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Annex 7

INDUSTRIAL POLLUTION REDUCTION PROGRAMME
DG/SRL/91/019

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

WASTE AUDIT

OACIANIC KNITTERS PVT LTD

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363, Bauddhaloka Mawatha, Colombo 7, SRI LANKA

Table of Contents

SUMMARY

Oacianic Knitters (Pvt) Ltd., is a Medium scale Knitting and dyeing factory located in a mainly industrial dominated urban area of Colombo South. Though it is located in an industrial area, disposal of effluent is a major issue due to lack of central disposal facilities and inadequate space within the premises.

This industry consumes 161 l of water and 0.64 l of furnace oil for manufacture of one kilogram of processed fabric.

Insufficient space among the machines, underloading of dyeing machines and heat losses are several reasons for reduction of production efficiency.

The steam utilization of this industry is 75% of the steam production.

Fabric cleaning process of scouring generates 20% of total COD and balance 80 % COD is due to material wastage in the other process operations.

Most expensive waste streams of this industry are polyester and cotton dyeing. These streams and the waste streams of soaping and scouring exceed the factory average waste stream cost.

Thirty seven waste minimization options were identified for this industry and the cost benefit analysis carried out for the ten highest priority options is shown in the Table. Of the options, three of the five proposed chemical substitutions, lagging of steam lines and non-acceptance of oil contaminated fabric have been implemented. Actual cost benefit for these are compared with the expected in the Table. The industry is interested in implementing other options such as installation of low liquor ratio jets, condensate recovery, upgrading of water treatment plant and lagging of jets. Due to lack of funds the implementation of these options have been delayed.

Option	Investment Rs.		Operating cost Rs./y		Net Savings Rs./y		Pay back period (M)		Environmental Benefits
	Exp.	Act.	Exp.	Act.	Exp.	Act.	Exp	Act.	
1. Chem. substitution Acetic acid NaHS Na sulphide Leverol	Nil	Nil	Nil	Nil	209,124 144,360 55,524 9,240 -	 174,244 28,764 - 46,272	N/A	N/A	2% reduction in organic load
2. Installation of temperature control system for winches	165,000	-	34,650	-	251,996	-	12	-	0.2% reduction in effluent vol., 2.5% in fuel consmpn.
3. Installation of press button switches	800	-	Nil	-	21,911	-	< 1	-	--
4. Lagging of steamlines	9,350	38,164	1,970	8,014	23,227	77,672	5	6	0.5% reduction in fuel consumption
5. Condensate recovery	93,918	=	19,728	-	176,765	-	6	-	4.7% reduction in fuel consmpn., 2% in effluent volume
6. Lagging of boiler	30,948	-	6,405	-	72,603	-	5	-	1.2% reduction in fuel consumption
7. Lagging of jets	182,520	-	38,329	-	211,907	-	10	-	7.5% reduction in fuel consumption
8. Avoid use of sequestering agent	Nil	-	299,760	-	75,525	-	N/A	-	2.5% reduction in organic load
9. Reduced oil in commissioned fabric	Nil	Nil	Nil	Nil	73,728	98,208	N/A	N/A	reduction in organic load
10. Improvement of boiler efficiency	Nil	-	Nil	-	66,338	-	N/A	-	2% reduction in fuel consumption

N/A Not Applicable Exp. Expected Act. Actual Consmpn. Consumption vol. volume

List of Abbreviations

COD	Chemical Oxygen Demand
^oC	^{o}Centigrade
h	hour
J	joule
^oK	^{o}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

OACIANIC KNITTERS (PVT) LTD

1.0 Introduction

Oacianic Knitters (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. Maduraiweeran, Chairman
1.3	Contact persons	: Messers. Vas Gunawardena (knitting), Sydney de Silva (Dyeing), Moorthy (Engineer), Pregalather (Finishing),

2.0 Site details

2.1 Location — No. 4 Kandawela Mawatha, Ratmalana (Annex B)

2.2 Physical Descriptions

(i)	Area	: $4136\ m^2$
(ii)	Topography	: Flat land
(iii)	Factory layout	: Attached (Annex C)
(iv)	Sealed surface	: 95% of the site
(v)	Depth to groundwater	: 3 m
(vi)	Surface water bodies	: None
(vii)	Surface drainage channels	: All drains are connected to a main drain and then to the public sewer system

2.3 Current use

(i)	Processes	: Knitting, dyeing, and finishing
(ii)	Products	: Dyed and printed fabrics
(iii)	Raw materials	: Yarn
(iv)	Major chemicals	: Caustic soda, dyes, detergents, softners and pigments and other general chemicals (Annex D)
(v)	Energy source	: Furnace oil, LP gas and electricity

2.4 Site drainage (type & discharge points)

(i)	Process effluent	: Through open drains to public sewer
(ii)	Domestic waste water	: Through open drains to public sewer
(iii)	Storm water	: Through open drains to public sewer
(iv)	Toilet effluent	: Through pipe drain to septic tanks

3.0 Environmental Emissions

3.1 Atmospheric emissions	: Cotton dust from knitting machines, flue gas from boilers, exhaust from dryers and stentors.
3.2 Aqueous discharge points	: Effluents from bleaching and dyeing.
3.3 Solid waste	: Cotton dust, paper and empty chemical packaging materials

4.0 Site history and Neighbouring sites

4.1 History of the site

(i)	Start date	: 1983
(ii)	Former use	: Textile factory

4.2 Current and former use of neighbouring sites

(i)	Northern	: Industries and residential buildings
(ii)	Southern	: Airport
(iii)	Western	: Weaving factory
(iv)	Eastern	: Packaging plant

4.3 Significant spills : None

5.0 Environmental Receptors

5.1 Abstraction points

(i)	Dug wells	: None
(ii)	Tube wells	: 3 tube wells within the premises
(iii)	Surface water	: None

5.2 Sensitive neighbours within 2 km

(i)	Residence	: Northern side
(ii)	Hospitals	: None
(iii)	Schools	: None
(iv)	Others	: None

5.3 Protected Natural Habitats : Attidiya Bird Sanctuary - 3 km to the east

5.4 Water Bodies

(i)	Surface	: Weras ganga, Bolgoda lake (Annex B)
(ii)	Sub-surface	: Residents in the neighbourhood use dug wells for domestic purposes and gardening

6.0 Solid Waste Issues

(i)	Type and disposal method	: Containers-sold; Cotton waste and polythene-burnt

7.0 Environment Licence issues

7.1 Current status : EPL issued in 1995

7.2 Current compliance issues :

PART 2 - WASTE MINIMISATION STUDY

1.0 General Information

WORKSHEET 1			
Name of the Company : Oacianic Knitters (Pvt) Ltd.			
Waste Minimisation Team			
	Name	**Designation**	
1.	Mr. H.N. Gunadasa	Manager (Environmental Technology), CISIR	
2.	Miss. G.V. Mallika	Research Officer, CISIR	
3.	Mrs. S. Wickramaratne	Research Officer,CISIR	
4.	Mrs. K.D. Attanayake	Senior Technical Officer, CISIR	
5.	Miss. S. de Costa	Research Officer,CISIR	
6.	Mr. R. Illankumaran	Research Officer, CISIR	
7.	Mr. K. Pavananthan	Research Officer, CISIR	
8.	Mr. Sydney de Silva	Processing Manager, Oacianic	
9.	Mr. V. Rajkumar	Production Assistant, Oacianic	
A.	**Major Raw Materials Consumption**		
	i) RAW MATERIAL		
	a) Yarn - Cotton		6.0 T/y*
	b) Polyester		120 T/y*
	c) Polyester/Cotton		100 T/y*
	d) Others (commissioned fabric)		
	Polyester		12 T/y*
	Polyester/cotton		30 T/y*
	ii) CHEMICAL		
	a) Dyes		8 T/y*
	b) Other chemicals		106 T/y*
B.	**Energy Consumption**		
	a) Electrical energy		40,580 kWh/M§
	b) Fuel for boilers		39,600 l/M§
	c) Others L P gas		2120 kg/M§
C.	**Water Consumption**		120000 m^3/y**

D.	**Production**	
1)	**INSTALLED CAPACITY**	
	Winch Dyeing	
	Winch 1	200 kg/batch
	Winch 2	125 kg/batch
	Winch 3	40 kg/batch
	Winch 4	150 kg/batch
	Jet Dyeing	
	Jigger	250 kg/batch
	New jets 1&2	150 kg/batch
	Jets 1 & 2	400 kg/batch
	Jets JF & JE	75 kg/batch
	Fongs	600 kg/batch
2)	**ACTUAL PRODUCTION - November 1994**	
	100% Cotton	13277 kg/M
	Polyester/Cotton blend	34907 kg/M
	100 % Polyester	15,753 kg/M
E.	**Type of Effluent Treatment**	No treatment
F.	**Any Other Relevant Information :** The plant has 85 workers and 25 working days per month	

* Major raw material consumption per year was calculated from the monthly average consumption figures provided by the industry.

** Annual water consumption was calculated from daily average consumption figure (400 m^3/day, 25 days/month)

§ Monthly energy consumption figures are actual consumption figures for November 1994.

2.0 Available Information

Maintenance of proper records with regard to machine wise and shade wise production figures made it easier for the study team to carry out the material balance. However in the absence of measurement facilities and emission records an energy balance was not carried out.

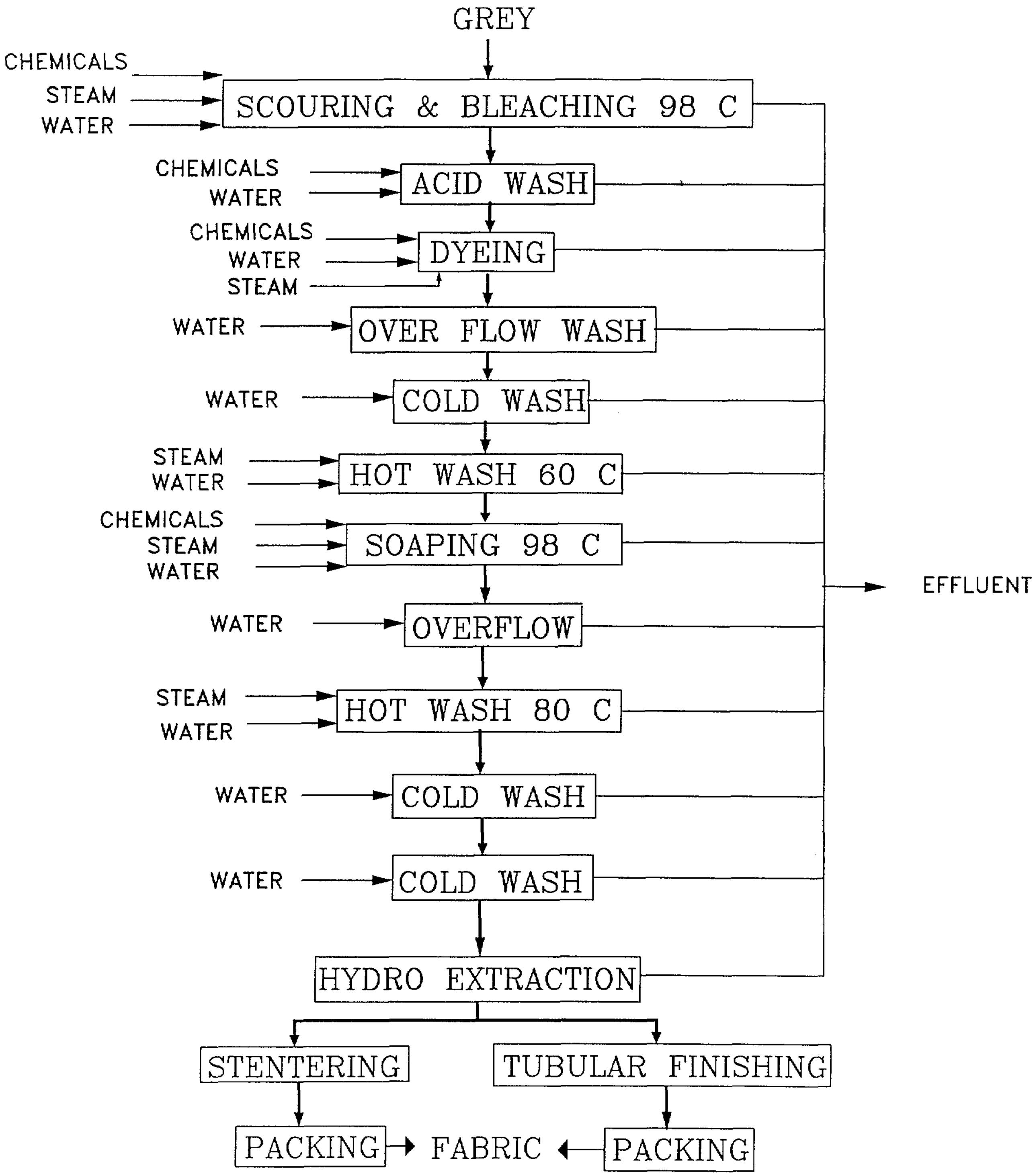
WORKSHEET 2		
Information	**Availability**	**Remarks**
Process flow diagram	Not available	
Material Balance	Not available	Actual consumption for each month available
Energy balance	Not available	Only bills for electricity and furnace oil are available
Water balance	Not available	Average monthly consumption available
Plant layout	Available	Satisfactory
Waste analysis	Not available	No analysis done
Emission records	Not available	No provision to record
Production log sheets	Available	Satisfactory
Maintenance log sheets	Not available	

