SEAM Programme

Guidance Manual
Piece Dyeing

Ministry of State for Environmental Affairs
Egyptian Environmental Affairs Agency

Entec UK Ltd., ERM
UK Department for International Development

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Implemented by:

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GUIDANCE MANUAL PRODUCED BY THE SEAM PROGRAMME

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About the SEAM Programme

The SEAM Programme – An Introduction

Support for Environmental Assessment and Management (SEAM) is a major environmental programme implemented by the Egyptian Environmental Affairs Agency (EEAA), Entec UK Ltd and ERM with support from the UK Department for International Development (DfID).

The SEAM Programme aims at improving environmental planning and services for the poor and strengthening decentralized environmental management. It has four components focussing on environmental management issues. These include developing Governorate Environmental Action Plans (GEAP) in five Governorates in Egypt (Sohag, Dakahleya, Qena, Damietta and South Sinai), delivering community environmental projects (CEPs) that benefit the poor, improving solid waste management and implementing cleaner production (CP) projects in industry to enhance competitiveness and reduce pollution.

The Cleaner Production Component

The main goal of the Cleaner Production component is to show that significant financial savings and environmental improvements can be made by relatively low-cost and straight-forward interventions, such as good housekeeping, waste minimization, process modification and technology changes. This approach was recognized as having two benefits – valuable materials can be recovered and reused, rather than being wasted, and industries move towards environmental (legislative) compliance.

1994-99 - Cleaner Production initiatives were successfully undertaken in medium to large scale Egyptian industrial units in the textiles, food processing and edible oil and soap sectors. 32 factories were audited and 21 Demonstration Projects implemented at a cost of LE16 million, with an average pay back of 6 months. Examples of interventions included water and energy conservation, ecolabelling for textile exports, oil and fats recovery, HACCP, recovery of cheese whey, etc.

(2000-05) - The programme focused primarily on micro, small and medium size enterprises (MSMEs) in Egypt. It focused on 4-5 main priority sectors in five governorates which are the food, metal foundries, textile, furniture and other miscellaneous small industries. About 100 audits and 30 demonstration projects are to be undertaken in MSME priority sectors including food processing, metal foundries, furniture, textiles, and other miscellaneous projects. The aim here is to enhance efficiency, reduce pollution, yield financial savings and improve the environment for surrounding communities.

More information on various sector manuals and case studies may be procured from http://www.seamegypt.org.

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1 PART I : PROCESSING OF TEXTILE FIBERS

1.1 TEXTILE FIBERS

Textile fibers are the basic raw materials in the textile industry. As shown in Annex 1, textile fiber can be classified into natural and man-made. The latter are further classified into semi-synthetics and 100% synthetics. Cotton and wool are the most common natural fibers, whereas polyester, nylon and acrylics are the most common synthetic fibers and viscose is the most common semi-synthetic fiber.
Cotton and wool are supplied in staple (short) fibers, while man made fibers are supplied as either staple or continuous filament. The steps required to transform fibers into finished fabrics include both dry and wet processes.

1.2 MAJOR DRY PROCESSES

Major dry processes include spinning followed by either knitting or sizing and weaving.

Spinning: It is the process of converting fibers into yarns or threads. It comprises drawing out the fibers, twisting them into yarns and winding the yarns onto a bobbin or cones.

Knitting: This is achieved by interlacing groups of loops of one or more yarns using special stitches on a tricot machine. Knitted products includes hosiery, underwear and outwear.

Sizing: It is the coating of warp yarns with sizing formulation to increase their tensile strength, softness and smoothness in order to withstand high stress during weaving. A sizing formulation consists mainly of a sizing agent (e.g. starch, polyvinyl alcohol) cooked in an aqueous solution containing some other additives (e.g. lubricants, humectants).

Weaving: This is performed on looms, where warp (lengthwise) yarns interlace with filling (running at right angle) yarns. Weaving is the most common method for producing fabrics.

1.3 MAJOR WET PROCESSES

Major wet processes include pretreatment, coloration (dyeing and/or printing) and finishing.

1.3.1 Pretreatments

Pretreatment processes are carried out to make the fabrics (and sometimes yarns) ready for subsequent coloration and finishing processes. Pretreatments include singeing, desizing, scouring, bleaching and mercerizing.

Singeing: This is performed by passing the fabric over a flame or a hot surface in order to burn-off and remove the projected fiber ends and achieve fabric smoothness. The fabric is then quenched in water to avoid catching fire.

Desizing: This is carried out to remove sizing materials applied during warp sizing. Size removal is performed by hydrolytic processes (rot, acid or enzymatic steep), oxidative processes, or just by hot washing. Hydrolytic methods are suitable for starch sizes, oxidative methods are suitable for starch and polyvinyl alcohol and hot washing is suitable for carboxymethyl cellulose.
Dazing effluent is heavily polluted with organic materials, expressed as BOD and COD.

Scouring: This is achieved to remove natural and acquired impurities from fabrics and yarns and improve their absorption. Scouring of man-made fibers is milder than that of cotton because the latter contains higher amount of impurities. Cotton contains natural impurities such as wax and pectins, and processing impurities such as residual sizes and oils; all of these can be removed by boiling in an alkaline solution. Scouring can be combined with desizing. It makes the fiber more absorbent for subsequent bleaching and dyeing.
Scouring effluent is alkaline in nature and contains organic pollutants (BOD and COD).

Bleaching: It is the process of whitening cotton and some synthetic fibers. It results in the destruction of colors and removal of residual sizes, other impurities and small particles of foreign matter. It is conducted after scouring or in combination using oxidizing agents such as hydrogen peroxide and sodium hypochlorite or reducing agents. Hydrogen peroxide bleaching is most common for cotton and conducted at 90 –100º C in a moderately alkaline solution. Hypochlorite bleaching is carried out on the cold. However, it is environmentally objectionable due to the evolution of the toxic chlorine gas during bleaching and to the formation of carcinogenic materials in the effluent.

Mercerizing: This is performed by impregnating coon fabric or yarns in cold concentrated caustic soda solution (15-30% w/v) for a short time under tension followed by washing. It results in increasing the tensile strength, luster, dye absorption and abrasion resistance.

1.3.2 Dyeing

Dyeing is performed for aesthetic reasons. It is conducted on fibers, yarns, fabrics and ready-made articles. Fabric dyeing is the most common dyeing method used today. It can be performed on winch, jet, jigger and continuous range.
The most important classes of dyestuffs are direct, sulphur, reactive, vat, acid, mordant, and disperse and. Table 1 shows the affinities of various classes of dyes to different textile fibers.

