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Annex 4

INDUSTRIAL POLLUTION REDUCTION PROGRAMME
DG/SRL/91/019

OPPORTUNITIES FOR WASTE MINIMISATION
IN THE TEXTILE PROCESSING INDUSTRY IN SRI LANKA

WASTE AUDIT

SASCONS KNITTING COMPANY PVT LTD

CEYLON INSTITUTE OF SCIENTIFIC AND INDUSTRIAL RESEARCH
363, Bauddhaloka Mawatha, Colombo 7, SRI LANKA

Table of Contents

SUMMARY

Sascon Knitting (Pvt) Ltd., processes knitted fabric. It is situated in a mixed residential area in the North Colombo Urban area, which is moderately sensitive to environmental issues. Discharge of untreated coloured effluent is a major adverse environmental issue for this industry.
The efficiency data obtained for this industry are given below.

(a) Water consumption - 145 l per kg of fabric processed (from which 30% is the undefined water consumption)
(b) Fuel consumption - 1.9 l per kg of fabric processed
(c) Theoretical steam utilization is 50% of the steam produced.

Considering the organic load of the effluent discharged, the fabric cleaning processes of scouring and bleaching generates only 32% of the total COD and the balance 68% of the organic load is due to the wastage of materials utilised in the processing.

The most expensive waste streams are the cotton and polyester dyeing effluent streams. Waste streams from reduction clearing, scouring and soaping also exceed the average value of waste stream cost.

27 waste minimization options were identified and cost benefit analysis done for 10 options identified to be of high priority, by the industry. Conclusions from the cost benefit analysis are summarised in the table below. Of these options only the chemical substitution option has been implemented at present. In addition, one of the other 17 options viz. Power factor improvement has also been implemented.

Option	Investment (Rs.)		Operating cost per year Rs.		Net saving per year Rs.		Pay back period		Environmental benefit
	Exp.	Act.	Exp.	Act.	Exp.	Act.	Exp.	Act.	
1) Lowering of jet liquor ratio from 1:8 to 1:7	Nil	-	Nil	=	69,600	-	N/A	-	2% reduction in effluent vol., 1% in fuel consn.
2) Chemical substitution:- Acetic acid NaHSO$_4$	Nil	Nil	Nil	-	180,960	177,360	N/A	N/A	9% reduction in organic load
3) Lagging of steam lines	10,700	-	2,247	-	12,313	-	10 months	-	0.4% reduction in fuel consn.
4) Lagging of boiler surface	13,420	-	2,818	-	9,461	-	17 months	-	0.3% reduction in fuel consn.
5) Neutralization of alkaline effluent using flue gas	166,200	-	175,420	-	232,580	-	9 months	-	reduction in acidic emissions
6) Heat recovery for Hot effluent	628,000	-	203,080	-	92,920	-	6 years	-	7% reduction in fuel consn.
7) Condensate recovery	34,300	-	7,200	-	246,720	-	2 months	-	3% reduction in effluent vol., 2.5 in fuel consn.,
8) Installation of press button switches	300	-	-	-	10,800	-	N/A	-	-
9) Lagging of jets	350,000	-	-	-	237,125	-	17 months	-	8% reduction in fuel consn.
10) Boiler tuning	-	-	-	-	124,750	-	N/A	-	3% reduction in fuel consn.
11) Power factor improvement	-	340,000	-	71,400	-	304,560	-	17 mths	saving in power consumption

* reduction in fuel consumption results in reduction of atmospheric emissions
N/A Not applicable vol. volume consn. consumption Exp. Expected Act. Actualmths months

List of Abbreviations

COD	Chemical Oxygen Demand
°C	°Centigrade
h	hour
J	joule
°K	°Kelvin
km	kilometre
kg	kilogram
kWh	kilo Watt hour
l	litre
min	minute
m	meter
mg	milligram
N	Newton
Ref	Reference
s	second
y	year
w/w	weight/weight
M	Month
T	Tonnes
d	day
g	gram

PART 1 - ENVIRONMENTAL STATUS

SASCON KNITTING COMPANY (PVT) LTD

1.0 Introduction

Sascon Knitting (Pvt) Ltd is a textile processing industry carrying out knitting, dyeing and printing of cotton, polyester and polyester cotton fabrics.

1.1 Organisational chart : Attached (Annex A)

1.2 Ownership : Mr. Y. Gnanam

1.3 Contact persons : Messers. S. Selladoray, JATP Jayasinghe, S Ubesekera.

2.0 Site details

2.1 Location No. 76/2, Minuwangoda Road, Ekala (Annex B)

2.2 Physical Descriptions

(i) Area : 19,273 m^2

(ii) Topography : Flat land

(iii) Factory layout : Attached (Annex C)

(iv) Sealed surface : about 20 %

(v) Depth to groundwater : 2 m

(vi) Surface water bodies : River 1 km from factory

(vii) Surface drainage channels : All floor drains are connected to a main drain and then to road drain

2.3 Current use

(i) Processes : Knitting, dyeing, finishing and garment manufacture

(ii) Products : Dyed and printed fabrics and garments

(iii) Raw materials : Yarn, dyes and chemicals

(iv) Major chemicals : List attached (Annex D)

(v) Energy source : Furnace oil and electricity

2.4 Site drainage (type & discharge points)

(i) Process effluent : Through open drains to adjoining lands

(ii) Domestic waste water : Through open drains to adjoining lands

(iii) Storm water : Through open drains to adjoining lands

(iv) Toilet effluent : Through pipe drain to septic tanks

3.0 Environmental Emissions

3.1 Atmospheric emissions : flue gas from boilers, exhaust from dryers and stentors.

3.2 Aqueous discharge points : Effluents from bleaching and dyeing.

3.3 Solid waste : Paper and empty chemical packaging materials, fabric off cuts

4.0 Site history and Neighbouring sites

4.1 History of the site

(i) Start date : Nov-80

(ii) Former use : Coconut estate

4.2 Current and former use of neighbouring sites

(i) Northern : Coconut estate

(ii) Southern : Garment industry

(iii) Western : Village

(iv) Eastern : Industry (Stores)

4.3 Significant spills : None

5.0 Environmental Receptors

5.1 Abstraction points

(i) Dug wells : None

(ii) Tube wells : 6 tube wells within the premises (2 not in use)

(iii) Surface water : None

5.2 Sensitive neighbours within 2 km

(i) Residence : Western side

(ii) Hospitals : None

(iii) Schools : Yes

(iv) Others : Industries

5.3 Protected Natural Habitats :

5.4 Water Bodies

(i) Surface : None

(ii) Sub-surface : None

6.0 Solid Waste Issues

(i) Type and disposal method : Offcuts-sold; Cardboard and polythene-partly sold and some burnt

7.0 Environment Licence issues

7.1 Current status : Not obtained

7.2 Current compliance issues : Non-conformance of effluent discharge to standards

PART 2 - WASTE AUDIT

1.0 General Information

WORKSHEET 1	
Name of the Company : SASCON KNITTING CO. (PVT) LTD	
Waste Minimisation Team	
Name	**Designation**
1. Mr. H.N. Gunadasa	Manager, Environmental Technology Group, CISIR
2. Mrs. S. Wickramaratne	Research Officer, CISIR
3. Mrs. K.D. Attanayake	Senior Technical Officer, CISIR
4. Miss. S. De Costa	Research Officer, CISIR
5. Mr. R. Ilangkumaran	Research Officer, CISIR
6. Mr. K. Pavanandan	Research Officer, CISIR
7. Mr. Sanath Ubeysekera	Dye Manager, Sascon
8. Mr. J.A.T.P.Jayasinghe	Engineer, Sascon
A. **Major Raw Materials Consumption**	
1) Yarn	
a) 48:52 Polyester cotton	272,700 kg/y *
b) Cotton	7104 kg/y *
c) Polyester viscose	2304 kg/y *
2) Chemicals	
a) Process chemicals	74,700 kg/y *
b) Dye	
Reactive	2916 kg/y *
Disperse	840 kg/y *
c) Raw water treatment chemicals	2496 kg/y *
Boiler water treatment chemicals	375 kg/y *
B. **Energy Consumption**	
a) Electrical energy	721,200 kWh/y*
b) Fuel for boilers	576,000 l/y*
C. **Water Consumption**	52,800 m^3 /y*

D.	**Installed Capacity**	
	High pressure Jet No. 4	500 kg/Batch
	High pressure Jet No. 3	300 kg/Batch
	High pressure Jet No. 1	100 kg/Batch
	Low pressure Jet No. 3	600 kg/Batch
	Low pressure Jet No. 1	70 kg/Batch
	Slitting machine	20 m/min
	Winches (2 Nos)	150 kg/Batch
	Hydro extractor (2 Nos)	75-80 kg/Batch
	Stentor - Heat setting/Finishing	8 m/min
	Vertical dryer	1.6 m/min
	Actual Production (March 95)	
	Grey production	23,265 kg/month
	Dyeing & finishing	30,291 kg/month
	Garment	147,614 Pieces/month
E.	**Type of Effluent Treatment**	No treatment
F.	**Any Other Relevant Information :** The organization has a total employment of 630, of which 530 are factory workers and the rest comprise of management and support staff. The company has a single shift per day.	

* Annual values were estimated from average monthly figures provided by client.

2.0 Availability of Information

Available information was very limited. The team had to collect most of the information first hand. The information required for the material and water balances was collected and the balances are presented in sections 5.0 and 6.0. In the absence of measurement facilities and emission records, it was found to be difficult to make an energy balance.

WORKSHEET 2		
Information	**Availability**	**Remarks**
Process flow diagram	Available	Not satisfactory
Material Balance	Not available	Only daily material consumption data available
Energy balance	Not available	Monthly electricity bills available
Water balance	Not available	No data available
Plant layout	Available	Satisfactory
Waste analysis	Not available	Has not been carried out regularly
Emission records	Not available	No provision for recording
Production log sheets	Available	Satisfactory
Maintenance log sheets	Not available	