3.0 PROCESS FLOW DIAGRAMS

The processes indicated in the worksheets 3.1 to 3.3 are used for dyeing of fabric and Worksheets 3.4 and 3.5 indicate the process steps for white fabric with a lower number of rinses etc. Material balances were carried out according to the process steps and conditions indicated in these process flow diagrams.

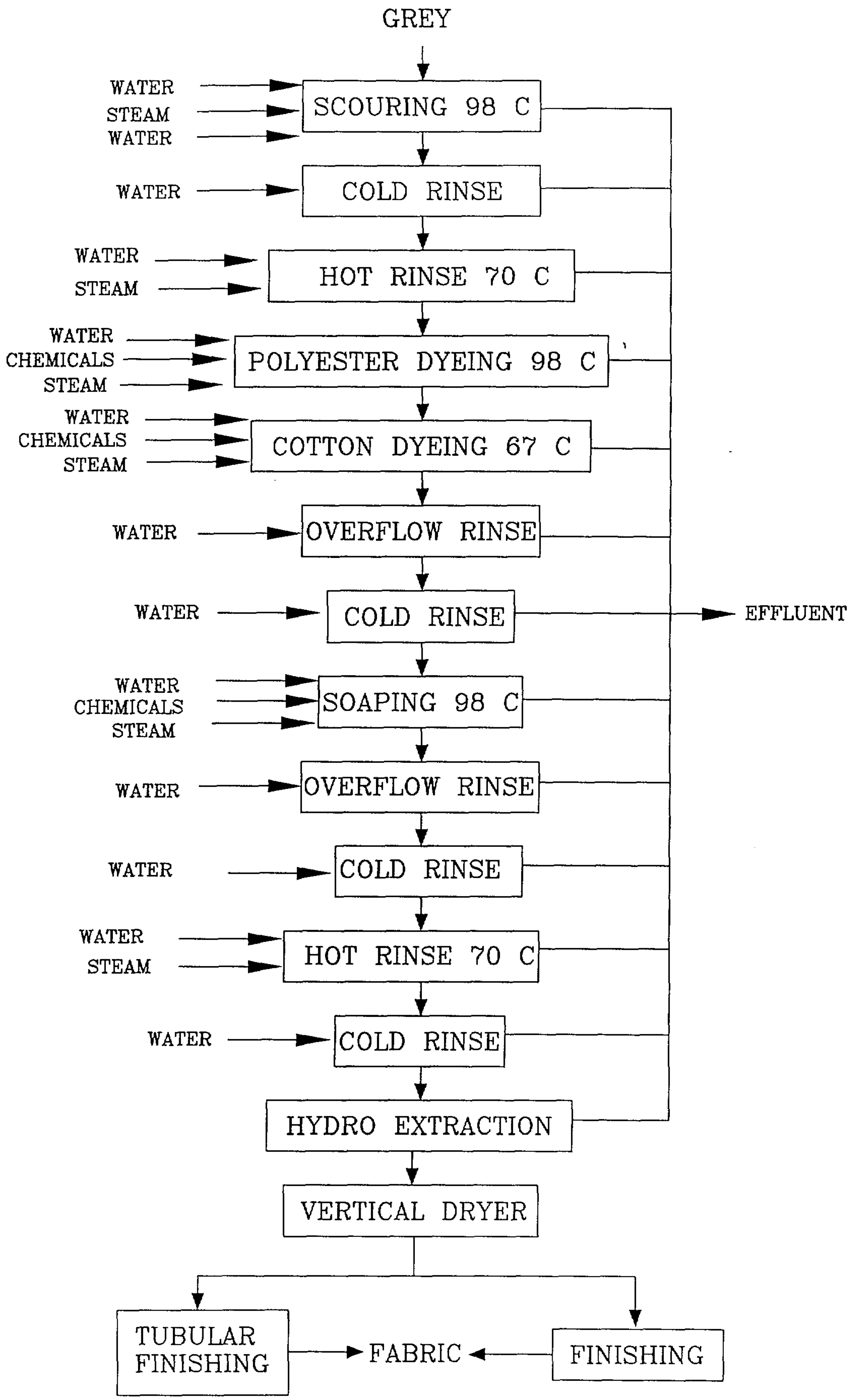
WORKSHEET 3.1

PROCESS FLOW DIAGRAM FOR 100% COTTON



WORKSHEET 3.2

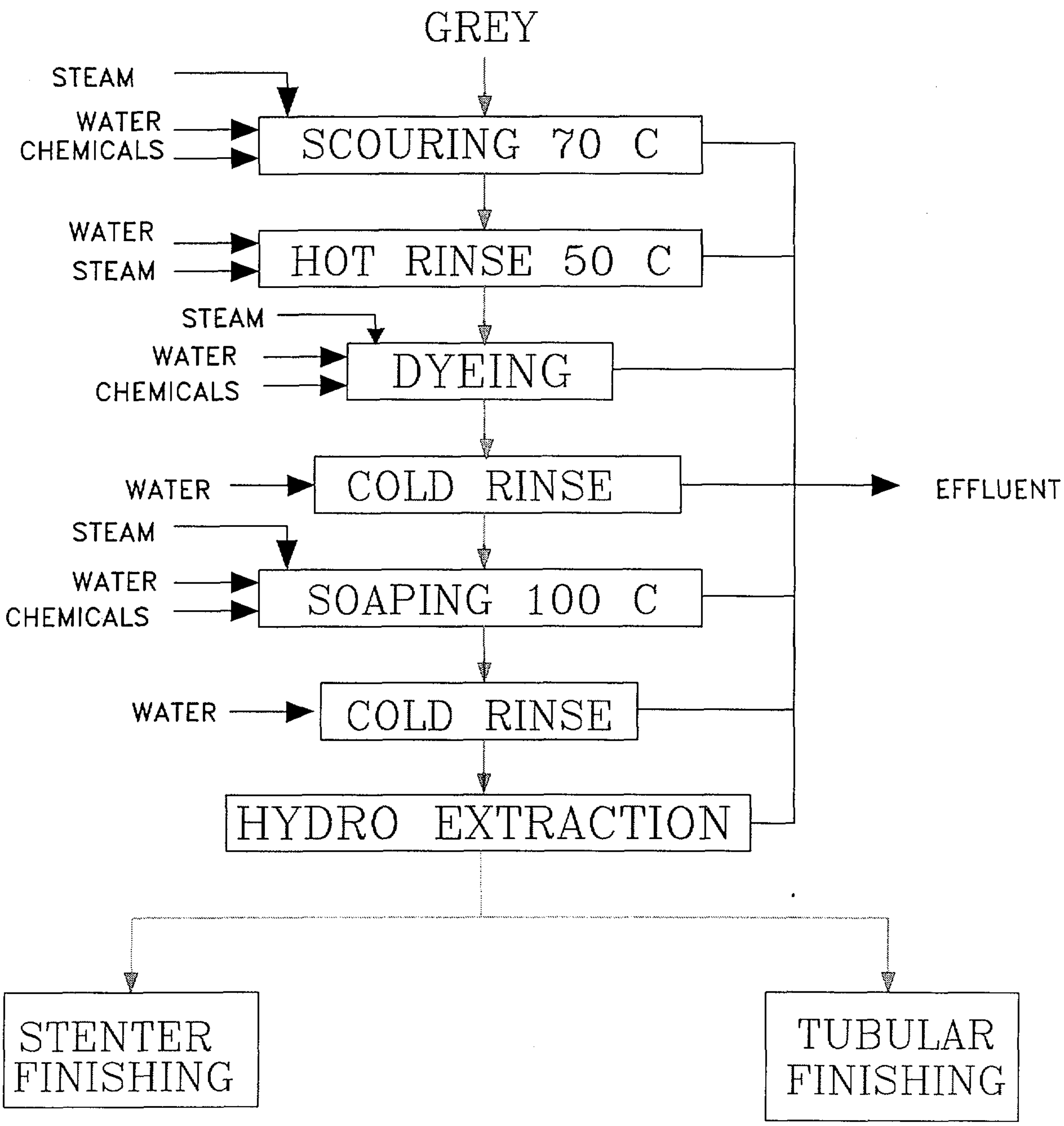
PROCESS FLOW DIAGRAM
COTTON/POLYESTER BLEND



WORKSHEET 3.3

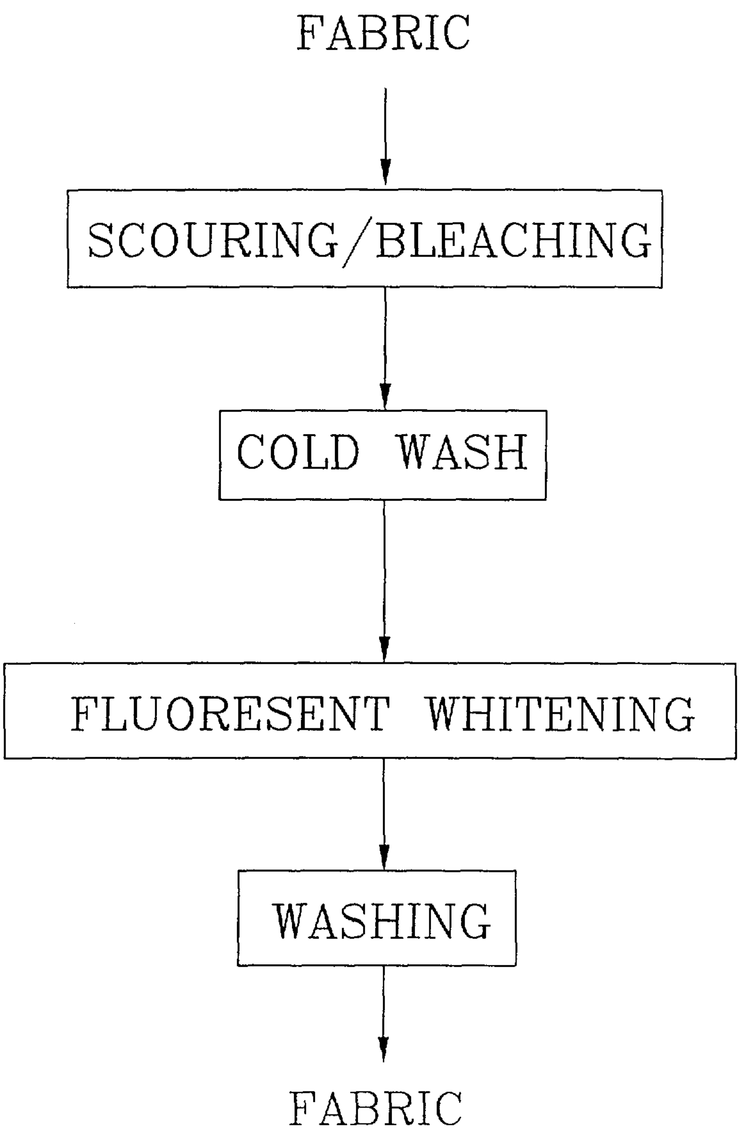
PROCESS FLOW DIAGRAM
100% POLYESTER DYEING

