage from pump glands (Black liquor)
Stock preparation	Spillage of additives, specially gums and dyes, due to improper handling ✓ Overflow of pulp from chest due to high level ✓ Splashing of pulp from chest due to low level ✓ Others Poor lay out
Paper machine	Open water hoses ✓ Overflow from fan pump pit/wire pit ✓ Overflow of tray water ✓ Others Vaccum pump seal water spillage

It would now be possible and desirable to record some basic cost data. At this stage, it would suffice to obtain the cost of direct input materials (purchase cost) which would be easily available from purchase and store records. A sample Worksheet 5A for the pulp mill section is shown below.

WORKSHEET 5A
Input Materials Cost: Pulp Mill Section

Chemicals	Cost/ton	Annual consumption	Consumption/ ton of paper	Cost ton of paper
Pulping chemicals	Rs 11000	1210 ton	0.137 ton	Rs 1507.5
Bleaching chemicals	–	–	–	–
Steam	Rs 250	22275 ton	2.25 ton	Rs 562.5
Electricity	Rs 2500/MW	3960 MW	0.4 MW	Rs 1000
Water	Rs 0.4/kL	1223442 kl	123.6 kL/T	Rs 49.5

Total = Rs 3119/tons of paper

Similar worksheets can easily be worked out for other sections, by replacing the first column in Worksheet 5A with the appropriate input materials in each section. A list of commonly used input materials in other sections is given below; this could be appropriately amended if need be.

- *Raw material preparation:* Wheat straw, rice straw, bagasse, rag, jute, waste paper (Indian), waste paper (imported), steam, electricity.

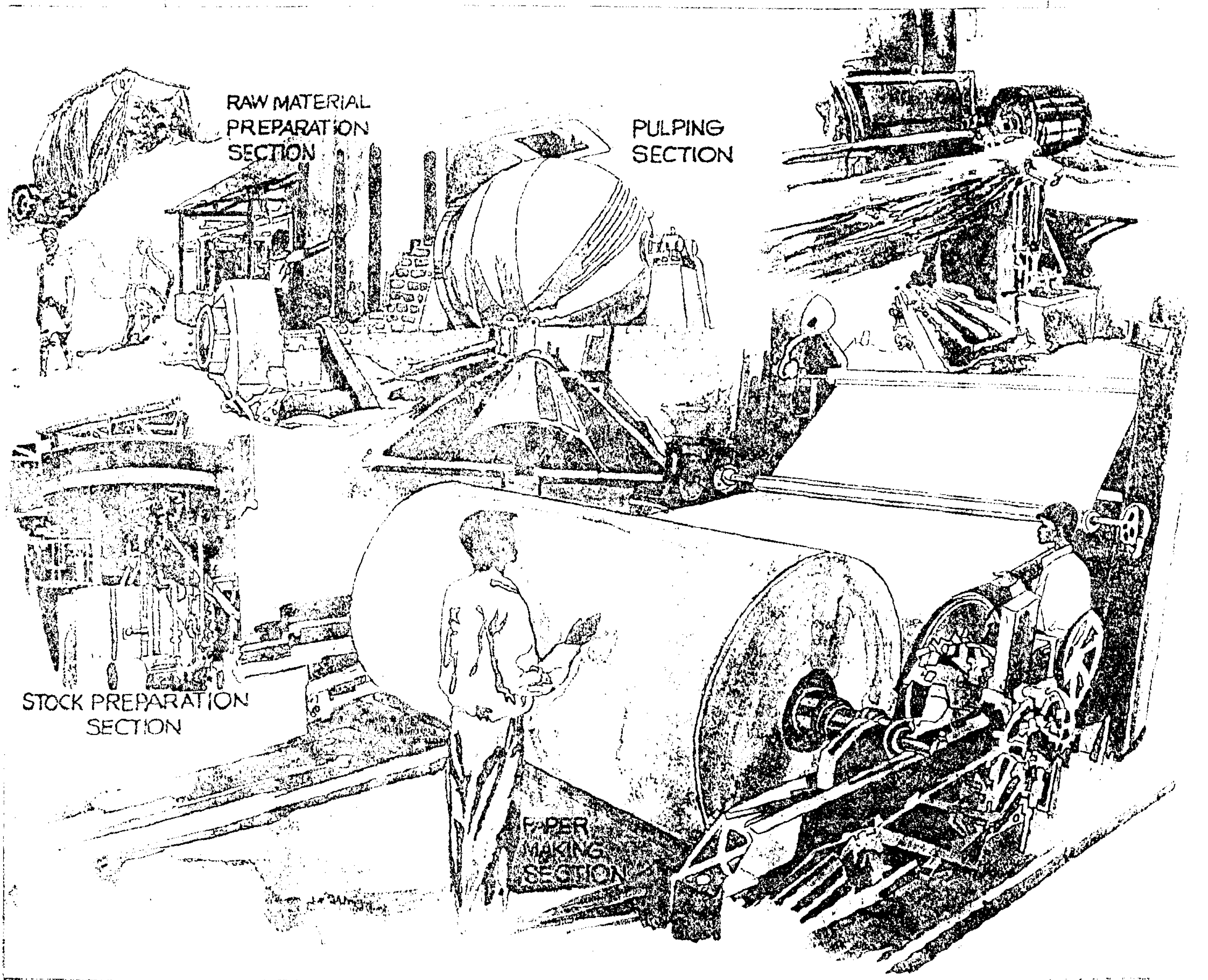
- *Stock preparation:* Alum, rosin, high gum, talc/soapstone, dye, steam, electricity.

- *Paper machine:* Kerosene, electricity, steam, water.

PREPARING PROCESS FLOW CHARTS

STEP II: ANALYSING PROCESS STEPS

The preparation of a detailed and correct process flow diagram is the first key step in the entire analysis and forms the basis for compilation of the material and energy balance. Flow charts are diagrammatic/schematic representations of production, created with the purpose of labelling process steps and the sources of waste streams and emission. A flow chart should list and, if possible characterise the input and output streams. Special care needs to be taken to recycle streams. Free or cheap inputs for water, air, sand, etc, should be particularly highlighted, as these often end up being the major cause of waste. Materials which are used occasionally and/or which do



not appear in output streams (dyes, kerosene, anthraquinone, etc) should be highlighted.

It is not necessary to cover the entire plant under this step. You may select just one section to begin with, one which has the maximum WM potential. Such focussed attention simplifies the task and avoids confusion.

MAKING MATERIAL AND ENERGY BALANCES

The second important step is to draw a material/energy balance of the selected unit or section. Material and energy balances are important for any WM programme, as they make it possible to identify and quantify previously unknown losses or emissions. These balances are also useful for monitoring the advances made in a prevention programme and evaluating its costs and benefits. The typical components of a material balance, as well as of an energy balance for the pulp making section, are discussed here.

While it is not possible to lay down comprehensive guidelines for establishing material balances, certain pointers might be useful.

- It is better to first draw up the overall material balance across each major section: raw material preparation, pulp-making, stock preparation and paper-making.

- When splitting up the total system, simple subsystems should be chosen. Suggested subsystems for these four major sections are:

› *Raw material preparation*
  - Cleaning (depithing, in case of bagasse)
  - Dewatering (in case of wet cleaning)

› *Pulp-making section*
  - Cooking (hydro pulping in the case of waste paper)
  - Blow tank
  - Washing
  - Refining
  - Screening
  - Centricleaning
  - Bleaching

› *Stock preparation section*
  - Blending

› *Paper-making section*
  - Centricleaning
  - Paper machine
  - Dewatering
  - Drying

Sample material and energy balances across the digestor (cooking) in the pulp-making section are given in Worksheets 6A and 6B, respectively.

★ *Important:* While preparing a material balance in a pulp and paper mill, the following points should be specially noted:

☆ It is essential to measure the Total Solid (TS) content of waste streams.

☆ The recycle streams often cross from one major section to another for example, water from paper machine is recycled to pulp bleaching and washing.

☆ To make the material balance, particularly the fibre and water balance, a consistency balance is often recommended. However, precise and continuous consistency measurement has been found to be difficult in the absence of costly instrumentation. It may be easier to construct the material balance by direct measurement of various water inlet streams, stage-wise product streams and waste water streams (with TS content).

The following measurement guidelines would be useful to avoid pitfalls while preparing the material balance:

- The measurements should be carried out on a per-day basis.

- The values could then be expressed of per ton of paper produced — that is, if 96 tons of wheat straw is measured as the daily consumption, and paper produced is measured as 40 tons, the consumption of wheat straw would be expressed as 96/40 = 2.4 tons/ton of paper. Wherever required, these could be extrapolated to a per-year basis, keeping a note of variations in raw material, paper quality etc, to determine annual figures for a feasibility analysis.

- All measurements of fibrous raw material should be converted to an oven-dry basis. This would simplify calculations due to variations in moisture content.

WORKSHEET 6A
Material Balance

Raw Materials:

Item	Quantity
1. Pulp	25 TPD
2. Dissolved Solids	31.9 TPD
3.	....

Auxiliary Materials:

Item	Quantity
1. Catalysts	....
2. Lubricant	....
3.	

Water Consumption:

Item	Quantity (TPD)
1. Showers	140
2. Washing	1900
3. Dilution	....
4. Cleaning	....
5.	

Process

Products:

Item	Quantity
1. Pulp	25 TPD
2.	....
3.	....

Solid Waste:

Item	Quantity
1.	....
2.	....

Waste Water:

Item	Qty	Contaminant
1. Process	2072	....
2. Condensate	....	....
3. Cooling	....	....
4. Overflow	....	....
5. Cleaning	....	....

AIR EMISSIONS:

Item	Qty	Contaminant
1.		
2.		

WORKSHEET 6B
Energy Balance (Digester)

Steam

Quality	Quantity
1.	112.5
2.	
3.	

Electricity

Quantity

Fuel Consumption

Item	Quantity
1. Coal	
2. Oil	
3. Agro residues	
4.	

Process

Products

Item	Heat Content	Qty
1.		
2.		
3.		

Energy Losses

Item	Heat Content	Qty
1.		
2.		

Waste Water

Item	Heat Content	Qty
1. Process		
2. Condensate		
3. Cooling		

MAKING A COMPONENT BALANCE

In the pulp and paper industry, it may be quite useful to evolve the component balance from the overall and section-wise material and energy balance. The most useful component balances are:

- Total solid balance
- Water balance

These balances give a direct indication of the efficiency of utilisation of fibrous raw material, chemicals and water. They give the relative importance of different waste streams in terms of quantum of loss, and would therefore, enable priorisation of various streams for developing Waste Minimisation measures. Typical samples of a total solid balance and water balance are given in Worksheets 7A and 7B, respectively.

WORKSHEET 7A

Solid Balance in the Pulp-making Section

Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid in TPD
Digestor	Agro NaOH Other	50.0 7.0	– –	– –	–
Blowtank	Cooked pulp	57.0 –	57.0 –	– –	– –
Washer	Cooked pulp	57.0	25.0	27.0	5.0
Screening	Washed pulp	25.0	24.8	–	0.2
Centri-cleaning	Screened pulp	24.8	24.7	0.1	–
Thickener	Cleaned pulp	24.7	24.35	0.35	–
Bleacher	Bleached pulp Hypo	–	–	–	–

WORKSHEET 7B

Water Balance in the Pulp-making Section

Total pulp production per day

Name Of Operation	% Consistency		Change in Pulp Water Content[1]	Water Used (m^3/d)		Water Used In the Operation	
	In	Out		Recycled Water	Fresh Water	Gross[2]	Net[3]
Digestor	93	18	117.4		114	114	114
Blow tank	18	6	274.2	274.2		274.2	0
Transfer pump	6	4	208.4		208.4	208.4	208.4
Potcher wash	4	4.5	-69.4		1970.6	2040*	1970.6
Transfer pump	4.5	4	69.4		69.4	69.4	69.4
Screen	4	1	1875	1275	600	1875	600
Centricleaner	1	0.8	625		625		625
Thickener	0.8	3.5	-2411		120	2031**	200

Total = 3707.4 m^3/d

* Discharged as waste water

** Partially recycled waste water = 2531 - (1275 + 274.2) = 981.8

Total fresh water required in pulping section = 3707 m^3/d

Total waste water = 3021.8 m^3/d

Water with pulp = 686.4 m^3/d.

1. Change in pulp water content = $\left(\frac{100}{\text{consistency in}} - \frac{100}{\text{consistency out}}\right) \times (TPD)$

2. Gross water used = algebraic sum of change in pulp water content, recycled water and fresh water

3. Net water used = algebraic sum of change in pulp water content and fresh water

1,2,3 to be provided in m^3/day

ASSIGN COST TO WASTE STREAM

In order to establish the profit enhancement potential of waste streams, a basic requirement would be to assign costs to them. This cost essentially reflects the monetary loss due to waste. Apparently, a waste stream does not appear to have any quantifiable cost attachable except where direct raw material/ product loss is associated with it, for example, fibre content in the waste water of a pulp and paper plant, unused dye loss in waste liquor, caustic loss in pulp wash water, etc. However, a deeper analysis would show several direct and indirect cost components associated with the waste stream. A list of possible cost components is given below.

- Cost of raw materials in waste
- Cost of product in waste
- Cost of steam and electricity consumed in processing the waste
- Cost of treatment of waste to comply with regulatory requirements
- Cost of waste disposal
- Cost of waste transportation
- Cost of maintaining required work environment
- Cost due to waste cess and its pumping requirements

The above (and others, if present) should be worked out for each waste stream/emission and finally as the total cost per unit of waste (Rs/kl or Rs/kg). Worksheet 8 would help in listing and assigning various cost components to the waste streams.

WORKSHEET 8
Waste and Emissions Cost (Total Cost)

Cost component	Quantity (kg/day) (1)	Unit cost (Rs/kg) (2)	Total cost (Rs/day) (1) x (2)
Fibrous material*	3200	6000**	19200
Chemicals (Waste)	350	11	3850
Steam	5000	0.25	1250
Other resource (Water consumption)	5940	0.41/m^3	2376.0
COD contribution	28500	100/ton	28500
Total Cost Assigned To Waste Stream			53926

**Fibrous material can be determined by analysing the TVSS in the waste stream.*

**Average cost of Fibre

REVIEW OF PROCESS TO IDENTIFY CAUSES

The process could then be reviewed in the context of most cost-intensive wastes. Through the material and energy balances developed, a 'cause analysis' should be carried out to locate and pinpoint the causes of Waste generation. These causes would subsequently become the tools for evolving Waste Minimisation measures. There could be a wide variety of causes for waste generation ranging from simple lapses on housekeeping to complex technological reasons as indicated below:

Technical Causes

- **Poor Housekeeping**
  - Leaking taps/valves/flanges
  - Continuous running of hose pipes
  - Overflowing tanks
  - Spillage of fibrous raw material from worn-out transfer belts
  - Contamination of pulp due to spillage of fibrous raw material
  - Spillage of caustic soda, hypo and other chemicals.

- **Operational and maintenance negligence**
  - Sub-optimal cooking conditions — improper temperature control
  - Low bath ratio
  - Suboptimal loading of digestors
  - Wearing out/absence of insulation of digestors, steam pipes, condensate
  - Pipes, etc
  - Improper maintenance of steam traps
  - Worn out wire mesh in the potcher drum and decker thickener, resulting in leakage/loss of fibre
  - Unnecessary running of refiners, resulting in overrefining
  - Improper maintenance of beater blades
  - Low and uncontrolled pressure of water in edge cutting nozzles and wire part cleaning showers
  - Continuance of worn-out press rolls with uneven surface, resulting in increased press picking and consequent production loss
  - Improper maintenance of condensate removal system from steam dryers.

- **Poor Raw Material Quality**
  - Use of dirty and degraded wheat straw/rice straw/elephant grass
  - Use of bagasse without depithing
  - Use of rice straw and elephant grass without leaf removal
  - Use of low grade lime for hypo preparation
  - Use of waste paper without deinking
  - Improper storage of fibrous raw material.

- **Poor layout**
  - Unplanned/ad hoc expansion
  - Improper collection and handling of

screening rejects

- Location of washed/bleached pulp section in close vicinity of digestor unloading area resulting in contamination of the former with unwashed pulp
- Improper routing of steam pipes resulting in unnecessary pressure drop.