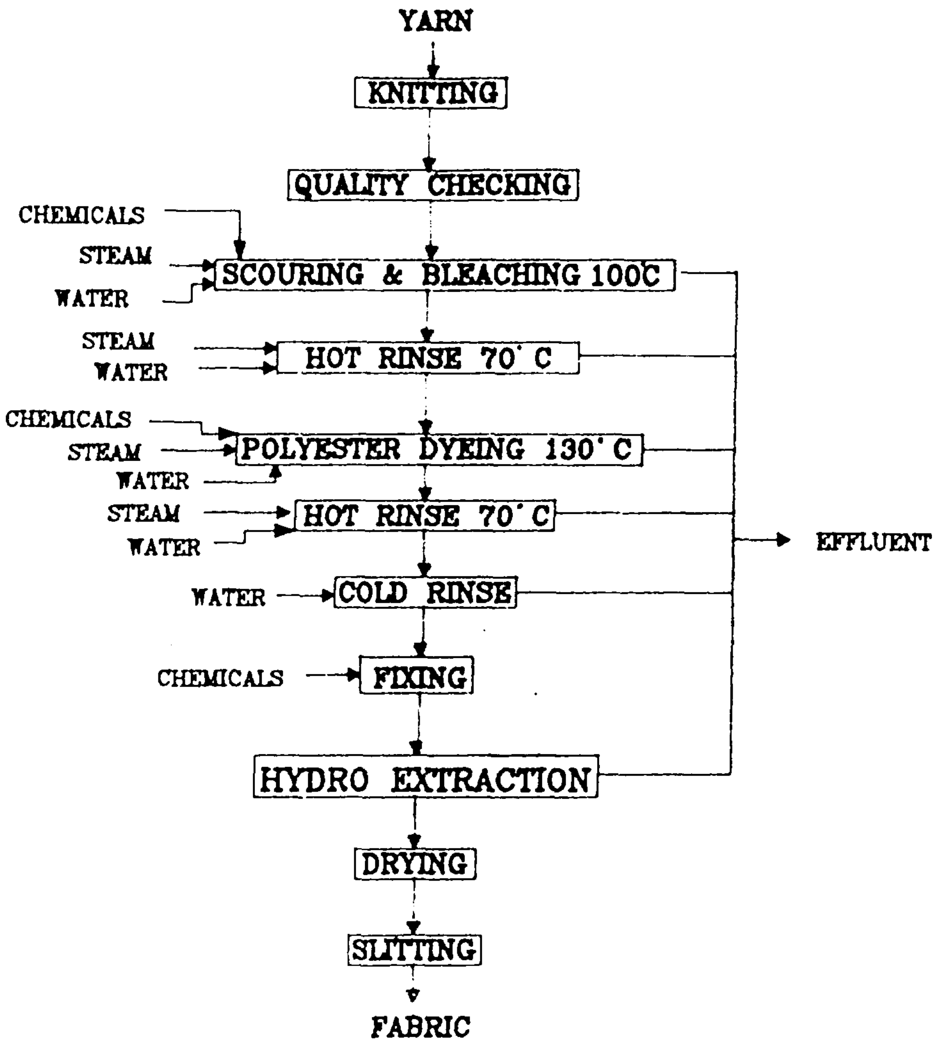
3.0 Process Flow Diagrams

There are a number of processes available for dyeing of fabrics. These depend entirely on the customer's requirements. The number of rinsing steps and pretreatment required will also vary with the shade of dye and quality of grey fabric. The dyeing process also varies with the type of machine used. (i.e. Jet dyeing, winch dyeing etc.) In this industry dyeing is predominantly carried out in jets. The processes given in the worksheets 3.1 to 3.5 are the most commonly used dyeing processes in the factory.