DYEING TEMP. 130 C FOR DARK SHADES &
100 C FOR LIGHT SHADES



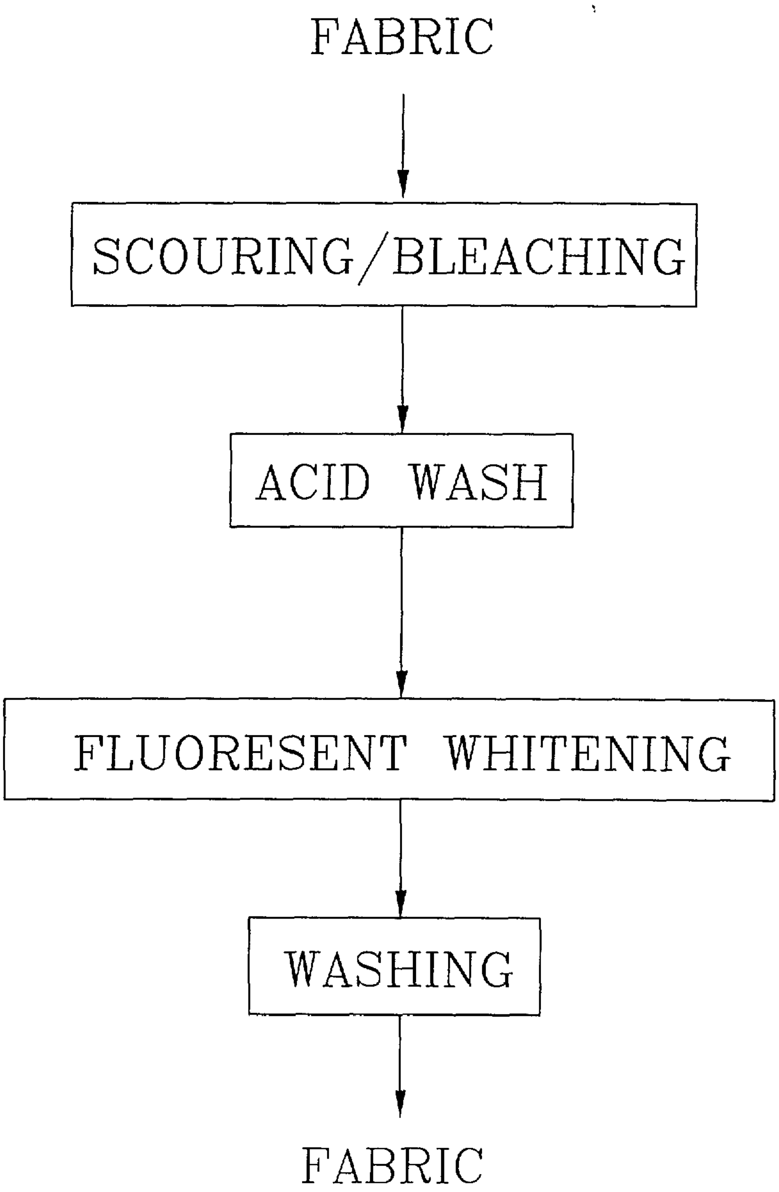
WORKSHEET 3.4

PROCESS FLOW DIAGRAM FOR WHITENING PROCESS (100% POLYESTER)



WORKSHEET 3.5

PROCESS FLOW DIAGRAM FOR WHITENING PROCESS (100% COTTON)



4.0 Housekeeping Status

It is difficult to financially quantify the losses indicated in Worksheet 4 under housekeeping status. However the study team feels that the steam losses in Winch dyeing can be minimised substantially. It is also strongly felt that insufficient space affects productivity significantly.

WORK SHEET 4 **GENERAL REMARKS RELATED TO HOUSEKEEPING**	
Sections	**Lapses in Housekeeping**
Raw material handling	Yarn wastage due to improper handling.
Winch dyeing	Steam wastage due to open dyeing. Water spillage due to use of uncontrolled valves.
Dyeing Area	Space between machines is not sufficient for easy transport of materials.

5.0 Material Balance

The Material balance is carried out using actual monthly production figures given by the industry for the month of November 1994 (Annexure E), liquor ratios (Annexure E) and process flow diagrams (Worksheets 3.1 to 3.5). Assumptions made and the formulae used are indicated below the Worksheet.

WORKSHEET 5

UNIT OPERATION	INPUT MATERIALS		OUTPUT MATERIALS		
			PRODUCT	WASTE STREAM	
	NAME	QUANTITY (kg)	QUANTITY (kg)	LIQUID (m^3)	SOLID (kg)
Scouring	Cotton fabric	13277	§12348 (7799)	§929	Nil
	Polyester	16754	§16252 (10264)	§502	
	Blend	31905	30948 (19545)	957	
	Water	622261		620465	
	Steam	73654		*37841	
	H_2O_2	1142		1142	
	NaOH	68		68	
	Other chemicals	1095		1095	
Acid washing	Cotton	12348 (7799)	12348 (7799)		Nil
	Water	98477		98477	
	Acetic acid	182		182	
Polyester Dyeing	Blend	25299 (15979)	25299 (15979)		Nil
	Polyester	10863 (6861)	10863 (6861)		
	Water	402562		419123	
	Steam	72058		*55497	
	Reactive dyes	51	38	13	
	Disperse dyes	441	419	22	
	Other chemicals	2061		2061	

Cotton Dyeing	Blend	25619	25619		Nil
		(15975)	(15975)		
	Cotton	4393	4393		
		(2774)	(2774)		
	Water	321621		332313	
	Steam	25736		*15044	
	Reactive dyes	39	29	10	
	Disperse dyes	395	375	20	
	Other chemicals	1672		1672	
Soaping	Blend	25980	25980		Nil
		(15979)	(15979)		
	Cotton	2838	2838		
		(4393)	(4393)		
	Polyester	11000	11000		
		(6861)	(6861)		
	Water	440280		460489	
	Steam	59545		*40000	
	Detergent & Other chemicals	598		598	
Cold Washing Cotton 2 rinses Polyester 2 rinses Blend 4 rinses	Fabric	60074	60074		Nil
		(37942)	(37942)	1676289	
	Water	1676289			
Hot Washing Cotton 2 rinses Polyester 1 rinse Blend 2 rinses	Fabric	60074	60074		Nil
		(37942)	(37942)		
	Water	1019502		1057255	
	Steam	81080		*43327	
Hydro extraction	Fabric	60074	60074		Nil
		(37942)	(11553)	26389	
	Water				
Drying	Fabric	60074	59435		
	Moisure	(11553)			♪12192
	Steam	16310		*16310	

Total Process effluent = 4900m^3/M
Total steam used in processes = 329 tonnes/M
All the fabrics are dyed except white shade fabrics.
Soaping is done only for dyed fabrics.

*	The recyclable steam condensate (total volume 208 m^3) is presently discharged into the cold water tank.
♪	Fabric moisture evaporates into atmosphere during the drying process.
**	Water is absorbed by dry fabric during the first wet process
§	Weight loss occurs from the fabric to the liquid stream during scouring
( )	Moisture absorbed in the fabric

ASSUMPTIONS

1) Calculation of the actual heat utilization for the dyeing operation is difficult due to insufficient data. However approximate steam consumption was calculated with the following assumptions.

   (i) Heat absorbed by the machine during the initial stages were not considered. Heat required to raise temperature of water is very high compared to the other absorption and losses.

   (ii) Steam consumed = $(cp_f \times m_f + cp_l \times m_l)(T_o - T_r)/h_s$
   cp_f(1.4 kJ/kg), cp_l(4.2 kJ/kg) - specific heats of fabric and liquid respectively (Ref 1)
   m_f,m_l - mass of fabric and liquid respectively
   T_o,T_r(30°C) - operating & room temperatures respectively
   h_s (2000 kJ/kg) - latent heat of steam

2) Moisture content of the fabric on wet weight basis

   Raw fabric = 7%
   After wet process = 43%
   After hydroextraction = 22%
   After drying = 6%

   eg: calculation of moisture content in raw fabric
   Raw weight of fabric = m
   Moisture in raw fabric = 0.07 x m

   Weight of fabric after scouring (m_1)
   = (100-percentage weight reduction) x m/100
   (weight reduction 7% for Cotton and 3% for Polyester and Blend) (ref 2)
   Moisture in fabric after wet process =$[m_1 \times 0.93/(1-0.43)] \times 0.43$

3) Fixation of dyes (ref 3)

   Reactive dyes 75%
   Disperse dyes 90%

4) Chemical consumption is calculated using recipes provided by the industry. (Annexure F)
Chemical consumption
= [percentage of chemical in the recipe (g/l or g/kg)] x volume of water (or weight of fabric).

It is assumed that almost 100% of the chemicals used are going out with the effluent and the amount of chemicals retained on the fabric is negligible.

5) Jigger and Washing machines were not operated during this month (November 1994).

6) Fabric weight after hydro extractor
m_1 - wet weight of fabric
m_2 - weight of fabric after hydro extractor
m_d - dry weight of fabric

$m_d = (1-0.43)\ m_1 = 0.57m_1$
$m_d = (1-0.23)\ m_2 = 0.77m_2$

$m_2 = (0.57/0.77)\ m_1 = 0.74m_1$

7) Fabric weight after drying - m_3
$m_3 =$ weight of fabric after drying
$m = 0.77m_2$
$= (1-0.06)m_3 = 0.96m_3$
$m_3 = (0.77/0.94)m_2 = 0.82m_2$

6.0 Total Water Balance

Worksheet 6.0 indicates the water consumption in individual processes both quantity and percentagewise, undefined losses and also the actual liquor ratios used in the processes.

WORKSHEET 6.0 TOTAL WATER BALANCE (NOVEMBER 1994)				
Operation	**Estimated consumption l/M**	**Production kg/M**	**Liquor ratio**	**% consumption**
Scouring	622,261	61,941	10	6.2
Acid washing	98,477	12,348	8	1.0
Polyester Dyeing	402,562	36,163	11	4.0
Cotton Dyeing	321,621	29,692	1	3.2
Soaping	440,280	40,555	11	4.4
Cold washing	1,676,289	59,548	26	16.8
Hot washing	1,019,502	59,548	17	10.2
Domestic *	159,375			1.6
Boiler water	337,135			3.4
Total	5,077,502			50
Actual water consumption	10,000,000			
Undefined consumption**	4,922,498			49.2

** Undefined consumption, 5357m^3 per month is quite a high value. It must be noted that overflow washings were not taken into consideration in the water balance and also the actual figure for water consumption was provided by the industry and actual measurements were not carried out.