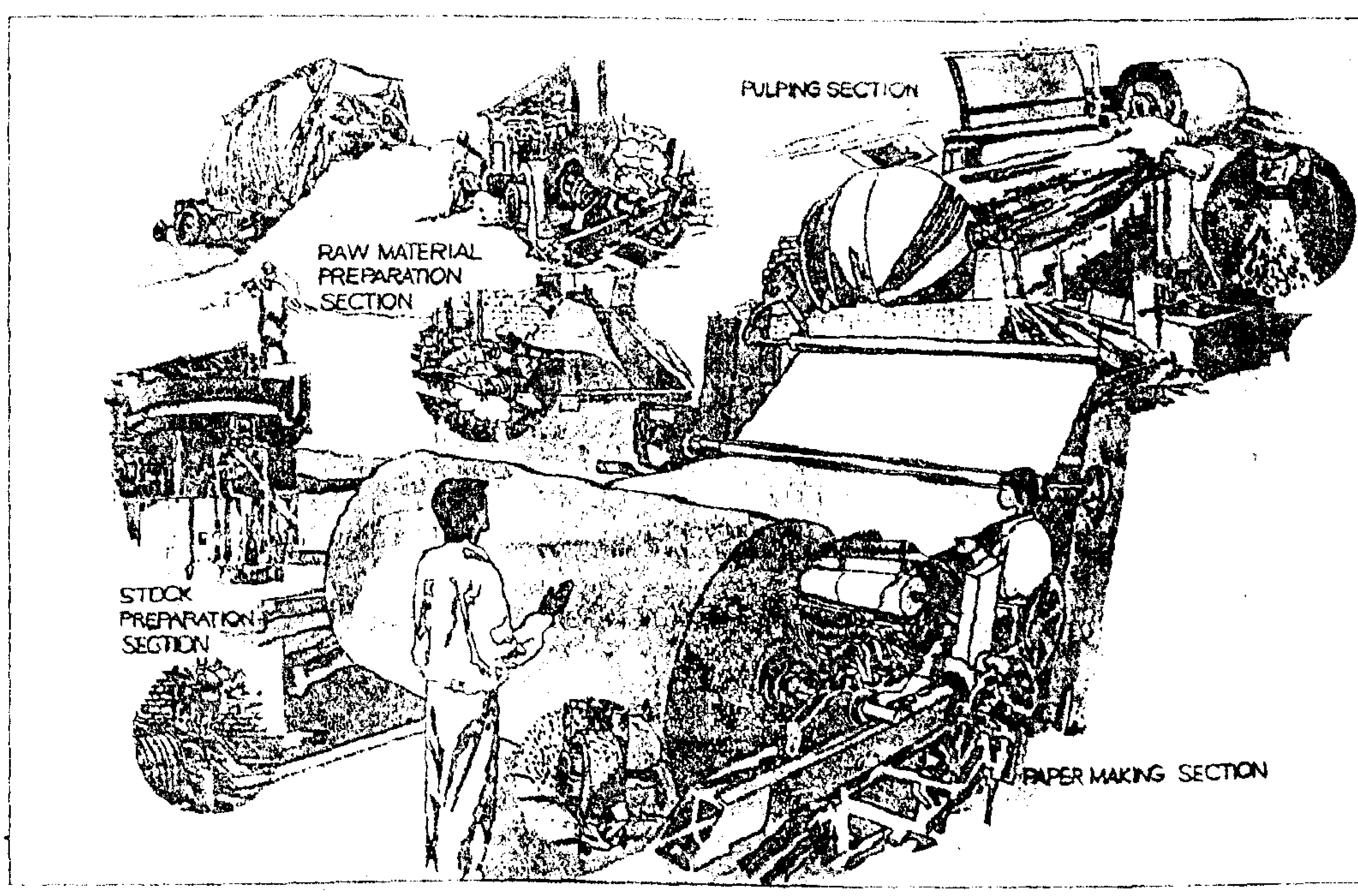
- **Bad technology**
  - Use of rotary screens instead of vibratory screens for cleaning of straw-based raw material
  - Use of dry depithers instead of wet depithers
  - Loading of dry raw material and cooking chemicals directly into digestors, instead of pre-impregnated raw material,
  - Use of open digestors instead of pressurised digestors
  - Use of potchers for washing instead of vacuum washers, resulting in higher water consumption and consequently weak black liquor
  - Use of chlorine bleaching instead of ozone/oxygen/peroxide bleaching
  - Use of cold refining instead of hot alkaline refining
  - Use of natural water vapour removal from steam dryers instead of high velocity hoods
  - Use of improper nozzles or even perforated pipes for wire and felt cleaning instead of better nozzles such as a fan flat type.

- **Poor process/equipment design**
  - Lack of provision of dust collection in the dedusting system
  - Unloading of cooked rag pulp from digestor on the floor, resulting in the contamination of cooked pulp with uncooked pulp and spillage of black liquor
  - Inadequate size of blow tank resulting in spillage of pulp
  - Use of oversized electrical motors, for example, in beaters, refiners and paper machine
  - Lack of capacitors for power factor improvement
  - Absence of broke pulper
  - Use of low pressure fibre saver in centricleaner
  - Absence of consistency regulator indicator
  - Inadequate capacity of couch pit and couch pit pump
  - Use of single felt instead of double felt in paper machine for short fibre pulp.

Managerial Causes

- **Inadequately trained personnel**
  - Increased dependence on casual contract labour
  - Lack of a formalised training system
  - Lack of training facilities
  - High turnover of senior technical personnel
  - Understaffing at the technical personnel level, hence work overpressure

- **Employee demotivation**
  - Lack of appreciation
  - Absence of reward/punishment system
  - Emphasis only on production, not on people
  - Lack of commitment and attention by top management



STEP III: ENERATING WASTE MINIMISATION)PPORTUNITIES

DEVELOPING WASTE MINIMISATION OPPORTUNITIES

Having identified and assigned causes to waste generation, Waste Minimisation measures can be determined. Summarising waste streams as shown in Worksheet 9 would help in making a quick qualitative estimate of the possibilities of Waste Minimisation.

In this step, techniques such as brainstorming and group discussions are used to determine all the possible options. Finding the potential options depends on the knowledge and creativity of team members. The range of Waste Minimisation measures discussed in Chapter III could also be of help in developing specific opportunities for your unit. Some other sources of help in developing Waste Minimisation opportunities could be:

- Other personnel from similar plants elsewhere
- The Central Pulp and Paper Research Institute
- Associations of agro residue-based pulp and paper mills
- The National Productivity Council
- The United Nations Industrial Development Organisation
- The United Nations Environment Programme Working Group on Pulp and Paper

SELECTING WORKABLE WASTE MINIMISATION OPPORTUNITIES

The options developed above are subsequently examined to assess their techno-economic feasiblity. The weeding-out process should be simple, fast and straightforward and is often only qualitative. There should not be any ambiguity or bias. The objective should be to avoid the unnecessary effort of undertaking detailed feasibility analyses of opportunities which are impractical or non-feasible (for example, conventional chemical recovery, or the use of hydrogen peroxide bleaching alone).

Worksheet 10 would help in identifying and listing which Waste Minimisation opportunities (a) can be implemented straightaway, without any feasibility analysis (obvious measures); (b) require further detailed feasibility analysis; and (c) can be rejected. Note that you only have to tick the appropriate category, and that no detailed analysis is required at this stage.

WORKSHEET 9
Summary of Waste Streams and Possibilities of Waste Minimisation

Section	Waste stream	Possibility of						
		Source reduction					Recycling	
		House-keeping	Input Material Change	Better Process Control	Equip-ment Modifcn	Tech Change	Onsite Reuse/ Recycle	Creation of By-product
Pulpmill	Pulp wash	Yes	No	Yes	Yes	Yes	Yes	Yes
Pulpmill	CC reject	No	No	Yes	Yes	Yes	Yes	No
Paper m/c	Couch decker	Yes	No	Yes	Yes	Yes	Yes	No

WORKSHEET 10
Selecting Workable WM Opportunities

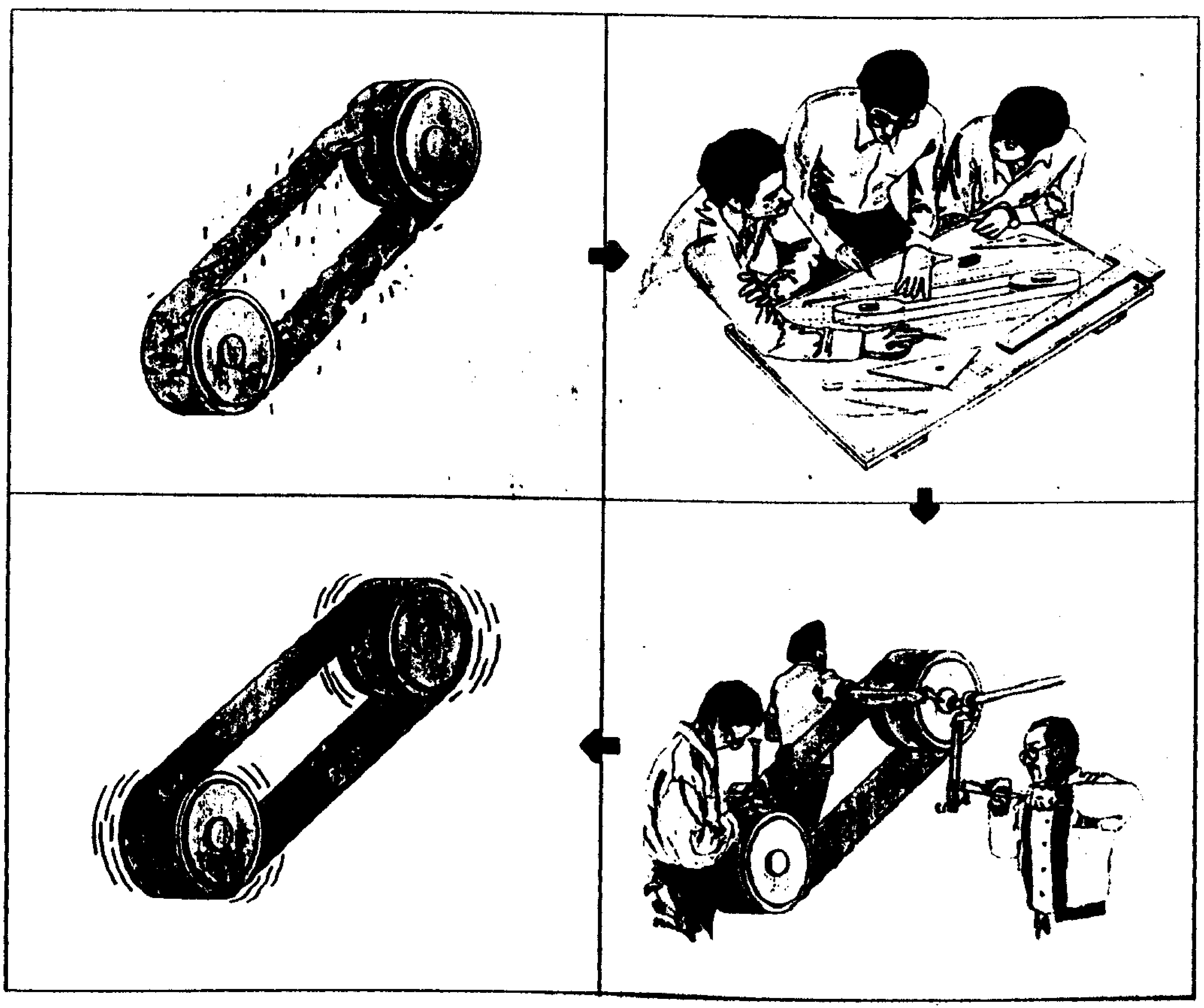
WM Opportunity	Category		
	Directly Implementable	Requires Further Analysis	Reject
Raw material section (Dedusting)	No	Yes	–
Pulping section (W S Bailing)	No	No	Yes
Stock preparation	Yes	No	No
Paper-making section			

STEP IV: SELECTING WASTE MINIMISATION SLUTIONS

The selection of a Waste Minimisation solution for implementation requires that it should not only be techno-economically viable but also environmentally desirable. The shortlisted opportunities selected above, which require further detailed analysis, should be studied from the following angles:

ASSESS TECHNICAL FEASIBILITY

The technical evaluation determines whether a proposed Waste Minimisation option will work for a specific application. The evaluation often begins with an examination of the impact of the proposed measure on process, product, production rate, safety, etc. In case there is significant deviation from the present process practices (for example, ozone bleaching in place of hypo bleaching in pulp-making), laboratory testing and trial runs might be required to assess the technical feasibility. A typical checklist for technical evaluation is provided in Worksheet 11.



WORKSHEET 11
Technical Feasibility Analysis

A. Technical Requirement

Component	Requirement (Yes/No)	Indigenous Availability
1. Hardware		
o Equipment	Yes	Yes
o Instrumentation	No	No
o Technology	Yes	Yes
2. Space	Yes (available in unit)	
3. Manpower	Yes (one operating shift)	Yes
4. Shutdown	Yes	

B. Technical Impact

Area	Impact	
	Positive	Negative
Production capacity	Yes (? %)	Nil
Product quality	Yes	Nil
Energy conservation		
Steam	Yes (0.1 T/ton of paper)	Nil
Electrical	No	Nil
Chemical consumption	Yes (? kg/ton of paper)	Nil
Safety		
Maintenance	Yes	Yes
Operational flexibility	No impact	-
Others	-	-

The measures which are technically not feasible (due to non-availability of technology, equipment, space or any other reason) should be listed separately for further studies by technical personnel. Technically feasible measures should next be subjected to an economic viability analysis.

ASSESS ECONOMIC VIABILITY

Economic viability often becomes the key parameter for the management to accept or reject the proposed Waste Minimisation measure. For a smooth take-off, it is essential that the first few Waste Minimisation measures to be reported to the management are economically attractive. Such a strategy helps in creating more interest and commitment. The economic analysis can be conducted using a variety of methods, for example, the payback period method, internal rate of return method, net present value method, etc. For low-investment, short-duration measures with attractive economic viablity, the simplest — the payback period method — is usually good enough.

A typical worksheet which would help in working out techno-economic viability is given below. It may have to be modified to suit the different options, but care should be taken to keep it as simple and transparent as possible.

WORKSHEET 12
Economic Viability Analysis

Name/description of the Waste Minimisation measure

Investment	**Rs**
Hardware	
o Pumps Deduster	2,00,00
o Piping Blower Conveyor	50,000
o Civil	–
o Circulation tank	–
o Holding tank	–
Equipment (specify) Cyclone	35,000
Land requirement	1,00,000
(Already available)	
Others	
Total	4,20,000

Annual Operating Cost	**Rs/yr**
Interest (15-18%) 15%	63,000
Depreciation 10%	42,000
Maintenance (2-4%) 2%	8,400
Manpower	
o Skilled One	36,000
o Unskilled Three	72,000
Energy	
o Steam	
o Electricity 40K whr	6,33,600
Chemicals	Nil
Cost due to shutdown	Nil
Others	–
Total	8,55,000

Savings	**Rs/yr**
Energy	
Steam (3 ton/day)	2,47,500
Electrical	Nil
Chemicals	
Caustic (200 kg/day)	7,80,000
Bleaching chemicals	Nil
Additives	Nil
Fibre	Nil
Raw material	Nil
Manpower	Nil
Due to increased production*	
Reduced environmental costs	
Treatment cost	5,00,000
Waste transport cost	–
Waste disposal cost	–
Others	–
Total	15,27,500

Net Savings
= (Savings – Operating cost)
= 6,72,500 Rs/yr

Payback
= (Investment/Net savings) x 12
= 4,20,000/6,72,500 X 12
= 8 months

* Increased production costs cannot be quantified as the increase is only in Preparatory Section

Even measures which are not economically viable should not be dropped out. It could be possible that some of these options might have a significant impact on the environment and may, therefore, warrant implementation even if they are economically unattractive.

EVALUATE ENVIRONMENTAL ASPECTS

The options for Waste Minimisation must be assessed with respect to their impact on the environment. In many cases, the environmental advantage is obvious: there is a net reduction in the toxicity and/or quantity of waste. Other effects could be changes in treatability of the waste, changes in applicability of environmental regulations, etc. In the initial stages, environmental aspects may not appear to be as compelling as the economic aspects. However, it should be realised that in days to come, and as is already happening in the developed countries, the environmental aspects will become the most important consideration, irrespective of the economic viability.

SELECT SOLUTIONS FOR IMPLEMENTATION

Following the technical, economical and environmental assessment, Waste Minimisation measures can be selected for implementation. Understandably, the most attractive ones would be those with the greatest financial benefits, provided technical feasibility is favourable. However, in a growing number of cases, specially when active pressure groups are present, the environmental factor takes the top priority.

In cases where a large number of WM measures have been developed, it could be confusing to decide and allocate priority to them with respect to implementation. Worksheet 14 would help in rating and prioritising the measures for implementation. It would also be useful in determining the resources required (finances, manpower, time, etc) and in evolving an implementation plan. A certain amount of subjectivity has been intentionally introduced to enable the team to grade the measures, even if they fall in the same category during the feasibility analysis.

WORKSHEET 13
Environmental Aspects Analysis

Name/description of the Waste Minimisation measure

Medium	Parameter	Impact on Environment	
		Qualitative	Quantitative
AIR	Particulates*	High	2.52 ton/day
	Gaseous		
	Others		
WATER	BOD	High	22kg/ton of paper
	COD	High	50kg/ton
	TS	High	70kg/ton
	Others water consumption	Medium	$20m^3$/ton
LAND	Solid waste		70kg/ton
	Organic	(extra solid waste	
	Inorganic	generation)	

* Fugitive emissions

WORKSHEET 14
Selecting WM Measures for Implementation

WM Measure	Category	Technical Feasibility (25)			Economic Feasibility (50)			Environmental Feasibility (25)			Total Points	Rank
		Low	Medium	High	Low	Medium	High	Low	Medium	High		
	Points	0-5	6-14	15-25	0-10	11-29	30-50	0-5	6-14	15-25		
Raw Material Dedusting		10			38					16	64	

It would be desirable to document the work done so far. Apart from becoming a reference document for seeking approvals and in implementation, the document would also be useful in obtaining finances from external institutions, reporting status to other agencies and establishing base levels for performance evaluation and review.