WORKSHEET 3.1

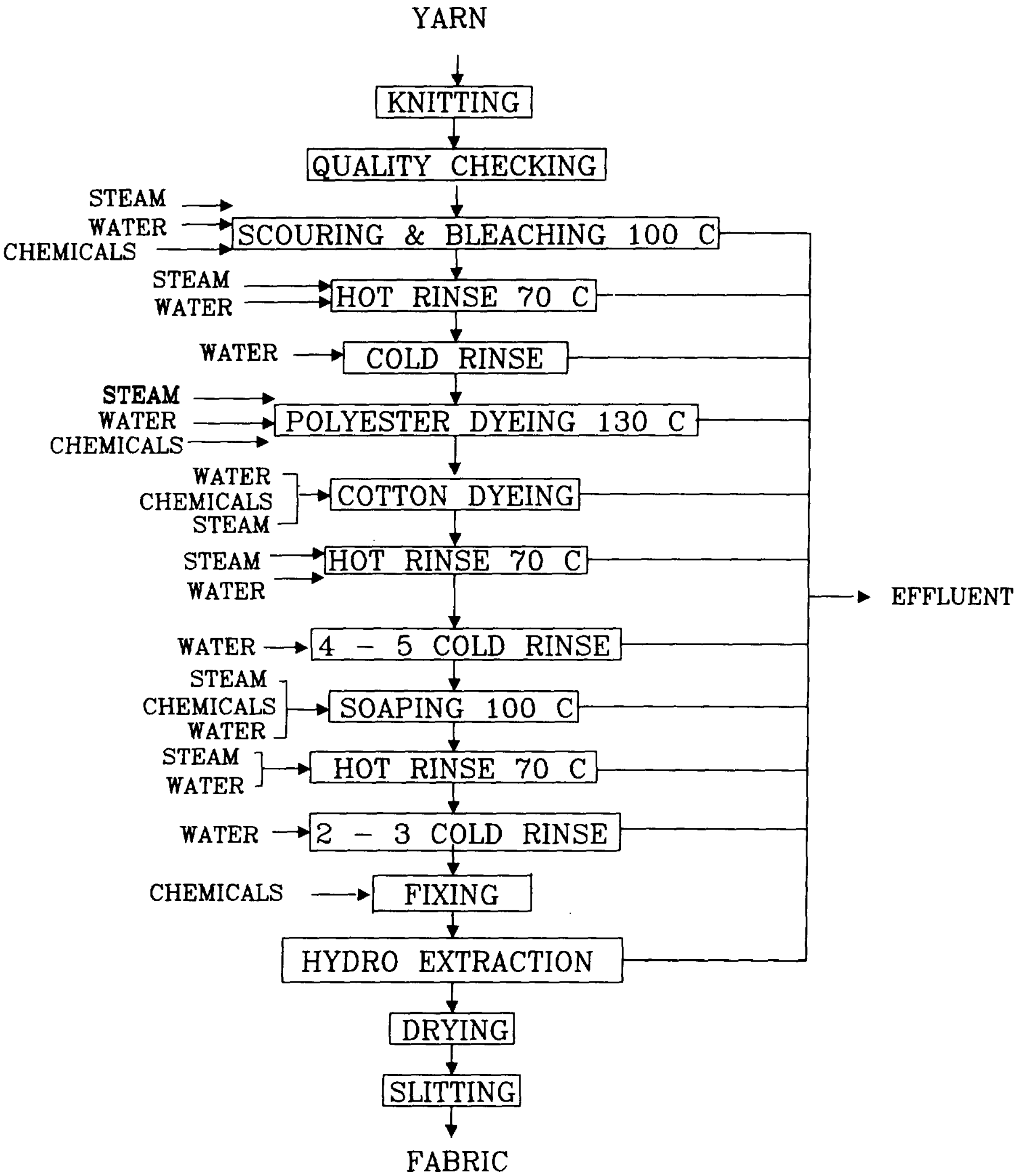
PROCESS FLOW DIAGRAM

BLENDED FABRIC – LIGHT SHADE



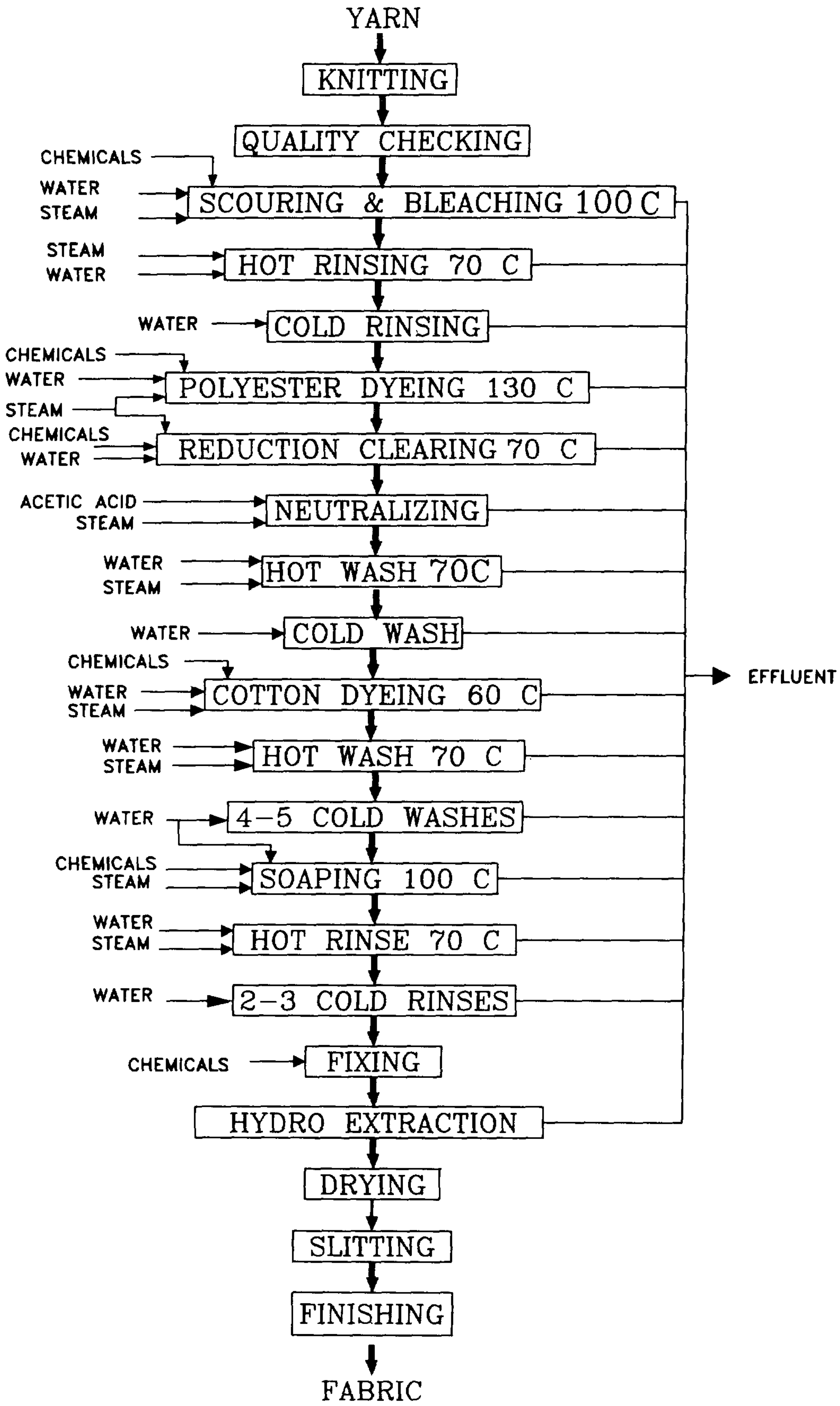
WORKSHEET 3.2

PROCESS FLOW DIAGRAM
BLENDED FABRIC – MEDIUM SHADES



WORKSHEET 3.3

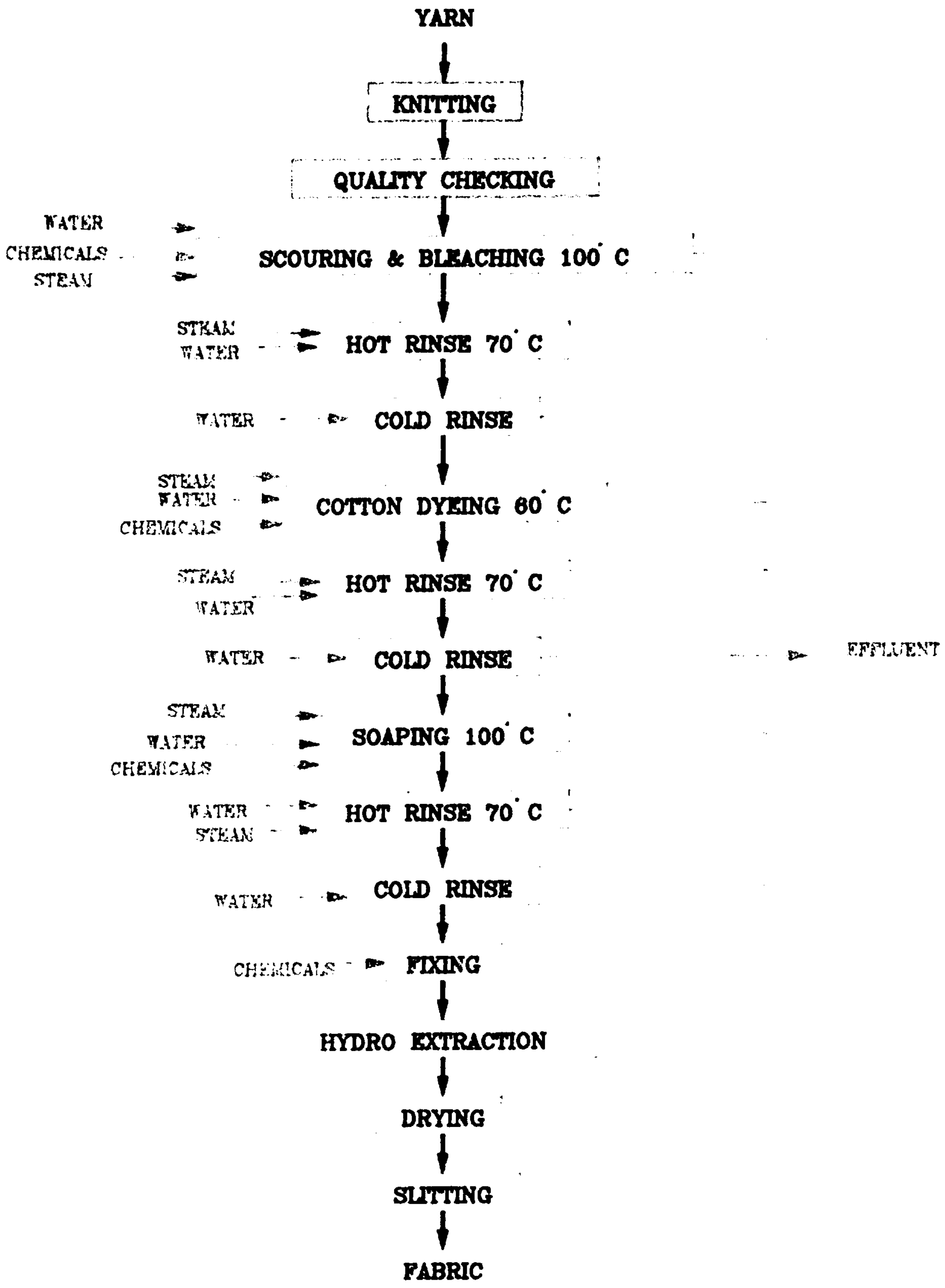
PROCESS FLOW DIAGRAM
BLENDED FABRIC – DARK SHADE



WORKSHEET 3.4

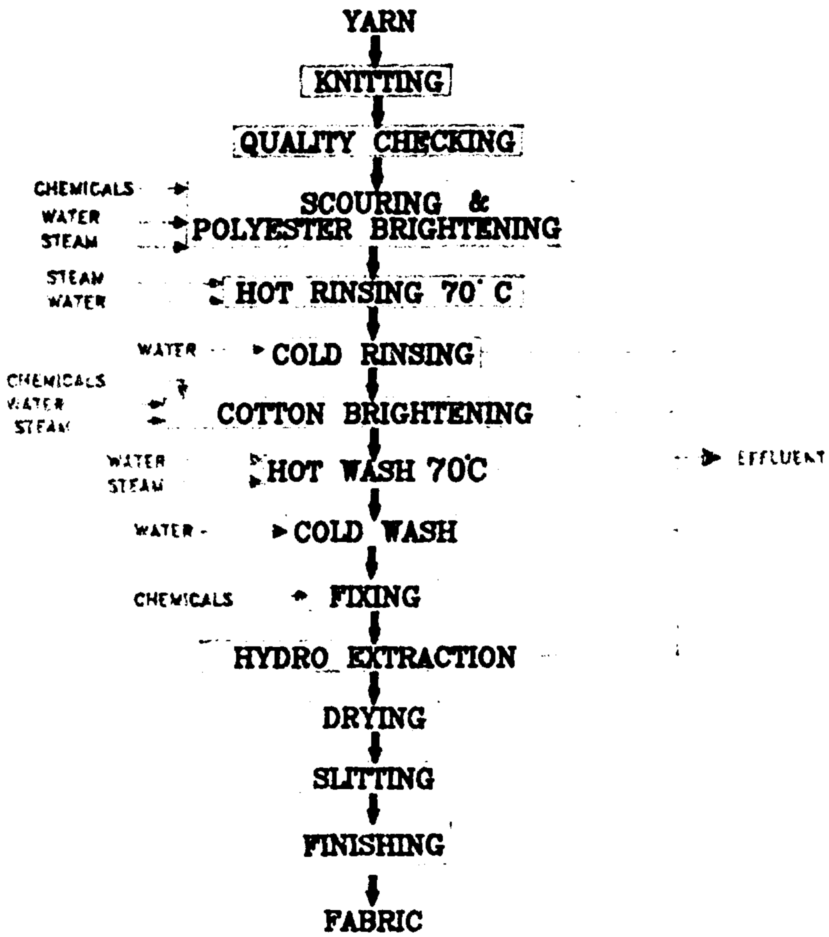
PROCESS FLOW DIAGRAM

COTTON



WORKSHEET 3.5

PROCESS FLOW DIAGRAM
OPTICAL BRIGHTENING



4.0 Housekeeping status

The Waste audit team had a detailed look at the plant and identified housekeeping lapses as described in Worksheet 4. Some of the losses caused by lapses in housekeeping cannot be quantified financially. However they would result in decreased productivity due to discomfort of the workers.

WORKSHEET 4 **GENERAL REMARKS RELATED TO HOUSEKEEPING**	
Sections	**Lapses in Housekeeping**
GENERAL	Minor steam leakages from valves and joints have not been rectified Temperature inside the factory is high due to unlagged hot surfaces and hot discharges Steam is emitted from the drain around the processing area due to hot discharges entering directly into the drain

5.0 Material Balance

Material balance presented in Worksheet 5 was carried out using actual material consumption figures for the month of March 1995 (Annexure E), and calculated values of water and steam consumptions based on liquor ratio and heat requirement respectively. (Assumptions and other calculation details are given below the worksheet)

WORKSHEET 5

Unit operation	Input material		Output material(Quantity in kg)		
			Product	Waste stream	
	Name	Quantity (kg)		Liquid	Solid/ Gaseous
Scouring/ bleaching	Polyester blend	25,335	¶24,575 (15,521)	¶760	Nil
	Cotton	431	¶401 (253)	¶30	
	Water	206,980		191,206	
	Steam	31,974		*31,974	
	Anti-foam	43		43	
	Caustic	112		112	
	Detergent	166		166	
	H_2O_2	328		***328	
	Stabiliser	104		104	
Polyester dyeing	Polyester blend	§24,575 (15,521)	§24,575 (15,521)		Nil
	Water	202,680		202,680	
	Steam	46,328		*46,328	
	Acetic acid	145		145	
	Ammonium sulfate	208		208	
	Disperser	62		62	
	Antifoam 1	42		42	
	Anticrease	207		207	
	Reactive dye	186	130	56	
	Disperse dye	54	51	3	
Reduction clearing	Polyester blend	§5,095 (3,217)	§5,095 (3,217)		Nil
	Water	40,763		40,763	
	Steam	3,733		3733	
	Caustic	41		41	
	Antifoam 2	16		16	
	Detergent	20		20	
	Hydros	122		122	

Neutralising	Polyester blend	§5,095	§5,095		Nil
		(3,217)	(3,217)		
	Water	40,763		40,763	
	Acetic acid	24		24	
Soaping	Polyester blend	§6,459	§6,459		Nil
		(4,079)	(4,079)		
	Cotton	§401	§401		
		(253)	(253)		
	Water	55,982		55,982	
	Steam	8,555		*8,555	
	Soaping agent	46		46	
	Anti foam 1	11		11	
Cotton dyeing	Cotton	§401	§401		Nil
		(253)	(253)		
	Polyester blend	§6,459	§6,459		
		(4,079)	(4,079)		
	Water	55,982		55,982	
	Steam	4,076		*4,076	
	Na_2SO_4	3,441		3,441	
	Na_2CO_3	398		398	
	Anticrease	57		57	
	Antifoam 2	12		12	
	Reactive dye	52	36	16	
	Disperse dye	16	15	1	
Hot washing	Water	510,722		510,722	Nil
	Steam	42,250		*42,250	
Cold washing	Water	686,986		686,986	Nil
Fixing	Fabric	§24,976	§24,976	Nil	Nil
		(15,774)	(15,774)		
	Chemical	N/A			
Hydro extraction	Fabric	§24,976	24,976		Nil
		(15,774)	(5,189)		
	Water			10,585	
Drying	Fabric	24,976	24,829		
		(5,189)	(5,189)		♪5,450
	Steam	6,910		*6,910	

Total volume of process effluent =1904 m^3/m.

( ) % moisture associated with fabric

* The recyclable steam condensate is presently discharged into the drainage system.
♪ Fabric moisture evaporates into atmosphere during the drying process.
** Water is absorbed by dry fabric during the first wet process.
§ Weight of the fabric (Moisture content 7 % weight/ weight)
*** Deactivated H_2O_2 (H_2O_2 is reduced and is discharged as water)
(Most of the other chemicals in the waste stream too may not be in their original form)
¶ Weight loss occurs from the fabric to the liquid stream during scouring.
N/A Data Not Available
Steam consumption - Calculated process stepwise - 147 m^3
- Calculated using boiler fuel consumption figure - 297 m^3

ASSUMPTIONS

1) Fabric undergoes 3 - 7 % weight reduction in scouring process.
Therefore 3% reduction in polyester blend and 7% reduction in cotton fabric is assumed. [Ref 1]
2) Moisture content of the fabric in weight basis (wet)
   - Grey fabric - 7%
   - After wet processing - 43%
   - After hydro extractor - 23%
   - After drying - 6%

   Figures are based on analytical results obtained for knitted fabric.
3) Reactive dyes and disperse dyes fixation was assumed to be 70% and 95% respectively. [Ref 2]. For all other chemicals it was assumed that there is no fixation.

CALCULATIONS

1) Weight reduction of fabric

Raw weight of fabric	= m_1 cotton
	= m_2 polyester blend
Weight after scouring	=0.93 m_1 for cotton
	=0.97 m_2 for polyester blend

2) Moisture absorbed into wet fabric

Moisture content of raw fabric	= $0.07(m_1+m_2)$
Moisture absorbed into wet fabric	=(total moisture in wet fabric - moisture content of raw fabric)
Dry weight of fabric after weight reduction	$=(0.93m_1 + 0.97m_2)0.93$
Total moisture in wet fabric after weight reduction	$=0.43x0.93(0.93m_1 + 0.97m_2)/(1-0.43)$
Moisture content in raw fabric after weight reduction	$=0.07x0.93(0.93m_1 + 0.97m_2)/(1-0.07)$
Moisture absorbed into fabric	$=(0.59m_1 + 0.61m_2)$

3) Water consumption

Water consumption for operation steps other than rinsing steps is calculated using liquor ratio of fabric. Liquor ratio for polyester blend and cotton are 1:8 and 1:10 respectively.
Liquor ratio = weight of fabric in kg /water consumption in kg (or litres)

Water consumption figure for rinsing is calculated using number of rinses and production figures for light, medium and dark shades and cotton and the liquor ratios.