1.3.2.1 Direct dyes

These are water soluble dyes with a high affinity for cellulosic (cotton, flax and viscose) fibers. Dyeing takes place faster at higher temperature or in the presence of salts (common salt or Glauber salt). In order to get even dyeing, dyeing is started at room temperature without salt. After some time, the temperature is gradually raised to about 60º C, salt is added and temperature raised to about 100ºC and dyeing continues till the dyebath is almost completely exhausted.
In their chemical structure, direct dyes contain solublizing groups, e.g. sodium sulfonate. Sometimes, these groups are not in their sodium form, which has no affinity for cellulose. This can result not only in wasting the dye but also in decreasing the depth of color on the fabric. As a general rule, direct dyes are pasted with a little amount of soda ash (to convert the solublizing groups, if present, to sodium sulfonate) before preparing their solutions.
Direct dyes are characterized by low wet fastness properties on the dyeings. After treatment with cationic dye fixing agents in a separate bath can improve its wet fastness.
Dyeing effluent is polluted with unexhausted dye and salts.

1.3.2.2 Sulphur dyes

Sulphur dyes are insoluble in water, and hence cannot dye cellulosic fibers. They must be first reduced in an alkaline medium to change them into soluble forms that have affinity for cellulosic fibers. The dyeing is carried out in an excess of the reducing agent to keep them in the reduced form throughout the dyeing period.

Table 1: Suitability of the most important dyestuffs to textile fibers

Dye	Cotton	Linen	Viscose	Wool	Polyester	Acrylics	Nylon
Direct	X	X	X				
Reactive	X	X	X	X			X
Sulphur	X	X	X				
Vat	X	X	X				
Azoic	X	x	X				
Disperse					X	X	X
Acid				X			
Chrome				X			
Mordant				X			
Basic				X		X	

The dye is dissolved by pasting it with cold water, adding the required amount of the reducing agent (either sodium sulphide/soda ash or glucose/caustic soda) and pouring boiling water. Boiling is continued for about 10-15 min. to completely dissolve the dye. The cellulosic material is entered into the dyebath, the temperature raised and the dye exhausted by adding common salt.

At the end of dyeing, the reduced water soluble form of the dye is oxidized into its original insoluble form. Oxidation can be performed by acidic potassium dichromate or hydrogen peroxide or merely by atmospheric oxygen on the acidified dyeings. Soaping process follows to remove surface and loose dye from the fabric in order to improve fastness properties. Sodium sulphide and potassium dichromate are environmentally objectionable due to the following reasons:

Both are toxic to humans and the aquatic organisms. Sodium sulphide has a bad smell during dyeing , corrosive to the sewage system, and causes tendering to dyeings upon storing in humid hot weather. Potassium dichromate is carcinogenic. Glucose/hydrogen peroxide are safer reducing/oxidizing agents that can produce dyeings with better qualities with smooth impact on the environment.

1.3.2.3 Reactive dyes

These are water soluble dyes containing reactive groups that can be attached to either cellulose or wool in the presence of an alkali, such as sodium carbonate, silicate, ….
Dyeing involves two steps, viz. exhaustion by the addition of common salt followed by fixation by the addition of an alkali to form the bond between the dye and the fiber.
There are 3 brands of reactive dyes:

- cold brand : which are highly reactive so that dyeing is performed at low temperature (20-30ºC).
- Intermediate brand: which can dye at about 60-70ºC.
- Hot brand: which can dye at about 80-90ºC

About 30% of reactive dyes are subjected to hydrolysis during dyeing. Hydrolyzed dye cannot react with the fibers. Rather it has a low affinity for the fiber, i.e. it has a low fastness. Therefore, after dyeing the dyed material is boiled with a detergent solution to remove the hydrolyzed dye as much as possible.

1.3.2.4 Vat dyes

Like sulphur dyes, vat dyes are insoluble in water and need to be solubilized before dyeing cellulose fibers. Solubilization is accomplished by sodium hydrosulfite/sodium hydroxide at about 50ºC for 10-20 min. The Solubilization process is called vatting. The solubilized form behave like direct dyes. Sodium hydrosulfite/sodium hydroxide should be in excess during dyeing to avoid dye oxidation and precipitation. The oxidized dye has no affinity to cellulose. After dyeing, the dyed materials should be aerated or treated with an oxidizing agent (hydrogen peroxide/acetic acid) to convert the soluble dye into its original insoluble form. The dyeings are then soaped at the boil to remove loosely attached dye. These dyes are of very good allround fastness properties (washing, perspiration, chlorine, etc.).

Unlike direct dyes, which are dyed at the boil, vat dyes are dyed at lower temperatures depending on the subclass. Vat dyes are divided into four subclasses:

- I_k dyes (cold dyeing dyes) which are dyed at 20-30ºC.
- I_w dyes(warm dyeing dyes) which are dyed at 30-40ºC.
- I_N dyes(normal dyeing dyes) which are dyed at 40-50ºC.
- I_N special dyes which are dyed at higher temperatures..

The dyeing rate in case of I_k and I_w is generally low; so an exhausting agent like common salt has to be added. I_N class has a fast rate and a retarding agent has to be used to get even dyeing.

1.3.2.5 Acid dyes

These dyes can dye wool, silk and nylon, in the presence of organic or inorganic acid, with brilliant colors. They have no affinity for cellulosics.

1.3.2.6 Mordant dyes

These dyes cannot dye fibers, including wool, without an auxiliary called a mordant. The mordant has an affinity for both the fiber and the dye. Salts of chromium, aluminium, copper, iron and tin are suitable mordants. In wool dyeing, only chromium salts are of importance and hence mordant dyes for wool are usually called chrome dyes.

Sodium or potassium dichromate are the most important mordant among chromium compounds. Sodium dichromate is cheaper and more soluble than potassium dichromate.
Chrome dyes have a wide range of colors of remarkable resistance to wet treatments, but the shade lack brilliancy.

1.3.2.7 Disperse dyes

These dyes are sparingly soluble in water and can dye polyester, nylon and acetate. Dyeing of polyester fibers is difficult because of its compact structure. There are three methods of polyester dyeing:

- At the boil at atmospheric pressure in the presence of a carrier which causes the fibers to swell and thus facilitating the entry of the dye inside the fibers. Carriers are environmentally objectionable because of their toxicity to humans and aquatic life.
- At 125-130 C at high pressure, where the fiber structure is opened by the thermal energy supplied.
- By padding the fabric in a dispersion of the dye, drying and thermosoling at high temperature (205-219 ºC / 45-60 sec.)