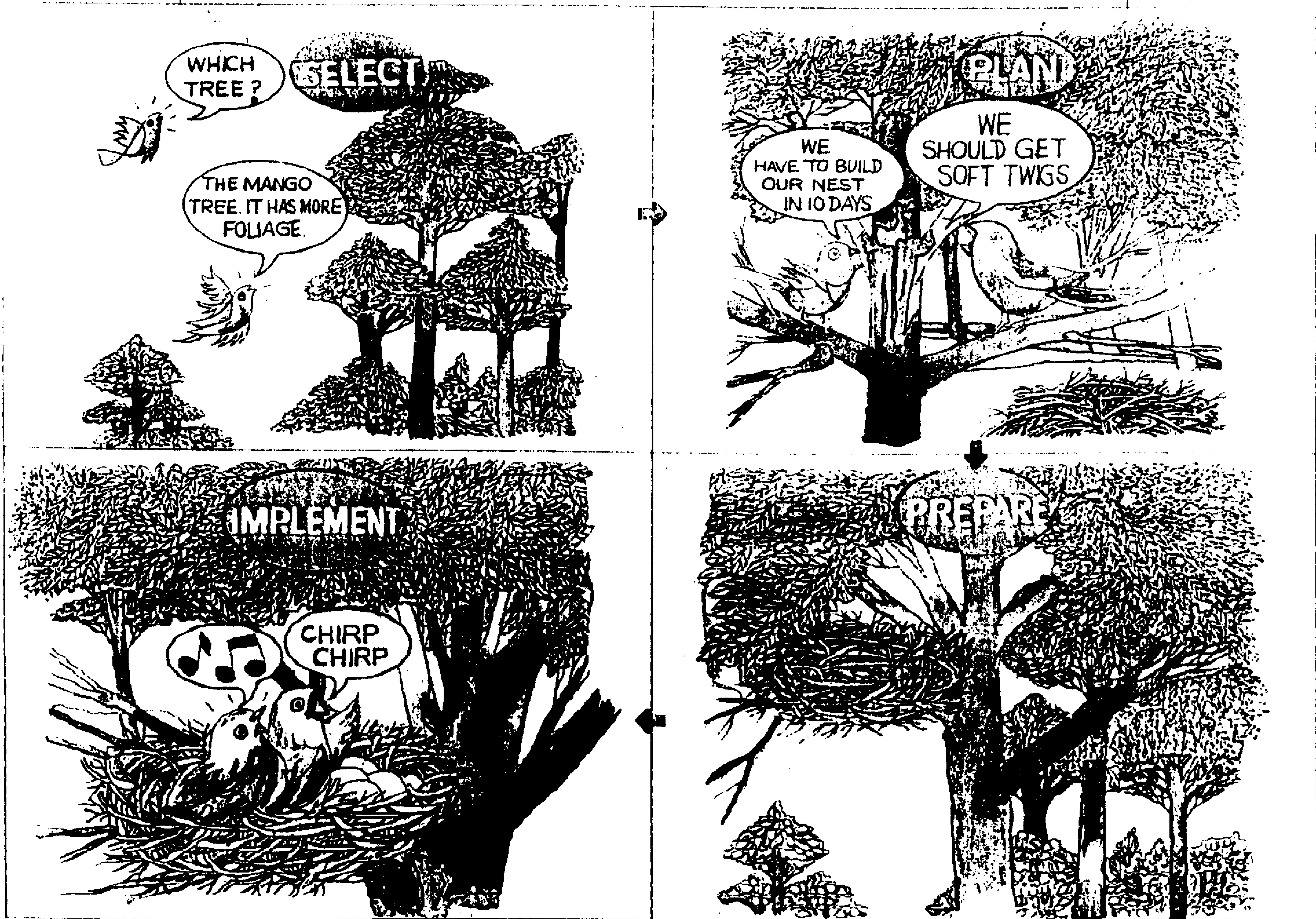
STEP V: IMPLEMENTING WASTE MINIMISATION SOLUTIONS

The selected solutions should next be taken up for implementation. A large number of solutions can be implemented as soon as they are identified (leakages sealed, taps closed, idle running stopped, etc); several others, though, would require a systematic plan of implementation.

PREPARE FOR IMPLEMENTATION

The Waste Minimisation team needs to prepare itself as well as other concerned groups in the industry to take up the job of implementation. The preparation would include seeking financial approvals, obtaining concurrence from concerned departments, establishing linkages in the case of multi-department solutions, etc. The above tasks require, in addition to the technical aspects, a careful handling of the concerned persons to ensure their support and cooperation throughout implementation. Good liaison, awareness and information dissemination assist implementation. Checklists of tasks involved, agencies/ departments to be approached, contacts needed, etc, provide useful help.

Worksheet 15 would help in implementation planning. It pinpoints the person(s) responsible for implementation, progress monitoring of implementation and the target date of completion. It also gives an overview of the expected economic and environmental benefits which could be compared with actual results obtained after implementation.



WORKSHEET 15
Implementation Plan

Selected WM Solution	Implementation Date	Responsible Person(s)	Output				Progress Evaluation	
			Economic		Environmental			
			Expected	Actual	Expected	Actual	Method	Period
Raw Material Dedusting	Short Term 10/9/94	Mr M.M. Chawla	1-42 S-6.72 P < 8 mon	1-3.1 S-5.06 P < 8 mon	High 50 kg COD/T	High 42 kg COD/T	Quarterly evaluation	6 months
	Medium Term							
	Long Term							

IMPLEMENT SOLUTIONS

Implementing Waste Minimisation solutions is analogous to any other industrial modification and does not require elaboration here. The tasks comprise layout and drawing preparation, equipment fabrication/procurement, transportation to site, installation and commissioning. Whenever required, simultaneous training of manpower should be undertaken, for an excellent measure may fail miserably if not backed by adequately trained people. To the extent possible, the implementation team should be aware of the job and its purpose, as several useful suggestions have often emerged from the implementation crew.

MONITOR AND EVALUATE RESULTS

Finally, the solutions implemented need to be monitored for performance evaluation. The results obtained should be matched with those estimated/worked out during technical evaluation and causes for deviation, if present, should be established. Worksheet 15 could also be used for this purpose. Shortcomings should be specifically highlighted and taken care of. A comprehensive report should be prepared to inform the management. The concerned personnel should be made aware of the results. Implementation is considered to be over only after successful commissioning and sustained stable performance over a reasonable length of time.

The biggest challenge in Waste Minimisation in the small scale industry lies in sustaining a Waste Minimisation programme. The euphoria of the WM programme dies out very soon, and the situation returns to where it started. The zeal and tempo of the Waste Minimisation team also tends to wane.

Often, it is the top management which is responsible for such tragic ends. Backing out on commitments, predominance of production at any cost, absence of rewards and appreciation for performers and shifting priorities are some of the commonly encountered reasons which need to be checked and avoided.

STEP VI: MAINTAIN WASTE MINIMISA

The monitoring and review of the implemented measures should be presented so that the desire to minimise waste is encouraged. Efforts should be made to integrate Waste Minimisation with the normal planning process of the company. The involvement of as large a number of employees as possible and rewarding the deserving is a sure key to long-term sustenance.

Having implemented Waste Minimisation solutions in the area under study, the Waste Minimisation team should go back to Step II — Analysing Process Steps — and identify and select the next wasteful steps. The cycle continues till all the steps are exhausted. By then, in the step taken first, additional Waste Minimisation opportunities will have become identifiable, allowing the cycle to continue.

In a nutshell, a philosophy of minimising waste must be developed within the company. This implies that Waste Minimisation should become an integrated part of the company's activities. All successful Waste Minimisation programmes to date have been founded on this philosophy.

Barriers To Waste Minimisation And Enabling Measures

The preceding chapters would have established that Waste Minimisation could indeed be a proactive approach for improving the shopfloor working environment, improving resource utilisation and thereby reducing product cost The dichotomy is that a large number of units have still not taken even the initial steps for Waste Minimisation. In the course of evolving and implementing Waste Minimisation programmes in the agro pulp and paper mills, discussed as Case Studies in subsequent sections, several barriers were encountered which slowed down the progress of the programme. It would be prudent to look into these barriers before hand and take appropriate measures to overcome them. The most important barriers and enabling measures specific to the pulp and paper sector are:

- Lack of commitment and involvement (from management as well as employees, caused by insufficient care for housekeeping, limited recognition for initiatives from workers (including limited job safety, fear of failure, etc).

- Lack of data (caused by poor record keeping, poorly developed management systems, lack of instrumentation and monitoring equipment, poor production planning, etc).

- Technical limitations (including limited access to technical information, limited availability of agro-based pulping knowhow, outdated equipment, limited in-house technical and maintenance skills and facilities, etc).

- Economic limitations (low prices for water

and agro residues, ad hoc investment policy, limited insight in production costs, poor production planning).

ENABLING MEASURES

The following key enabling measures for entrepreneurs could then be elaborated:

- Development of information systems (collection of baseline production data, materials and energy consumption data, economic data, reporting and feedback procedures).

- Enhancing involvement and participation (involvement of workers, emphasis on non-production issues, reward schemes, delegation of decision powers, etc).

The following section schematically represents some of the possible barriers, catalysts and enabling measures. For the sake of clarity and ease of understanding, the schematics have been classified in the following categories:

- Organisational barriers
- Systemic barriers
- Attitudinal barriers
- Economic barriers
- Other barriers.

ORGANISATIONAL BARRIERS, CATALYSTS AND ENABLING MEASURES

Catalysts

- 'Family' supervision
- Direct involvement and supervision from owners
- Sharing of information (within and outside the company)

Barriers

- Non-involvement of workers in WM
- Authority only with the owner
- High employee turnover
- Payment on 'production basis'

Enabling Measures

- Select WM team with leader who has authority to implement WM
- Include concerned supervisors and operators in WM team
- Recognise efforts of WM team
- Assign costs to various inputs

SYSTEMIC BARRIERS, CATALYSTS AND ENABLING MEASURES

Catalysts

- In-house fabrication facility
- Proper documentation and planned layout
- Good housekeeping

Barriers

- Lack of:
  - documentation and records
  - planning
  - analysis of data
  - management systems
  - housekeeping
  - in-house maintenance
- Non availability of information on:
  - toxicity of materials
  - safe substitutes
  - cleaner technologies
  - WM experiences

Enabling Measures

- Conduct training session with WM team to clarify WM objectives, methodologies, importance of planned production, data collection and analysis and problem-solving approach
- Housekeeping drive should start with top-down approach
- Develop generic and specific manuals
- Conduct sectorial and national work-shops to increase awareness

BEHAVIOURAL AND ATTITUDINAL BARRIERS, CATALYSTS AND ENABLING MEASURES

Catalysts

- Employees are willing to accept changes
- Early success of WM implementation

Barriers

- Fear of failure
- 'Not Me First' syndrome
- Indifference
- Fast shifting priorities
- Trading rather than manufacturing approach
- Suspicion of project objectives
- Lack of leadership

Enabling Measures

- Prioritisation of options by WM team
- Experiment with low-cost options
- Publicise early successes
- Encourage experimentation
- Calculate and control manufacturing costs
- Management review of WM progress on simple indicators on a regular basis

ECONOMIC BARRIERS, CATALYSTS AND ENABLING MEASURES

[redacted]

- Financially attractive WM options
- Company financially sound

Barriers

- Internal:
  - Shortage of working capital
  - Low return on WM investment
  - Ad hoc investment criteria
- External:
  - Low environmental costs
  - Changing excise duties (short term policies)
  - Job work
  - Seasonal nature of some industries
  - Lack of grants and subsidies

Enabling Measures

- Internal:
  - Planned investments
  - Assign costs to waste streams
- External:
  - Develop special WM financial schemes
  - Long-term industrial policy
  - Fiscal incentives for low resource-consuming WM practices

OTHER BARRIERS, CATALYSTS AND ENABLING MEASURES

Catalysts

- Management's concern for the environment
- Pressure from environmental authorities

Barriers

- WM options not owned up by the company
- Lack of regulations on environmental management systems, air emissions and solid waste

Enabling Measuress

- All WM options should be generated at the shopfloor
- Form area-wise, voluntary WM groups

Case Study 1

Waste Minimisation At Ashoka Pulp And Paper Mills, Delhi

INTRODUCTION

Ashoka Pulp and Paper Mills is an agro residue-based pulp and paper mill producing unbleached semi-kraft paper. The average production of the mill is 36 tons/day (TPD).

The mill participated in the project **DESIRE** (**DE**monstration in **S**mall **I**ndustries for **Re**ducing wast**E**) with the twin objectives of reducing production cost and bringing about cost effective compliance with environmental regulations. The pressure from the local public to improve environmental performance and the need to conserve water due to water shortages, specially in the summer months, were other reasons behind the companyÕs decision to actively pursue Waste Minimisation (WM). Accordingly, a Waste Minimisation programme was launched with assistance from the National Productivity Council.

The six-step methodology discussed in Chapter 4 was followed to get the best results.

STEP I: GETTING STARTED

FORMING A WASTE MINIMISATION TEAM

A Waste Minimisation team consisting of the following was constituted:

Mr Shiv Kumar	Director (Team Leader)
Mr M.S. Negi	Works Manager (Team member)
Mr Ramkumar	Operator (Team member)
External Experts	(NPC and UNIDO)

The team first collected general information about the company as per Worksheet 1.

WORKSHEET 1
General Information

NAME OF THE COMPANY: ***Ashoka Pump and Paper Mills WM Team***

Name	Designation
1. Mr Shiv Kumar	Director (Team leader)
2. Mr M.S. Negi	Works Manager (Team member)
3. Mr Ramkumar	Operator (Team member)
External Experts (NPC and UNIDO)	

A. MAJOR RAW MATERIAL CONSUMPTION	
Fibrous Raw Material	
a) Wheat Straw	16335 T/yr
b) Waste Paper	5346 T/yr
Chemicals	
a) Caustic Soda	987 T/yr
b) Alum	475 T/yr
c) Rosin	47.5 T/yr
B. ENERGY CONSUMPTION	
a) Electrical energy	10450 MW/yr
b) Bagasse	18150 T/yr
C. WATER CONSUMPTION	1864500 M^3/yr

D. PRODUCTION

INSTALLED CAPACITY

Pulp-making	
Agro pulp	30 T/day
Waste paper pulp	20 T/day
Paper-making	36 T/day

ACTUAL PRODUCTION

Pulp	36 T/day
Paper	36 T/day
	11880 T/year

E. TYPE OF EFFLUENT TREATMENT Primary and secondary

Information available was very limited and only process flow diagrams and plant layouts were available as shown in Worksheet 2. The team had to collect all other information first hand.

WORKSHEET 2
Available Information

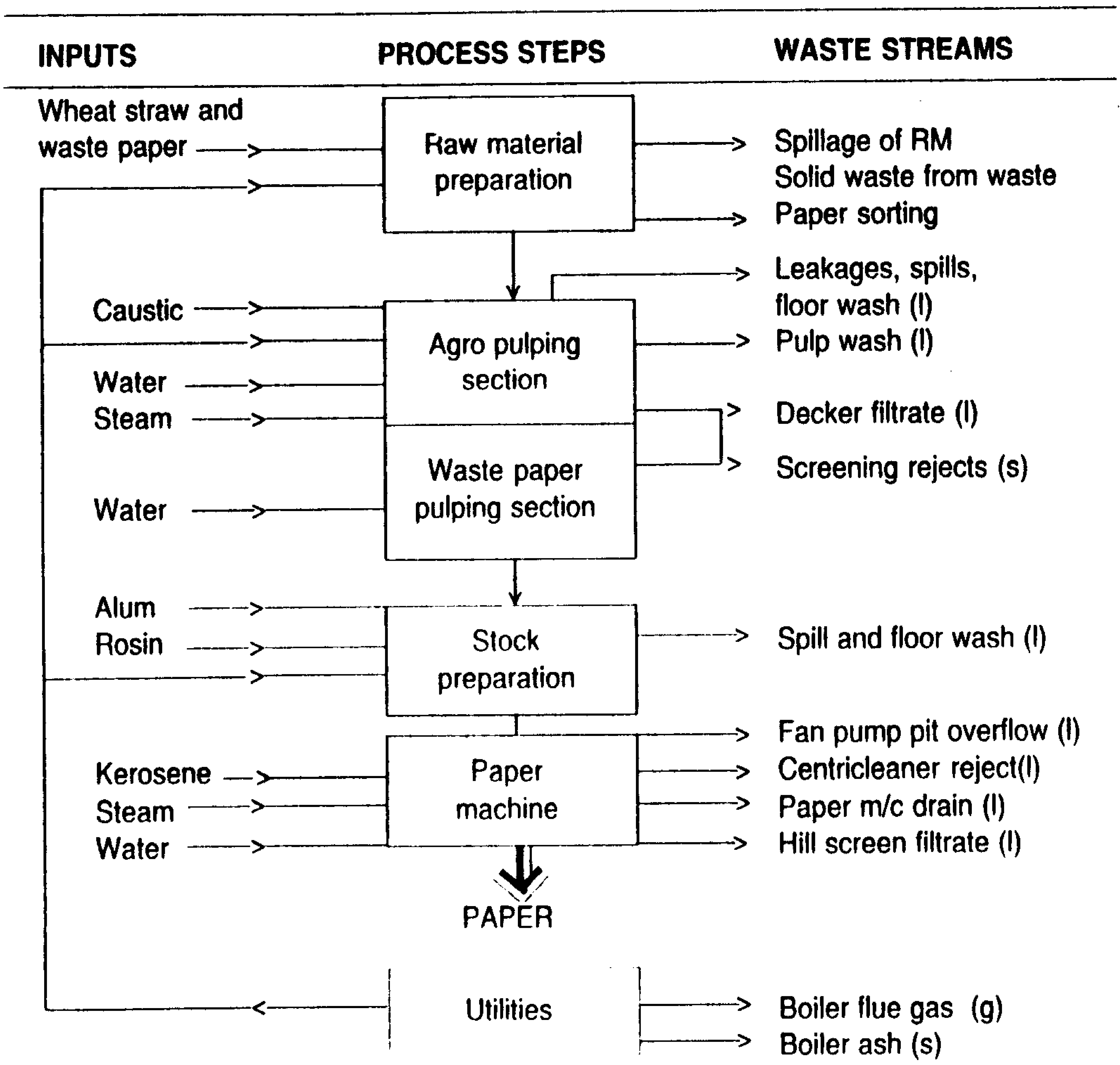
Information	**Availability**	**Remarks**
Process flow diagram	Yes	Unorganised but useful
Plant layout	Yes	Reasonably OK

No other information was available.

PROCESS STEPS AND WASTE STREAMS

A process flow diagram showing the major process steps and waste streams was made as shown in Worksheet 3.

WORKSHEET 3
Process Flow Diagram Indicating Waste Streams



The WM team had a detailed look at the plant and identified housekeeping lapses as described in Worksheet 4.