ASSUMPTIONS MADE

* Domestic water consumption is estimated from usage per head; 75 l/worker/day and the number of workers and working days per month amount to 85 and 25 respectively.

1) Actual water consumption was calculated from average daily consumption figure (400m^3/day) provided by the industry
2) Boiler water consumption was calculated from average fuel oil consumption (1320 l/day) and boiler efficiency (generally 70% in industries).
Enthalpy of steam at boiler pressure(8 atm) - 2775 kJ/kg
Heat capacity of fuel - 40500 kJ/l (Ref 1)
Boiler water consumption = 1320 x 25(days) x 40500 x 0.7/2775 = 337135.14 l

7A. COD ANALYSIS TABLE

COD analysis was carried out for each discharge from 1 jet, winch and the fongs machine during the processing 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. COD analysis was carried out by Central Environmental Authority laboratory staff on 13.11.1995.

Average COD of process effluent based on above values - 1760 mg/l
Average COD of process effluent based on total water consumption (assuming other waste water generated has negligible COD) - 862 mg/l

WORKSHEET 7A					
STREAM	**WATER l/batch**	**COD mg/l**	**COD kg/batch**	**COD %**	**WATER %**
Jet					
Polyester dyeing	750	2850	2	9	6
Rinse of polyester dyeing	750	510	neg*	2	6
Cold rinse (cotton dyeing)	750	690	1	2	6
Soap washing (cotton dyeing)	750	905	1	3	6
Cotton dyeing	750	1800	1	6	6
Winch machine (cotton)					
Scouring	1500	4365	7	28	12
Hot rinse	1500	1855	3	12	12
Cold rinse	1500	496	1	3	12
Fongs machine (cotton)					
Scouring	3000	2435	7	31	24
Total	12750		23	100	100

* Neg -Negligible

7B. WASTE AND EMISSIONS COST

Material consumption figures from the material and water balances (worksheets 5 & 6) and COD analysis data (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 7B				
UNIT OPERATION	COST COMPONENT	QUANTITY (kg/MONTH)	UNIT COST (Rs/1000kg)	TOTAL COST (Rs/MONTH)
Scouring	Chemicals§	2305	62,000	142,910.00
	Water	622261	7.81	4,860.00
	Steam*	73654	1200	88,385.00
	COD removal**	1720	30,000	51,600.00
	Total cost assigned to waste stream **Cost assigned per m^3 of effluent (622 m^3)**			**287,755.00** **463.00**
Acid washing	Acetic acid***	182	79,000	14,378.00
	Water	98477	7.81	769.00
	COD removal**	60	30,000	1,800.00
	Total cost assigned to waste stream **Cost assigned per m^3 of effluent (98 m^3)**			**16,947.00** **173.00**
Polyester Dyeing	Chemicals§	2061	62,000	127,782.00
	Reactive dyes§	13	1,505,000	19,565.00
	Disperse dyes§	22	1,327,000	29,194.00
	Water	402562	7.81	3,144.00
	Steam*	72058	1200	86,470.00
	COD removal**	277	30,000	8,310.00
	Total cost assigned to waste stream **Cost assigned per m^3 of effluent (403 m^3)**			**274,465.00** **681.00**
Cotton dyeing	Chemicals§	1672	62,000	103,664.00
	Reactive dyes§	10	1,505,000	15,050.00
	Disperse dyes§	20	1,327,000	26,540.00
	Water	321621	7.81	2,512.00
	Steam*	25736	1,200	30,583.00
	COD removal**	711	30,000	21,330.00

	Total cost assigned to waste stream **Cost assigned per m³ of effluent (322 m³)**			**199,979.00** **621.00**
Soaping	Chemicals§	598	62,000	37,076.00
	Water	440280	7.81	3,439.00
	Steam*	59545	1,200	71,454.00
	COD removal**	534	30,000	16,020.00
	Total cost assigned to waste stream **Cost assigned per m³ of effluent (400 m³)**			**127,989.00** **291.00**
Cold washing	Water	1676289	7.81	13,092.00
	COD removal**	861	30,000	25,830.00
	Total cost assigned to waste stream **Cost assigned per m³ of effluent (1676 m³)**			**38,922.00** **23.00**
.Hot washing	Water	1019504	7.81	7,962.00
	Steam*	81080	1,200	97,200.00
	COD removal **	2272	30,000	68,160.00
	Total cost assigned to waste stream **Cost assigned per m³ of effluent (1020 m³)**			**173,222.00** **170**
Composite Effluent	**Total cost assigned to waste stream** **Total waste stream (4581 m³)** **Cost assigned per m³ of effluent**			**1,119,279.00** **244.00**

* Details of steam cost calculation are given in Annexure G

** Cost of disposal of effluent was calculated on the basis of COD (Annexure H) and unit cost of disposal includes both Chemical and Biological treatment costs.
Acid washing COD load is calculated from average COD values obtained from other textile industries since COD analysis was not carried out for this stream.

*** Cost component has been given separately for Acetic acid as substitution for this has been suggested as a waste minimisation option.

§ Unit cost of chemicals and dyes for all the processes was calculated based on the monthly chemical cost provided by industry.

Utility costs and utility costs/kg fabric are given in Annexure I.

8.0 WASTE MINIMISATION OPTIONS

Most of the options identified by the waste audit team were based on observations during visits to the industry and these options along with other details are presented in Worksheet 8.0.

For each option, actions were identified which would help in assessing the costs and benefits of implementing the options. Quantification and analysis listed under the actions helped in indicating the importance of implemememtation of some of the options identified during the visits by the team. eg. steam condensate recovery and reuse as boiler feed water. 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 for implementing the options was decided in discussion with the management of the industry.

WORKSHEET 8.0								
Area/Process	Unit operation	Waste Minimisation (WM) Option	Actions to assess WM options	Category	Effect	Timing	Priority	Cost
RAW MATERIAL HANDLING	All operations	1.1 disposal of packaging materials	* identification & quantification of the material * Recycling of by product * Cost benefit analysis	RR	WM	ST	5	L
	Knitting	1.2 Yarn waste	* identification of the material and quantification * Prevention and control of the wastage * Cost benefit analysis	RC	WM	ST	4	L_1
	Purchasing	1.3 Reduce oil content of commissioned fabric & yarn	* Check oil content * Estimate cost of additional process chemicals required for removal of oil	MC	PR	ST	6	L
DYEING	Dyeing	2.1 Employ cold pad batch dyeing	* Carry out trials * Estimate water, energy & chemical savings	TC EM	WM ES	LT		H
		2.2.1 Prevention of under capacity operation	* Collection of information of orders * Production planning based on the supply and demand * Evaluation of cost benefit analysis (comparison with present operation)	RC	WM ES	MT		L
		2.2.2 Installation of low capacity machines	* Determination of required capacity * Estimation of chemical & water savings with low capacity machines	EM	WM ES	MT	8	H

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 - Wastewinimisation
H - High cost
M - Medium Cost
PR - Pollution Reduction
ST - Short term
1 - 10 - Increasing priority
HK - Housekeeping

Area/ Process	Unit operation	Waste Minimisation (WM) Option		Actions to assess WM options	Category	Effect	Timing	Priority	Cost
DYEING	Dyeing	2.3	Chemical Substitution Sulphur dyes Leverol with Cottoclarin KD Acetic acid with Formic acid Common salt with Glauber salt Sodium sulfide with hydrol Sodium hydrosulfide with Thiourea dioxide	* Consult textile expert * Determine cost benefit * Carry out trials	MC	WM PR	ST	8	M
	Dyeing	2.4	Elimination/ reduction of chemicals a) Dispersing agent b) Sequestering agents	* Consult textile expert & evaluate present chemical consumption * Carry out trials without dispersing agent * Estimate savings and COD reduction * Estimate cost of water treatment or use of municipal water for dyeing only * Estimate savings in sequestering agent	RC	PR WM	ST	8	L
	Dyeing	2.5	Reuse of white dye bath discharges	* Estimate cost of construction of tank * Quantify water & chemical savings & estimate cost benefit	RR	PR WM	MT	7	M
2a) WINCH DYEING	All operations	2a.1	Prevention of open heating	* Identification & prevention of difficulties for closed steaming * Measure steam consumption & estimate losses	RC	ES	LT	3	L
	All operations	2a.2	Installation of temperature control system	* Identification of required temperature & working temperature * Calculation of losses due to overheating * Estimation of cost for temp control system	PC	ES	MT	6	M
	All operations	2a.3	Introduction of indirect steam heating	* Estimate steam use & condensate recovery * Estimation of energy & water savings * Estimation of capital required	RC	ES	MT	4	H
		2a.4	Replacement of winch with advanced dyeing machine (fongs)	* Identification of machine * Estimation of savings * Cost benefit analysis	EM	WM ES	LT	6	H

Area/ process	Unit operation	Waste Minimisation (WM) option		Actions to assess WM options	Category	Effect	Timing	Priority	Cost
JET DYEING	All operations	2b.1	Repairing of automatic control systems for heating	* Measure temperature & identify required repairs * Estimation of cost * Calculation of savings (heat waste, time)	PC	ES	MT	4	M
	All operations	2b.3.1 2b.3.2	Cooling water recovery for process water Heating of water after cooling using stenter or oiler exhaust or hot effluent	* Estimate quantity of water & temperature * Estimate cost of construction of tanks * Calculation of water and heat savings * Selection of waste heat source * Estimate cost of heat exchanger & benefits	RC RC	WM ES	MT	5	M M
	All operations	2b.4	Insulation of jet dyeing machine	* Estimation of heat loss * Steam recovery	RC	ES	MT	4-5	H
	All operations	2b.5	Increasing of loading capacity of new Jet 1 & 2 (To decrease liquor ratio)	* Identification of possibilities to install high capacity motor * Estimation of saving of water and heat	RC	WM	MT	5	M
	All operations	2b.6	Replacing the jets with low liquor ratio ones	* Estimate required capacity * Estimate water & chemical savings	EM	WM ES	MT- LT	7-8	H
	All operations	2b.7	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	ST	5	L

Area/Process	Unit operation	Waste Minimisation (WM) Option		Actions to asses WM options	Category	Effect	Timing	Priority	Cost
FONGS DYEING	All operations	3.1	Insulation of fongs	* Estimate surface area & cost of lagging * Estimate present heat losses	RC	ES	ST	3	M
HYDRO EXTRACTOR	Water extraction	4.1	Recycle of water for dyeing operation	* Estimation of volume of water * Estimation of required capital items * Cost benefit analysis	RC	WM	MT	6	M
	Water extraction	4.2	Replace hydro extractor with squeezee	* Check moisture removal efficiency * Estimate electricity savings * Estimate resale value of hydro extractor	EM	ES	LT	5	H
VERTICAL DRYER	Drying	5.1	Using of low humidity air from outside for drying	* Estimation of humidity difference * Calculation of steam savings * Estimation of capital cost	RC	ES	LT	2	M
STENTER	Finishing	6.1	Introduction of low humidity air from outside	* Estimation of humidity difference * Calculation of steam savings * Estimation of capital cost	RC	ES	LT	2	M
	Finishing	6.2	Avoid overdrying of fabric	* Check moisture content of fabric * Install moisture meter * Estimate energy savings	RC	ES WM	MT	4	L
	Finishing	6.3	Installation of a vacuum slit device	* Check moisture content with & without Vacuum slit device * Estimate cost of installation * Estimate energy savings	EM	ES WM	LT	4	H