1.3.3 Printing

Printing is a process of local dyeing. Printing can be achieved using dyes or pigments. In the case of using dyes, the dye should has an affinity to the textile fabric being printed. Pigment printing can be applied to nearly all textile substrates, where a binder is used to bind the pigment color onto the substrate. A viscous printing paste, containing the dye or the pigment in addition to a thickener and some other additives, is applied to the substrate, followed by drying and curing (by the action of heat or steam) insures the fixation of the color onto the substrate. Subsequent washing is essentially to remove the remainder of the printing paste. In case of pigment printing with 100% kerosene thickened paste, washing is unnecessary.

1.3.4 Chemical Finishing

The most important chemical finishing includes:

1. Easy care finishing of cotton fabric using special resins to improve its resiliency, dimensional stability and drying properties.
2. Soft finishing, which can be performed for all textile fibers, to improve handle and smoothness, using the following agents:
    a. Silicone based softeners (including elastomers)
    b. Reactive and non reactive softeners (cationic for colored fabric and nonionic for white fabric)
3. Special finishing, including water and water/oil repellency, flame retardancy, antistatic charges, anti microbes, etc.

2 PART II :OUTLINES OF CLEOPATRA DYEHOUSE

2.1 GENERAL INFORMATION

Owner: Mr. El-Mansoub M. El-Mansoub
Location: El-Dairas, Aga; Dakahleya
No. of employees: 3 including the owner
Tel.: 050 6452966

2.2 ACTIVITY

- The dyehouse dyes used article (mainly jean pants). It offers its service mainly o laundries (that collects pieces from individuals) and to a low extent to individuals.
- Size of production:
  Summer (June to Sept.): 900 – -1000 piece / month.
  Rest of year (May – Oct.): 2000-2500 piece / month.
  Price of dyeing L.E.-5 – 6 /piece.
- Distribution of colors in production:
  Black 35% using sulphur black
  Dark blue 35% using direct dyes
  Brown 10% using direct dyes
  Olive 5 % using direct dyes
  Others 15 % using direct dyes

2.3 RAW MATERIALS

2.3.1 Consumption

	Quantity in Kg		Unit Price (LE /Kg)
	Summer	Winter	
Direct dyes	30	60	---
Sulphur Black	60	150	12
Sodium Hydroxide	65	170	3.5
Sodium Sulphide	95	240	7
Sodium carbonate	10	20	1.6
Acetic acid	16	35	6
Pot. Dichromate	8	18	7
Salt	300	700	0.15
Soap (detergent)	5	15	1

2.3.2 Dyestuffs

Sulphur Black:

Sulphur black BR 522 (China) (LE 12 / kg(

Direct :(all from Isma dye, Kafr El-dawar, Alex.)

-Direct Navy Blue BN	166 %	(LE 60 / Kg)
-Isma Fast Blue 4 GL	100 %	(LE 65 / Kg)
-Direct Violet 6 B	200 %	(LE 60 / Kg)
-Olive Green B		(LE 50 / Kg)
-Direct Brown RN	166 %	(LE 32 / Kg)
-Direct Black FG	200 %	(LE 29 / Kg)
-Chrysophenine G (yellow)	250%	(LE 35 / Kg)
-Isma Fast Yellow G	100 %	(LE 40 / Kg)
-Isma Fast Red 8B	125 %	(LE 65 / Kg)
-Direct F. Orange		(LE 40 / Kg)

2.3.3 Machinery

- Stainless dyebath container, (size 80 l)
- 2 old garment dyeing machines.
- Small steam boiler (fuel is LPG)

3 PART III: DIRECT DYEING AT CLEOPATRA DYEHOUSE

3.1 OPTIMISING MANUAL DIRECT DYEING

3.1.1 Baseline Conditions

Dyeing is conducted in a stainless steel container that can accommodate 4 jeans pants (3.2 – 3.5 Kg), in a solution of 70 l; i.e. LR= 20-22 l/k.

3.1.1.1 Recipe

a- Color composition

To attain the required color on a pant (weight about 0.85-1 kg), the color is composed from mixed dyestuffs. The most common color is as follows

Color	Mixed dyestuffs	Amount of dye (owp) (%)	Total Shade (%)
Dark blue	Direct Navy Blue	3	3.45
	Direct Black FG	0.45	
Blue	Isma fast Blue	2.2	2.95
	Direct Navy Blue	0.75	
Brown	Direct Brown RN	2.5	3.1
	Direct Black FG	0.6	
Olive	Olive Green B	2	2
Grey	Direct Black FG	0.3	0.33
	Direct Brown RN	0.03	

owp: owing to weight of pant.

b- Dyeing recipe

Color	Shade (%)	Na_2CO_3 kg/batch	NaCl (kg/batch)
Dark blue	3.5	400	9.5
Blue	2.95	400	9.5
Broun	3.1	-	8.5
Olive	1.5	-	8.5
grey	0.33	-	6.5

c- Fixation recipe

Acetic acid 200 g/ 30 l at 60°C.

3.1.1.2 Process description (as shown in Annex 2)

About 70 l are poured into the dyeing container, and heated to 60°C in about 80 min (using LPG). During heating soda ash (400 g, only in case of blues) is added, followed by the dye. In the mean time, the pants (3 pieces in case of blues, 4-5 for other colors) are cold rinsed, hanged and loaded into dyeing bath at 60°C. After 10 min of heating and stirring, ½ the amount of salt is added; the same is repeated after further 10 min. Heating / stirring continues for extra 10 min, where the temperature reaches about 80°C, then the pants are unloaded, cold rinsed (3 times), turns inside – out and fixed in acetic acid before air drying.

3.1.1.3 Energy Consumption

One LPG pump is used to process about 15-16 batches in summer and about 13-14 batches in winter.

3.1.1.4 Material balance (based on Annex 2)

Since blue is the most common. The following balance pertains to dark blue direct dyeing.

	Inputs (kg)	Outputs (kg)	
Pants	2.5 (average)	wet pants	5
Water	2.0	wastewater	217.6875
Soda ash	0.4		
Dye	0.0875		
Salt	9.5		
Acetic acid	0.200		
Total	222.6875	Total	222.6875

3.1.1.5 Product quality

Color	Wash Fastness	Rubbing Fastness	
		Wet	Dry
Dark blue	1-2	1-2	2
Brown	1-2	1-2	2
Olive	1-2	1-2	2

3.1.1.6 Effluent quality

Dyeing effluent analysis for dark blue, brown and olive colors are shown as follows:

Color	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
Dark blue	1188	3265	101700
Brown	1125	4762	86460
Olive	750	3882	74500

3.1.2 Dyeing optimization

Since dark blue and brown represent the dominant color used in the establishment, optimization was carried out regarding them.