WORKSHEET 4
Housekeeping Status

Section	Lapses in Housekeeping
Raw material handling	❍ RM spillage during handling
Pulp mill section	❍ RM/pulp spillage during digestor/MCD loading/unloading ❍ Leakage/spillage of caustic ❍ Spillage of screen rejects and its interference with product stream ❍ Loss of fibre due to defective wire mesh of potcher drums and pulp deckers
Stock preparation	❍ Spillage of additives due to improper handling ❍ Splashing of pulp from chest due to low level
Paper machine	❍ Open water hoses ❍ Overflow from fan pump pit/wire pit ❍ Overflow of tray water

In parallel, the WM team collected information on costs and annual consumption of the major direct input materials. This information is summarised in Worksheet 5.

WORKSHEET 5
Input Materials Cost

Input Materials	Cost/Ton (In Rupees)	Annual Consumption	Consumption/ Ton of Paper (In Rupees)	Cost/Ton Of Paper
RAW MATERIAL				
Wheat straw	Rs 800	16335 T	1.375 T	Rs 1100
Waste paper	Rs 7000	5346 T	0.45 T	Rs 3150
PULP MILL				
Caustic	Rs 11000	987 T	0.083 T	Rs 913
Steam	Rs 250	37390 T	3.2 T	Rs 800
Power	Rs 2500/MW	4752 MW	0.4 MW	Rs 1000
Water	Rs 0.4/M³	990000 M³	83.5 M³	Rs 34
STOCK PREPARATION				
Alum	Rs 2500	475 T	0.04 T	Rs 100
Rosin	Rs 42000	47.5 T	0.004 T	Rs 168
PAPER M/C				
Kerosene	Rs 6000/M³	132 M³	0.011 M³	Rs 66
Steam	Rs 250	26135 T	2.2 T	Rs 550
Power	Rs 2500/MW	5700 MW	0.48 MW	Rs 1200
Water	Rs 0.4/M³	858000 M³	72.0 M³	Rs 29
TOTAL COST OF INPUT RM				**Rs 9110**

STEP II: ANALYSING PROCESS STEPS

PREPARING PROCESS FLOW CHARTS

A detailed process flow chart indicating inputs, outputs, unit operations, sources of wastes, etc, of the mill was prepared, and is as given below.

MAKING A MATERIAL BALANCE

A material balance of various input and output streams across all the three sections of paper making was made, and is as follows:

WORKSHEET 6
Material Balance

Unit Operation	Input Material Name	Input Material Quantity in TPD	Output Material Quantity in TPD	Waste Stream Liquid in TPD	Waste Stream Solid/Gas in TPD
PULP MILL Digestor	Wheat straw Caustic Water Steam	49.3 2.9 160.0 115.2	Cooked pulp 277.0	Nil	Vent vapour 50.4
Hydro-pulper	Waste paper Water	12.2 451.0	Waste paper pulp 463.2	Nil	Nil
Blow tank	Cooked pulp Water	277.0 275.0	Blow pulp 552.0	Nil	Nil
Washer	Blow pulp Water	552.0 1872.0	Washed pulp 526.6	BL 1897.4	Nil
Screening	Washed pulp Water Back water	526.6 1140.0 835.0	Screened pulp 2501.4		Reject 0.2
Thickener	Screen pulp Water	2501.4 60.0	Thick pulp 673.4	B/W* 1888	
STOCK PREPARATION Mix chest	Thick pulp Waste paper pulp	673.4 463.2	Mix pulp 1136.6	Nil	Nil
Blending chest	Mix pulp Additives	1136.6 1.7	Blend pulp 1138.3	Nil	Nil
PAPER M/C C-cleaner	Blend pulp Back water	1138.3 2860.0	CC pulp 3736.0	Reject 262.3	Nil
Dewatering	CC pulp Water	3736.0 1700.0	Dewatered pulp 80.0	B/W* 5360	Nil
Drying	Dewatered pulp Steam	80.0 79.0	Paper 36.0	Condensate 79.0	Vapour 44.0

**Partial recycled*

In the absence of measurement facilities, making an energy balance was difficult. However, a steam quantity balance was made as part of the component balance. Assessment was also carried out on one of the major sources of heat loss from processes/equipments.

MAKING A COMPONENT BALANCE

Based on the above basic data, component balances were derived for total solids and for water. These are shown in Worksheet 7A and 7B:

WORKSHEET 7A
Total Solids Balance

Unit Operation	Input Material Name	Input Material Quantity in TPD	Output Material Quantity in TPD	Waste Stream Liquid in TPD	Waste Stream Solid/Gas in TPD
PULP MILL Digestor	Wheat straw Caustic	49.3 2.9	Cooked pulp 52.2	Nil	Nil
Hydro-pulper	Waste paper	12.2	Waste paper pulp 12.2	Nil	Nil
Blow tank	Cooked pulp	52.2	Blow pulp 52.2	Nil	Nil
Washer	Blow pulp	52.2	Wash pulp 26.8	BL 25.4	Nil
Screening	Washed pulp	26.8	Screen pulp 26.6	Nil	Reject 0.2
Thickener	Screen pulp	26.6	Thick pulp 23.2	B/W 3.4	Nil
STOCK PREPARATION Mix chest	Thick pulp Waste paper pulp	23.2 12.2	Mix pulp 35.4	Nil	Nil
Blending chest	Mix pulp Additives pulp	35.4 1.7	Blend pulp 37.1	Nil	Nil
PAPER M/C	Blend pulp	37.1	Paper 36.0	Drain 1.1	Nil

A modified worksheet, which was easier to make and more explicit was used for making the Water Balance.

WORKSHEET 7B
Total Water Balance

Operation	Fresh Water Use	Waste Water
Digestor		
O Water	160.0	Nil
O Steam	115.0	
Blow tank	275.0	Nil
Washing	1872.0	1872.0
Screening	1140.0	Nil
Thickener	60.0	1053.0
Stock preparation	Nil	Nil
Paper m/c CC	Nil	260.0
Wire showers	1700.0	1402.0
and Misc	325.0	
Inclined screen	Nil	923.0
TOTAL	**5647.0**	**5510.0**

The difference in fresh water use and waste water generated was due to:

- Steam vent from digestors (approximately 50 TPD)
- Steam vapours formed during paper drying (approximately 44 TPD)
- Moisture in finished paper (approximately 3 TPD)
- Unaccountable losses, such as evaporation loss (approximately 40 TPD).

ASSIGNING COST TO WASTE STREAMS

As a prerequisite to assigning cost to waste streams, detailed analysis of each waste stream was carried out to assess the pollution load and hence work out the treatment and other costs. The findings of the analysis are summarised in Worksheet 8A.

WORKSHEET 8A
Waste Stream Analysis

Waste Water Source	Flow (m^3/day)	BOD (kg/d)	TSS (kg/d)	COD (kg/d)	TS (kg/d)
Potcher mechano-chem digestor	887	1401	1113	8009	11043
Potcher spherical digestor	985	2362	1451	13894	14381
Decker filtrate	1053	560	1017	1179	3377
Pulp mill combined	**2925**	**4323**	**3581**	**23082**	**28801**
Centricleaner I	136	15	111	38	815
Centricleaner II	125	22	86	60	738
Fan pump pit overflow	80	53	50	116	225
Inclined screen (I)	414	200	506	532	1283

Waste Water Source	Flow (m^3/day)	BOD (kg/d)	TSS (kg/d)	COD (kg/d)	TS (kg/d)
Inclined screen (II)	509	296	1121	788	1701
Paper machine Drain (I) Drain (II)	 808 514	 93 115	 85 81	 270 328	 806 455
Paper m/c combined	**2586**	**794**	**2040**	**2132**	**602[illegible]**
Total mill combined	**5511***	**5117**	**5621**	**25214**	**34824**

** After recycling*

The costs assignable to waste streams were then worked out and are presented in Worksheet 8B.

WORKSHEET 8B

Waste and Emissions Cost

Waste Stream	Fibre Loss		Other Loss		Water Loss		Treatment		Total
	Qty TPD	**Cost Rs/D**	**Qty TPD**	**Cost Rs/D**	**Qty TPD**	**Cost Rs/D**	**COD TPD**	**Cost Rs/D**	**Rs/day**
Wash water	1.5	6000	Fuel 25.4	value 12700	1872	749	22.0	22000	41449.0
Decker excess	0.6	3600	Nil	Nil	1053	421	1.2	1200	5221.0
CC reject	0.08	653	Nil	Nil	261	104	0.2	200	957.0
Paper m/c drain	0.22	1760	Nil	Nil	1402	561	0.71	710	3031.0
Inclined screen	1.10	8800	Nil	Nil	923	369	1.3	1300	10469.0
Screen reject			By-product 0.2	100					100.0
Total cost of waste/day									**Rs 61227**

IDENTIFYING CAUSES OF WASTE GENERATION

A cause analysis was carried out to identify the reasons for waste generation.

Waste Streams	Causes
Wash water	*Purposeful:* • Removal of lignin and ligno-compounds in pulp • Reduction of pH of pulp • Improvement of Kappa number • Removal of excess fines and dust from pulp *Unintentional:* • Leakage in wire drum • Poor washing efficiency
Decker back water	*Purposeful:* • Thickening of pulp *Unintentional:* • Leakage in wire drum • Improper recycling of decker filtrate • Insufficient BWT capacity causing overflow of back water tank
CC reject	*Purposeful:* • Removal of sand and grit *Unintentional:* • Errors in manual control • Pressure variation at inlet to centricleaner • Variation in level of feed tank • Variation in feed consistency
Paper m/c drain	*Purposeful:* • Cleaning of wire and felt • Floor washing *Unintentional:* • Overflow of fan pump pit • Inadequate pit capacity • Unnecessary addition of fresh water in pit • Open hoses • High paper breakage at machine
Hill screen filtrate	*Purposeful:* • Recovering fibre from couch pit water *Unintentional:* • Excess filtrate • Poor equipment efficiency
Johnson screen reject	*Purposeful:* • Removal of uncooked fibre bundles • Removal of unwanted material from waste paper pulp

STEP III: GENERATING WASTE INIMISATION PORTUNITIES

DEVELOPING WM OPPORTUNITIES

The WM team, equipped with adequate baseline and cost data, then started exploring WM opportunities. To facilitate the process, a summary of waste streams was prepared and the possibility of application of different WM techniques was assessed as shown in Worksheet 9.

WORKSHEET 9
Summary of Waste Streams and Possibilities of WM

Section	Waste Stream	POSSIBILITY OF						
		Source Reduction					Recycling	
		House Keeping	Input Material Change	Better Process Control	Eqpmt Modification	Technology Change	Onsite Reuse/ Recycle	Creation of By-product
PULP MILL								
	Wash water	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Decker back water	No	No	Yes	Yes	Yes	Yes	No
	Johnson reject	No	No	Yes	Yes	No	Yes	Yes
PAPER M/C								
	CC reject	No	No	Yes	Yes	No	Yes	Yes
	Paper m/c drain	Yes	No	Yes	Yes	No	Yes	No
	Hill screen reject	No	No	Yes	Yes	Yes	Yes	No

With this analysis forming the basic premise, about 50 WM options were generated.

	Source Reduction					Recycling		
WM Technique →	House-keeping	Input Material Change	Better Process Control	Eqpmt Modification	Technology Change	On-site recycle	By-products	TOTAL
No of options	10	2	8	6	11	11	2	50

SELECTING VIABLE WM OPPORTUNITIES

A summarised list of the WM opportunities developed above was prepared. The options, to select viable opportunities which could be implemented directly or after requiring techno-economic feasibility analyses, were examined as shown in Worksheet 10.

WORKSHEET 10
Selecting Workable WM Opportunities

WM Opportunity	Section	Category: Directly Implement-able	Category: Requires Further Analysis	Category: Reject
SOURCE REDUCTION				
■ **Good housekeeping**				
1. Installation of an appropriate chute to avoid spillage of screening rejects	PP	Yes		
2. Installation of raw material conveyor to reduce handling loss	RM		Yes	
3. Covering of all vibratory screens and chemical dosing tanks by proper lids to prevent spills	PP and SP	Yes		
4. Installation of self-closing valves for all pressurised raw water hose pipes to minimise water wastage	All	Yes		
5. Insulation of condensate pipeline	PM	Yes		
6. Insulation of steam pipeline	All	Yes		
7. Insulation of condensate tank	PM	Yes		
8. Insulation of feed water pipeline and tank	U	Yes		
9. Insulation of drum and MG dryer ends	PM	Yes		
10. Insulation of digestor	PP	Yes		
■ **Process change**				
❑ **Input material change**				
1. High yield pulping process using Anthroquinone	PP		Yes	
2. Substitution of cooking chemicalsÕ for example, alkaline-sodium sulphite	PP		Yes	
❑ **Better process control**				
1. Optimisation of pulping process for extended cooking with NaOH	PP	Yes		
2. Segregation of initial concentrated black liquor	PP	Yes		
3. Optimising alum dosage	SP	Yes		
4. Installation of consistency indicator in machine chest	PM		Yes	
5. Pulp consistency regulation by installation of additional small capacity dilution line from fan pump pit	PM	Yes		
6. Adjustment of edge cutter to reduce side trimming loss	PM	Yes		

WM Opportunity	Section	Category		
		Directly Implement-able	Requires Further Analysis	Reject
7. Combustion optimisation in boiler	U	Yes		
8. Proper hardness control of boiler feed water	U	Yes		
❑ **Equipment modification**				
1. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoid press picking	PM		Yes	
2. Modification of existing rifflers for better sand removal from centricleaner rejects	PM	Yes		
3. Installation of additional dryers (two) in paper machine to reduce specific power consumption	PM		Yes	
4. Installation of high velocity hood in paper machines to improve drying efficiency	PM		Yes	
5. Installation of high pressure nozzles, that is, fan flat type for felt and wire cleaning	PM		Yes	
6. Use of lower HP motor for induced draft fan	U		Yes	
❑ **Technology change**				
1. Installation of wheat straw dedusting system and reusing of the fines and dust as fuel in the boiler	RM		Yes	
2. Wet cleaning of wheat straw	RM			Yes
3. Installation of disk mill for removal of fines and dust	RM			Yes
4. Installation of screw press for pulp dewatering	PP		Yes	
5. Installation of counter-current multi-stage vacuum washers for pulp washing	PP			Yes
6. Installation of twin-wire belt press for pulp dewatering	PP			Yes
7. Hot stock refining in alkaline condition	PP	Yes		
8. Installation of double felt after couch roll to prevent paper breakage due to fines	PM		Yes	
9. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	PM		Yes	

WM Opportunity	Section	Category		
		Directly implement-able	Requires Further Analysis	Reject
10. Solar evaporation of concentrated black liquor	PP			Yes
11. Installation of water softener for boiler feed water to reduce blow down and other losses	U		Yes	
Recycling				
Onsite recovery/reuse				
1. Recycle concentrated black liquor in digestor, replacing fresh water to maintain bath ratio	PP	Yes		
2. Chemical recovery from black liquor	PP			Yes
3. Biogas generation from black liquor	PP			Yes
4. Recycle back water to replace fresh water	All	Yes		
5. Recover fibres from centricleaner rejects by installation of high pressure fibre savers	PM	Yes		
6. Recycle/reuse decker filtrate for pulp washing and dilution	PP	Yes		
7. Recycle fan pump pit overflow to couch pit	PM	Yes		
8. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after filtration through multiplex filters	PM		Yes	
9. Fibre recovery from back water and reuse of filtrate for wire and felt cleaning through installation of micro filters	PM			Yes
10. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	All		Yes	
11. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	U		Yes	
Creation of useful by-product				
1. Manufacture of lignosulphates from black liquor	PP			Yes
2. Recovery of lignin from black liquor for application as soil conditioner	PP			Yes

The WM opportunities are targetted towards:

- Recovery of fibre
- Recycling of back water
- Water conservation
- Recovery of by-products
- Reduction in effluent treatment cost
- Reduction in chemical consumption
- Energy conservation

STEP IV: CTING WM OLUTIONS

The shortlisted opportunities selected above, which were directly implementable (Category 1), were immediately taken up for implementation. Those requiring further detailed analysis (Category 2) were studied from the point of view of their feasibility.

TECHNICAL FEASIBILITY ASSESSMENT

The technical feasibility analysis showed that none of the 18 options of Category 2 had any major technical requirements with respect to space, manpower and plant shutdown. The technology was indigenously available for all the options. Similarly, no significant impact was identifiable with regard to product quality, safety, maintenance and operational flexibility. Worksheet 11 was modified to suit the technical feasibility of this mill. The overall technical feasibility was assessed as low, medium or high, depending upon the extent of technical requirement and adverse technical impacts.

WORKSHEET 11
Technical Feasibility Analysis

WM Opportunity Requiring Technical Feasibility Analysis	Technical Requirement		Technical Impact			Overall Tech Feasibility
			Prodn Capacity	Savings in		
	Eqpt	Inst		Energy	Input Mat'l	
1. Installation of raw material conveyor to reduce handling loss	Yes	No	None	Neg	Pos	Med
2. Insulation of drum & MG dryer ends	No	No	Pos	Pos	None	High
3. High yield pulping process using Anthroquinone	No	No	Pos	None	Neg	Med
4. Substitution of cooking chemicals, that is, alkaline-sodium sulphite	No	No	Pos	None	Neg	Med
5. Installation of consistency indicator in machine chest	No	Yes	Pos	Pos	Pos	High
6. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoid press picking	Yes	No	Pos	Pos	Pos	High
7. Installation of additional dryers (two) in paper machine to reduce specific power consumption	Yes	No	Pos	Pos	None	High
8. Installation of high velocity hood in paper machine to improve dying efficiency	Yes	No	Pos	Pos	None	High
9. Installation of high pressure nozzles that is, fan flat type for felt and wire cleaning	Yes	No	None	Pos	Pos	High
10. Use lower HP motor for induced draft fan	Yes	No	None	Pos	None	Med

WM Opportunity Requiring Technical Feasibility Analysis	Technical Requirement		Technical Impact			Overall Tech Feasibility
	Eqpt	Inst	Prodn Capacity	Savings in Energy	Savings in Input Mat'l	
11. Installation of wheat straw dedusting system and reusing the fines and dust as fuel in the boiler	Yes	No	Pos	Pos	Pos	High
12. Installation of screw press for pulp dewatering	Yes	No	Pos	Neg	Nor	Med
13. Installation of double felt after couch roll to prevent paper breakage due to fines	Yes	No	Pos	Pos	Pos	High
14. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	Yes	No	None	Pos	Pos	High
15. Installation of water softener for boiler feed water to reduce blow down and other losses	Yes	No	None	Pos	Neg	Med
16. Recycle fibre lean stream, that is, wire pit waste water, in cleaning showers after filtration through multiplex filters	Yes	No	None	None	None	High
17. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	Yes	No	Pos	None	Pos	Med
18. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	Yes	No	None	Pos	None	Med

ECONOMIC VIABILITY ASSESSMENT

The above 18 options were subjected to economic analysis. The detailed investment costs, operating costs and savings were computed. The payback period was worked out for each option. The overall economic viability was assessed as high, medium or low, depending upon the payback period being less than one year, one to three years and more than three years, respectively. The summarised results are given in the modified Worksheet 12.