4) Steam consumption

Is calculated using heat requirement for each process to achieve required temperature and properties of boiler steam.

Steam consumed = $(cp_f \, x m_f + cp_l \, x m_l)(T_o - T_r) / h_f$
cp_f, cp_l; specific heat of fabric & liquid.
cp_f=1.4 kJ/kg°K cp_l=4.2 kJ/kg°K [Ref 3]
m_f, m_l; mass of fabric & liquid
T_o, T_r; operating & room temperature T_r=30°C
h_f ; Latent heat of steam h_f=2000 kJ/kg

Heat absorbed into the machine and other losses are neglected.

5) Chemical consumption

Chemical consumed
= (consumption according to the recipe) (quantity of fabric) (Liquor ratio)
eg; for scouring process in High Pressure jet 4 for polyester blend
Caustic concentration 0.5 g / l
Liquor ratio 1:8
Fabric weight 25,335 kg / month
Caustic consumed = (0.5x25,335x8) /1000 kg

It is assumed that quantity of chemicals retained on the fabric is negligible

Recipes are given in Annexure F.

6) Loss of dyes

Quantity of dye going out with effluent = (quantity of dyes / month) (100 - % fixation)
Reactive dyes 70 % fixation
Disperse dyes 95 % fixation [Ref 2].

7) **Fabric weight after hydro extractor - m_2**

m_1 - wet weight of fabric put into hydro extractor
m_2 - weight after hydro extractor
m - dry weight of fabric

$m = (1 - 0.43)m_1 = 0.57\ m_1$
$= (1 - 0.23)m_2 = 0.77\ m_2$
$m_2 = (0.57 / 0.77)\ m_1$
$= 0.74\ m_1$

8) **Fabric weight after drying - m_3**

$m = 0.77\ m_2$
$m = (1-0.06)m_3$
$= 0.94\ m_3$
$m_3 = (0.77 / 0.94)m_2$
$= 0.82\ m_2$

6.0 Total Water Balance

A breakdown for water consumption for each unit operation using production figures for March 1995, was calculated on a theoretical basis, and is presented in Worksheet 6. This enabled the determination of the high water consuming activities and the undefined losses.

WORKSHEET 6.0				
Operation	**Product kg/month**	**Liquor ratio**	**Estimated water consump. (m^3)**	**Percentage**
Scouring				
Cotton	430	10	4.3	
Blend	25,335	8	203	
Total	25,765		207.3	4.71
Polyester dyeing				
Blend	25,335	8	203	4.61
Cotton Dyeing				
Cotton	430	10	4.3	
Blend	6,720	8	51.6	
Total	7,150		55.9	1.27
Reduction clearing				
Blend	5,096	8	41	0.93
Neutralizing				
Blend	5,096	8	41	0.93
Soaping				
Cotton	430	10	4.3	
Blend	6,719	8	51.6	
Total	7,150		55.9	1.27
Hot washing				
Cotton (3 rinses)	430	10	13	
Blend	25,335	8	498	
Total	25,765		511	11.61
Cold washing				
Cotton (7 rinses)	430	10	30	
Blend	25,335	8	657	
Total	25,765		687	15.61
Boilers			295	6.7
Domestic usage			993.7	22.58
Total estimated water consumption			3,090.8	70.24

Actual water consumption			4,400	
Undefined water consumption			1,309	29.75

* Actual water consumption given by client is estimated from water pump capacity.

The factory does not have any provision to measure water consumption as well as effluent volume.
The 29 % undefined water consumption may be attributed to floor washing, leakage or additional rinses.

* Boiler water consumption was estimated utilizing figures available for fuel oil consumption assuming boiler efficiency 70% & calorific value of oil 40,500 kJ/l

* Cooling water could not be estimated as measurements could not be carried out. It is being re-cycled in a closed system.

* Water consumption for processing was estimated using liquor ratio of fabric.
Water consumption = (number of discharges / month) (Liquor ratio x fabric weight/batch) for a machine.

* Domestic water comsumption is estimated from usage per head
(workers 530, working days for the month 25, usage per head 75 l)
(530 x 25 x 75) = 993,750 l

7.A COD Analysis of effluent

COD analysis was carried out for each discharge from all machines operated on one day to obtain an understanding of the discharges that contribute the highest to the pollution load. Results are presented in Worksheet 7A. COD values are co-related with volume of water discharged/ batch. The COD analysis was carried out by Central Environmental Authority (CEA) laboratory staff on 17 . 10. 1995.

Average COD of effluent, based on these values, considering process effluent only is 1015 mg/l.
Average COD of effluent, considering other waste water discharged too (assuming their COD is negligible) is 440 mg/l.

WORKSHEET 7.A				
STREAM	COD mg/l	WATER l/batch	COD kg/batch	COD%
Dyeing of Polyester (High Pressure Jet 1) - Dark shade				
Scouring/Bleaching	2290	800	1.83	4.22
Hot Wash	660	800	0.53	1.22
Cold wash	114	800	0.09	0.21
Polyester Dye	1390	800	1.11	2.56
Reduction clearing	700	800	0.56	1.29
Neutralising	610	800	0.49	1.12
Cold wash	132	800	0.11	0.24
Cotton dye	610	800	0.49	1.12
Cold wash	38	800	0.03	0.07
Soaping	630	800	0.50	1.16
Dyeing Polyester (High Pressure Jet 4) - light shade				
Machine washing	1280	4000	5.12	11.79
Scouring	1960	4000	7.84	18.05
Hot Wash	140	4000	0.56	1.29
Polyester Dyeing	1760	4000	7.04	16.21
Hot Wash	1063	4000	4.25	9.79
Cold wash	660	4000	2.64	6.08
Optical brightening (Low Pressure Jet 3)				
Scouring+ Polyester brightener	2350	1800	4.23	9.74
Hot Wash	1530	1800	2.75	6.34
Cold wash	550	1800	0.99	2.28
Cotton brightener	710	1800	1.28	2.94
Hot Wash	370	1800	0.67	1.53
Cold wash	180	1800	0.32	0.75
TOTAL	19727	42800	43.43	100

7.B WASTE AND EMISSIONS COST

Material consumption figures from the material and water balances (Worksheets 5 & 6) and COD analysis data presented in Worksheet 7A, were utilised to estimate the amount of waste generated from each unit operation and its cost. This is presented in Worksheet 7B.

WORKSHEET 7.B				
UNIT OPERATIONS	**COST COMPONENT**	**QUANTITY (kg/MONTH)**	**UNIT COST (Rs/kg)**	**TOTAL COST (Rs/MONTH)**
SCOURING	Chemicals	753	99.76	75,120
	Steam***	31,914	1.15	36,700
	Water	206,980	0.00827	1,710
	COD removal**	390	30	11,700
	Total Cost Assigned to Waste Stream **Cost assigned per m³ effluent**			**125,230** **525**
POLYESTER DYEING	Acetic Acid*	145	85	12,325
	Chemicals	519	165	85,635
	Reactive Dye	56	1,505	84,280
	Disperse Dye	2.7	1,328	35,855
	Steam***	46,328	1.15	53,275
	Water	202,680	0.00827	1,675
	COD removal**	320	30	9,600
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**282,645** **1,135**
REDUCTION CLEARING	$NaHSO_4$*	122	50	6,100
	Chemicals	77	209	16,095
	Steam***	3,733	1.15	4,295
	Water	40,763	0.00827	335
	COD removal**	29	30	870
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**27,695** **620**
NEUTRALIZING	Acetic Acid*	24	85	2,040
	Water	40,763	0.00827	335
	COD removal**	25	30	750
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**3,125** **75**

SOAPING	Chemicals	57	314.5	17,925
	Steam***	8,555	1.15	9,840
	Water	55982	0.00827	460
	COD removal**	37	30	1,110
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**29,335** **450**
COTTON DYEING	Chemicals	3,808	21.46	81,720
	Steam***	4,076	1.15	4,685
	Water	55,982	0.00827	463
	Reactive Dye	16	1,505	24,080
	Disperse Dye	1	1,328	1,330
	COD removal**	38	30	1,140
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**113,420** **1,890**
HOT WASH	Water	510,722	0.00827	4,225
	Steam***	42,250	1.15	48,590
	COD removal**	437	30	13,110
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**65,925** **120**
COLD WASH	Water	686,986	0.00827	5,680
	COD removal**	60	30	1,800
	Total Cost Assigned to Waste Stream **Cost assigned per m³ of effluent**			**7,480** **10**
COMPOSITE EFFLUENT	**Total Cost Assigned to Waste Stream** **Total waste stream** **Cost assigned per m³ of effluent**			**654,855** **1940 m³** **340**

* Cost component has been given separately for these two chemicals as substition of these two have been suggested (Section 8.0). Acetic acid can be replaced by Formic acid and $NaHSO_4$ can be replaced by Diosyn HF.

** Unit cost of treatment includes both chemical and biological treatment cost, based on the COD load of the effluent. (Details are given in Annexure G)

*** Details of steam cost calculation is given in Annexure H.
Utility costs and utility costs/kg fabric are given in Annexure I.

8.0 Waste minimisation options

Waste minimisation options were identified by the waste audit team based mainly on observations made during visits to the industry. Losses identified from the material and water balances helped in identifiying some of the options. The options identified together with other details are presented in Worksheet 8.

Actions were identified for each option, which would help in assessing the costs and benefits of implementing the option. It is anticipated that these actions would help the industrialist subsequently in determining the suitability of implementation. The time required to implement the option and the cost also were noted, as it is these features, that would help in motivating the industry in its implementation/nonimplementation. The priority that would be given for implementing each option was determined in discussion with the management of the industry.