3.1.2.1 Dye concentration

Dye concentration, or shade, was changed. The product (pants) was visually evaluated in terms of depth of shade. Results follows.

In case of dark blue

Direct Navy Blue	Shade (%) Direct Black FG	Total	Soda ash (g/batch)	Depth of shade
3	0.45	3.45	400	Satisfactory
2.5	0.375	2.875	333	Satisfactory
2	0.3	2.3	260	Satisfactory
1.5	0.2275	1.728	200	Unsatisfactory

In case of brown

Direct Brow RN	Direct Black FG	Total	Depth of shade
3.1	0.8	3.9	Satisfactory
2.25	0.6	2.85	Satisfactory
1.7	0.4	2.1	Satisfactory
1.2	0.28	1.68	Unsatisfactory

It can be seen that: -

1- In case of dark blue : dye shade can be reduced to 2.3 % with a satisfactory depth of shade on the pants and

2- In case of brown: dye shade con is reduced to 2.1 % with a satisfactory depth of shade.

3.1.2.2 Salt

The amount of salt was reduced in case of blue and brown colors. The impact of reduction on the depth of shade is shown as follows: -

Dark blue		Brown	
Salt (Kg/batch)	**Depth of shade**	**Salt(kg/ batch)**	**Depth of shade**
9.5	Satisfactory	8.5	Satisfactory
8	Satisfactory	7	Satisfactory
6.5	Satisfactory	6.5	Satisfactory
4.5	Satisfactory	5.5	Satisfactory
3.0	Unsatisfactory	3	Unsatisfactory

Accordingly, salt amounts of 6-5 kg/batch and 5.5 kg/ batch represent optimal amounts for dark blue and brown colors, respectively.

3.1.2.3 Fixing agent

In the following experiments, fixing of the dye onto the dyeing was conducted using the following techniques: -

1- Addition of 25 g sodium persulfate in the dyeing liquor before dye addition, and carrying out dyeing at optimum dye shade and salt concentration, while omitting acetic acid fixation.

2- Carrying out dyeing at optimum dye shade and salt concentration, and replacing acetic acid fixation by either NaCl (10 g/l, 50°C / 5 min) or $MgCl_2$ (2g/l, 50°C / 5 min).

The following is the quality of dyeings (dark blue, brown and olive) fixed with the aforementioned techniques compared to acetic acid fixing method.

Fixing agent	Property	Dark blue	brown	olive
acetic	Depth of shade	Satisfactory	Satisfactory	Satisfactory
acid	wash fastness	1-2	1-2	1-2
$Na_2S_2O_8$	Depth of shade	Satisfactory	Satisfactory	Satisfactory
	wash fastness	2-3	2-3	2-3
$MgCl_2$	Depth of shade	Satisfactory	Satisfactory	Satisfactory
	wash fastness	2	2	2
NaCl	Depth of shade	Satisfactory	Satisfactory	Satisfactory
	wash fastness	2	2	2

It can be seen that:

1- $Na_2S_2O_8$ represent the optimal fixing agent, however it is not widely available in the Egyptian marker.

2- NaCl is preferable than $MgCl_2$ or acetic acid in terms of dyeing quality and cost.

3.1.3 Water / Energy Reduction

3.1.3.1 Energy (adjustments in the heating system)

As has already has been mentioned in sulphur black dyeing, the dyeing and fixing containers were provided with suitable lids, and the stove of the fixing container was provided with a suitable shield to conserve heat from dissipation.

Saving due to these adjustments: -

1- Reducing heating time of dyebath to 60 min. instead of 80 min.

2- Reducing heating time of oxidation bath to 50 min. instead of 70 min.

Total heating time before adjustments =
Time of (dyebath heating + dyeing + fixation bath heat + fixation)
= 80 + 35 + 70 + 10
= 195 min

Time saved = 20 + 20 = 40 min.

% Energy saved = (40 ÷ 195) X 100 = 12.5 %

3.1.3.2 Water / Energy and chemicals (Dyebath reuse)

a- Dyebath reuse for the same color

The enterprise is already practicing dyebath reuse for the same caters directly after taking out the dyed paints from the dyebath as follows: -

1- Add the required amount of dye (dissolved in 0.5 l) to the dyebath depending on optimum shade, as follows: -

Colour	Shade (%)
Dark blue	2.3
Brown	2.1
Olive	1.5

2- Add about 4 - 5 l of water
3- Load the rinsed – hanged pants to the dyebath with stirring.
4- After 10 min. add about 10% of the optimum amount of salts.
5- Continue stirring for extra 10 min, unload the pants, cold rinse (3 times) and fix using NaCl.

This reuse can be performed for 9-10 cycle.
Savings per cycle (dark blue) can be calculated as follows:
water saved = 70 – 5 = 65 l
% Saving in water = (65 ÷ 210) x 100 = 30%
Time saved in heating = 80 min
% Energy saved = (80 ÷ 195) X 100 = 41%
Salt saved = 90 % x 65 = 5.85 k

b- Dyebath reuse for different colors

There are two directions of dyebath reuse for different colors, depending on the similarity of colors. These are:

1- Grey followed by olive followed by brown.
2- Blue followed by dark blue.

The first direction encounters about 20% of the extent of colors in the enterprise. The second represents 80% of coloring processes.
Procedure is the same as that described in item **an** above.

3.1.4 Conclusions of optimising manual direct dyeing

3.1.4.1 Optimal Dyeing Recipe

- No of pants 4 for all colors, and 3 for blues.
- Volume of water in dyeing container 70 l.

- **a- Exhaustion recipe (per one batch)**

I. Dark blue

* Direct Navy Blue 2% shade
* Direct Black FG 0.3 % shade
* Soda ash 260 g/batch
* Salt 6.5 k/batch

II. <u>Brown</u>

* Direct Brown	1.7 % shade
* Direct Block FG	0.4 shade
* Salt	6.5 kg/batch

III. <u>Olive (work done by the establishment itself)</u>

* Olive Green	1.5 % shade
* Salt	6.5 Kg/batch

IV. <u>Grey (work done by the establishment itself)</u>

* Direct Blaek FG	0.2 % shade
* Direct Brown RN	0.02 % shade
* Salt	4-5 kg/batch

- **<u>b- Fixation Recipe</u>**

NaCl 10 g/l in a container containing 30 l at 50°C / for 5 min).

3.1.4.2 Procedure

Same as that shown in Annex 2. However heating time of the dye container is reduced to 60 min instead of 80 min.