WORKSHEET 12
Economic Viability Analysis

WM Opportunity Requiring Economic Viability Analysis	Investment in Rs	Optn Cost in Rs/yr	Savings Gross in Rs/yr	Savings Net in Rs/yr	Pay-back in yrs	Overall Economic Viability
	All figures in lakhs					
1. Installation of raw material conveyor to reduce handling loss	2.0	1.4	2.8	1.4	2	Med
2. Insulation of drum and MG dryer ends						
3. High yield pulping process using Anthroquinone	Nil	14.0	14.0	Nil	Nil	Low
4. Substitution of cooking chemicals namely, alkaline-sodium sulphite	Nil	Nil	Nil	Nil	Nil	Low
5. Installation of consistency indicator in machine chest	1.0	0.1	1.6	1.5	< 1	High
6. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoid press picking	2.0	2.4	7.4	5.0	< 1	High
7. Installation of additional dryers (two) in paper machine to reduce specific power consumption	15.5	6.2	28.5	22.3	< 1	High
8. Installation of high velocity hood in paper machine to improve drying efficiency	34.0	60.0	38.0	22.0	2	Med
9. Installation of high pressure nozzles, that is, fan flat type, for felt and wire cleaning	1.0	0.8	1.5	0.7	2	Med
10. Use of lower HP motor for induced draft fan	1.0		1.2	1.2	<1	High
11. Installation of wheat straw dedusting system and reusing the fines and dust as fuel in the boiler	5.0	12.0	20.0	8.0	<1	High
12. Installation of screw press for pulp dewatering	1.0	5.0	8.0	3.0	<1	High
13. Installation of double felt after couch roll to prevent paper breakage due to fines	2.5	1.0	7.5	6.5	<1	High
14. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	3.0	1.0	2.4	1.4	2	Med
15. Installation of water softener for boiler feed water to reduce blow down and other losses	1.0	0.5	2.5	2.0	<1	High
16. Recycle fibre lean stream, that is, wire pit wastewater in cleaning showers after filtration through multiplex filters	2.0	1.5	2.0	0.5	>3	Low
17. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	3.0	0.5	3.5	3.0	<1	High
18. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	2.0	1.5	5.5	4.0	<1	High

ANALYSING ENVIRONMENTAL ASPECTS

The above options were then subjected to an analysis of environmental aspects. It was found that the beneficial environmental impact was most significant on water media in terms of reduction in COD load. TS load and waste water volume. The beneficial impact on reduction in the air pollution load and solid waste generation was relatively small and therefore only qualitative assessment was carried out. The overall impact of reducing environmental degradation was assessed as high, medium and low. principally based on reduction in the water pollution load (90 per cent weightage), followed by air pollution (9 per cent) and solid waste reduction (1 per cent). respectively.

WORKSHEET 13
Analysis of Environmental Aspects

WM Opportunity Requiring Technical Feasibility Analysis	Redn in Water Pollution Load of COD Kg/day	TS Kg/day	Flow (m^3/day)	Qualitative Assessment of Reduction in Pollution: Air	Solids	Overall Env Assessment
1. Installation of raw material conveyor to reduce handling loss	Nil	Nil	Nil	Yes	No	Low
2. Insulation of drum and MG dryer ends	Nil	Nil	Nil	Yes	No	Low
3. High yield pulping process using Anthroquinone	150	200	100	No	No	Med
4. Substitution of cooking chemicals' namely, alkaline-sodium sulphite	NIL	NIL	300	No	No	Low
5. Installation of consistency indicator in machine chest	50	60	75	No	No	Med
6. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoid press picking	300	10	75	Yes	No	High
7. Installation of additional dryers (two) in paper machine to reduce specific power consumption	Nil	Nil	Nil	No	No	Low
8. Installation of high velocity hood in paper machines to improve drying efficiency	Nil	Nil	Nil	Yes	No	Low
9. Installation of high pressure nozzles, namely, fan flat type, for felt and wire cleaning	Nil	Nil	800	No	No	Low
10. Use of lower HP motor for induced draft fan	Nil	Nil	Nil	No	No	Low
11. Installation of wheat straw dedusting system and reusing the fines and dust as fuel in the boiler	1800	2200	Nil	No	Yes	High
12. Installation of screw press for pulp dewatering	7600	8000	1100	No	No	High
13. Installation of double felt after couch roll to prevent paper breakage due to fines	60	75	75	No	No	Low
14. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	90	120	Nil	No	No	Low

WM Opportunity Requiring Technical Feasibility Analysis	Redn in Water Pollution Load of COD Kg/day	TS	Flow (m³/day)	Qualitative Assessment of Reduction in Pollution: Air	Solids	Overall Env Assessment
15. Installation of water softener for boiler feed water to reduce blow down and other losses	Nil	Nil	Nil	No	No	Low
16. Recycle fibre lean stream, that is, wire pit wastewater in cleaning showers after filtration through multiplex filters	300	700	600	No	Yes	High
17. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	1200	1600	600	No	No	High
18. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	Nil	Nil	Nil	No	No	Low

SELECT SOLUTIONS FOR IMPLEMENTATION

After completing the feasibility analyses, the 18 measures had to be prioritised from the point of view of their implementation. Due to the companyÕs limited capacity for providing finances, manpower and other resources, it was not possible to take up all the measures for implementation at one go. The measures were, therefore, rated for overall effectiveness. Profits being most important to the company, the economic feasibility had 50 per cent weightage, the remaining being equally divided between technical feasibility and environmental feasibility. A range of points was chosen for each category of feasibility, as shown below:

Technical Feasibility (25)			Economic Feasibility (50)			Environmental Feasibility (25)		
Low	Medium	High	Low	Medium	High	Low	Medium	High
0-5	6-14	15-25	0-10	11-29	30-50	0-5	6-14	15-25

Within the above range, points were allotted in each category for each option, depending upon a subjective assessment. The respective points for each option, along with overall ranking, is given in Worksheet 14.

WORKSHEET 14
Selecting WM Measures for Implementation

WM Opportunity Requiring Economic Viability Analysis	Feasibility: Technical (25)	Economic (50)	Environmental (25)	Total Points (100)	Overall Rank
1. Insulation of raw material conveyor to reduce handling loss	8	15	2	25	16
2. Insulation of drum and MG dryer ends	20	12	3	35	15
3. High yield pulping process using Anthroquinone	10	0	11	21	17

WM Opportunity Requiring Economic Viability Analysis	Feasibility			Total Points	Over-all Rank
	Tech-nical (25)	Eco-nomic (50)	Environ-mental (25)	(100)	
4. Substitution of cooking chemicals; for example, alkaline sodium sulphite	10	0	4	14	18
5. Installation of consistency indicator in machine chest	16	30	8	54	7
6. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoid press picking	20	44	23	87	1
7. Installation of additional dryers (two) in paper machine to reduce specific power consumption	22	35	5	62	6
8. Installation of high velocity hood in paper machines to improve drying efficiency	22	22	5	49	9
9. Installation of high pressure nozzles, for example, fan flat type for felt and wire cleaning	18	15	4	37	14
10. Use of lower HP motor for induced draft fan	12	30	2	44	11
11. Installation of wheat straw dedusting system and reuse of the fines and dust as fuel in the boiler	16	35	16	67	5
12. Installation of screw press for pulp dewatering	14	40	24	78	3
13. Installation of double felt after couch roll to prevent paper breakage due to fines	24	48	5	77	4
14. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	24	25	4	51	8
15. Installation of water soften for boiler feed water to reduce blow down and other losses	8	32	3	43	12
16. Recycle fibre lean stream, that is, wire pit waste water, in cleaning showers after filtration through multiplex filters	17	7	17	41	13
17. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	14	45	24	83	2
18. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	8	35	5	48	10

STEP V:
EMENTING
WASTE
IMISATION
OLUTIONS

SELECTING SOLUTIONS FOR IMPLEMENTATION

Of all the 50 measures developed in Worksheet 10, the 22 directly implementable measures and 10 (ranking 1 to 12 and barring 5 to 7) out of the 18 requiring detailed feasibility analysis were taken up for implementation. The total expenditure required was estimated to be Rs 40 lakh and due approvals were taken from the management. The measures were classified based on implementation time requirement as short-term (< 3 months), medium-term (3 months to 1 year) and long-term (> 1 year), subject to availability of funds. The responsibility of implementing the measures was assigned and the progress was planned to be monitored by the Director himself, on a monthly basis. Thus, an Implementation Plan was prepared, as shown in Worksheet 15.

WORKSHEET 15
Implementation Plan

WM Opportunity	Implementation Date	Gains				Remarks
		Economic		Environmental		
		Expected	Actual	Expected	Actual	
SHORT-TERM						
1. Installation of an appropriate chute to avoid spillage of screening rejects	Dec '94	Nil	—	Low	—	In absence of direct economic gains management decided to defer implementation of these three measures
2. Covering of all vibratory screens and chemical dosing tanks by proper lids to prevent spills		Nil		Low		
3. Installation of self closing valves for all pressurised raw water hose pipes to minimise water wastage.	—	0.2	—	Low	—	
4. Insulation of condensate pipeline	Aug '93	0.25	0.27	Low	Low	
5. Insulation of steam pipeline	Aug '93	10.4	0.27	Low	Low	
6. Insulation of condensate tank	Aug '93	1.2	1.00	Low	Low	
7. Insulation of feed water pipeline and tank						
8. Insulation of digestor	Sep '93	2.5	2.2	Low	Low	
9. High yield pulping process using Anthroquinone	Sep '93	3.0	3.6	COD 1T/D	Cod 1.2T/D	Withdrawn due to poor chem quality
10. Substitution of cooking chemicals, namely, alkaline-sodium sulphite	Sep '93	Nil	Nil	Low	Low	Withdrawn due to dour problem
11. Optimisation of pulping process for extended cooking with NaOH	Sep	2.0	2.5	Cod 8T D	Cod 1T D	
12. Segregation of initial concentrated black liquor	Aug '93	Nil	Nil	Low	Low	
13. Optimising alum dosage	Aug '93	0.1	0.1	Low	Low	
14. Installation of consistency indicator in machine chest	Oct '94	1.5		TS 60 COD 50 kg/D		Delayed due to non-availability of good instmt
15. Adjustment of edge cutter to reduce side trimming loss	Sep '93	10.5	10.7	Low	Low	
16. Combustion optimisation in boiler	Sep '93	1.0	0.7	Low	Low	

WM Opportunity	Implementation Date	Gains: Economic Expected	Economic Actual	Environment Expected	Environment Actual	Remarks
17. Proper hardness control of boiler feed water	Sep '93	NQ	NQ	Low	Low	
18. Modification of existing rifflers for better sand removal from centric leaner rejects	Sep '93	Nil	Nil	Low	Low	
19. Use of lower HP motor for induced draft fan	Dec '94	1.0	—	Nil	Nil	Exact HP to be established
20. Hot stock refining in alkaline condition	Nov '93	NQ	NQ	NQ	NQ	
21. Recycle back water to replace fresh water	Aug '93			Flow 11500	1620	All measures were implemented simultaneously
22. Recycle/reuse decker filtrate for pulp washing and dilution	Aug '93	8.0	8.8	T/D TS		
23. Recycle fan pump pit overflow to couch pit	Aug '93			0.5T/D COD 0.5T/D	0.6T/D 6T/D	
24. Recovery of fibres from centri-cleaner rejects by installation of high pressure fibre savers	Sep '93	1.5	—	COD 0.6T/D TS 8T/D	— —	Not implemented due to delay in procurement of pumps
25. Recycle concentrated black liquor in digestor replacing fresh water for maintaining bath ratio	Oct '93	3.5	3.0	COD 1.2T/D TS 1.5T/D	1.0 1.0	Savings lower due to low NaOH recovery
MEDIUM-TERM						
1. Installation of raw material conveyor to reduce handling loss.	Dec '94	1.4	—	Low	—	
2. Insulation of drum and MG dryer ends	Dec '94		—	Low	—	Delayed due to shutdown reqmt
3. Pulp consistency regulation by installation of additional small capacity dilution line from fan pump pit	Not reqd	0.6	—	Low	—	Not reqd due to low variation in gain
4. Replacement of existing press roll (upper one) by MS rolls to reduce kerosene oil used to avoiding press picking	Dec '93	5.0	4.9	COD 0.3T/D	0.3T/D	Also fugitive emissions of kerosene oil avoided
5. Installation of additional dryers (two) in paper machine to reduce specific power consumption	July '94	22.3	20.4	Nil	Nil	Phased impt'n since capital intensive
6. Installation of high pressure nozzles, namely, fan flat type for felt and wire cleaning	Not reqd now	0.7	—	Low	—	Fresh water recommit is felt very low

WM Opportunity	Implementation Date	Gains				Remarks
		Economic		Environment		
		Expected	Actual	Expected	Actual	
7. Installation of wheat straw dedusting system and reusing the fines and dust as fuel in the boiler	COD Dec '94	8.0	—	1.8T/D TS 2.2T/D	—	Under implementation
8. Installation of screw press for pulp dewatering	Dec '93	3.0	NIL	COD 7.6T/D TS 8T/D	Nil Nil	Available pulp design failed. Better disjoin required
9. Installation of double felt after couch roll to prevent paper breakage due to fines	Jan '94	6.5	7.1	Low	Low	
10. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	Jan '94	1.4	1.2	Low	Low	
11. Installation of water softenr for boiler feed water to reduce blow down and other losses	Jan '95	2.0	—	Low	—	
12. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after fitration through multiplex filters		0.5		Low		Payback very high. Saves only fresh water
13. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	Nov '94	3.0	—	COD 1.2T/D TS	—	Under implementation
LONG-TERM						
1. Increase heat recovery from flue gases through economiser and recycle it as hot water in MCD and digestors	Nov '94	4.0	—	Low	—	Under implementation
2. Installation of high velocity hood in paper machines to improve drying efficiency	Dec '94	22.0	—	Low	—	Under implementation

IMPLEMENTING SOLUTIONS

The above plan formed the basis of the implementation. Some of the straightforward measures were implemented while the plan was being drawn up. The operators were actively involved. Priority status was accorded to the measures with a high rate of return, since the management was able to muster enough financial resources to implement the measures. Therefore, some of the obvious measures, which did not have a good rate of return, were left out. Overall, the implementation went on smoothly and, by and large, the targets were adhered to.

MONITORING AND EVALUATING RESULTS

The results of the implementation were compared with those estimated during the planning stage. No significant deviations were recorded.

OVERALL RESULTS

The overall results achieved after the one-year implementation period. are given in the following table:

Parameters	Before	After	%Change
Production capacity (In TPD)	36	42	+17%
Flow (m3/T)	153	92	-40%
COD (kg/T)	700	498	- 29%
TS (kg/T)	980	700	- 40%
COST (in Rs lakh/year)			
Effluent treatment	116	97	- 17%
Chemical	155	144	- 7%
Energy	430	393	- 8.6%

Investment on WM measures = Rs 35.5 lakh
Net Annual Savings = Rs 66.4 lakh
Overall Payback = Less than a year
* *Including savings in reduced effluent treatment cost*

STEP VI: MAINTAINING WASTE MINIMISATION SOLUTIONS

The results achieved were so attractive and encouraging, that the management got more committed towards WM. It has already taken up some long-term and capital intensive measures for implementation. It has also decided to take up measures a which have lower rate of returns. In a rare gesture of environmental consciousness, the management has pooled the entire savings, and simultaneously investment in an extensive effluent treatment plant which is now operational and giving excellent results. Waste Minimisation in this company has now come to stay.

Notes

Case Study 2

Waste Minimisation At Raval Paper Mills, Rae Bareli

INTRODUCTION

Raval Paper Mills is an agro residue-based pulp and paper mill producing 10 tons per day (TPD) of unbleached semi kraft paper and 15 TPD of bleached writing printing paper. The average production of the mill is 2 TPD.

The mill participated in the project **DESIRE** (**DE**monstration in **S**mall **I**ndustries for **R**educing wast**E**) with the twin objectives of reducing production costs and cost-effective compliance with environmental regulations. The pressure from the local public for improving environmental performance and the need to conserve water due to ensuing water shortages, specially in summer, were other reasons behind the company's decision to actively pursue Waste Minimisation (WM). Accordingly, the WM programme was launched with assistance from the National Productivity Council.

THE WM PROGRAMME

The six-step methodology as discussed in Chapter 4 was followed to get the best results.

STEP I: GETTING STARTED

FORMING A WASTE MINIMISATION TEAM

A Waste Minimisation team consisting of the following was constituted:

Mr Sinha	Works Manager (Team Leader)
Mr Laxman Singh	Project Manager
Mr Raman Kumar	Pulp Mill In-charge
Mr D. P. Singh	Maintenance In-charge
Mr Ajay Singh	Lab Analyst
Mr Dinesh Singh	Operator

External Experts (NPC and UNIDO)

The team first collected general information about the company as per Worksheet 1.