Area/Process	Unit operation	Waste Minimisation (WM) Option		Actions to assess WM options	Category	Effect	Timing	Priority	Cost
THERMIC BOILER	All operations	7.1	Improvement of boiler efficiency	* Carry out boiler efficiency study * Check possibility of heat recovery * Estimate cost of heat recovery	RC	ES	MT	6	L
STEAM BOILER	All operations	8.1	Improvement of boiler efficiency	* Carry out boiler efficiency study * Check possibility of heat recovery * Estimate cost of heat recovery	RC	ES	MT	6	L
	All operations	8.2	Condensate recovery from jets, vertical dryer	* Estimate total condensate recovery (quantity & heat) * Estimate cost of collection tank & pump * Estimate savings in boiler treatment chemicals	RC	ES WM	ST	7	M
	All operations	8.3	Boiler feed water quality improvement	* Analysis and treatment * Estimation of heat losses due to scale formation	RC	ES WM	MT	6	L-M
	All operations	8.4	Lagging the steam lines	* Estimate the length & diameter of pipelines to be lagged * Estimate cost of lagging * Estimate energy savings	RC	ES WM	ST	5	M
	All operations	8.5	Construction of a separate tank for cooling water	* Quantify the volume & determine the temperature * Estimate cost of construction of a separate tank	RC	ES WM	ST	7	M

Area/Process	Unit operation	Waste Minimisation (WM) Option	Actions to asses WM options	Category	Effect	Timing	Priority	Cost
STEAM BOILER	All operations	8.6 Lagging unlagged surface area	* Estimate the area of unlagged boiler surface * Measure Surface temperature * Compare cost of lagging with energy savings	RC	WM ES	MT	6	M
WATER TREATMENT	All operations	9.1 Water quality improvement	* Analysis of treated water * Evaluation of present water treatment * Suggestions for further improvement especially for removal of iron * Estimation of savings and quality improvement * Cost estimation	QI RC	PR WM	ST-MT	6	L-M
HEAT SETTING	Heat setting	10.1 Reduce heat loss when it is being utilised for narrow width fabric	* Insulated cover (sliding for open areas heat is being lost)	RC	ES	ST	4	L
GENERAL	All operations	11.1 Reducing energy (electricity) cost	* Staggered utilisation of pumps, machines etc. to prevent electricity surcharge * Soft starters for motors to reduce KVA demand	RC	ES	MT		L-M

9. COST BENEFIT ANALYSIS

From Worksheet 8.0, ten options with highest priority were selected and cost benefit analysis was carried out. The investment, savings and payback period for these options are presented in Worksheets 9.1 to 9.10 and the relevant details are indicated below the respective Worksheet. For quantification of waste in order to calculate savings, information from the material balance (worksheet 5.0), process flow sheets (worksheets 3.1 - 3.5), COD analysis (worksheet 7A) etc. were used. Individual measurements were carried out for information required with respect to energy. The investment is based on the technology identified by the Waste Audit team.

WORK SHEET 9.1			
Chemical Substitutions (Option 2.3 in worksheet 8)			
	Rs	**Saving**	**Rs/y**
Investment	Nil	Chemicals Treatment cost	144,204 64,920
		TOTAL	**209,124**
	Rs	**Net saving** =(saving - annual operating cost)	**209,124**
Annual operating cost	Nil	**Pay back period** =(Investment/Net saving)12 **= Not Applicable**	

Chemical Saving = (present chemical consumption x unit cost)-(chemical needed to replace x unit cost)

Treatment cost saving = (percentage COD reduction) x (treatment cost Rs 30/kg)
or
=(Chemical consumption x COD - substitute chemical consumption x COD) x treatment cost

I) **Acetic acid by Formic acid (83% COD reduction & 50% chemical saving)**

Chemical saving = 182 (kg/M) x 79 (Rs/kg) - 91 (kg/M) x 78 (Rs/kg)
= Rs 7280/M
COD reduction = 182 (kg/M) x 1.04 (kg/kg) - 91 (kg/M) x 0.34 (kg/kg)
= 158.34 kg COD/M
Treatment cost reduction = Rs 4750/M

II) **Sodium hydrosulphide by Thiourea dioxide (Reducton HF), (85% COD reduction)**

Chemical saving = 68 (kg/M) x 90 (Rs/kg) - 68/6 (kg/M) x 190 (Rs/kg)
= Rs. 3967

COD reduction = 68 (kg/M) x 0.33 (kg/kg) - 68/6 (kg/M) x 0.33 (kg/kg) x 0.15
= 22 kg/M

Treatment cost reduction = Rs 660/M

III) **Sodium sulphide by Hydrol (only chemical saving)**

Chemical saving = 154 (kg/M) x 45 (Rs/kg) - 154 (kg/M) x 40 (Rs/kg)
= Rs 770/M

Total monthly saving

Chemical = Rs 12,017

Treatment cost = Rs 5410

This option will reduce 2% of the totol COD (i.e 180 kg/M)

Details about chemical substitution were obtained from (ref 3)

WORK SHEET 9.2			
Installation Of Temperature Control System For Winches (option 2a.2 in worksheet 8) (4 numbers)			
Investment	**Rs** Nil	**Saving**	Rs/y
Temperature control system	165,000	Steam	193,478
		Net saving =(saving - annual operating cost)	**158,828**
Annual operating cost	**Rs**		
Interest (21%)	34,650	**Pay back period** =(Investment/Net saving)12	= **12 Months**

Cost of temperature control unit = Rs 41,250/unit (in 1990 US$ 750) (ref 4)

Current total steam consumption in winches at 100°C = 47,026 kg/M

Steam consumption at optimum temperature (80°C) = 47,026(80-30)/(100-30)
= 33,590 kg/M

Steam saving = 13,436 kg/M
= 13,436(Rs 1.20)/M
= Rs 193,478/y

This option will reduce total effluent due to the reduction of steam condensate by 0.2% of the total

WORKSHEET 9.3			
Installation of press button switches for jets (8 numbers)(option 2b.7in worksheet 8)			
Investment	**Rs** Nil	**Saving**	**Rs/y**
Press button switches	800	Electricity	21,911
	Rs	**Net saving** =(saving - annual operating cost)	**21,911**
Annual operating cost	Nil	**Pay back period** =(Investment/Net saving)12 = **1 Month**	

Number of bulbs	=	8
Operating hours	=	3600/y (assuming 12 hours operation of jets)
Total power loss	=	8 x 0.12 x 3600
Unit cost of electricity	=	Rs. 6.34
Electricity savings/ y	=	Rs. 21,911

WORK SHEET 9.4			
Lagging unlagged steam lines (option 8.4 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Lagging Cost	9,350	Steam	25,197
		Net saving =(saving - annual operating cost)	**23,227**
Annual operating cost	**Rs**		
Interest (21%)	1,970	**Pay back period** =(Investment/Net saving)12	= **5 Months**

Lagging cost

Diameter of pipe (mm)	Length(m)	Unit cost(Rs/m)	Lagging cost(Rs)
100	10	374	3740
50	14	299	4186
25	7	203	1421

*Lagging costs were obtained from local suppliers

Total lagging cost	= Rs 9,350
Total unlagged area (A)	= 5.89 m^2
Unlagged surface temperature	= 113^0 C
Temperature difference after lagging(TD)	= (113-40) = 73^0C
Heat transfer coefficient (h)	= $1.25(TD)^{1/8}$ = 5.22 Wm^{-2} K^{-1}
Total energy loss (Q)	= A x h x(TD) x working hours x days/y x 3600/1000 kJ
Steam saving	= (Q/H) x steam cost = (21,000 x 1.2) = Rs. 25,197

Enthalpy of steam (H) at 8 atm operating pressure = 2770 kJ/kg

* Technical data from (Ref 5)

This option will reduce requirement of steam production by 0.5% or fuel consumption by 0.5%

WORK SHEET 9.5			
Condensate recovery and reuse as Boiler feed water (option 8.2 in worksheet 8.0)			
Investment	**Rs**	**Saving**	**Rs/y**
Pipe installation etc.	123,300	Fuel saving	154,862
Collection tank	40,650	Boiler water treatment cost	22,139
Lagging of:-		Water cost	19,493
Collection tank	20,094		
Pipes	3,124	**Total**	**296,494**
Feed water tank	8,750		
		Net saving	**176,765**
TOTAL	**93,918**	=(saving - annual operating cost)	
Annual operating cost	**Rs/y**	**Pay back period**	
Interest (21%)	19,728	=(Investment/Net saving)12	
			= 6 Months

Existing pump is used for pumping water from main sump to boiler feed water tank.
Technical data from (ref1)

Total volume of condensate	= 208m^3/M
Average temperature of condensate	= 90^{0}C
Heat savings	= 208 x 1000 x 4.2 x 60
	= 52416000 kJ/M
Calorific value of fuel oil	= 40,500 kJ/l
Boiler efficiency	= 70%
Fuel saving	= (52,416,000/40,500)/0.7 l/M
	= 1848(l/M) x 12(M) x 6.98(Rs/l)
	= Rs.154,862
Boiler water treatment cost saving	= 208 x 8.87(Rs/m^3) x 12
	= Rs 22,139/y
Water cost saving	= 208 x 7.81 x 12

Cost - Collection tank (2 m^3 capacity circular tank with 1.5 m, 1.2 m height).

Cost of four metal sheets	= Rs 8,000 x 4
Excavation and civil work	= Rs 3650
Construction	= Rs 5,000
Lagging (18.65 m^2)	= 18.65 x Rs 1,560
	= Rs 29,094
Cost of carbon steel pipe (50m length, 37.5mm diameter carbon steel)	= Rs 12,300 (Rs 246/m length)
Feed water tank lagging	
Area for lagging	= 5.6 m^2
Cost of lagging	= Rs 1560 /m^2
	= Rs 19,493/y

This option will reduce boiler water consumption by 62% or fuel consumption by 6%.