3.1.4.3 Material balance of the modified process (Dark blue color)

	Inputs (kg)	Outputs (kg)	
Pants	2.5 (average)	wet pants	5
Water	210	wastewater	214.56
Soda ash	0.26		
Salt	6.8		
Total	**219.56**	**Total**	**219.56**

3.1.4.4 Comparison between conventional and modified manual dyeing process (Dark blue color/one batch)

Item	Conventional		Modified	
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)
Direct Navy Blue	0.075	4.5	0.0425	2.55
Direct Black FG				
Soda ash	0.012	0.33	0.01	0.2
Salt	0.4	0.64	0.26	0.416
Acetic acid	9.5	1.425	6.8	1.02
Water	0.2	1.2	-	
Energy*	210	0.1575	210	0.1575
		0.333		0.265
- Total		**8.5855**		**4.68**
Time	**195 min**		**155 min**	

*Energy cost of conventional =1 pump x LE 5/pump ÷ 15 batches = LE 0.333
* Energy cost of modified =0.795 X 0.333 = LE 0.265 (see 3-1)

3.1.4.5 Dyeings quality

Depth of shade of modified and conventional is satisfactory. However, wash fastness is slightly improved in case of modified than that conventional.

3.1.4.6 Effluent quality

Comparing effluent quality for dark blue, brown and olive color before and after modification is given as follows: -

Color	Situation	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
Dark blue	before	1188	3265	101700
	after	750	3061	82400
Brown	before	1125	4762	86460
	after	625	3129	79100
olive	before	750	3887	74500
	after	500	2993	61600

It can be seen that the pollution load of effluent is highly reduced after modification comparing to that before modification.

3.1.4.7 Cost savings for dye bath reuse by the modified method (5 cycles; dark blue)

Water saving = (70-5) l/batch X 5 batches
= 325l
= 0.325m^3 x LE 0.75 /m^3
= LE 0.244

Energy savings = 0.41 X LE 5 x 5 batches ÷ 15 batch
= LE 0.68
Salt savings = 5.85 X 4 batch x LE 0.15 / kg
= LE 3.51
Total savings = 0.244 + 3.51 + 0.68
= LE 4.434 / 5 batch
Time saved = 60 min x 4 batches
= 4 h

3.2 OPTIMISING MACHINE DIRECT DYEING

3.2.1 Baseline Conditions (Conventional Dyeing)

Dyeing is performed in an old garment dyeing machine that is heated with steam and operates with electricity. The machine is loaded with 12 kg of pants (about 14 pants) and filled with about 80-85 l of dyeing solution; that is equivalent to a LR of 6.67-7.1 l/kg.

3.2.1.1 Recipe

a- Color composition

Color composition and shades are the same as that of manual dyeing. The most common colors are as follows.

Color	Mixed dyestuffs	Amount of dye (owp) (%)	Total Shade (%)
Dark blue	Direct Navy Blue	3	3.45
	Direct Black FG	0.45	
Blue	Isma fast Blue	2.2	2.95
	Direct Navy Blue	0.75	
Brown	Direct Brown RN	2.5	3.1
	Direct Black FG	0.6	
Olive	Olive Green B	2	2
Grey	Direct Black FG	0.3	0.33
	Direct Brown RN	0.03	

owp : owing to weight of pant.

b- Dyeing recipe

Color	Shade (%)	Na۲CO ۳ kg/batch	NaCl (kg/batch)
Dark blue	3.5	400	9.5
Blue	2.95	400	9.5
Brown	3.1	-	8.5
Olive	1.5	-	8.5
gray	0.33	-	6.5

3.2.1.2 Process description (illustrated in Annex 3)

- 14 pants (about 12 kg) are loaded in the machine. Each pant is wrapped around itself, like a sandwich, as has already been mentioned in machine sulphur black dyeing, before loading in the machine. This ensures disentanglement of pants during dyeing. The pants are first given a cold rinse.
- Dyeing then starts by filling the machine with fresh water and addition of dye solution (where the dye is dissolved in 1 l hot water) while the machine is running. In case of blues, 400 g of soda ash are dissolved in about 3 l of water taken from the machine, and added before dye addition.
- The temperature is raised to 90-95ºC in about 30 min., at which salt is added. However, in cases of blues and gray an extra time of 15 min. is given after reaching 90-95ºC before salt addition to ensure homogeneous distribution of dyes in the pants.
- An hour is allowed to pass after salt addition to ensure good exhaustion, and then the bath is discharged. Fixation is performed in a separate container outside the machine in 3 batches (5, 5,and 4 pants). The first and second batches are treated in 30-35 l of an aqueous solution containing 150 g of acetic acid; then 50 g of acetic acid are added and the solution is adjusted to the original level before treating the third batch. Each batch is treated for 5 min. at 60ºC.
- The pants are then hanged and air dried.

3.2.1.3 Energy Consumption

One LPG pump is used to process about 15-16 batches in summer and about 13-14 batches in winter.

3.2.1.4 Material balance (based on Annex 3)

Since blue is the most common. The following balance pertains to dark blue direct dyeing.

	Inputs (kg)	Outputs (kg)	
Pants	12 (average)	wet pants	24
Water	430	wastewater	428.514
Soda ash	0.4		
Dye	0.0.414		
Salt	9.5		
Acetic acid	0.200		
Total	**452.514**	**Total**	**452.514**

3.2.1.5 Product quality

Color	Wash Fastness	Rubbing Fastness	
		Wet	Dry
Dark blue	1-2	1-2	2
Brown	1-2	1-2	2

3.2.1.6 Effluent quality

Dyeing effluent analysis for dark blue color is shown as follows:

Color	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
Dark blue	210	1333	77000

3.2.2 Dyeing optimization

Since dark blue and brown represent the dominant color used in the establishment, optimization was carried out regarding them.

3.2.2.1 Dye shade and amount of dye/batch

Optimal dyeing shades reached in manual dyeing were tried in machine dyeing with satisfactory depth of shade of the dyeings. Upon reducing the shades below the optimal, unsatisfactory results were obtained. Accordingly, optimal dye shades and amount/batch are listed below.

Item	Dark blue		Brown	
	Direct Navy Blue	Direct Black FG	Direct Brown RN	Direct Black FG
-Shade (%)	2	0.3	1.7	0.4
-Amount (g/batch)	240	36	204	48

3.2.2.2 Soda ash (only in case of blues)

The following table shows the effect of reducing the amount of soda as/batch on the depth of shade of blue dyeings.