WORKSHEET 1

General Information

NAME OF THE COMPANY: ***Raval Paper Mills***

Name	Designation
1. Mr Sinha	Works Manager (Team Leader)
2. Mr Laxman Singh	Project Manager
3. Mr Raman Kumar	Pulp Mill In-charge
4. Mr D.P. Singh	Maintenance In-charge
5. Mr Ajay Singh	Lab Analyst
6. Mr Dinesh Singh	Operator
External Experts (NPC and UNIDO)	

A. MAJOR RAW MATERIAL CONSUMPTION

Fibrous raw materials

a) Wheat straw	7,920 T/yr
b) Rice straw	2,640 T/yr
c) Elephant grass	990 T/yr
d) Bagasse	660 T/yr
e) Waste paper unbleached	1,129 T/yr
f) Waste paper bleached	1,923 T/yr
g) Rags	825 T/yr

Chemicals

a) Caustic Soda	907.0 T/yr
b) Alum	660.0 T/yr
c) Rosin	49.5 T/yr
d) Highgum	16.5 T/yr
e) Soap stone	501.0 T/yr
f) Dye	0.9 T/yr
g) Starch	45.5 T/yr
h) Lime	550.0 T/yr
i) Chlorine	370 T/yr
j) Polyelectrolite	0.2 T/yr
k) Whitening agent	1.1 T/yr

B. ENERGY CONSUMPTION

a) Electrical energy	7,000 MW/yr
b) Rice husk	13,000 T/yr

C. WATER CONSUMPTION 1,452,000 M^3/yr

D. PRODUCTION

INSTALLED CAPACITY

Pulp making	
Agro pulp	20 T/day
Waste paper pulp	10 T/day
Paper making	30 T/day

ACTUAL PRODUCTION

Pulp	25 T/day
Paper bleached	15 T/day
Paper unbleached	10 T/day
	8,252 T/year

E. TYPE OF EFFLUENT TREATMENT Primary and secondary

The information available was reasonably good to start the audit. A compiled list of available information is shown in Worksheet 2.

WORKSHEET 2
Available Information

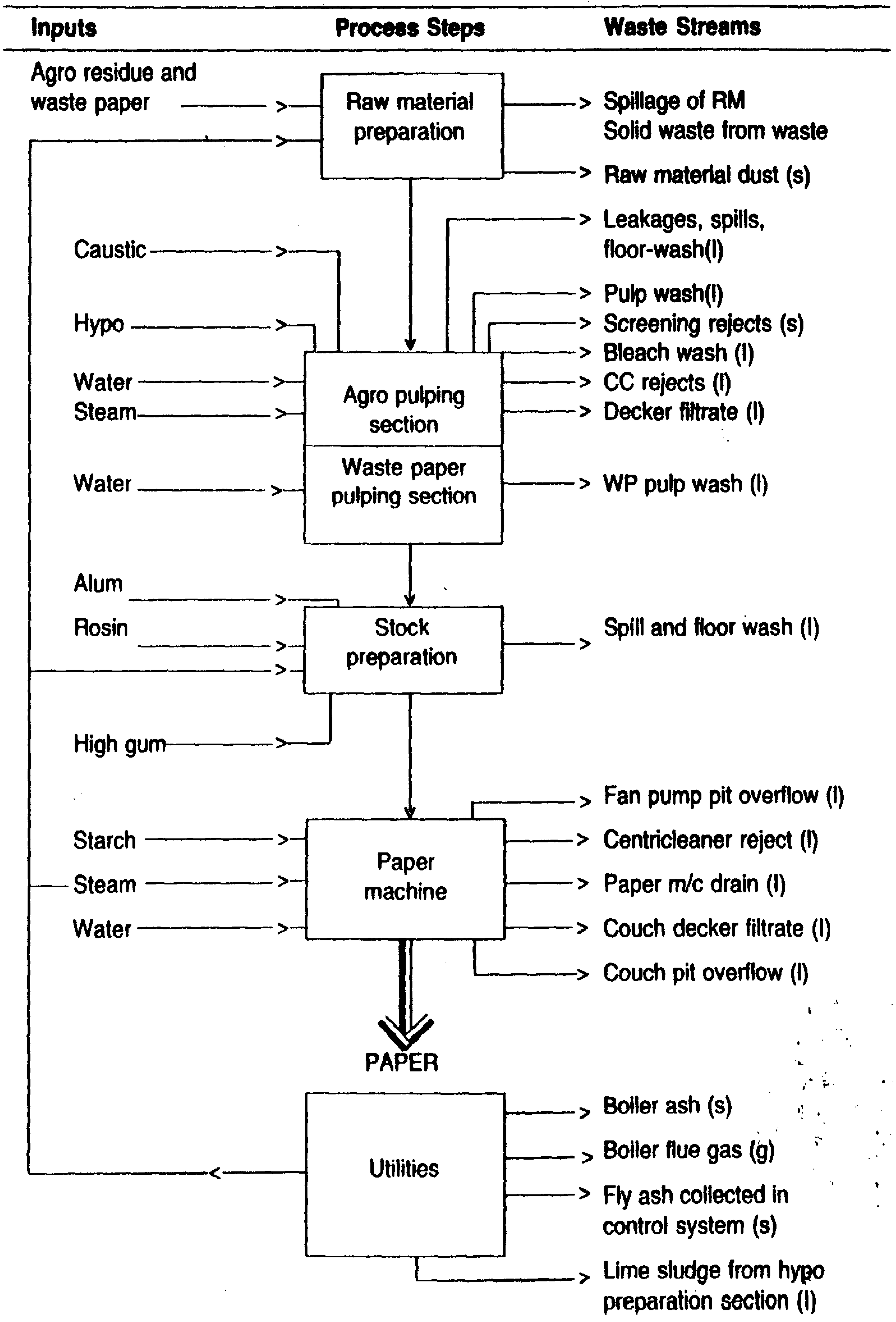
Information	Availability	Remarks
Process flow diagram	Yes	Useful, needs upgradation
Material balance	Yes	Only fibre balance useful
Water balance	Yes	Reasonably good
Plant layout	Yes	Not updated
Waste analysis	Yes	Only few parameters
Production log sheets	Yes	Important and useful

No other information was available.

PROCESS STEPS AND WASTE STREAMS

A process flow diagram showing the major process steps and waste streams was made as shown in Worksheet 3.

WORKSHEET 3
Process Flow Diagram Indicating Waste Streams



The WM team had a detailed look at the plant and identified the following housekeeping lapses.

WORKSHEET 4
Housekeeping Status

Sections	Lapses in Housekeeping
Raw material handling	❍ RM spillage during storage and conveying
Pulp mill section	❍ RM/pulp spillage during digestor loading/unloading ❍ Leakage/spillage of caustic and bleach liquor ❍ Spillage of screen rejects and its interference with product stream ❍ Improper handling of lime sludge from hypo section ❍ BL spillage from rag digestor unloading area
Stock preparation	❍ Spillage of additives due to improper handling ❍ Splashing of pulp from chest due to low level
Paper machine	❍ Open water hoses ❍ Overflow from fan pump pit/wire pit/couch pit ❍ Improper layout of steam and condensate pipelines

In parallel the WM team collected information on cost and annual consumption of major direct input materials. This information was summarised in Worksheet 5.

WORKSHEET 5
Input Materials Cost

Input Materials	Cost/Ton (in Rupees)	Annual Consumption	Consumption/Ton of Paper	Cost/Ton of Paper (in Rupees)
RAW MATERIAL SECTION				
Wheat straw	Rs 800	7920 T	0.960 T	Rs 768
Rice straw	Rs 700	2640 T	0.320 T	Rs 224
Elephant grass	Rs 600	990 T	0.120 T	Rs 72
Bagasse	Rs 850	660 T	0.080 T	Rs 68
Waste paper (unbleached)	Rs 6500	1,129 T	0.140 T	Rs 910
Waste paper (bleached)	Rs 9000	1,923 T	0.233 T	Rs 2097
Rags	Rs 3000	825 T	0.010 T	Rs 30

Input Materials	Cost/Ton (in Rupees)	Annual Consumption	Consump-tion/Ton of Paper	Cost/Ton of Paper (in Rupees)
PULP MILL				
Caustic	Rs 11000	907 T	0.110 T.	Rs 1210
Steam	Rs 250	28,882 T	3.5 T	Rs 875
Lime	Rs 1400	550 T	0.162 T	Rs 227
Chlorine	6500	370 T	0.109 T	709
Power	2500/MW	3466 MW	0.42 MW	1050
Water	0.4/M^3	890000 M^3	109.0 M^3	44
STOCK PREPARATION				
Alum	2500	660 T	0.08 T	200
Rosin	42000	49.5 T	0.006 T	252
High gum	21000	16.5 T	0.002 T	42
Talc	1300	501 T	0.100 T*	130
Dye	200000	0.90 T	0.106 kg	21
PAPER M/C				
Starch	9000	45.5 T	0.005 T	45
Steam	250	18980 T	2.3 T	575
PE	300000	0.2 T	0.04 kg	12
Whitening	55000	1.1 T	0.13 kg	7
Power	2 500 Rs/MW	3961 MW	0.48 MW	1200
Water	0.4 Rs/M^3	507540 M^3	61.5 M^3	25
TOTAL COST OF INPUT RM				**Rs 10,793**

* *Used only for bleached paper manufacturing.*

PREPARING PROCESS FLOW CHARTS

A detailed process flow chart was prepared indicating inputs, outputs, unit operations, sources of wastes, etc, of the mill.

MAKING A MATERIAL BALANCE

A material balance of the various input and output streams across all the three sections of paper-making was made as shown in Worksheet 6.

WORKSHEET 6
Material Balance

Unit Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid/Gas in TPD
PULP MILL Digestor	Wheat straw Rice straw Elephant grass Bagasse Rags Caustic Water Steam	24.0 8.0 3.0 2.0 0.3 2.8 109.0 88.0	Cooked pulp 234.8	Nil	Vent vapour 38.3
Hydro-pulper	WP unbleached WP bleached Water	3.5 5.8 214.0	Waste paper pulp 222.9	Nil	Nil
Blow tank	Cooked pulp Water	234.8 280.0	Blow pulp 514.8	Nil	Nil
Washer	Blow pulp Water Back water	514.8 1309.0 220.0	Washed pulp 491.8	Bleached 1552	Nil
Screening	Washed pulp Water Back water	491.8 580.0 430.0	Screened pulp 1501.0		Reject 0.8
Centricleaning	Washed pulp Back water	1501.0 430.0	Centricleaned pulp 1902.0	CC reject 29	Nil
Thickener	Screen pulp Water	1902.0 30.0	Thick pulp 563.0	316 WW B/W 1053	Nil
Pulp distribution	Thick pulp	563.0	Bleaching 304.0 For unbleached paper —259.0	Nil	Nil
Bleaching	Thick pulp Lime Chlorine White water Water	304.0 1.6 1.1 550.0 50.0	Bleach pulp 272.7	Bleach wash 634	Nil

Unit Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid/Gas in TPD
STOCK PREPARATION					
Mix chest	Bleach pulp Waste paper pulp	272.7 140.0	Mix pulp 412.7	Nil	Nil
Blending chest	Mix pulp Additives	412.7 2.9	Blend pulp 415.6	Nil	Nil
PAPER M/C C-cleaner	Blend pulp White water	415.6 1028.0	CC pulp 1371.5	Reject 72.5	Nil
Dewatering	CC pulp Water	1371.5 600.0	Dewatered pulp 35.0	W/W 1935.5	Nil
Drying	Dewatered pulp Steam	35.0 34.5	Paper 15.0	Conden-sate 34.5	Vapour 20.0

** Partial recycled*

WORKSHEET 6A (CONTD)
Unbleached Paper Stream

Unit Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid/Gas in TPD
STOCK PREPARATION					
Mix chest	Thick pulp Waste paper pulp	259.0 203.4	Mix pulp 462.4	Nil	Nil
Blending chest	Mix pulp Additives	462.4 1.0	Blend pulp 463.4	Nil	Nil
PAPER M/C C Cleaner	Blend pulp Back water	463.4 713.0	CC pulp 1126.1	Reject 50.3	Nil
Dewatering	CC pulp Water	1126.1 1121.0	Dewatered pulp 24.1	W/W 12223	Nil
Drying	Dewatered pulp Steam	24.1 23.0	Paper 10.0	Conden-sate 23.0	Vapour 14.0

In the absence of measurement facilities, it was found difficult to make an energy balance. However, a steam quantity balance was made as part of the component balance. An assessment was also made of the major heat losses from the processes and equipments.

MAKING A COMPONENT BALANCE

Based on the data provided, component balances were derived for total solids and water. These are shown in Worksheet 7A.

WORKSHEET 7A

Total Solids Balance

Unit Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid/Gas in TPD
PULP MILL Digestor	Agro residue Caustic	37.3 2.8	Cooked pulp 40.1	Nil	Nil
Hydro-pulper	Waste paper	9.3	Waste paper pulp 9.3	Nil	Nil
Blow tank	Cooked pulp	40.1	Blow pulp 40.1	Nil	Nil
Washer	Blow pulp	40.1	Wash pulp 17.3	BL 22.2	Nil
Screening	Washed pulp	17.9	Screen pulp 17.1	Nil	Reject 0.8
Thickener	Screen pulp	17.1	Thick pulp 16.6	B/W 0.5	Nil
Pulp distribution	Thick pulp	16.6	Bleaching 9.0 Kraft paper 7.6	Nil	Nil
Bleaching	Thick pulp Lime Chlorine	9.0 1.6 1.1	Bleach pulp 8.9	Bleach wash 2.0	Lime sludge 0.8
STOCK PREPARATION Mix chest	Bleach pulp Waste paper pulp	8.9 4.9	Mix pulp 13.8	Nil	Nil
Blending chest	Mix pulp Additives pulp	13.8 2.9	Blend pulp 16.7	Nil	Nil
PAPER M/C	Blend pulp	16.7	Paper 15.0	Drain 1.7	Nil

WORKSHEET 7A
Kraft Paper Making

Unit Operation	Input Material		Output Material	Waste Stream	
	Name	Quantity in TPD	Quantity in TPD	Liquid in TPD	Solid/Gas in TPD
STOCK PREPARATION					
Mix chest	Thick pulp Waste paper pulp	7.6 2.9	Mix pulp 10.6	Nil	Nil
Blending chest	Mix pulp Additives pulp	10.6 1.0	Blend pulp 11.6	Nil	Nil
PAPER M/C	Blend pulp	11.6	Paper 10.0	Drain 1.6	Nil

A modified worksheet was used for making the water balance —which was easier to make and more explicit.

WORKSHEET 7B
Total Water Balance

Operation	Fresh Water Use	Waste Water
Digestor		
◌ Water	109.0	Nil
◌ Steam		87.0
Blow tank	280.0	Nil
Washing (Agro)	1309.0	1,552.0
Washing (Waste paper)	220.0	214.0
Screening	580.0	Nil
Pulp mill CC	Nil	29.0
Thickener	30.0	316.0
Bleaching	20.0	632.0
Paper m/c CC	Nil	132.0
Wire showers and Miscellaneous	1721.0	438.0
Couch decker filtrate	20.0	978.0
TOTAL	**4376.0**	**4291.0**

The difference in fresh water use and waste water generated was due to:

- Steam vent from digestors (approximately 38 TPD)
- Steam vapours formed during paper drying (approximately 34 TPD)
- Moisture in finished paper (approximately 2 TPD)
- Unaccountable losses, such as evaporation loss (approximately 10 TPD)

ASSIGNING COST TO WASTE STREAMS

As a prerequisite to assigning cost to the waste streams, detailed analysis of each waste stream was carried out to assess the pollution load and hence work out the treatment and other costs. The findings of the analysis were summarised in Worksheet 8A.

WORKSHEET 8A

Waste Stream Analysis

Wastewater Source	Flow m^3/day	BOD kg/d	TSS kg/d	COD kg/d	TS kg/d
Unbleached potcher	1209	3712	4938	20660	18090
Beater wash	320	196	295	1125	4700
Pulp mill CC*	29	23	58	73	100
Pulp mill decker filtrate	316	51	395	170	554
Bleach potcher	632	165	654	414	1903
Hydro pulper potcher	214	80	142	250	400
Pulp mill combined	**2720**	**4227**	**6482**	**22692**	**25747**
Paper machine CC	132	138	498	393	750
Wire pit water	438	222	533	531	1273
Couch decker filtrate	978	464	880	1148	2500
Paper m/c combined	**1538**	**824**	**1911**	**2072**	**4523**
Total mill combined	**4258**	**5051**	**8393**	**24764**	**30270**

The costs assignable to waste streams were then worked out and are presented in the Worksheet 8B.

WORKSHEET 8B
Waste and Emissions Cost

Waste Stream	Fibre Loss		Other Loss		Water Loss		Treatment		Total
	Qty TPD	Cost Rs/D	Qty TPD	Cost Rs/D	Qty TPD	Cost Rs/D	COD TPD	Cost Rs/D	Rs/day
Wash water agro	2.9	13000	Fuel value 22.2	11,100	1552	621	21.8	21800	46521.0
Wash water Waste paper	0.1	500	Nil 22.2	Nil 11100	214	86	0.25	250	836.0
Pulp mill Decker excess	0.3	1800	Nil	Nil	316	126	0.17	170	2096.0
Bleach wash	0.26	1830	Residual Cl_2 0.05	325	632	253	0.4	400	2808.0
Pulp mill CC reject	0.04	210	Nil	Nil	29	12	0.1	100	322.0
Paper machine CC reject	0.2	1600	Nil	Nil	132	53	0.4	400	2053.0
Paper M/c Wire pit O/f	0.4	3000	Nil	Nil	438	175	0.5	500	3675.0
Couch decker excess	0.6	4800	Nil	Nil	978	390	1.1	1100	6290.0
Screen reject			By-product 0.8	800					800.0
Total Cost Of Waste/Day									**Rs 65,401**

IDENTIFYING CAUSES OF WASTE GENERATION

A cause analysis was carried out to identify the reasons for waste generation.