WORK SHEET 9.6			
Lagging unlagged portion of the Boiler (option 8.6 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Lagging cost	**30,498**	Steam	79,008
		TOTAL	79,008
Annual operating cost	**Rs**	**Net saving** =(saving - annual operating cost)	**72,603**
Interest (21%)	6,405	**Pay back period** =(Investment/Net saving)12	**= 5 Months**

Boiler Unlagged area (A)	= 19.55 m^2
Unlagged surface temperature	= 1100°C (measured)
Temperature Difference (TD)	= (110-40) = 70^0C
Heat transfer coefficient(h)	= 5.151 $W/m^2\ {}^0K$ (ref 3)
Total heat loss (Q)	= A x h x (TD) x operating time
Steam saving	= (Q/H) x steam cost, H-steam enthalpy
Lagging cost	= Rs 1560/m^2

(Lagging costs were obtained from local suppliers)

WORKSHEET 9.7			
Lagging unlagged Jets (J1,J2,NJ1,NJ2) (option 2b.4 in worksheet 8)			
Investment	**Rs**	**Saving**	**Rs/y**
Lagging cost	**182,520**	Furnace oil	249,426
		TOTAL	**249,426**
Annual operating cost	**Rs**	**Net saving** =(saving - annual operating cost)	**211,097**
Interest (21%)	38,329	**Pay back period** =(Investment/Net saving)12	**= 10 Months**

J1 :- Jet1, J2 :- Jet2, NJ1 :- New jet1, NJ2 :- New jet2

Total Unlagged Jets surface area (A)	= 117 m^2
Maximum surface temperature	= 127^0C (measured)
Average surface temperature	= 98^0C
Temperature difference after lagging(TD)	= $(98-40)^0C$
Heat transfer coefficient(h)	= 4.84 W/m^2K (ref2)
Total heat loss (Q)	= A x h x (TD) x operating time (714 hours)
Boiler efficiency	= 70%
Furnace oil saving	= (Q/40500kJ/l)/(0.7)
	= Rs 249,426/y
Cost of lagging	= Rs 1560/m^2

* Cost of lagging obtained from local suppliers

WORK SHEET 9.8			
Use municipal water for dyeing to avoid use of sequestering agent (option 2.4 in worksheet 8.0)			
Investment	**Rs** Nil	**SavingRs/y**	
		Chemical saving (Calagon P.T)	278,640
		Well water saving	93,645
		TOTAL	**372,285**
Annual operating cost	**Rs**	**Net saving** =(saving - annual operating cost)	**72,525**
Municipal water	299,760	**Pay back period** =(Investment/Net saving)*12	**= Not applicable**

In September 1995
Total dyed fabric production = 61,649 kg
Amount of sequestering agent (Calagon P.T) used = 251 kg

In November 1994
Total dyed fabric production = 42,027 kg
Therefore assumed Calagon P.T consumption = 172 kg
Water used for dyeing = 999.201 l (from material balance 5.0)

Chemical saving = (172 kg)(Rs135/kg)12(M)
= Rs 278,640/y

Municipal water cost = (999.201m^3) x (Rs25/m^3) x 12(M)
= Rs 299,760/y

Deep well water saving = (999.201 m^3)(Rs 7.81/m^3)12(M)
= Rs 93,365/y

WORK SHEET 9.9			
Reduce mineral oil content of the commissioned fabric and yarn (option 1.3 in worksheet 8.0) (at least by 75%)			
	Rs	**Saving**	**Rs/y**
Investment	Nil	Chemical saving	73,728
		TOTAL	**73,728**
	Rs	**Net saving** = (saving - annual operating cost)	**73,728**
Annual operating cost	Nil	**Pay back period** =(Investment/Net saving)12	**=Not applicable**

Avoid purchasing of commissioned fabric with more mineral oil content and request the supplier to reduce oil content of commissioned fabric and yarn . Industry currently uses Ultravon FL to remove the oil

Chemical saving = Consumption x Price x Reduction percentage
= 33 x 248.25 x 0.75
= Rs 6,144/M
= Rs 73,728/y

Assumptions made

* Treatment saving not considered
* Percentage reduction of oil will give the same percentage of chemical saving.

WORK SHEET 9.10			
Improvement of boiler combustion efficiency (option 8.1 in worksheet 8)			
	Rs	**Saving**	**Rs/y**
Investment	Nil	Furnace oil	66,338
		TOTAL	**66,338**
	Rs	**Net saving** =(saving - annual operating cost)	**66,338**
Annual operating cost	Nil	**Pay back period** =(Investment/Net saving)12	**= Not applicable**

Current combustion efficiency of the boiler 89.5 %
Combustion efficiency was measured by staff of the 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.

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

Current furnace oil consumption	= 39,600 l/M
Furnace oil saving	= (39,600 - 39,600 x 0.895/0.915) x 12
	= 9,504 (l/y) x 6.98(Rs/l)
	= Rs 66,338/ y

This option will reduce the boiler oil consumption by 2% of total .

10.0 IMPLEMENTATION OF WASTE MINIMISATION OPTIONS

The status of implementation of the ten waste minimisation options identified to be of high priority for this mill is summarised in Worksheet 10. Only chemical substitution options, lagging of steam lines and non acceptance of yarn which has a high content of oil have been implemented. Reasons for non-implementation are given. Comparision 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 are given following 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.

Implementation of the three options gave the following savings to the industry:-

I Without treatment cost savings

Total annual savings	**= Rs 352,698.00**
Investment	**= Rs 38,164.00**
Interest on investment (21%)	**= Rs 8,014.00**
Pay back	**= less than 1.5 Months**

II With treatment cost savings

Total annual saving	**=Rs 433,074.00**
Investment	**=Rs 38,164.00**
Interest on investment (21%)	**=Rs 8,014.00**
Pay back	**= less than 1 month**

WORKSHEET 10.0										
Waste minimization 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) Chemical(kg)	3.92 3.77	117.38 324.09	0.64 1.88	19.22 136.61	98.36 164.87	0.88 2.60	26.47 188.14	90.91 135.95	Implemented
b) Common Salt for Glauber Salt	Chemical(kg)	55.19	220.7	-	-	-	-	-	-	Not implemented Trials are instead being carried out with low salt dyes
c) Thiourea dioxide (reduction HF) for Sodium hydrosulfide	COD (kg) Chemical(kg)	0.4 1.1	10.52 95.7	0.06♪ 0.18	1.76♪ 33.79	8.77♪ 61.91	0.23 0.69	6.80 61.80	3.72 33.9	Not implemented but chemical consumption has been reduced by minimising number of machine washing steps by changing process sequence from light to dark and then washing.
d) Hydrol for Sodium sulfide	Chemical(kg)	2.41	108.38	2.41	96.34	12.04	-	-	-	Not implemented as use of sulphur dyes and sodium sulfide has been stopped
e) Cottaclarin KD for Leveral	COD Chemical(kg)	2.97 5.94	89.15 1634.44	§	§	§	2.64 6.59	79.10 1582.03	10.05 52.403	Implemented by substituting with Univadine Lu as more readily available than Cottaclarin.
2) Installation of temperature controller in winches	Fuel (l)	124.8	871.10	89.2	622.62	248.48	–	–	–	Only temperature gauges have been installed as it is proposed to replace these machines. Temperature gauges have not brought savings as workers are not looking at these.
3) Press button switches installation for jets	Electricity (kWh)	4.50	28.56	-	-	28.56	-	-	-	Not implemented as savings are perceived to be small and implementation impracticable
4) Lagging steam lines	Fuel (l)	619.4	4323.4	617.5	4310.2	13.2	603.35	4211.35	112.2	Implemented

5) Condensate recovery	Fuel (l) Chemical(kg) Water (l)	619.4 5270	4323.4 46.8 41.11	599.1 2019.7	4181.7 17.9 15.75	141.7 28.9	-	-	-	Not Implemented Awaiting funds required for high investment.
6) Lagging boiler surface area	Fuel (l)	619.4	4323.4	613.5	4282.2	41.2	-	-	-	Not implemented as it is thought that this would hinder frequent cleaning and maintenance which is done by opening back end of the boiler.
7) Avoid use of sequestering agent by using good quality process water	Chemical(kg) Water(l)	4.1 23.8	552.5 122.05	0 23.8	0 390.69	552.5 -262.68	-	-	-	Not implemented as municipal water is not available. Awaiting funds to upgrade water treatment system.
8) Reduce mineral oil in commissioned fabric♫	Chemical (kg)	33000/Month	8184000/ Month	8250 /Month	2046000/ Month	6138000/ Month	0	0	8184000/ Month	Customers have been warned and such batches are now not accepted.
9) Improvement of boiler efficiency	Fuel (l)	619.4	4323.4	605.8	4229.82	93.58	-	-	-	Not implemented. Boiler supplier has been requested to monitor efficiency .
10) Lagging of jets	Fuel (l)	619.4	4323.4	552.8	3858.71	464.69	-	-	-	Not implemented due to high investment required.

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

Note:- For before implementation and expected consumption and savings calculations, total production for November 1994 (63937 kg) was taken to calculate unit consumption for all options except for No. 2 (18592 kg), and No. 7 (42027 kg). Production for the respective processes were taken for these two options. For actual consumption and savings after implementation calculations production figures given by the industry for a time period for that option was utilised (125425 kg was taken for options 1a and 1c, 53491 kg for option 1e, 132592 for option 4).

♪ Expected consumption was calculated for the replacement of Sodium Hydrosulphide by Thiourea dioxide.

§ Expected value was not calculated due to the lack of information available in chemical reduction as well as COD reduction.

♫ Ultravon FL was used to remove oil contamination of fabric, now this chemical is not required. The consumption and price was taken as in November 1994. Treatment cost reduction is not considered. Values are given with respect to a time period (month) and not unit production for this option, as no information was available on the quantity of commissioned fabric.

COST BENEFIT CALCULATION FOR IMPLEMENTED OPTIONS

Monthly production figure for Nov.94 was used in the calculations (63,937 kg)

1. **Chemical substitution** (Option 1)

(1a) Substitution of Formic acid for Acetic acid

Before implementation

Acetic acid consumption (Nov.94)	= 240.95 kg for the production of 63937 kg
Cost per month	= 240.95 (kg) x Rs 86
	= Rs 207,220
Treatment cost per month	= COD x Treatment cost/kg of COD
	= 240.95(kg) x 1.04(kg COD/kg) x 30(Rs/kg COD)
	= Rs 7518

After implementation

Formic acid consumption	= 325 kg for the production of 125245 kg
	= 166 kg for 63937 kg of production
Cost per month	= 166 kg x 72.5(Rs/kg)
	= Rs 12,035
Treatment cost per month	= 166 x 0.34 (kg COD/kg) x 30 (Rs/kg COD)
	= Rs 1693.2

Actual Chemical Saving per year = Rs 104,244.00
Actual Treatment Cost Saving per year = Rs 69,900.00

(1c) Substitution of Thiourea dioxide for Sodium hydrosulfide

This option was not implemented but number of machine washing steps were reduced.

Before Implementation

Sodium hydrosulfide consumption	= 68 kg for 63937 kg of production
Cost per month	= 68 kg x 90 Rs/kg
	= Rs 6120
Treatment cost per month	= 68 x 0.33 x 30 (Rs/kg COD)
	= Rs 673

After reducing the number of washing steps

Sodium hydrosulfide consumption	= 86 kg/125245 kg of production
	= 44 kg/63937 kg of production
Cost per month	= Rs 3960
Treatment cost per month	= Rs 436

Actual chemical savings per year = Rs 25,920
Actual Treatment cost saving per year = Rs 2,844

(1e) Substitution of Leverol with Cottaclarin KD or Univadine Lu

Before implementation

Leverol consumption	= 380 kg for 63937 kg of production
Cost per month	= 380 kg x 275 Rs/kg

	= Rs 104,500
Treatment cost per month	= 380 kg x 0.5 kg COD/kg x 30 Rs/kg COD
	= Rs 5700

After implementation

Univadine Lu consumption	= 353 kg/53490 kg of production
	= 422 kg/63937 kg of production
Cost per month	= 422 kg x 240 (Rs/kg)
	= Rs 101,280
Treatment cost per month	= 422 kg x 0.4 (kg COD/kg) x 30 (Rs/kg COD)
	= Rs 5064

Actual annual Chemical cost saving = **Rs 38,640**
Actual annual Treatment cost saving = **Rs 7,632**

2. Lagging of unlagged steam lines (Option 4)

Before Implementation

Fuel consumption = 39,600 l/M (63937 kg production)

After implementation

Fuel consumption = 80,000 l/ 132592 kg of production
= 38,577 l/M (63937 kg of production)

Investment

Lagging cost	= Rs 28,164.00
Labour cost	= Rs 10,000.00
Total cost	= Rs 38,164.00
Annual interest on investment	= Rs. 8014.00

Savings

Fuel savings	= 12,276 l/y
Savings on fuel cost	= Rs 85,686/y
Net annual savings	= Rs 77,672

Pay-back period

(Investment/Net annual savings)12 = 6 months

3. Reducing oil content in the commissioned fabric (Option 8)

Such fabric is not accepted now. Ultravon FL was used earlier to remove oil. It is not required now.