WORKSHEET 8								
Process unit	**Unit operation**	**Waste Minimisation (WM) option**	**Actions to assess WM options**	**Category**	**Effect**	**Priority**	**Timing**	**Cost**
Jet Dyer	All operations	1. Heat recovery unit for discharges	- Determine the temperature of discharge - Estimate cost of installing a H.R.U.	RR	ES WM	5	MT	H
	All operations	2. Substitute chemicals giving high COD & BOD loads * $NaHSO_4$ substitution * Acetic acid substitution * Dye substitution	- Determine the chemicals giving high Pollutant contribution - Determine pollution contribution from substitutes & cost of treatment - Carry out Cost Benefit Analysis	MC	PR CR	5	ST	L
	Dyeing	3. Select dyes which exhaust with minimum salt	- Determine the specific dyes with reduced salt concentration - Compare the cost	MC	PR WM	2	LT	M
	Dyeing	4. Employ Rapid Inverse Dyeing	- Carry out trials - Estimate savings in chemicals, Water, Energy	TC	WM CR	7	ST	M
	Dyeing	5. Avoid reduction clearing for light & medium shades	- Carryout trials	TC	WM PR		ST	L
	Dyeing	6. Select dyes with higher fixation rates & less dye concentration in the effluent	- Discuss with expert & determine dyes to be replaced - Estimate cost benefit considering effluent treatment costs	MC	WM PR		ST	M

CR - Chemical Reduction
IC - Inventory Control
MC - Material Change
QI - Quality Improvement
SI - Safety Improvement
EM - Equipment Modification
L - Low Cost
MT - Medium Term
RC - Resource Conservation
TC - Technology Change
ES - Energy Savings
LT - Long Term
PC - Process Control
RR - Resource Recovery
WM - Waste Minimisation
H - High cost
M - Medium Cost
PR - Pollution Reduction
ST - Short term
1 - 10 - Increasing priority
HK - Housekeeping

Process unit	Unit operation	Waste Minimisation (WM) Option	Actions to assess WM options	Cate gory	Effect	Priority	Timing	Cost
Jet Dyer	All operations	7. Recycling of some of the rinses eg: optical brightening discharges for cold rinses	- Carry out COD analysis of rinses - Discuss with industry regarding the possibilities	RR	WM ES	3	MT	M
	All operations	8. Separate the cooling water tank from the cold water storage tank	- Estimate quantity and temp of cooling water - Estimate energy losses in the present system - Estimate cost of separating the tank	RR	ES WM	4	MT	M
	All operations	9. Use lower liquor ratios in jets (increased ratio for dyeing step only)	- Carry out trials	RC	ES WM	8	ST-MT	L
	All operations	10. Lagging the jets	- Determine surface area - Determine cost of lagging - Estimate energy savings	RC	ES WM	5	MT	M
	Dyeing	11. Employ pad batch dyeing	- Carry out trials	TC	WM PR ES		LT	H
	All operations	12. Install Press button switches for view glass lights	- Calculate the amount of energy losses by keeping light on during process - Estimate cost of installing switches	EM	ES	5	ST	L

Process unit	Unit operation	Waste Minimisation option	Actions to assess WM options	Cate gory	Effect	Priority	Timing	Cost
Stenter	Drying	13. Reduce pickup from padding mangles	- Measure pickup with used padding mangles - Measure pickup with new padding mangle - Estimate energy savings - Find the cost of grinding - Carry out CBA	RC	ES WM		ST	L
	Drying	14. Avoid overdrying of fabric	- Determine moisture content of fabric after drying - Determine the present temperature - Calculate energy savings if moisture content is maintained at 8% - Estimate energy losses - Find out the cost of installing moisture meters	RC	ES WM		ST	L
	Drying	15. Installation of a vacuum slit device	- Estimate moisture content with and without vacuum slit - Estimate energy savings with vac. slit - Find out the cost of vacuum slit	RC	ES WM		MT	H
Vertical dryer	Drying	16. Maximise utilisation of available heat for latter part of drying, after stopping the steam	- Carry out trials	RC	ES WM		ST	L

Process unit	Unit operation	Waste Minimisation (WM) option	Actions to assess WM options	Cate gory	Effect	Priority	Timing	Cost
Boiler	All operations	17. Lagging the unlagged steam lines	- Measure the length of pipeline without lagging - Estimate heat losses & carry out cost benefit of lagging	RC	ES WM	8	S	M
	All operations	18. Lagging the boiler surface	- Determine the surface area - Estimate the cost of lagging	RC	ES	8	MT	M
	All operations	19. Improve boiler efficiency	- Carry out boiler efficiency study - Carry out flue gas analysis	RC	ES WM	7	S-MT	LC
	All operations	20. Replacing the boiler with a low capacity one	- Estimate energy losses with existing boiler - Estimate cost of replacing with a low capacity one	RC	ES WM	4	LT	H
	All operations	21. Condensate recovery from jets, vertical dryer	- Estimate temp, volume and cost of tank & pump - Estimate energy & chemical savings	RR	ES WM	8	S	M
	All operations	22. Improve boiler water treatment	- Estimate the cost of replacing the resin in the softening plant - Check the blow down frequency	RC	ES	6	MT	M

Process unit	Unit operation	Waste Minimisation (WM) option	Actions to assess WM options	Cate gory	Effect	Priority	Timing	Cost
General	Effluent treatment	23. Segregation of coloured effluent from alkaline effluent	- Estimate the cost of segregation - Estimate cost of treatment with and without segregation	TC	CR	4	LT	H
	Effluent treatment	24. Neutralization of the alkaline effluent with the flue gas	- Carry out trials - Estimate cost of installing the scrubber	RC	CR	4	LT	M
	All operations	25. Improve process water quality	- Determine the consumption of process chemicals required due to poor process water quality - Determine the extra cost of treatment - Determine savings in process chemicals	RC	CR	3	MT	M
	Ironing	26. Use of steam heating for ironing boilers instead of electrical heating	- Estimate electricity savings, cost of safety valve & pressure reducing valve	RC	ES	4	MT	M
	Knitting	27. Reduce oil content in the yarn	- Determine the oil content - Calculate COD contribution - Determine chemical savings possible if oil content is reduced	RC	PR		MT	L

9.0 COST BENEFIT ANALYSIS

Cost Benefit analysis was carried out for the 10 waste minimisation options given the highest priority by the management (from Worksheet 8). The investment, savings and pay back period for each option is presented in a worksheet, while relevant details for each calculation are presented below the respective worksheet.

WORKSHEET 9.1	
Lower the liquor ratio of the jets from 1:8 to 1:7.5 in all process steps except in the dyeing step (Option 9 in worksheet 8)	
Investment — Rs: Nil	**Saving** (Rs/y) Steam: 71,260 Water: 9,240 **TOTAL: 80,500**
Annual operating cost — Rs/y: Nil	**Net saving** =(Saving - Operating Cost): **80,500** **Payback period** =(Investment/Net Saving)12 **Not applicable**

Details about the saving of water and steam by reducing liquor ratio from 1:8 to 1:7 is given below

PROCESS	Steam (l/month)	Water(l/month)
Scouring	1,862	12,667
Reduction clearing	214	2,547
Soaping	475	3,229
Hot washing	2,613	31,114
Cold washing	-	41,056
Neutralizing	-	2,547

Unit cost of water = 8.27 Rs / m^3
Water saving = 93,160 kg / month (2% of total water consumption)
= 770 Rs / month
Unit cost of steam = 1.15 Rs / kg
Steam saving = 5164 kg / month
= 71,263 Rs / y

WORKSHEET 9.2			
Chemical substitution: acetic acid to formic acid and $NaHSO_4$ to diosyn HF (Option 2 in Worksheet 8)			
Investment	**Rs** Nil	**Saving** Chemicals Treatment cost **TOTAL**	**Rs/y** 109,668 63,360 **180,960**
Annual operating cost	**Rs/y** Nil	**Net saving** (saving - operating cost) **Payback period** (Investment/Net Saving)12 = **Not applicable**	**180,960**

	Current monthly consumption	Substitution	Rate (Rs / kg)
Acetic acid	125 kg		85
$NaHSO_4$	200 kg		50
Formic acid		62 kg	78
Diosyn HF		35 kg	190

(Chemical costs were obtained from the industry and suppliers)

Saving in chemical cost	= (125x85 + 200x50) - (62x78 + 35x190) Rs/month = 109,668 /y
COD reduction	= (125 x 1.04 x 0.83 + 200 x 0.4 x 0.85) kg COD (9% reduction of total COD)
Unit treatment cost	= 30 Rs /kg COD
Treatment cost saving	= 63,360 Rs/y

COD value of acetic acid and $NaHSO_4$ are 1.04, 0.4 (kg/kg) respectively. By replacing acetic acid with formic acid & $NaHSO_4$ with Diosyn HF a 83% and 85% COD reduction can be achieved respectively. [Ref 2]

WORKSHEET 9.3			
Lagging the unlagged steam lines (Option 17 in worksheet 8)			
	Rs	**Saving**	**Rs/y**
Investment		Fuel oil	14,560
Lagging (glass wool)	10,700	**Net saving**	**12,313**
Annual operating cost			
Interest (21%)	2,247	**Payback period**	
		(Investment/Net Saving)12	= 10 Months

Total area exposed to ambient environment	= 7 m^2
Average surface temperature	= 100°C
Lagged surface area temperature	= 40°C
Convective heat transfer coefficient	= 10 W/m^2 °K [ref 4]
Heat loss	= (100-40)x10x7x3600/1000 kJ/h
	= 15,120 kJ/h
Boiler efficiency	= 70 %
Calorific value of oil	= 40,500 kJ/l
Operating hours per day	= 13
Energy loss (l of oil/h)	= 15,120/(0.7x40,500)
	= 0.533 l oil/h
	= 0.533x13x300 l/y
	= Rs 14,560/y
Lagging cost (obtained from supplier)	= Rs 10,700

Diameter of pipe	Length(m)	Lagging cost (Rs)
25 mm	4.5	911 (@247)
37.5 mm	5	1312 (@320)
50 mm	15	4490 (@365)
100 mm	10	3821 (@460)

WORKSHEET 9.4			
Lagging of the boiler surface (Option 18 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Lagging (glass wool)	13,420	Fuel oil	11,410
		Net saving	**8,590**
Annual operating cost	**Rs/y**		
Interest	2,818	**Payback period** = (Investment/Net Saving)12	= 18 Months

Area of the boiler to be lagged - 8.6 m^2
Average surface temperature - 112°C
Lagged surface area temperature - 40°C
Heat transfer coefficient - 5.317 W/m^2 °K (Ref 4)

Heat loss = 11,852 kj/h
Energy loss = 0.418 l of oil /h
Savings = Rs. 11,410 /y

Lagging cost = Rs. 1560/m^2

WORKSHEET 9.5			
Neutralization of alkaline stream using flue gas (Option 24 in worksheet 8)			
Investment	**Rs**	**SavingRs/y**	
Neutralizing plant	166,200		
		Chemical HCl	408,000
	Rs/y	**Net saving** (Saving - operating cost)	**232,580**
Annual operating cost			
Depreciation (10%)	16,620	**Payback period** =(Investment/Net Saving)*12	=9 months
Maintenance (3%)	4,900		
Interest(21%)	34,900		
Electricity	119,000		
Total	**175,420**		

Acidic and basic chemicals used in the factory per month

Chemicals	Amount(kg)	Amount(kmols)
$(NH_4)SO4$	100 kg	1.96 (H+)
NaOH	250 kg	6.25 (OH-)
Na_2CO_3	1000 kg	23 (OH-)
Acetic acid	125 kg	2.08 (H+)

Neutralizing chemical needed =25.23 kmol (H^+)
Molecular wt of HCl = 36.5 kg/kmol
=920 kg HCl
Unit price of HCl = 37 Rs/kg
=34,073/month

Effluent flow rate = 2000 m^3/month

Average boiler operating time = 6.67 h/day
Design capacity of plant = 12 m^3/h
Energy demand of plant = 12 kW
Electricity cost = 12x6.67x4.96x300 Rs.
= 119,000 Rs./ y
Capital cost of plant
with capacity of 12 m^3/ hr = 1,66,200 Rs

Cost of equipment a = cost of equip.b {capacity .equip. a/capacity equip .b}$^{0.6}$
[Ref 5]

WORKSHEET 9.6			
Heat recovery from hot effluent (Option 1 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Heat exchanger	560,000	Fuel oil	296,000
Pump (2 Nos)	60,000		
Piping & valves	8,000	**Net saving**	**92,920**
Total	**628,000**	**Payback Period**	
Annual operating cost	**Rs/y**	=(Investment/ Net Saving)12	= 6 years
Interest (21%)	131,880		
Electricity	4,000		
Maintenance (2%)	11,200		
Depreciation (10%)	56,000		
Total	**203,080**		

Sascon discharges 236 m^3 at 100°C & 205 m^3 at 130°C during a month from jets.