Waste Streams	Causes
Wash water agro	*Purposeful:* • Removal of lignin and ligno-compounds in pulp • Reduction of pH of pulp • Improvement of Kappa number • Removal of excess fines and dust from pulp *Unintentional:* • Leakage in wire drum • Poor washing efficiency

Waste Streams	Causes
Wash water (WP)	*Purposeful:* ● Removal of inerts and impurities *Unintentional:* ● Leakage in wire drum ● Poor washing efficiency
Decker back water	*Purposeful:* ● Thickening of pulp *Unintentional:* ● Leakage in wire drum ● Improper recycling of decker filtrate ● Insufficient BWT capacity leading to overflow of back water tank
Bleach wash water	*Purposeful:* ● Removal of residual lignin and lingo-compounds in pulp ● Improve the brightness of pulp *Unintentional:* ● Leakage in wire drum ● Poor washing efficiency ● Degradation of fibre ● Unutilised chlorine
CC reject (pulp mill)	*Purposeful:* ● Removal of sand and grit *Unintentional:* ● Errors in manual control ● Pressure variation at inlet to centricleaner ● Variation in level of feed tank ● Variation in feed consistency
CC reject (paper m/c)	*Purposeful:* ● Removal of impurities accompanied with additives ● Removal of inerts *Unintentional:* ● Errors in manual control ● Pressure variation at inlet to centricleaner ● Variation in level of feed tank ● Variation in feed consistency
Paper m/c wire pit	*Purposeful:* ● Cleaning of wire and felt ● Floor washing *Unintentional:* ● Overflow of wire pit ● Inadequate pit capacity ● Unnecessary addition of fresh water in pit ● Open hoses ● High paper breakage at machine
Couch decker filtrate	*Purposeful:* ● Recovering fibre from couch pit water *Unintentional:* ● Excess filtrate ● Poor equipment efficiency
Johnson screen reject	*Purposeful:* ● Removal of uncooked fibre bundles ● Removal of unwanted material from waste paper pulp

STEP III: [G]ENERATING WM [OPPORT]UNITIES

DEVELOPING WM OPPORTUNITIES

The WM team, now equipped with adequate baseline and cost data, started exploring WM opportunities. To facilitate the process, a summary of waste streams was prepared and the possibility of applying different WM techniques were assessed as shown in Worksheet 9.

WORKSHEET 9

Summary of Waste Streams and Possibilities of Waste Minimisation

Waste Stream	POSSIBILITY OF						
	Source Reduction					Recycling	
	House Keeping	Input Material Change	Better Process Control	Eqpmt Modification	Technology Change	Onsite Reuse/ Recycle	Creation of By-product
PULP MILL							
Agro wash	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WP wash	Yes	No	No	Yes	Yes	Yes	No
o Decker	No	No	Yes	Yes	Yes	Yes	No
o Bleach wash	Yes	Yes	Yes	Yes	Yes	Yes	No
o CC reject	No	No	Yes	Yes	No	Yes	Yes
o Johnson reject	No	No	Yes	Yes	No	Yes	Yes
PAPER m/c							
o CC reject	No	No	Yes	Yes	No	Yes	Yes
o Wire pit O/f	Yes	No	Yes	Yes	No	Yes	No
o Couch decker filtrate	No	No	Yes	Yes	Yes	Yes	No

With the above analysis forming the premise about 64 WM options were generated.

Waste Minimisation Technique ⇨	Source Reduction					Recycling		Product Reformulation	TOTAL
	House Keeping	Input-Material Change	Better Process Control	Eqpmt Modification	Technology Change	On-site Recycle/ Reuse	By-products		
No of options	15	7	8	9	11	11	2	1	50

SELECTING VIABLE WM OPPORTUNITIES

A summarised list of the WM opportunities developed above was prepared. The options were examined as shown in Worksheet 10 to select workable opportunities which could be directly implemented or required further techno-economic feasibility analysis.

WORKSHEET 10
Selecting Workable WM Opportunities

WM Opportunity	Category			
	Section	Directly Implementable	Requires Further Analysis	Reject
SOURCE REDUCTION				
■ **Good housekeeping**				
1. Installation of an appropriate chute to avoid spillage of screening rejects	PP	Yes		
2. Repair of raw material convéyor to prevent uncooked material in potcher (washed pulp)	RM	Yes		
3. Covering of all vibratory screens and chemical dosing tanks by proper lids to prevent spills	PP and SP	Yes		
4. Modification of digestor loading chute to prevent spillage of RM	PP	Yes		
5. Installation of self closing valves for all pressurised raw water hose pipes to minimise water wastage	All	Yes		
6. Avoidance of spillage of lime sludge from hypo-preparation section by proper containment	PP	Yes		
7. Insulation of condensate pipeline	PM	Yes		
8. Insulation of steam pipeline	All	Yes		
9. Insulation of condensate tank	PM	Yes		
10. Insulation of feed water pipeline and tank	U	Yes		
11. Insulation of drum and MG dryer ends	PM		Yes	
12. Insulation of digestor	PP	Yes		
13. Provision of dyes in rag pulp dumping area for proper collection of black liquor	PP	Yes		
14. Provision of shed for raw material storage	RM	Yes		
15. Provision of shed for boiler fuel storage	RM	Yes		
■ **Process change**				
❑ **Input material change**				
1. High yield pulping process using Anthroquinone	PP		Yes	
2. Substitution of cooking chemicals such as alkaline-sodium sulphite	PP		Yes	
3. Bleaching with NaOCl	PP			Yes

WM Opportunity	Category			
	Section	Directly Implementable	Requires Further Analysis	Reject
4. Bleaching with H_2O_2	PP			Yes
5. Bleaching with O_2	PP			Yes
6. Replacement of existing dye with less or non toxic dye	SP		Yes	
7. Usage of dye fixing agent	SP		Yes	
❑ **Better process control**				
1. Optimisation of pulping process for extended cooking with NaOH	PP	Yes		
2. Segregation of initial concentrated black liquor	PP	Yes		
3. Optimising alum dosage	SP	Yes		
4. Installation of consistency indicator in machine chest	PM		Yes	
5. Pulp consistency regulation by installation of additional small capacity dilution line from fan pump pit	PM	Yes		
6. Adjustment of edge cutter to reduce side trimming loss	PM	Yes		
7. Combustion optimisation in boiler	U	Yes		
8. Proper hardness control of boiler feed water	U	Yes		
❑ **Equipment modification**				
1. Replacement of existing press roll (upper one) by MS rolls to reduce press picking	PM		Yes	
2. Modification of existing rifflers for better sand removal from centri cleaner rejects	PM	Yes		
3. Modification of existing raw material dedusting system	PP		Yes	
4. Installation of high velocity hood in paper machines to improve drying efficiency	PM		Yes	
5. Installation of high pressure nozzles, such as fan flat type for felt and wire cleaning	PM		Yes	
6. Use of lower HP motor for induced draft fan	U		Yes	
7. Installation of seperate water tank and pump for side cutting nozzles and breakage due to pressure fluctuation	PM		Yes	
8. Couch pit modification to prevent overflow during paper breakages	PP	Yes		

WM Opportunity	Category			
	Section	Directly Implementable	Requires Further Analysis	Reject
9. Installation of appropriate dust control system in RM cleaning section	RM		Yes	
❑ **Technology change**				
1. Installation of bagasse depither and reusing the fines and pith as fuel in boiler	RM		Yes	
2. Wet cleaning of raw material	RM			Yes
3. Installation of disk mill for removal of fines and dust	RM			Yes
4. Installation of screw press for pulp dewatering	PP		Yes	
5. Installation of countercurrent multistage vacuum washers for pulp washing	PP			Yes
6. Installation of twin-wire belt press for pulp dewatering	PP			Yes
7. Hot stock refining in alkaline condition	PP	Yes		
8. Installation of double felt after couch roll to prevent paper breakage due to fines	PM		Yes	
9. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	PM		Yes	
10. Solar evaporation of concentrated black liquor	PP			Yes
11. Installation of water softener for boiler feed water to reduce blow down and other losses	U		Yes	
■ **Recycling**				
❑ **Onsite recovery/reuse**				
1. Recycle concentrated black liquor in digestor replacing fresh water for maintaining bath ratio	PP	Yes		
2. Chemical recovery from black liquor	PP			Yes
3. Biogas generation from black liquor	PP			Yes
4. Recycle back water to replace fresh water	All	Yes		
5. Recover fibres from centricleaner rejects by installation of high pressure fibre savers	PM	Yes		
6. Recycle/reuse of decker filtrate for pulp for pulp washing and dilution	PP	Yes		

WM Opportunity	Category			
	Section	Directly Implementable	Requires Further Analysis	Reject
7. Recycle fan pump pit overflow to couch pit	PM	Yes		
8. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after filtration through multiplex filters	PM		Yes	
9. Fibre recovery from back water and reuse of filtrate for wire and felt cleaning through installation of micro filters	PM		Yes	
10. Fibre recovery from fibre rich waste streams through sedimentation save all system	All		Yes	
11. Increase heat recovery from fuel gases through economiser and recycle it as hot water in MCD and digestors	U		Yes	
□ Creation of useful by product				
1. Manufacture of lignosulphates from black liquor	PP			Yes
2. Recovery of lignin from black liquor for application as soil conditioner	PP			Yes
■ Product Reformulation				
1. Manufacture of high ash (filler) containing paper (neutral-sizing)	PM			Yes

The WM opportunities are targetted towards:

- Recovery of fibre
- Recycling of back water
- Water conservation
- Recovery of by-products
- Reduction in effluent treatment cost
- Reduction in chemicals consumption
- Energy conservation

TEP IV:
NG WM
JTIONS

The shortlisted opportunities selected on the previous pages which are directly implementable (Category 1), were straightaway taken up for implementation. Those requiring further detailed analysis (Category 2) were studied from the point of view of their feasibility.

TECHNICAL FEASIBILITY ASSESSMENT

The technical feasibility analysis showed that none of the 20 options of Category 2 had any major technical requirements with respect to space, manpower and plant shut-down. The technology is indigenously available for all the options. Similarly, no significant impact was identifiable with regard to product quality, safety, maintenance and operational flexibility. Worksheet 11 was modified to suit the technical feasibility of this mill. The overall technical feasibility was assessed as low, medium or high, depending upon the extent of technical requirements and adverse technical impacts.

WORKSHEET 11
Technical Feasibility Analysis

WM Opportunity Requiring Technical Feasibility Analysis	Technical Requirement		Technical Impact			Overall Technical Feasibility
			Prodn Capacity	Savings in		
	Eqpt	Inst		Energy	Input Mat'l	
1. Insulation of drum and MG dryer ends	No	No	Pos	Pos	None	High
2. High yield pulping process using Anthroquinone	No	No	Pos	None	Neg	Med
3. Substitution of cooking chemicals, such as alkaline-sodium sulphite	No	No	Pos	None	Neg	Med
4. Replacement of existing dye with less or non toxic dye	No	No	None	None	Pos	Med
5. Usage of dye fixing agent	No	No	None	Pos	Neg	Med
6. Installation of consistency indicator in machine chest	No	Yes	Pos	Pos	Pos	High
7. Replacement of existing press roll (upper one) by MS rolls to reduce press picking	Yes	No	Pos	Pos	Pos	High
8. Modification of existing raw material dedusting system	No	No	Pos	Pos	Pos	High
9. Installation of high velocity hood in paper machines to improve drying efficiency	Yes	No	Pos	Pos	None	High
10. Installation of high pressure nozzles, such as fan flat type, for felt and wire cleaning	Yes	No	None	Pos	Pos	High
11. Use of lower HP motor for induced draft fan	Yes	No	None	Pos	None	Med
12. Installation of appropriate dust control system in RM cleaning section	Yes	No	None	Neg	None	Low
13. Installation of bagasse depither and reusing the fines and pith as fuel	Yes	No	Pos	Pos	Pos	High
14. Installation of screw press for pulp dewatering	Yes	No	Pos	Neg	None	Med

WM Opportunity Requiring Analysis	Technical Requirement		Technical Impact			Overall Technical Feasibility
	Eqpt	Inst	Prodn Capacity	Savings in Energy	Savings in Input Mat'l	
15. Installation of double felt after couch roll to prevent paper breakage due to fines	Yes	No	Pos	Pos	Pos	High
16. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	Yes	No	None	Pos	Pos	High
17. Installation of water softener for boiler feed water to reduce blow down and other losses	Yes	No	None	Pos	Neg	Med
18. Recycle fibre lean stream, that is, were pit waste water in cleaning showers after filtration through multiplex filters	Yes	No	None	None	None	High
19. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	Yes	No	Pos	None	Pos	Med
20. Increase heat recovery from gases through economiser and recycle it as hot water in digestors	Yes	No	Pos	None	Pos	Med

ECONOMIC VIABILITY ASSESSMENT

The 20 options mentioned above were subjected to an economic analysis. The detailed investment costs, operating costs and savings were computed. The payback period was worked out for each option. The overall economic viability was assessed as high, medium or low, depending upon the payback period being less than one year, one to three years and more than three years, respectively. The summarised results are given in Worksheet12.

WORKSHEET 12

Economic Viability Analysis

WM Opportunity Requiring Economic Viability Analysis	Investment in Rs	Optg Cost in Rs/yr	Savings Gross in Rs/yr	Savings Net in Rs/yr	Payback in yrs	Overall Economic Viability
	All figures in lakhs					
1. Insulation of drum and MG dryer ends	2.5	Nil	3.5	3.5	< 1	High
2. High yield pulping process using Anthroquinone	Nil	14.0	14.0	Nil	Nil	Low
3. Substitution of cooking chemicals, such as alkaline-sodium sulphite	Nil	Nil	Nil	Nil	Nil	Low
4. Replacement of existing dye with less or non toxic dye	Nil	Nil	Nil	Nil	Nil	Low
5. Usage of dye fixing agent	Nil	Nil	0.2	0.2	< 1	High

WM Opportunity Requiring Economic Viability Analysis	Invest-ment in Rs	Optg Cost in Rs/yr	Savings		Pay-back in yrs	Overall Econ-omic Viability
			Gross in Rs/yr	Net in Rs/yr		
	All figures in lakhs					
6. Installation of consistency indicator in machine chest	1 2	0.1	1.4	1.3	<1	High
7. Replacement of existing press roll (upper one) by MS rolls to reduce press picking	2.2	2.6	6.8	4.2	<1	High
8. Modification of existing raw material dedusting system	0.5	Nil	2.3	2.3	<1	High
9. Installation of high velocity hood in paper machines to improve drying efficiency	32.0	34.0	60.0	26.0	2	Med
10. Installation of high pressure nozzles, such as fan flat type, for felt and wire cleaning	1.0	0.7	1.5	0.8	2	Med
11. Use of lower HP motor for induced draft fan	1.0	Nil	1.0	1.0	<1	High
12. Installation of appropriate dust control system in RM cleaning section	3.0	3.5	Nil	Nil	Nil	Low
13. Installation of bagasse depither and reusing the fines and pith as fuel	3.5	4.5	6.0	1.5	<3	Low
14. Installation of screw press for pulp dewatering	4.5	5.0	8.0	3.0	<2	Low
15. Installation of double felt after couch roll to prevent paper breakage due to fines	3.0	1.2	8.5	7.3	< 1	High
16. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	3.0	0.8	2.0	1.2	< 3	Med
17. Installation of water softener for boiler feed water to reduce blow down and other losses	1.0	0.5	2.5	2.0	<1	High
18. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after filtration through multiplex filters	2.5	1.4	2.2	0.6	> 3	Low
19. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	4.0	0.5	3.0	3.0	< 2	Med
20. Increase heat recovery from flue gases through economiser and recycle it as hot water in digestors	1.5	1.2	5.5	4.3	<1	High

ANALYSING ENVIRONMENTAL ASPECTS

The above options were then subjected to an analysis of their environmental aspects. It was found that the most beneficial environmental impact was in the on water media, in terms of reduction in COD load, TS load and waste water volume. The beneficial impact of the reduction in air pollution load and solid waste generation was relatively small and hence only qualitative assessment was carried out. The overall impact of reducing environmental degradation was assessed as high, medium and low, principally based on reduction in water pollution load (90 per cent weightage), followed by air pollution (9 per cent) and solid waste reduction (1 per cent).