Soda ash (g/batch)	400	300	200	100
Depth of shade	satisfactory	satisfactory	satisfactory	unsatisfactory

Accordingly, the optimal soda ash amount is 200 g/batch.

3.2.2.3 Salt

The effect of salt quantity on the depth of shade of both dark blue and brown colored dyeings is shown in the following table.

Dark blue		Brown	
Salt (kg./batch)	**Depth of shade**	**Salt (kg./batch)**	**Depth of shade**
9.5	satisfactory	8.5	satisfactory
8	satisfactory	7	satisfactory
6	satisfactory	5.5	satisfactory
4	unsatisfactory	4	unsatisfactory

Accordingly 6 or 5.5 kg salt/batch represents optimal salt quantity for dark blue or brown color.

3.2.2.4 Exhaustion time at 90-95°C

The effect of reducing exhaustion time (60 min. after salt addition) on the depth of shade of dyeings is shown in the following table.

Exhaustion time	**Depth of shade**	
	Dark blue	**Brown**
60	satisfactory	satisfactory
45	satisfactory	satisfactory
30	unsatisfactory	satisfactory
20	unsatisfactory	unsatisfactory

Hence, 45 min. or 30 min. represents optimal exhaustion time for dark blue or brown colors.

3.2.2.5 Fixing agent

Manual dyeing proved that NaCl (10 g/l in the fixation bath) was the optimal fixing agent. However, the brightness of dark blue was not satisfactory. Magnesium chloride/formic acid system was used in comparison with acetic acid (conventional) and NaCl. The results are tabulated as follows.

Fixing agent	Property	Dark blue	Brown
Acetic acid (200 g/batch)	Depth of shade Wash fastness	satisfactory 1-2	satisfactory 1-2
NaCl (300g/batch)	Depth of shade Wash fastness	Satisfactory(dull) 2	satisfactory 2
$MgCl_2$/formic acid (60 g/60 g/batch)	Depth of shade Wash fastness	Satisfactory(bright) 2	satisfactory 2

It is clear that NaCl results in satisfactory depth of shade of all colors, but with dullness in brightness of dark blue. This defect is omitted in case of magnesium chloride/formic acid system. Accordingly, NaCl is the optimal fixing agent for brown color (based on depth of shade and cost) and magnesium chloride/formic acid system is the optimal fixing agent for dark blue color.

3.2.3 Reduction in water and energy consumption

3.2.3.1 Energy

It has been shown (2-2-4) that exhaustion time was reduced from 60 min. to 45 or 30 min for dark blue or brown color. This is reflected on heat reduction during exhaustion time, which can be calculated as follows:
% energy reduction in exhaustion period =
100 (original exhaustion time – optimal exhaustion time) ÷ original exhaustion time
This amounts to 20% or 50% reduction for dark blue or brown color.
Now, assuming that the total amount of heat energy consumed during dyeing process are divided according to the following percentages:

- 50% for raising the temperature to 90-95ºC in the machine.
- 25% for maintaining the temperature at 90-95ºC during exhaustion.
- 25% for performing fixation outside the machine.

Accordingly, % energy reduction in exhaustion period amounts to 5% or 12.5% of total dyeing energy for dark blue or brown color.

3.2.3.2 Water and energy

The approach to reduce water and energy in this phase of the project was to increase the amount of pants per a batch, and to investigate its effect on the depth pf shade of the dyeings. Trials were carried out on dark blue color using Direct Navy Blue and Direct Black FG at a shade of.2% and 0.3%, respectively. Readjusting of amount of dyes and fixing agents to suit the increase in number of pants was done. Results obtained are listed below.

No. of pants	Dyeing recipe (g)		Fixation recipe (g)		Dyeings quality	
	Direct Navy Blue	Direct Black FG	Magnesium chloride	Formic acid	Depth of shade	uniformity
14	240	36	60	60	satisfactory	uniform
16	274	41	68	68	satisfactory	uniform
18	308	46	76	76	satisfactory	uniform
20	342	51	85	85	satisfactory	Not uniform

It is clear that optimal number of pants per a batch is 18 pants, then
% reduction in water consumption = {(18-14) ÷ 14} x 100 = 28 %
% reduction in energy consumption = {(18-14) ÷ 14} x 100 = 28 %

3.2.4 Conclusions of optimising machine direct dyeing

3.2.4.1 Recipes

No of pants per a batch = 18 (or about 15 kg)
Volume of dyeing liquor = 80 l

Dyeing recipe

Item	Dark blue					Brown			
	Direct Navy Blue	Direct Black FG	Total dyes	Soda ash	Salt	Direct Brown RN	Direct Black FG	Total dyes	Salt
Shade (%)	2	0.3	2.3			1.7	0.4	2.1	
Amount (g/batch of 18 pant)	310	45	355	200	6000	263	62	325	4000

Fixation recipe

- 10 g/l NaCl (i.e. 300 g NaCl in 30 l) for brown.
- Magnesium chloride/formic acid (60 g/60 g in 30 l) for dark blue.

3.2.4.2 Procedure

Procedure is the same as that shown in Annex 3. However exhaustion time after salt addition is reduced to 45 min. for dark blue or 30 min. for brown, instead of 60 min. for conventional dyeing.

3.2.4.3 Material balance (1 batch of modified dark blue dyeing)

Inputs (kg)		Outputs (kg)	
Pants	15 (average)	wet pants*	30
Water	430	wastewater	421.675
Soda ash	0.2		
Dye	0.355		
Salt	6		
Magnesium chloride	0.06		
formic acid	0.06		
Total	**451.675**	**Total**	**451.675**

(*) 100% wet pick up

3.2.4.4 Conventional vs. Modified Dark Blue Dyeing

I. Cost and Time (based on a batch of 18 pants)

Item	Conventional		Modified	
	Quantity (kg)	Cost(LE)	Quantity (kg)	Cost(LE)
Direct Navy Blue	0.465	27.9	0.31	18.6
Direct Black FG	0.068	1.87	0.045	1.24
Soda ash	0.4	0.64	0.2	0.32
Salt	9.5	1.43	6	0.9
Acetic acid	0.2	1.2		
Magnesium chloride	-	-	0.06	0.36
Formic acid			0.06	0.3
water	552	0.276	430	0.215
Energy*		1.66		1.32
Total cost		**34.976**		**23.255**

(*)Assuming that the cost of electricity is the same as that of steam, them
Energy cost of conventional = 2(2 pumps x LE 5/pump ÷ 12 batch) = LE 1.66/batch
Energy cost of modified =2(2 pumps x LE 5/pump ÷ 115 batch)= LE 1.32/batch

Time of modified is 15 min. shorter than that of conventional.