Shell and tube heat exchanger specifications

Overall heat transfer coefficient	= 1000 W/m^2K
Effluent flow rate	= 6 l/s
Fresh water flow rate	= 5.8 l/s
Head loss on tube side	= 37 N/m^2
Head loss on shell side	= 232 N/m^2
Heat transfer area required	= 50.4 m^2
Effluent outlet temperature	= 60°C
Log mean temp difference	= 25°C
Heat recoverable	= {236(100-60)+205(130-60)}4.2x1000 kJ/month
	= 99.91×10^6 kJ/month
Boiler efficiency	= 70 %
Calorific value of oil	= 40,500 kJ/l
Energy loss (l of oil/month)	= 99.91×10^6 / (0.7x40,500)
	= 3,524 l oil
Annual saving	= Rs 296,000/y
Estimated cost of the heat transfer equipment (stainless steel)	= 560,000 Rs.

Price \$ = $885A^{0.432}$ (A - ft^2) [Ref6]

WORKSHEET 9.7			
Condensate recovery from jets and dryer (option 21 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Piping with lagging	23,800	Fuel oil	109,960
Feed water tank lagging	10,500	Treatment chemicals	137,280
		Water	14,190
TOTAL	**34,300**		
		TOTAL	**261,430**
Annual operating cost	**Rs/y**		
Pumping cost and interest	7,200	**Net saving** =(Saving-Operating Cost)	**254,230**
		Payback period =(Investment/Net Saving)12	= 2 months

Condensate amount that can be collected (from material balance; indirect heating)	= 143,820 kg
Temperature of condensate	= 90°C
Feed water temperature	= 30°C
Energy that can be saved by recycling	= 143,820x4.2(90 - 30) kJ/month
	= 1278 l oil/month
	= 107,385 Rs/y
Monthly boiler water treatment cost	= 14,300 Rs
Treatment cost saving	= (14,300 x 0.8) Rs
(80 % boiler water can be recycled)	= 137,280 Rs/y
Water saving	= 143 m^3
Unit cost of water	= 8.27 Rs
Water saving	= 14,190 Rs/y
Installation of Condensate collection pipe with lagging (70 m length, 37.5 mm diameter)	= 23,800 Rs
Existing feed water tank lagging cost	= 6.7(m^2)Rs 1560
	= 10,500 Rs

(Lagging costs were obtained from suppliers)

WORKSHEET 9.8			
Install press button switches for view glass lights (Option 12 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Press button switches (3 Nos)	300	Electricity	10,800
		Net saving =(Saving-operating cost)	**10,800**
Annual operating cost	**Rs/y** Nil		
		Payback period =(Investment/Net Saving)12	< one month

No of bulbs	= 5 (in 3 jet machines)
Operating hours	= 3600 h/year
Power of a bulb	= 120 W
Total power loss	= 5*.12*3600 kWh/year
	= 2160 kWh/year
Unit cost	= 5 Rs/kWh
Saving	= 10,800 Rs/year
No of buttons needed	= 3
Cost of a button	= 100 Rs

WORKSHEET 9.9			
Lagging of the jet surface area (Option 10 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Lagging Cost	350,000		
		Fuel	338,750
		Net saving	**265,250**
	Rs/y	(Saving-Operating Cost)	
Annual operating cost	73,500		
		Payback period	
		=(Investment/Net Saving)12	=16 months

Unlagged area = 225 m^2
Average surface temperature = 120°C
Average lagged surface temperature = 40°C
Convective heat transfer coefficient = 5.3 $J/m^2\,^oKs$ [Ref 6]
Time duration = 13 (h)x300 (days)
= 3900 h/y
Energy loss (kJ/y) = 225x0.0053(120 - 40)3900x3600
= 1.339×10^9 kJ/year
Boiler efficiency = 70 %
Calorific value of oil = 40,500 kJ/l
Energy loss (l of oil/y) = $1.339 \times 10^9/(0.7 \times 40500)$
= 47,245 l oil
= Rs 338,750
Lagging cost = Rs 350,000
(obtained from supplier)

WORKSHEET 9.10			
Tuning the boiler to increase the combustion efficiency from 85% to 90%			
	Rs	**Saving**	**Rs/y**
Investment	Nil	Fuel oil	124,750
Annual operating cost	Nil	**Net saving** (Saving-Operating Cost)	**124,750**
		Payback period =(Investment/Net Saving)*12	Not applicable

By optimising the air/fuel ratio the combustion efficiency of the boiler fuel can be increased. Fuel saving for a 2% increase in boiler efficiency can be calculated as follows:-

Current combustion efficiency	= 85%
Fuel oil consumption for March 95	= 26729 l
Combustion efficiency can be tuned to	= 90%
Fuel oil consumption reduced to	= 25244 l
Unit cost of oil	= 7 Rs/ l
Saving	= (26729 - 25244) x 7 x 12 Rs/y
	= 124,750 Rs

Combustion efficiency was measured by staff of Process & Plant Engineering Division of CISIR. Improvement in boiler efficiency was considered only in terms of combustion efficiency as measurement facilities were inadequate to study total boiler efficiency.

10.0 IMPLEMENTATION OF WASTE MINIMISATION OPTIONS

The status of implementation of the ten waste minimisation options identified to be of high priority for the industry is summarised in Worksheet 10. The industry has implemented only chemical substitution options and power factor improvement. Reasons for non-implementation are given. Comparison of the actual savings with the theoretical expected savings (from Worksheet 9.1 - 9.10) with respect to unit production is also given in Worksheet 10.

Details of the actual savings obtained by the industry for a year for the two options implemented are given below the worksheet. The treatment component of the saving is given separately, since this is not an actual saving at present. This saving will be obtained only when the industry installs and operates an effluent treatment system.

A summary of the annual savings obtained by the industry by implementing the two options is given below:-

I Without treatment cost savings

Total annual savings	= Rs 437,920.00
Investment	= Rs 340,000.00
Annual interest on investment (21%)	= Rs 71,400.00
Pay back period	= 11 Months

II With treatment cost savings

Total annual saving	= Rs 481,920.00
Investment	= Rs 340,000.00
Annual interest on investment (21%)	= Rs 71,400.00
Pay back	= 10 Months

Worksheet 10.

Waste minimisation option	Parameters	Before Implementation		After implementation						Remarks
		Actual Consumption/ Generation*		Expected Consumption/ Generation*		Expected Saving	Actual Consumption/ Generation*		Actual Saving	
		per kg of Fabric (10^{-3})	Rs/kg of Fabric (10^{-3})	per kg of Fabric (10^{-3})	Rs/kg of Fabric (10^{-3})	Rs/kg of Fabric (10^{-3})	per kg of Fabric (10^{-3})	Rs/kg of Fabric (10^{-3})	Rs/kg of Fabric (10^{-3})	
1) Chemical substitution										
a) Formic acid for Acetic acid	COD (kg)	40.41	1212.30	6.86	206.09	172.71	7.42	222.54	154.25	Implemented
	Chemical(kg)	38.85	3302.76	19.27	1503.06	1793.76	21.81	1701.83	1600.93	
b) A.D reduct for Hydros	COD (kg)	24.86	746.03	3.73	111.90	634.13	-	-	-	Implemented
	Chemical(kg)	62.16	3108.48	10.87	2067.1	1040.85	14.54	1701.8	1406.68	
2) Power factor Improvement	Electricity (kVA)	-	348	-	-	-	-	240	25,380	This option is not in the identified 10 options
3) Installation of press button switches for jets	Electricity (kWh)	4.504	28.56	-	-	28.56	-	-	-	Not installed, since workers say fabric movement has to be continuously visible
4) Lagging steam lines	Fuel (l)	1037.37	7437.98	1032.67	7404.22	-	-	-	-	Not implemented Awaiting for funds required for investment

5) Condensate recovery	Fuel (l) Chemical(kg) Water (l)	1037.37 - 5270	7437.98 46.2 94.68	1000.64 - 5899.24	7188.95 9.25 48.78	248.95 36.95 45.90	-	-	-	Not implemented Quotation called for.
6) Lagging boiler surface area	Fuel (l)	1037.37	7437.98	1033.68	7411.51	26.47	-	-	-	Not implemented. Awaiting for funds required for investment
7) Heat recovery for hot effluent	Fuel (l)	1037.37	7437.98	941.63	6751.50	686.48	-	-	-	Not Implemented due to high capital cost
8) Lagging of jets	Fuel(l)	1037.37	7437.98	930.45	6671.29	766.69	-	-	-	Not implemented Awaiting funds required for investment
9) Improvement of boiler efficiency	Fuel (l)	1037.37	7437.98	979.74	7024.70	413.28	-	-	-	Not implemented
10) Lowering liquor ratio	Water (l) Fuel (l)	57849 158.34	478.42 1135.36	54230 148.50	448.50 1064.75	-	-	-	-	Cannot be implemented due to formation of crease mark.
11) Neutralizing of alkaline effluent using flue gas **	Treatment chemical (kg)	35.71	1321.12	-	-	-	-	-	-	Not implemented due to high investment

Note For before implementation and expected unit consumption and generation calculations, production figures utilized were 3217 kg for options 1 a), 1 b), 25766 kg for other options.

For after implementation unit consumption and generation calculations productions figures utilized were 4193 kg for options 1 a) and 1 b).

* Consumption of chemicals, water, fuel etc./ Generation of COD

** At present Sascon is not carrying out neutralisation of effluent due to poor enforcement of environmental regulations. There is no saving if this option is implemented at present therefore.

COST BENEFIT CALCULATION FOR IMPLEMENTED OPTIONS

(1a) Substitution of Formic acid for Acetic acid

Before implementation

Acetic acid consumption (Mar.95)	= 125 kg for the production of 3,217 kg
Cost per month	= 125(kg) x Rs 85
	= Rs 10,625
Treatment cost per month	= COD x Treatment cost/kg of COD
	= 125kg x 1.04(kg COD/kg) x 30(Rs/kg COD)
	= Rs 3,900

After implementation

Formic acid consumption	= 91.5 kg for the production of 4193.7 kg
Cost per month	= 91.5 kg x 78(Rs/kg)
	= Rs 7,137
Treatment cost per month	= 91.5 x 0.34 (kg COD/kg) x 30 (Rs/kg COD)
	= Rs 933

Actual annual Chemical Saving = Rs 41,856

Actual annual Treatment Cost Saving = Rs 35,604

(1b) Substitution of A.D reduct for Hydros

Before Implementation

Sodium hydrosulfide consumption	= 200 kg for 3217 kg of production
Cost per month	= 200 kg x 50 Rs/kg
	= Rs 10,000
Treatment cost per month	= 200 x 0.4 x 30 (Rs/kg COD)
	= Rs 2400

After implementation

A.D reduct consumption	= 61 kg for 4193 kg of production
Cost per month	= 61 kg x Rs 117/kg
	= Rs 7137

Treatment cost savings could not be calculated due to lack of COD data.