WORKSHEET 13
Analysis of Environmental Aspects

WM Opportunity Requiring Analysis of Environmental Aspects	Redn in Water Pollution Load of		Flow m³/day	Qualitative Assessment of Redn in Pollution		Overall Environmental Assessment
	COD kg/day	TS		Air	Solids	
1. Insulation of drum and MG dryer ends	Nil	Nil	Nil	Yes	No	Low
2. High yield pulping process using Anthroquinone	130	160	80	No	No	Med
3. Substitution of cooking chemicals, such as alkaline-sodium sulphite	Nil	Nil	240	No	No	Low
4. Replacement of existing dye with less or non toxic dye	Low	Toxicity		No	No	Med
5. Usage of dye fixing agent	Low	Toxicity		No	No	Med
6. Installation of consistency indicator in machine chest	75	100	75	No	No	Med
7. Replacement of existing press roll (upper one) by MS rolls to reduce press picking	1450	75	100	No	No	High
8. Modification of existing raw material dedusting system	1500	2100	Nil	No	Yes	High
9. Installation of high velocity hood in paper machines to improve drying efficiency	Nil	Nil	Nil	Yes	No	Low
10. Installation of high pressure nozzles, such as fan flat type, for felt and wire cleaning	Nil	Nil	650	No	No	Low
11. Use of lower HP motor for induced draft fan	Nil	Nil	Nil	No	No	Low
12. Installation of appropriate dust control system in RM cleaning section	Nil	Nil	Nil	Yes	No	Low
13. Installation of bagasse depither and reusing the fines and pith as fuel	150	200	40	No	Yes	Med
14. Installation of screw press for pulp dewatering	6500	7800	900	No	No	High
15. Installation of double felt after couch roll to prevent paper breakage due to fines	55	80	60	No	No	Low
16. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	85	100	Nil	No	No	Low
17. Installation of water softener for boiler feed water to reduce blow down and other losses	Nil	Nil	Nil	No	No	Low

WM Opportunity Requiring Analysis of Environmental Aspects	Redn in Water Pollution Load of		Flow m^3/day	Qualitative Assessment of Redn in Pollution		Overall Environmental Assessment
	COD kg/day	TS		Air	Solids	
18. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after filtration through multiplex filters	220	580	560	No	Yes	High
19. Fibre recovery from fibre rich waste streams through sedimentation saveall system	1950	1100	480	No	No	High
20. Increase heat recovery from fuel gases through economiser and recycle it as hot water in digestors	Nil	Nil	Nil	No	No	Low

SELECT SOLUTIONS FOR IMPLEMENTATION

After completing the feasibility analysis, the above 18 measures had to be prioritised from the point of view of implementation. Due to the companyÕs limited capacity for providing finances, manpower and other resources, it was not possible to take up all the measures for implementation at one go. The measures were, therefore, rated for overall effectiveness. Profits being most important to the company, the economic feasibility had 50 per cent weightage, the remaining being equally divided between technical feasibility and environmental feasibility. A range of points was chosen for each category of feasibility as shown:

Technical Feasibility (25)			Economic Feasibility (50)			Environmental Feasibility (25)		
Low	Medium	High	Low	Medium	High	Low	Medium	High
0-5	6-14	15-25	0-10	11-29	30-50	0-5	6-14	15-25

Within the above range in each category, points were given for each option depending upon a subjective assessment. The respective points for each option, along with overall ranking, is given in Worksheet 14.

WORKSHEET 14
Selecting WM Measures for Implementation

WM Opportunity Requiring Economic Viability Analysis	Feasibility			Total Points (100)	Overall Rank
	Technical (25)	Economic (50)	Environmental (25)		
1. Insulation of drum and MG dryer ends	8	34	2	44	9
2. High yield pulping process using Anthroquinone	8	8	10	26	17
3. Substitution of cooking chemicals, such as alkaline sodium sulphite	12	7	4	23	18

WM Opportunity Requiring Economic Viability Analysis	Feasibility			Total Points (100)	Overall Rank
	Technical (25)	Economic (50)	Environmental (25)		
4. Replacement of existing dye with less or non-toxic dye	7	8	7	22	19
5. Usage of dye fixing agent	8	30	9	47	7
6. Installation of consistency indicator in machine chest	8	15	10	33	15
7. Replacement of existing press roll (upper one) by MS rolls to reduce press picking	17	36	20	75	2
8. Modification of existing raw material dedusting system	22	40	18	80	1
9. Installation of high velocity hood in paper machine to improve drying efficiency	18	20	3	41	11
10. Installation of high pressure nozzles that is, fan flat type, for felt and wire cleaning	16	13	3	32	16
11. Use of lower HP motor for induced draft fan	8	35	2	45	8
12. Installation of appropriate dust control system in BM cleaning section	4	7	4	15	20
13. Installation of bagasse depither and reusing the fines and pith as fuel	16	8	10	34	14
14. Installation of screw press for pulp dewatering	12	25	22	59	4
15. Installation of double felt after couch roll to prevent paper breakage due to fines	22	48	4	74	3
16. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	16	17	3	36	13
17. Installation of water softener for boiler feed water to reduce blow down and other losses	8	32	3	43	10
18. Recycle fibre lean stream, that is, wire pit waste water in cleaning showers after filtration through multiplex filters	23	8	22	53	5
19. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	8	16	16	40	12
20. Increase heat recovery from flue gases through economiser and recycle it as hot water in digestors	8	35	5	48	6

SELECTING SOLUTIONS FOR IMPLEMENTATION

Of all the 64 measures developed in Worksheet 10, the 31 directly implementable measures and 10 (ranking one to 10) from 20 requiring detailed feasibility analysis, were taken up for implementation. The total expenditure required was estimated to be Rs 28.0 lakh and due approvals were taken from the management. The measures were classified based on implementation time requirements as short-term (< 3 months), medium-term (3 months to 1 year) and long-term (> 1 year) subject to availability of funds. The responsibility of implementing the measures was assigned and the progress was to be monitored by the Director himself on monthly basis. Thus an Implementation Plan was prepared as shown in Worksheet 15.

Few options have not been implemented in spite of the fact that they are high in overall ranking. At the same time, some of the options which are low in overall ranking were implemented earlier due to:

- In-house availability of required skills
- Fabrication facilities
- Easy availability of required mechanical equipment, and
- Their having been already implemented and proven in other units

WORKSHEET 15
Implementation Plan

WM Opportunity	Implementation Date	Gains				Remarks
		Economic		Environment		
		Expected	Actual	Expected	Actual	
SHORT-TERM						
1. Installation of an appropriate chute to avoid spillage of screening rejects	Nov '94	Nil	—	Low	—	In absence of direct economic gains, management decided to defer implementation of these three measures
2. Repair of raw material conveyor to prevent uncooked material in potcher (washed pulp)	—	Nil	—	Low	—	
3. Covering of all vibratory screens and chemical dosing tanks by proper lids to prevent spills	—	0.25	—	Low	—	
4. Modification of digestor loading chute to prevent spillage of RM	Sep '93	0.2	0.17	Low	Low	
5. Installation of self closing valves for all pressurised raw water hose pipes to minimise water wastage	Dec '94	0.4	—	Low	—	
6. Avoidance of spillage of lime sludge from hypo-preparation section by proper containment	Aug '93	NQ	NQ	Med	Med	Local supply not available
7. Insulation of condensate pipeline	Aug '93	0.5	0.6	Low	Low	
8. Insulation of steam pipeline	Aug '93	1.0	0.8	Med	Med	
9. Insulation of condensate tank	Aug '93	0.5	0.4	Low	Low	
10. Insulation of feed water pipeline and tank	Sep '93	0.4	0.2	Low	Low	

WM Opportunity	Implementation Date	Gains: Economic Expected	Economic Actual	Environment Expected	Environment Actual	Remarks
11. Insulation of digestor (new)	Mar '94	1.5	1.8	Low	Low	Digestor erected in Jan '94
12. Provision of dykes in rag pulp dumping area for proper collection of black liquor	Dec '94	0.2	—	TS 35 and COD 28T/D	—	Considered as low priority option
13. Provision of shed for raw material storage	Jan '95	1.5	—	Low	—	Storage land procurement delayed
14. Provision of shed for boiler fuel storage	Jan '95	0.7	—	Low	—	
15. Optimisation of pulping process for extended cooking with NaOH	Sep '93	1.2	0.8	Med	Med	
16. Segregation of initial concentrated black liquor	Sep '93	Nq	Nq	Low	Low	
17. Optimising alum dosage	Sep '93	0.1	0.1	Low	Low	
18. Pulp consistency regulation by installation of additional small capacity dilution line from fan pump pit	Aug '93	1.0	0.7	Low	Low	
19. Adjustment of edge cutter to reduce side trimming loss	Aug '93	0.3	0.3	Low	Low	
20. Combustion optimisation in boiler	Aug '93			Low	Low	
21. Proper hardness control of boiler feed water	Aug '93	2.2	1.8	Low	Low	
22. Modification of existing rifflers for better sand removal from centricleaner rejects	Sep '93	0.2	0.1	TS 1 T/D	TS 0.8 T/D	
23. Installation of seperate water tank and pump for side cutting nozzles and breakage due to pressure flictuation	Oct '93	2.0	1.5	Cod 0.3 T/D TS 0.4 T/D	0.3 0.4	
24. Couch pit modification to prevent overflows during paper breakages	Dec '93	8.0	8.3 —	TS 1 T/D	0.8	
25. Hot stock refining in alkaline condition	Dec '93	NQ	NQ	Low	Low	
26. Recycle conc black liquor in digestor replacing fresh water for maintaining bath ratio	Sep '93	1.1	1.2	Low	Low	
27. Recycle back water to replace fresh water				Flow 950	900	
28. Recycle/reuse of decker filtrate for pulp washing and dilution	Oct '93	7.0	6.6	TS 0.5 COD	0.4	
29. Recycle fan pump pit overflow to couch pit				0.4 T/D	0.35	

WM Opportunity	Implementation Date	Gains				Remarks
		Economic		Environment		
		Expected	Actual	Expected	Actual	
30. Recover fibres from centri-cleaner rejects by installation of high pressure fibre savers	Jan '94	1.5	1.3	TS 0.1T/D	0.1	
MEDIUM-TERM						
1. Insulation of drum and MG dryer ends	Feb '95	2.5	—	Low	—	Technique not demonstrated elsewhere
2. High yield pulping process using Anthroquinone	Aug '93	2.5	2.0	Med	Med	Discontinued due to poor chemical quality
3. Substitution of cooking chemicals that is, alkaline-sodium sulphite	Sep '93	Nil	Nil	Low	Low	Discontinued
4. Replacement of existing dye with less or nontoxic dye	Mar '95	Nq	Nq	Reduced Toxicity		Supply not available
5. Usage of dye fixing agent	Mar '94	0.2	0.1	Reduced Toxicity		
6. Installation of consistency indicator in machine chest	Feb '95	0.8	—	COD 75kg/D TS 100kg/D	— —	Delayed due to non-availability of reliable instrument
7. Replacement of existing press (upper one) by MS rolls to reduce press picking	Oct '93	4.2	4.5	COD 0.5 TS 0.1 Flow 100T/D	0.45 100	
8. Modification of existing raw material dedusting system	Oct '93	2.3	2.5	COD 1.5 TS 2.1T/D	1.6 2.2	
9. Installation of high velocity hood in paper machine to improve drying efficiency	Jan '95	26	—	Low	—	Under implementation
10. Installation of high pressure nozzles, that is, fan flat type, for felt and wire cleaning	Jan '95	0.8	—	Flow 650 T/D	—	Reliable supplier not available
11. Use of lower HP motor for induced draft fan	Mar '94	1.0	1.2	Low	Low	
12. Installation of appropriate dust control system in RM cleaning section	Jan '95	Nil	—	Low	—	Financial crisis and low priority
13. Installation of bagasse depither and reusing the fines and pith as fuel	Feb '95	1.5	—	Med	—	Intermittent usage, hence low priority

WM Opportunity	Imple-mentation Date	Gains				Remarks
		Economic		Environment		
		Expected	Actual	Expected	Actual	
14. Installation of screw press for pulp dewatering	Jan '95	3.5	—	COD 6.5T/D TS 7.8 Flow 900T/D	—	Results awaited from other units
15. Installation of double felt after couch roll to prevent paper breakage due to fines	Jan '94	7.3	7.0	Med	Med	
16. Installation of broke pulper in paper machine section to avoid reprocessing cost of pulp	Jan '95	1.2	—	Low	Low	Financial crisis
17. Installation of water softener for boiler feed water to reduce blow down and other losses	Mar '94	2.0	1.8	Low	Low	
18. Recycle fibre lean stream, that is, wire pit wastewater in cleaning showers after filtration through multiplex filters	Apr '94	0.6	0.5	COD 0.2 Flow 560T/D	0.2 500	
19. Fibre recovery from fibre-rich waste streams through sedimentation saveall system	Jan '95	3.0	— 0.9	COD — TS 1.1 Flow 480T/D	— —	Under . Imple-mentation
20. Increase heat recovery from flue gases through economiser and recycle it as hot water in digestors	Apr '94	4.3	4.0	Low	Low	

IMPLEMENTING SOLUTIONS

The above implementation plan formed the basis of implementation. Some of the straight-forward measures were implemented while the plan was being drawn up. The operators were actively involved. Priority status was accorded to the measures having a high rate of return, since the management was able to muster enough financial resources to implement the measures. Thus some of the obvious measures which did not have a good rate of return were left out. Overall, the implementation went on smoothly and, by and large, the targets were adhered to.

MONITORING AND EVALUATING RESULTS

The results of implementation were compared with those estimated during the the planning stage. No significant deviations were recorded.

OVERALL RESULTS

The overall results achieved after the one year implementation period are given in the following table:

Parameters	Before	After	% Change
Production capacity (in TPD)	25	27	+8%
Flow (m^3/T)	170	120	-30%
COD (kg/T)	990	657	-34%
TS (kg/T)	1210	714	-41%
COST (in Rs lakh/yr)			
Effluent treatment	72	55	-25%
Chemical	148	138	-6.5%
Energy	422	401	-5%

Investment on WM measures = Rs 27.5 lakh
Net annual savings = Rs 50.3* lakh
Overall payback = Less than a year

** Including savings in reduced effluent treatment cost*

The results achieved were so attractive and encouraging, that the management got more committed towards WM. It has already taken up some long-term and capital intensive measures for implementation. It has also decided to take up the measures with lower rate of returns. In a rare gesture of environmental consciousness, the management has pooled the entire savings and simultaneously invested in an extensive effluent treatment plant which is now operational and giving excellent results. The Waste Minimisation Programme in this company has now come to stay.

STEP VI: MAINTAINING WASTE MINIMISATION SOLUTION

Sources For Additional Information

This manual is intended to provide the requisite technical assistance to agro residue-based pulp and paper industries in implementing a Waste Minimisation (WM) programme. The six-step methodology proposed in the manual would help in systematically evolving and implementing the programme. We would consider that the manual has fulfilled its purpose if it enables you to effectively launch the WM programme. During the course of WM studies, you may sometimes require additional information. There is some more information available elsewhere and a few reputed publications on WM related to the pulp and paper industry are given below — just in case you need them.

PUBLICATIONS RELATED TO WASTE MINIMISATION IN SMALL PULP AND PAPER MILLS

- *Small Scale Papermaking*, 1989, ILO Geneva Publication. Technology series, Technical Memorandum No 7.

- *Small Pulp and Paper Mills in Developing Countries*, Concept publication, New Delhi, 1991, Berker. J., Ed.

- *Small Paper Mills using Non-wood Fibers in Developing Countries: A Case Study on India* by Jorg Becker and Arthur W. Western. A report for the German Appropriate Technology Exchange (GATE), a division of the German Agency for Technical Cooperation (GTZ).

- *Environmental Protection through Sound Water Management in Pulp and Paper Industry*, publication of Pira International, Leatherhead, England, 1990.

- *Study on Technology Forecasting Assessment Based on Long Range Quantitative Modelling for Indian Paper Industry*, by NPC, India, and CPPRI and Forest Research Institute.

- UNEP — Working Group on CP in Pulp and Paper Industries in the Framework of UNEPIE/PAC Cleaner Production Programme, October 1992. Technical Research Center of Finland, Non-waste Technology Research Unit.

- Assistance to Non-wood-based Pulp and Paper Industry (Project No DG/Ind/89/114/11-01) by CPPRI/UNIDO for GOI.

- *Pulp and Paper Manufacturing: Secondary Fibers and Non-wood Pulping, Vol 3*, published by the Joint Text Book Committee of the Paper Industry; TAPPI, Atlanta, USA (Third Edition).

- Quarterly Journal, Indian Pulp and Paper Technical Association, IPT.

CTAPI/UNIDO

You may even need some external expert assistance to advise and guide you in areas where you don't feel confident and would like to consult professionals from reputed organisations. You may approach the following organisations for expert advice and help:

- Director (Environment Division),
National Productivity Council,
5-6 Institutional Area,
Lodi Road,
New Delhi 110 003.
Telephone: 4611243
Telex: 031-66059 NPC IN
Fax: 99-11-4615002

- Director,
National Environmental,
Engineering Research Institute,
Nehru Marg,
Nagpur.
Telephone: 0712-526071
Telex: 0751-233 NERI IN
Fax: 0712-531529

- Indian Institute of Technology,
Powai, Bombay,
Telephone: 91-22-5792545
Telex: 91-22-5783480

Fax: 011-72313 IITB IN

● Advisor (Environment),
Confederation of Indian Industries,
Institutional Area,
Lodi Road,
New Delhi 110003.
Telex: 031-66655/65401 CII IN
Fax: 011-4633168/4626149

● Director,
Central Pulp & Paper Research Institute,
Institute of Paper Technology — Campus,
Saharanpur 247001.
Telephone: 0132-27227
Telex: 0596-225 CPRI IN

● Director,
Indian Pulp & Paper,
Technology Technical Association
(IPPTA),
Institute of Paper Technology — Campus,
Saharanpur 247001.
Telephone: 0132-26345
Telex: 0596-225 CPRI IN

● Secretary,
Indian Agro Paper Mills Association,
701, Pragati Tower-26,
Rajendra Place,
New Delhi 110008.
Telephone: 5712378/5712112
Telex: 031-65886 SIVA IN

● United Nations Environment Programme,
Industry and Environment Tour Mirabonu,
39-43, Andre Citroen,
75 739 Paris Cedex 15, France.
Telephone: 33-1-44371450
Telex: 204997 .F
Fax: 33-1-44371474

● United Nations Industrial Development Organisation,
Industrial Development Officer,
Pulp & Paper,
PO Box 400,
Vienna International Center,
A-1400 Vienna, Austria.
Telephone: 211-31-3844
Telex: 135612
Fax: 232156s

So don't wait! Let's start.
Already, in the last 90 minutes, while you were absorbed in this manual, a lot of money has flowed down the drain.

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WASTE MINIMISATION IS THE SURER AND MORE SUSTAINABLE WAY TO PROFITS.

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Technical Manual Series:

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III. Waste Minimisation in Textile Dyeing and Printing Industries

Series II. and III. are under print at present

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