Savings

Previous consumption of Ultravon FL = 33 kg (Nov.94)

Chemical savings = 33 (kg) x 248 (Rs/kg) x 12 (M)
= Rs 98,208/y

Actual annual chemical cost saving = **Rs 98,208/y**

11.0 CONCLUSIONS

The Process flow diagrams depict the activities involved in each type of processing, inputs, outputs and process conditions. These along with production figures indicated in Annexure E proved to be invaluable in doing subsequent estimations. (eg. material and water balances, worksheets 5.0 and 6.0).

Carrying out the material balance enabled the quantification of different inputs and outputs in different processes and these figures were used in subsequent estimations (eg. calculation of steam condensate from jet operations for use as boiler feed water).

The water balance indicates highest water consuming processes and also the need to do further studies on water consumption to determine the reasons for a high undefined percentage.

COD analysis table (worksheet 7A) shows the percentage contribution of individual process discharges from different machines to the waste stream pollution load. Quantification of COD also helped in the calculation of the treatment cost.

Calculation of the wastes and emissions costs (worksheet 7B) for individual processes indicates the financial loss. These values were used in calculating the savings in implementing options which reduce the generation of waste.

Thirty seven waste minimisation options were identified. The majority of these were seen to be Resource Conservation options (24). Others were Material change (2), Resource Recovery (2), Technology Change (1), Equipment Modification (7), Process Control (2) and Quality Improvement (1). Most of the options were either Low Cost (14) or Medium Cost (15). Cost benefit analysis was carried out for the 10 options identified as high priority. Four of these did not require any investment and the expected savings were quite substantial. Pay back periods for the rest of the options ranged from one to twelve months.

Most of the machines are being used under capacity since the customer requirement is for smaller batches of fabric in different colours. Installation of low capacity machines with low liquor ratios has been identified as one of the priority options therefore, even though it involves a high capital investment.

The industry has at present implemented only some of the chemical substitution options, lagging of the steam lines and non-acceptance of oil contaminated fabric. It is expected that options like lagging of jets, purchasing of low liquor ratio jets etc. will be implemented, when finances are available.

12.O References

1 JOHN H PERRY (1963)
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pg 3-133

2 R.H PETERS (1967)
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pg 172

3 CHITTARANJAN DESAI (October, 1995)
Report on first mission to Sri Lanka, Industrial Pollution Reduction Programme, UNIDO, Sri lanka.

4 PETERS & TIMMERHAMS
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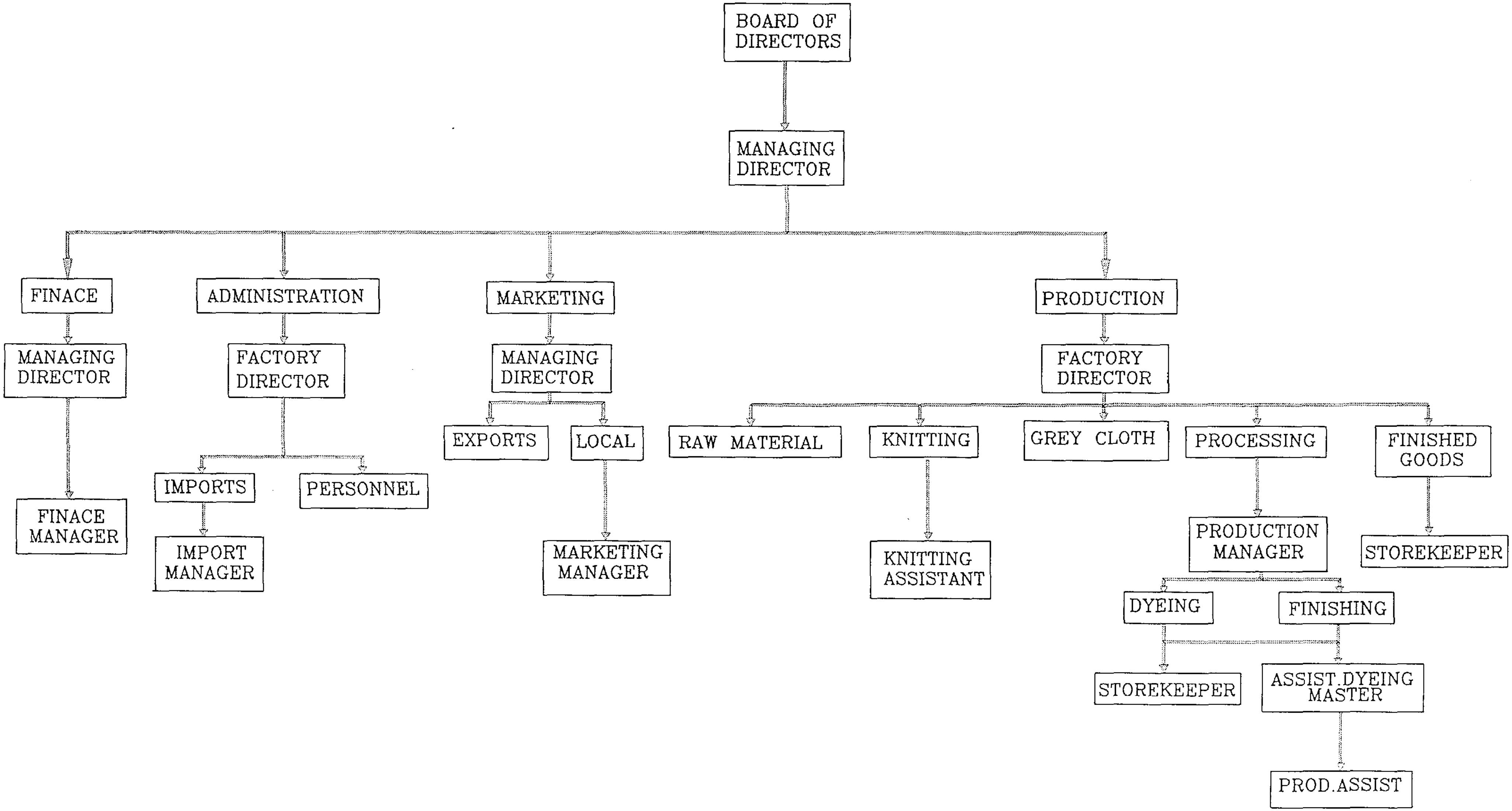
5 ESSTOP & McCONKEY (1993)
Applied Thermodynamics
Logman Scientific & Technical (5th edition)

ANNEXURE A

OACIANIC KNITTERS (PVT) LTD.

ORGANIZATION CHART



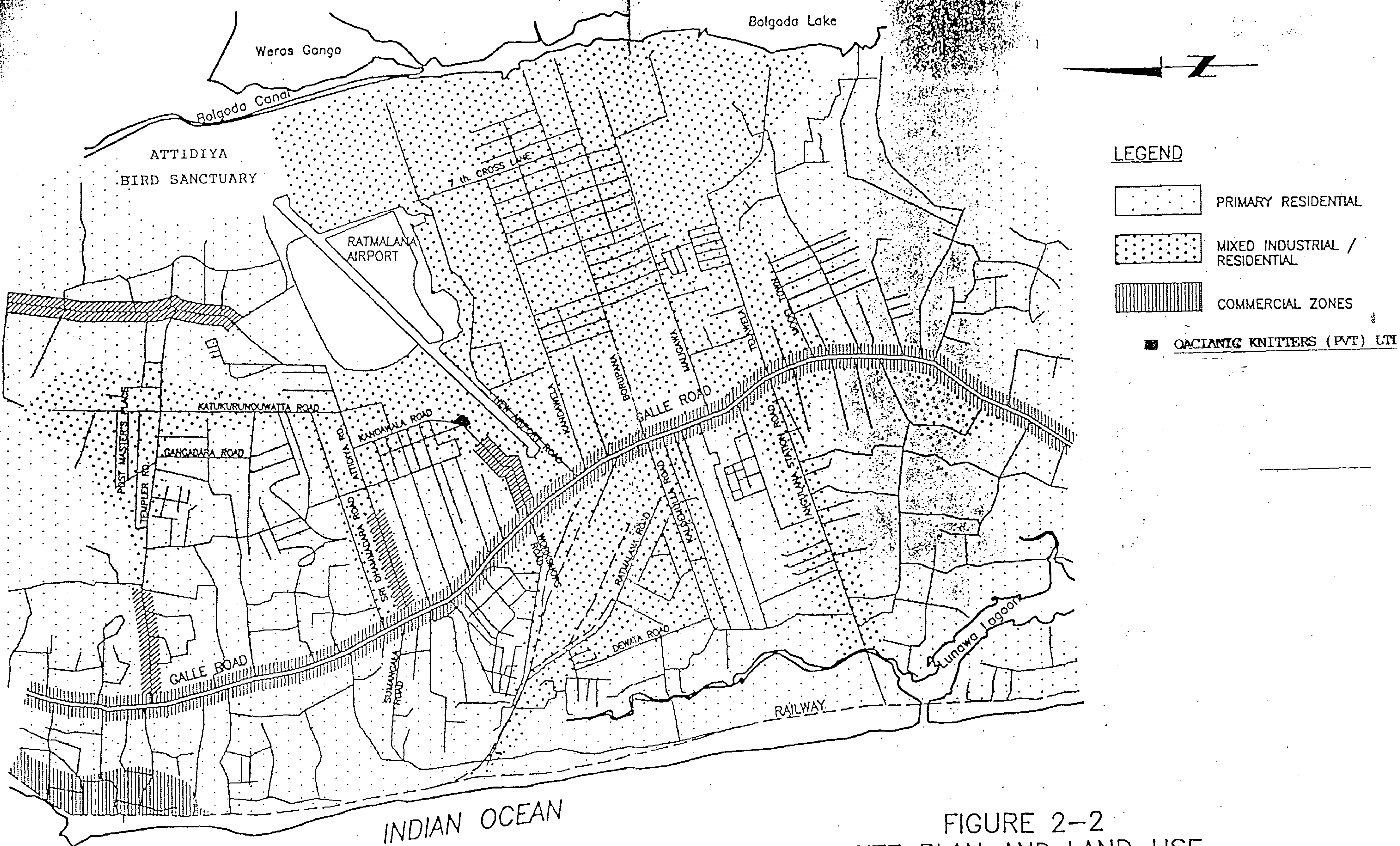
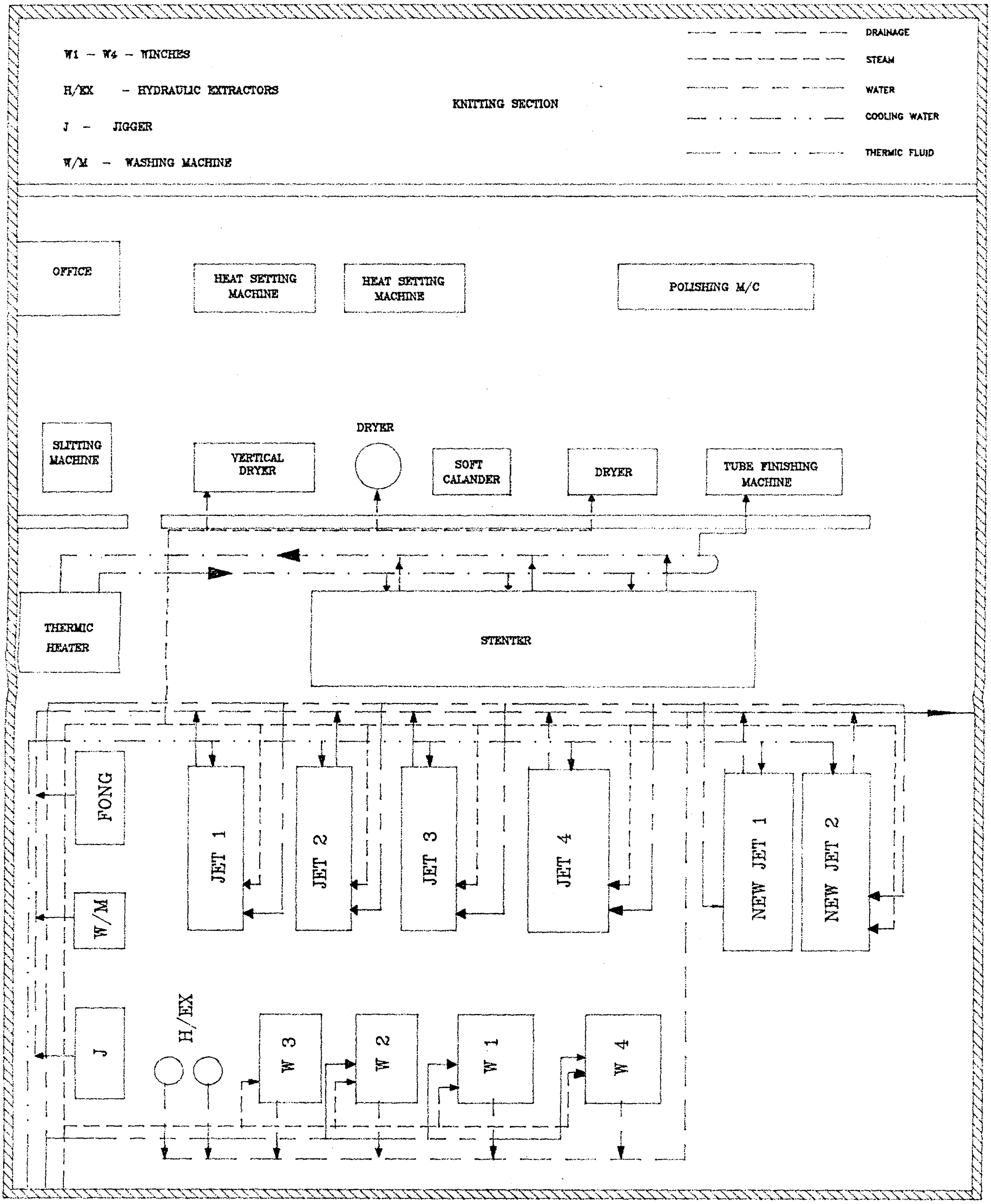