Actual annual chemical savings = Rs 34,356

(Monthly average production figure of 3705 kg was used in the annual calculations)

2. Power factor improvement

Before implementation

KVA consumption (March '95)	= 348	
Cost per month	= 348 x Rs 235	
		= Rs 81,780

After implementation

KVA consumption (July '96)	= 240	
Cost per month	= 240 x Rs 235	
		= Rs 56,400

Actual annual Power Saving = Rs 304,560

Investment = Rs 340,000

Annual interest on investment (21%) = Rs 71,400

Pay back period = 17 months

11.0 CONCLUSIONS

The process flow diagrams prepared depict the activities involved in the processing of the major products and the inputs and sources of output, together with process conditions. These were seen to be invaluable in the preparation of subsequent worksheets (eg. material and water balances).

Carrying out the material balance, enabled the quantification of the inputs and outputs for the unit operations. These values have been useful in identifying waste minimisation options. eg. quantification of steam emitted suggested that recovery of steam would be a valuable waste minimisation option. The quantity was utilised in the Cost Benefit analysis.

Carrying out the water balance enabled the identification of the highest water consuming activities and the undefined water consumption.

The COD balance enabled the identification of the percentage contribution of each discharge to the pollution load. Quantification of the COD also helped in the calculation of the treatment cost.

Calculation of the Wastes and Emissions costs enabled the consideration of the wastes generated in terms of the financial loss. On implementation of the options, the reduction in the financial value of the wastes can be determined.

On the basis of observations made, and values obtained in the material balances and other quantifications, 27 waste minimisation options were identified. Of these 27, 15 were Resource Conservation, 4 Technology Change, 4 Resource Recovery, 3 Material Change and 1 Equipment Modification. Considering the cost of implementation, 9 were considered to be Low Cost, 13 Medium Cost and 5 High Cost.

Of the 10 highest priority options for which Cost Benefit analysis was carried out, it was seen that 4 options did not require any investment. However upto date, only one of the options requiring no investment has been implemented. The other three options have not been implemented due to lack of conviction about the benefits or practical problems faced during trials. The industry says that funds are not available for implementation of the other options, even though one is expected to have a payback period of 2 months. However they have improved the power factor, which was earlier not identified to be of high priority, at an investment of Rs. 340,000/-. The savings obtained are calculated to give this option a payback period of 17 months.

11.0 REFERENCES

1. R.H PETERS (1967)
   Textile chemistry II
   pg 172

2. CHITTARANJAN DESAI (August, 1995)
   Report on first mission to Sri Lanka, Industrial Pollution Reduction Programme, UNIDO, Sri Lanka.

3. JOHN H. PERRY (1963)
   Chemical engineer's hand book
   Fourth edition,
   pg 3-133

4. EASTOP & McCONKEY
   Applied Thermodynamics
   Fifth edition (1993), Logman Scientific & Technical

5. PETERS & TIMMERHAMS
   Plant design and economics for chemical engineering
   pg 169, 205

6. WILLIAM M. VATAVUK (August 1995)
   Chemical Engineering

ANNEXURE A

ORGANIZATION CHART OF SASCON

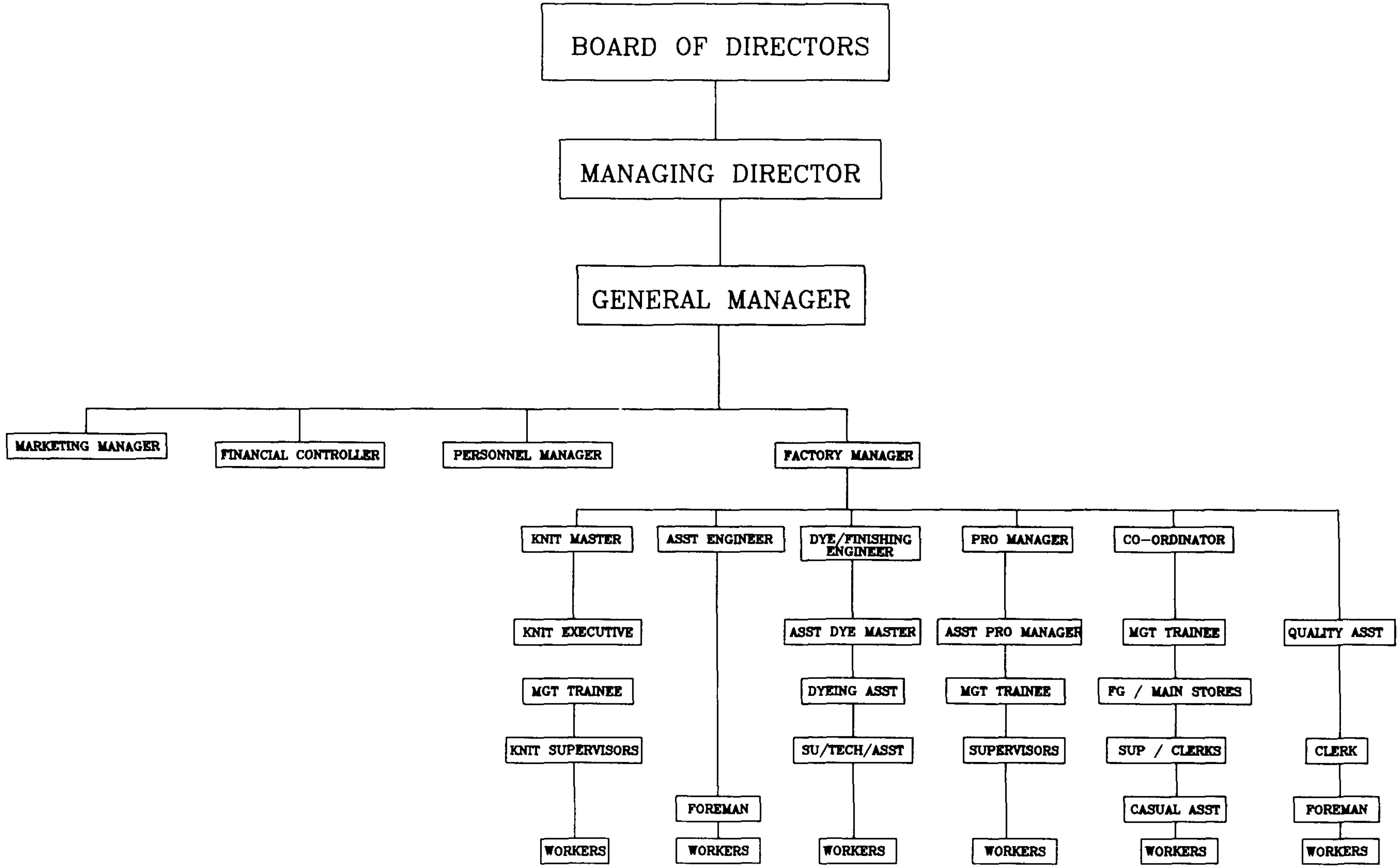
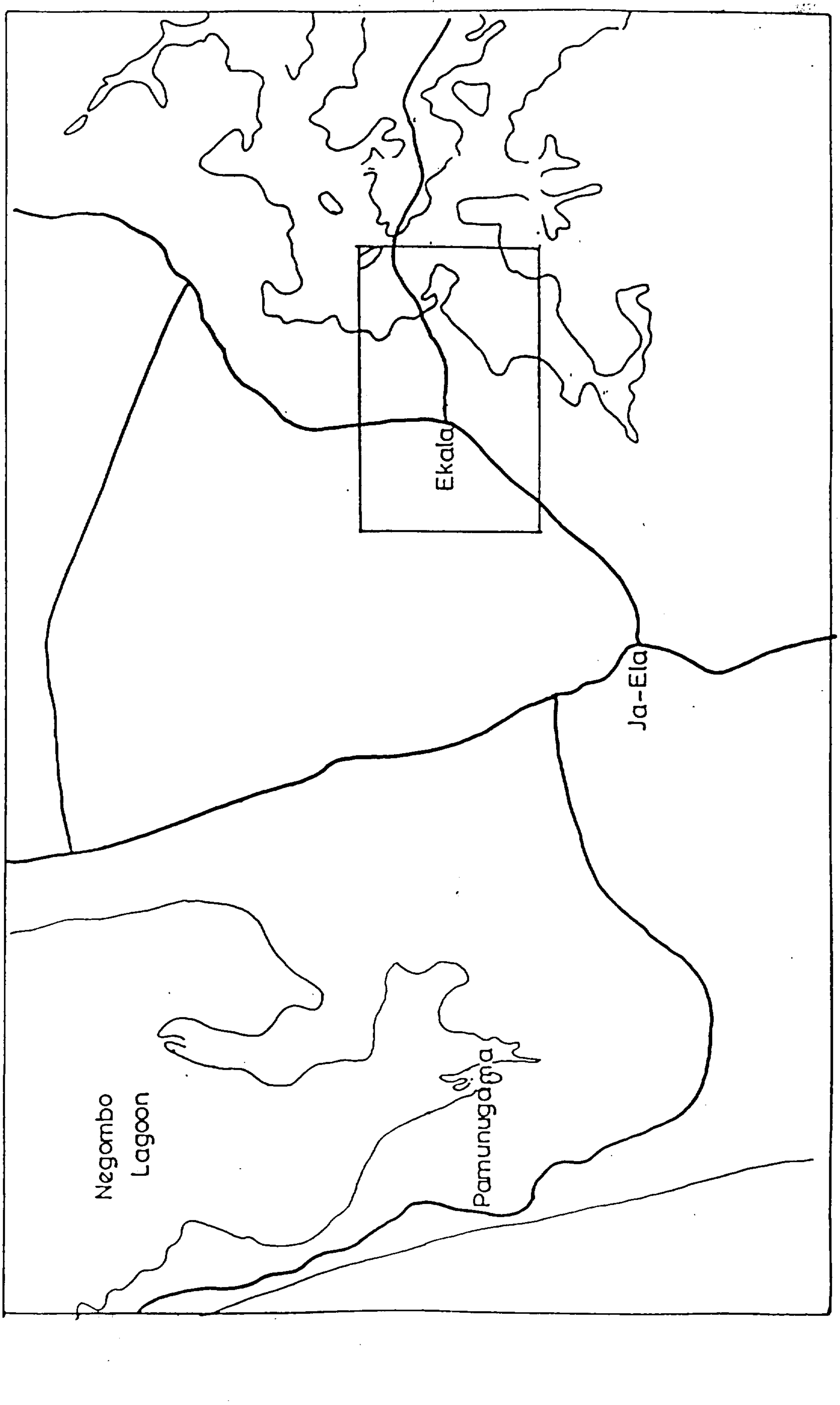
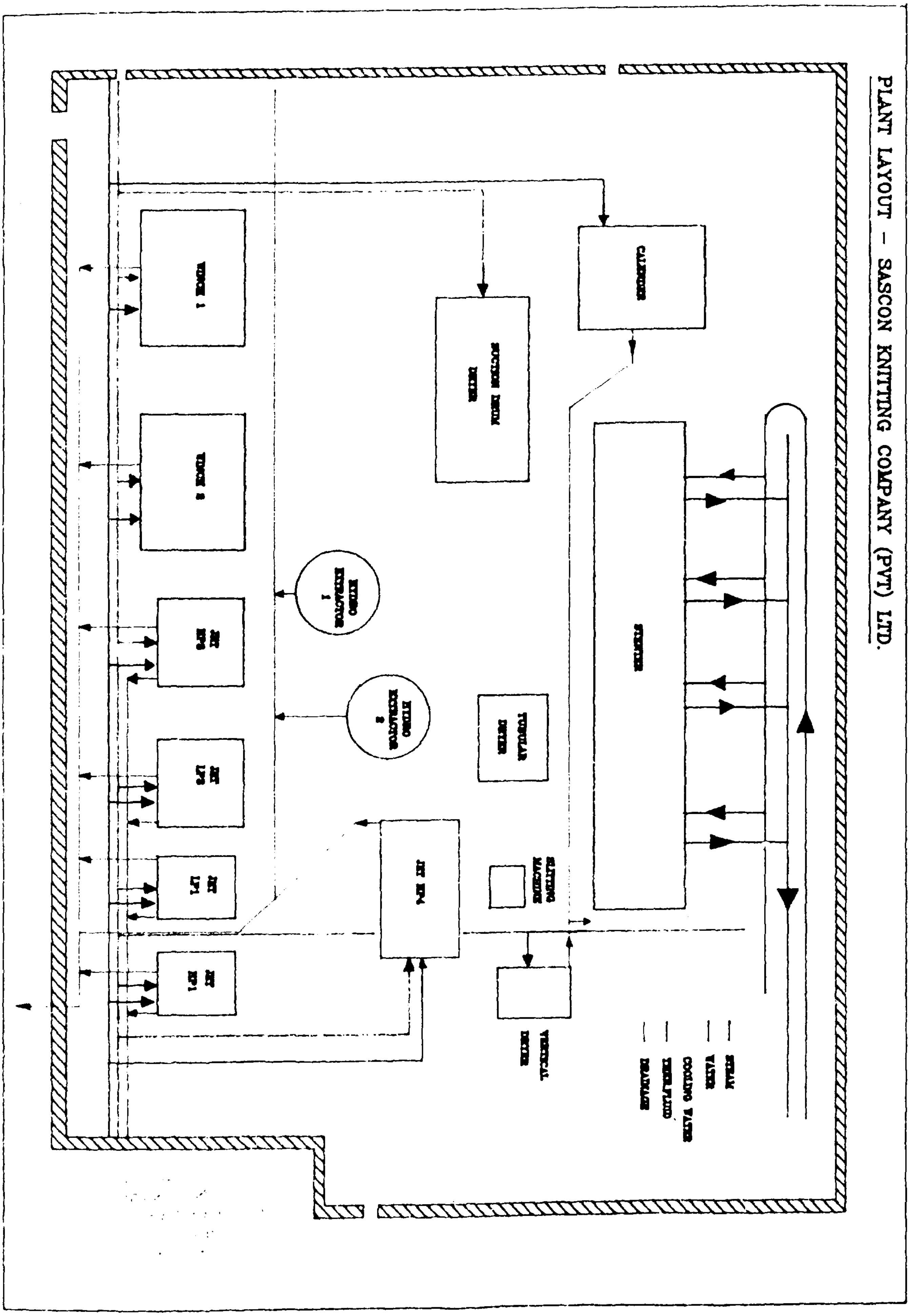