II. Quality of Dyeings

Process	Fastness			Depth of shade	handle
	Dry rubbing	Wet rubbing	wash		
Conventional	2	1-2	1-2	satisfactory	rough
Modified	2-3	2	2	satisfactory	soft

III. Effluent Quality

Process	BOD	COD	TDS
Conventional (mg/l)	210	1333	77000
Modified (mg/l)	140	633	57000

4 PART IV : SULPHUR BLACK DYEING AT CLEOPATRA DYEHOUSE

4.1 OPTIMISING MANUAL DYEING

4.1.1 Baseline Conditions (conventional Manual Dyeing)

Dyeing is conducted in a stainless steel container that can accommodate 4 jeans pants (3.2 – 3.5 Kg), in a solution of 70 l; i.e. LR= 20-22 l/k.

4.1.1.1 Recipe (for a batch of 4 pants)

Dyeing bath

- Weigh of dye (sulphur black BR 522, China; 50 g for a pant) =
  50 g / pant x 4pants = 200 g.

An extra 25 % of this amount is added to compensate oxidation during dyeing. That is actual amount of dye used = 1.25 x 200 = 250g.

- Sodium Sulphide = 320 g.
- Sodium hydroxide = 212 g.
- Salt 8.5 k

Oxidation bath

- Potassium dichromate	35 g
- Acetic acid	70 g

4.1.1.2 Process description (illustrated in Annex 4)

About 70 L water are poured into the container and heated using LPG to about 60°C (in about 75-80 min). In the mean time the pants are given a cold rinse for 5 min and hanged to drain most of its water. Dyeing bath is prepared at 60°C by addition the dye with stirring, followed by sodium sulphide then caustic soda (all in about 10 min). After 5 min the pants are introduced into the container (one by one) with stirring (using a wooden rod), while heating continuous. The pants are stirred for 2 min., left unstirred for 2 min; stirring – unstirring continues until temp. reaches 80 – 85 °C (in about 20 min). The process continues for extra 30 min at 85 °C. then the pants are taken out of the bath and given 4 cold rinses; each for 5 min. The pants are then turned inside-out, hanged to get rid of most water, oxidized, rinsed and air dried.

4.1.1.3 Energy consumption

One LPG pump (about 10 kg) is used as a fuel to process about 13-14 batches in summer or 11-12 batches in winter.

4.1.1.4 Material balance (based on one batch as shown in Annex 4)

	In puts (Kg)	Outputs (kg)
Pants	3.35 (average)	
Water	260	
Dye	0.25	
Na_2S	0.40	Wet pants 7*
NaOH	0.212	Wastewater 265.997
Salt	8.5	
$K_2Cr_2O_7$	0.035	
Acetic acid	0.07	
Total	**272.997**	**265.997**

* 100 % wet pick up

4.1.1.5 Product quality

Wash fastness: 2-3
Dry rubbing fastness: 2-3
Wet rubbing fastness: 1-2
Deepth of shade: satisfactory
Handle: rough

4.1.1.6 Effluent quality

BOD 410 (mg/l)
COD 2250 (mg/l)
TDS 77000 (mg/l)
Sulphide 172 (mg/l)
Hexavalent chromium 34 (mg/l)

4.1.2 Substitution of sodium sulphide by glucose and dichromate by hydrogen peroxide in sulphur black dyeing

Current situation:

The use of sodium sulphide (as a reducing agent) and acidified dichromate (as an oxidizing agent) in sulphur black dyeing is environmentally objectionable due to the following reasons: -

1- Both are toxic and hazardous to handle
2- Both generate effluents that are difficult to treat and damaging to the environment.
3- Both leave residues in the final products that are harmful to the user (allergy and possibly cancer) and to the product (were sodium sulphide or sulphur on the product can be oxidized in humid hot atmosphere into acidic gases that tender the product during the storing).

Recommendation:
To replace these compounds with safer substitutes. In one of SEAM 1 cleaner production projects, it was found that glucose and hydrogen peroxide are suitable –substitute for sodium sulphide and dichromate respectively. Accordingly both are recommended for safer manual sulphur black dyeing. Optimal dyeing quality was obtained using the following recipe :

Dye: glucose: caustic soda = 1 : 2 : 1 (by weight).
H_2O_2: acetic acid = 1 : 1 (by weight).
H_2O_2, 1g/1

4.1.2.1 Feasibility of substitution

Trials 1, 2 and 3

In trial 1:

The same sequence shown in Annex 4 is adopted, with the following modifications :

- **dyeing bath preparation :**

Instead of the conventional chemicals, we used the following substitutes, arranged in the sequence of addition: -

Caustic soda	250 g
Glucose	500 g
Dye	250 g

- **oxidation bath :-**

In stead of dichromate, H_2O_2 is used; where acetic acid 50 g is first added, followed by H_2O_2 (50 g). Results of this trial showed that dyeing is not uniform, where some batches on the pants are darker than other batches. This can be due to the partial oxidation of the dye in the dyeing bath, as time is elapsed, which gives rise to uneven dyeing.

In trial 2:

- To keep the dye in a reduced form, glucose is introduced into the dyeing bath at batches, as follow: -

Caustic soda	250 g
Glucose	300 g (60 % of total)
Dye	250 g

- 10 min after pants loading, 20 % of glucose (100 g) is added.
- 10 min after salt addition, the rest of glucose (100 g) is added.
- Dyeing and oxidation are continued as usual.

Results: even dyeing with satisfactory color strength

Trial 3:

Trial 3 is carried out to check the reproducibility of trial 2. same results were obtained.

4.1.3 Dyeing optimization

4.1.3.1 optimising of the amount of dye / pant

Trials were carried out to check the effect of reducing the amount (or concentration) of dye on the depth of shade of the dyeings. Amounts of dye used were 250, 230, 200, 170 and 140 g per batch. The dye/ glucose / caustic soda ratio was kept constant at 1/ 2 / 1. Oxidation batch and dyeing sequence were carried out as described in trial 2. The dyeings were evaluated visually for depth of shade. Given below is depth of shade as a function of dyeing (reduction) receipe:

4.1.3.2 Receipe

Glucose (g)	Dye (g)	Caustic soda (g)	Depth of shade
500	250	250	Satisfactory
460	230	230	Satisfactory
400	200	200	Satisfactory
340	170	170	Unsatisfactory
280	140	140	Unsatisfactory

Accordingly, a dyeing reduction receipe containing glucose / dye / caustic soda of 400 g / 200 g /200g is the optimal receipe.