FIGURE 2–2
SITE PLAN AND LAND USE
SCALE: 1:20000

ASSOCIATED ENGINEERING

MACHINERY PLANT LAYOUT
OACIANIC K NITTERS (PVT) LTD



ANNEXURE C

ANNEXURE D

LIST OF MAJOR CHEMICALS & DYES

Chemicals	**Quantity kg/month**
Acetic acid	240.95
Ammonium Sulphate	37.75
Dispersant	221.00
Bleaching powder	0.50
Cibafluid U	27.95
Dispersant NS 40	3.00
Hydrogen Peroxide	1,462.50
Invadine N.F.	13.85
Invatex PC	27.00
Irgasol CO New	28.75
Levagol HTC	26.90
Perintrol FH-H	3.00
Product 3CSR	89.26
Setamol TX 506	275.65
Sodium Carbonate	1,953.54
Sodium Chloride	3,529.00
Sodium Hydrosulphide	68.00
Sodium Hydroxide	288.90
Sodium Silicate	188.00
Sodium Sulphide	153.80
Sulphuric Acid	30.50
Sumahite PEB	72.27
Tinoclorite ON	12.50
Ultravon FL	32.60
Uvitex C.I.D.	25.02
Alfa N/Blue BF-HR	3.91
Alfa Red Red 3BF	28.11
Alfa Red Yellow 3GF	4.16
Alfa Red Yellow 3RF	34.37
Alfa T/Blue G	5.83
Ambifix Black BF-GR	11.81
Cibacron Blue FR	2.3
Cibacron Navy Blue FG	0.04

Cibacron Orange FR	0.06
Cibacron Red FB	1.27
Cibacron Scarlet F3G	0.10
Cibacron Yellow F3R	0.44
Dispersal Black EXSP 300	0.17
Dispersal Blue R 150% (Blue 56)	4.07
Dispersal Navy Blue EXBF 150%	4.07
Dispersal Orange CBN	0.13
Dispersal Rubine B(RED B)	7.03
Palanil Black FD-BE	84.80
Palanil Black FD-BN	150.08
Palanil Blue BGCF	20.16
Palanil Brown FE3	0.14
Palanil Yellow 3G	30.83
Rathalin Rubine 3B	16.17
Rathalin Black BLR 200%	22.16
Remazol Black B Gran	12.50
Resolin Yellow Brown	0.03
Serilin Scarlet BB-LS 150	0.01
Serilin N/Blue GR-LS 200	0.00
Serilin Brown 2BLS	0.15
Sullpphote Black Grains 00%DR	150.99
Sumifix Brill Blue B Special	1.88
Sumifix Supra Blue BRF	0.19
Terasil Brill Blue 54 895	3.33
Terasil Brill Pink 36	8.20
Terasil Brill Violet B.L.	3.48
Terasil Dispersal Red P4B	0.01
Terasil Golden Yellow 2RS	1.23
Terasil Red 5G	6.01
Terasil Red R	15.00

ANNEXURE E

PRODUCTION STATISTICS (NOVEMBER 1994)

MACHINES (capacity in kg) (machine liquor ratio)	100% COTTON				BLEND				100% POLYESTER			
	D	M	L	W	D	M	L	W	D	M	L	W
Winch 4 (150) (1:10)	1015(8)*	-	150 (1)*	922 (6)*	-	213 (2)*	1713 (16)*	282 (2)*	-	-	-	-
Winch 1 (200) (1:10)	-	334 (2)*	-	826 (5)*	-	749 (5)*	2754 (18)*	865 (5)*	-	402 (3)*	437 (4)*	1777 (14)*
Winch 2 (125) (1:10)	-	-	-	-	-	1018 (9)*	2500 (23)*	207 (2)*	-	1167 (12)*	548 (6)*	478 (6)*
Winch 3 (40) (1:10)	83 (6)*	-	-	70 (3)*	-	15 (1)*	29 (1)*	19 (2)*	-	15 (1)*	4 (1)*	-
New jet 2&1 (150) (1:17)	-	-	-	-	2913 (24)*	717 (7)*	1404 (12)*	-	1179 (12)*	-	298 (3)*	-
Jet 2&1 (400) (1:10)	-	613 (2)*	306 (1)*	-	1383 (5)*	1583 (4)*	7032 (18)*	310 (1)*	4823 (15)*	886 (3)*	-	3300 (12)*
Jet JF&JE (75) (1:10)	-	-	-	-	782 (11)*	157 (2)*	-	-	1363 (18)*	77 (1)*	-	-
Fongs (600) (1:7)	-	859 (2)*	1362 (3)*	6736 (12)*	-	-	1125 (2)*	4140 (7)*	-	-	-	-

* Total number of batches

Jigger and washing machine were not operated during this month

Total production of November 1994

100% Cotton 13,277 kg
Blend 31,910 kg
100% Polyester 16,754 kg

D - Dark, M - Medium, L - Light, W - White

ANNEXURE F

MAJOR PROCESS CHEMICAL RECIPES

Operation	Name of chemicals/Dyes	Chemical concentration g/l or % of fabric weight		
		100% Cotton D M L W	100% Polyester D M L W	Cotton/Polyester blend D M L W
Scouring and bleaching (g/l)	H_2O_2	3 4 5 8	- - 2 5	3 3 5 7
	NaOH	1 2 2 3	- - - -	- - - -
	Detergent	1 1 1 1	1 1 1 1	1 1 1 1
	Organic stabilizer	0.5 1 1 1	- - - -	- - - -
Cotton dyeing(g/kg fabric)	Reactive dyes (g/kg)	2 -- 8		1 - 4
	Disperse dyes (g/kg)	8		1 - 4
	Detergent (g/l)	1		1
Soaping (g/l)	Detergent (g/l)	2 1 0.5 -	1 0.5 0.5 -	2 1 0.5 -
Polyester dyeing	Dispersing agent(g/l)		0.2 - 1	0.2 - 1
	Reactive dyes (g/kg)		0.5 - 1	0.5 - 1
	Disperse dyes (g/kg)		8	4
	Levelling agent (g/l)		0.2 - 1	0.2 - 1
Acid washing(% of fabric weight)	Acetic acid*	1% for all shade		

D-Dark shade, M-Medium shade, L-Light shade, W-White

* Formic acid is being used presently in place of Acetic acid.

ANNEXURE G

ESTIMATION OF THE STEAM COST

(Based on a days consumption)

Fuel oil cost	= 1980(l) x 6.98(Rs/l)
	= 13820.4
Cost of fuel pumping(600min)	= 0.75(kW) x (600/60) x 6.34(Rs/kWh)
	= 47.55
Electric oil heater cost	= 12(kW) x (600/60) x 6.34(Rs/kWh)
(600min)	= 760.8
Water cost	= 14.4(m^3) x 7.81(Rs/m^3)
	= 112.5

* Water pumping cost considered as negligible

Boiler water treatment	= 1177(Rs/day)
Air compressor power	= 15(kW) x (600/60) x 6.34(Rs/kWh)
	= 951
Labor cost	= 280 (Rs/day)
Total cost	**= 17149.25**
Total steam produced	**= 14400 kg**
Unit steam cost	**= 1.19 Rs/kg**

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

Average steam cost = **1.20 Rs/kg**

ANNEXURE H

ESTIMATION OF EFFLUENT DISPOSAL 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
Chemical consumption	
Coagulant Alum (400 mg/l)	= 80 kg/day
Flocculant Polymer (2 mg/l in dry solid basis)	= 400 g/day
Neutralizer Lime (120 mg/l)	= 24 kg/day
Cost (Rs)	
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 (0.2W x 3)	= 18 kWh
Dosing pump (0.1 x 3)	= 7.2 kWh
Flash mixer (0.5 kW)	= 12 kWh
Clarifier scraper (0.5kW)	= 18 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
Labor cost (24 labor hours per day)	
Total cost of labor including EPF, ETF, and annual overtime	= Rs 25/h
Labor cost	= Rs 600/day
Sludge handling cost	= Rs 150/day
Total operational cost	= Rs 3726/day
COD removal required per day	= 200(800-250) x 10^{-3} kg/day
	= 110 kg/day
Cost for COD removal	= 3276/110
	= Rs 29.78/ kg
	= Rs 30/ kg

ANNEXURE I

UTILITY COSTS

UTILITY	UNIT COST (Rs)	COST (Rs/kg FABRIC)
WATER	7.81 /m^3	1.17
STEAM	1.20 / kg	5.46
ELECTRICITY	6.34 / kWh	3.45
FUEL OIL	6.98 / l	3.74
TREATMENT COST*	30 / kg COD	3.20§

§ Treatment cost per kg of fabric is calculated from total effluent treatment cost (Rs 204,390/month) and total production (63937 kg/M) in November 1994.

* An effluent treatment plant is not available presently.