Figure 1. Location map of the study area.

ANNEXURE B




PLANT LAYOUT – SASCON KNITTING COMPANY (PVT) LTD.
TUBULAR DRIER
HYDRO EXTRACTOR 1
HYDRO EXTRACTOR 2
VERTICAL DRIER

Annexure D

List of major chemicals and dyes

DESCRIPTION	**QUANTITY kg/month**
Cibacron Yellow F3R	15.0
" Red FB	10.0
" Blue FR	10.0
" Navy FR	25.0
" Yellow F4G	1.0
" Black CN	30.0
" Scarlet F3G	1.0
Ambifix Black BFGR	60.0
" Red BF-3B	10.0
" Yellow BF-4R	25.0
" Navy BF-2G	30.0
" Blue BF-R	10.0
" Yellow BF-3G	5.0
" Turg Blue BF-G	5.0
" Orange BF-2R	1.0
Intrasil Blue 3RLN	10.0
Megasperse Scarlet F2R	1.0
Palanil Yellow 3G	1.0
" Red BEL	15.0
" Navy Blue GTN-CF	15.0
" Blue BGCF	5.0
" Yellow Brown RCF	10.0
Terasil Red 4G	1.0
" Yellow 4G	1.0
" Golden Yellow R	1.0
Dianix Black RXFS 22%	10.0

CHEMICALS

Acetic Acid	125.0
Albatex FFO	20.0
Appolene P132	25.0
Ammonium Sulphate	100.0
Caustic Soda	250.0
Calatac VB	100.0
Dispersant NS 40	100.0
Fumexol SD (antifoam)	150.0
Foryl 197	75.0
Hydrogen Peroxide	600.0
Invadine LU	10.0
Levegal D.T.E	5.0
Miranon JU	200.0
Univadine DIF	20.0
Cibafluid C	120.0
Sodium Sulphate	3000.0
Sodium Hydro Sulphate	200.0
Soda Ash	1000.0
Tinofix ECO	50.0
Uvitex CID	25.0
" EBF	50.0

Annexure E

I Production data of March 1995 for polyester blend (kg)

	HP4	HP1	HP3	LP3	LP1	TOTAL
LIGHT SHADE	9418 (22)	170.8 (3)	4440.4 (15)	4804 (27)	42.8 (1)	**18876**
MEDIUM SHADE	757 (3)	216.7 (3)	284 (1)	-	166 (2)	**1364**
DARK SHADE	1810 (4)	579.2 (7)	2326.3 (8)	380 (2)	-	**5095**
TOTAL	**11985**	**966.7**	**7050.7**	**5184**	**208.8**	**25335**

II Production data of March 1995 for 100% cotton (kg)

	HP4	HP3	HP1	LP3	LP1	TOTAL
LIGHT SHADE	-	-	-	-	90(2)	**90**
MEDIUM SHADE	-	-	-	-	-	-
DARK SHADE	-	135(1)	146(2)	-	60	**341**
TOTAL	-	**135**	**146**	-	**150**	**431**

HP1, HP3, HP4 - High Pressure jets
LP1, LP3 - Low Pressure jets
(**) - No of batches

Annexure F

RECIPES FOR MAJOR PROCESSES

Scouring

Hydrogen Peroxide	1.5 g/l
Caustic Soda	0.5 g/l
Prestogen K	0.5 g/l
Miranon Ju (Detergent)	0.8 g/l
Fumexol SD (Antifoaming agent 1)	0.2 g/l

Polyester part dyeing

Acetic acid	0.7 g/l
$(NH_4)_2SO4$	1.0 g/l
Univadin DIF (Dispersing agent)	0.3 g/l
Fumexol SD (Antifoaming agent 1)	0.2 g/l
Ciba fluid (Anticreasing agent)	1.0 g/l

Reduction clearing

Hydros	3.0 g/l
Caustic soda	1.0 g/l
Miranon JU (Detergent)	0.5 g/l
Albatex FFO (Antifoaming agent 2)	0.4 g/l

Neutralizing

Acetic acid	0.5 g/l

Cotton part dyeing

Na_2SO_4	60 g/l
Na_2CO_3	7 g/l
Cibafluid C (anticreasing agent)	1 g/l
Albatex FFO (Antifoaming agent 2)	0.2 g/l

Soaping

Foryl 197 (Soaping agent)	1 g/l
Fumexol SD (Antifoaming agent 1)	0.2 g/l

Annexure G

ESTIMATION OF EFFLUENT TREATMENT COST ON THE BASIS OF COD REMOVAL

Assumptions

a) Capacity of plant - 200 m^3/day
b) Typical COD of textile effluent after equalization - 800 mg/l
c) Chemical consumption
Coagulant, Alum (400 mg/l) - 80 kg/day
Flocculant, Polymer (2 mg/l on dry solid basis) - 400 g/day
Neutralizer, Lime (120 mg/l) - 24 kg/day

Cost (Rs)

Chemicals	
Alum (Rs 16/kg)	=1280
Polymer (Rs 1000/kg)	=400
Lime (Rs 5/kg)	=120
Total Chemical cost	**=1800/day**

Electricity	
Feed pump (1 kW)	=24 kWh
Chemical preparation(0.25x3)	=18 kWh
Dosing pump (0.1x3)	=7.2 kWh
Flash mixer (0.5 kW)	=12 kWh
Clarifier scraper(0.75kW)	=18 kWh
Sewage pump (0.5 kW)	=12 kWh
RBC (1.5 kW)	=36 kWh
Secondary clarifier scraper(0.75 kW)	=18 kWh
Total power	=145.7 kWh

Electricity cost (Rs 5/kWh) =726 Rs

Labor cost for operation of treatment plant (24 labor hours per day)
Total cost of labor including EPF, ETF, and annual overtime =Rs 25/hr

Labor cost	**=Rs 600/day**
Sludge handling cost	**=Rs 150/day**
Total operational cost	**=Rs 3276/day**

COD removal required per day	$=200(800-250)10^{-3}$ kg/day =110 kg/day
Cost for removal of 1 kg COD	=3276/110 =Rs 29.78/ kg =Rs 30/ kg

Annexure H

ESTIMATION OF THE STEAM COST

Fuel oil cost	= 1053(l)x7.17(Rs/l)
	= 7550
Cost of fuel pumping(351 min)	= 3.7(kW)(351/60)(4.98)(Rs/kWh)
	= 107.79
Electric oil heating cost (40 min)	= 12(kW)(40/60)4.98(Rs/kWh)
	= 39.84
Water cost	= 7.85(M^3)(8.27)(Rs/m^3)
	= 64.92
Water pumping cost(51 min)	= 7.5(kW)(51/60)(4.98)(Rs/kWh)
	= 31.75
Boiler water treatment	= 7.85(m^3)48.5(Rs/m^3)
	= 380.725
Air compressor power	= 11(kW)(351/60)4.98
	= 320.463
Labour cost	= 120 (Rs/day)
Total cost	= 8615.50 Rs
Total steam produced	= 7850 kg
Unit steam cost	**= 1.098 Rs/kg**

Steam cost was estimated for two days to get average unit steam cost

Average steam cost = **1.15 Rs/kg**

Annexure I

UTILITY COSTS

UTILITY	UNIT COST (Rs.)	COST Rs./kg FABRIC
WATER	8.27 / m^3	1.20
STEAM	1.15 / kg	9.5
ELECTRICITY	4.96 /kWh	2.5
FUEL OIL	7.17 /l	10.08
TREATMENT COST~	30 / kg COD	1.52

~ TO BE INSTALLED