This is equivalent to a shade of 50 g dye / a pant. (About 5 % shade).

4.1.3.3 Optimising Oxidation Recipe

Dyeing was effected as described in trial 2 using optimum reduction recipe, i.e. glucose / dye / caustic soda of 400 g / 200 g / 200 g. pants were cut into 5 pieces, which were oxidized using different oxidation recipe, and evaluated visually for depth of shade. The results are given in the following table.

Oxidation recipe		Depth of shade
Acetic acid (g)	H_2O_2	
50	50	Satisfactory
35	35	Satisfactory
20	20	Satisfactory
10	10	Unsatisfactory
0	0	Unsatisfactory

Accordingly, an oxidation recipe of acetic to H_2O_2 of 20 g/ 20 g represents the optimal recipe

4.1.4 Reduction of water- energy

4.1.4.1 Energy (adjustments in the heating system)

It was noticed that the dyeing and oxidation containers have no lids (cover). So, both were supplied with suitable lids. Also, the stove that used to heat the oxidation bath was supplied with a suitable shield to reduce heat dissipation. This result in the following savings

1- Heating time of the dye container to 60°C (where the reduction receipe is added) is reduced to 60 min. instead of 80 min.
2- Heating time of the oxidation container to 60°C is reduced to 45 min instead of 60 min.

Total heating time before adjustments = time to heat dyeing container to 60°C + time of exhausting + time to heat oxidation container to 60°C + time of oxidation.

= 80 + 60 + 60 + 45 +10
= 255 min

Time saved = 20 + 15 = 35 min

% Energy saved = (35/255) × 100 = 13.7 %

4.1.4.2 Water *(Water reuse)*

Water of first cold rinse was used for the first rinse after exhaustion.

This result in a water saving of = (20/260) × 100 =7.7 %

4.1.4.3 Water Eenergy and Chemicals (dye bath reuse)

After exhaustion, the dye bath still contains salt, caustic soda and a little dye/ glucose, in addition to water and energy. Accordingly it can be reused. dyebath can be reused after making the following adjustment :

Additional water	= 5 l
Additional caustic soda	= 180 g (instead of 200)
Additional glucose / dye	= zero
Additional salt	= 0.5 k

Procedure

1- Add water (5 l)
2- Add caustic soda (180 g) with stirring, then 240 g glucose (in 240 min. / water) with stirring, then the dye (200 g). Stir for 3 min., then load the wet pants with stirring. After 10 min. add 80 g of glucose. Add 0.5 k of salt. continue dyeing for further 30 – 35 min, so that total time between caustic addition and end of exhaustion reaches 60 – 65 min.
3- Rinse, oxidize and rinse again using acidified hydrogen peroxide..

Savings

- Water saved = 70 l – 5 l = 65 l
  % Saving in water = (65/260) × 100 = 25 %
- energy saved = 80 min. (heating of dye container before chemicals addition)
- % saving in energy = 80 min./255 min. (total time) = 31 %
- salt saved = 8.5 – 0.5 = 8 K

Extent of dye bath reuse

Reuse was performed for 5 times without impairing depth of shade of dyes.

4.1.5 Conclusions of Optimising Manual Sulphur Black Dyeing

4.1.5.1 Optimal dying recipe

- No of pants : 4 /batch
- Volume of water in dyeing container : 70 l
- Dyeing recipe
  Exhaustion

  Glucose : dye : caustic soda 400g : 200 g : 200 g

  Oxidation

  H_2O_2 / acetic acid, 20 g / 20 g in a container of 30 l.

Procedure (illustrated in Annex 5)

The fabric is given a cold rinse and hanged. Dyeing bath was heated to 60 c/60, then glucose (240 g), dye (200g) and NaOH (200g) are added with stirring in the mentioned sequence. The pants are loaded with stirring. After 10 min. add 80 g glucose, and continue dyeing with stirring for further 30 min. Take out the pants from the dyeing bath and rinse them 4 times in a cold bath. Oxidation follows using acetic acid /H2O2 (20g/20g) at 60 C. The pants are cold rinsed, hanged and air-dried.

Material balance (one batch/Annex 5)

	Inputs(Kg)	outputs(Kg)
Pants	3.35 (average)	Wet pants 7 Waste water 337.17
water	240	
Glucose	0.400	
Dye	0.200	
NaOH	0.200	
Acetic acid	0.020	
H_2O_2(35 %)	0.020	
Total	**244.17**	**244.17**

4.1.5.2 Comparison between conventional and modified dyeing process

Item	Conventional		Modified	
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)
Dye	0.200	2	0.2	2
Na_2S	0.4	2.8	--	--
NaOH	0.212	0.466	0.2	0.44
Glucose	--	--	0.4	1
Salt	8.5	1.275	0.85	1.075
Acetic acid	0.07	0.42	0.02	0.12
Dichromate	0.035	0.298	--	--
H_2O_2	--	--	0.02	0.05
Water	260	0.13	240	0.12
Energy *		0.385		0.332
Total cost		**7.774**		**5.337**

*Energy cost of conventional = 1 pump x LE 5/pump / 13 batch = LE 0.385

Energy cost of modified = (1-0.137) x 385 = LE 0.332

Time for modified = 125 min, in comparison with 140 for congenital.

4.1.5.3 Dyeing quality

	Conventional	Modified
Wash fastness	2-3	2-3
Dry rubbing fastness	2-3	2-3
Wet rubbing fastness	1-2	2-3
Depth of shade	satisfactory	satisfactory
Handle	rough	soft

4.1.5.4 Effluent quality

	Conventional	Modified
BOD (mg/l)	410	538
COD (mg/l)	2250	3120
TDS (mg/l)	77000	57000
Sulphide (mg/l)	172	2.5
Hexavalent chromium (mg/l)	34	Nil

4.1.5.5 Saving in costs for5 times dye bath reuse

- Water saving = (70-5) l /batch x 5 batches = 325 l
- Cost of water saved = 0.325 x 0.75 = 0.244 L.E.
- Energy saving = (0.31 x 5 L.E. x 5 batches) / 13 batches = 0.6 L.E.
- Salt saving = 4 batches x 8 K/batch x 0.15 L.E./K = 4.8
- Total savings = 0.244 + 0.6 + 4.8 = 5.684 L.E./s batches
- Time saved = 60 min. x 4 batches = 4 h

4.2 OPTIMISING MACHINE SULPHUR BLACK DYEING

4.2.1 Baseline Conditions (conventional Machine Dyeing)

Dyeing is performed in an old garment dyeing machine that is heated with steam and operates with electricity. The machine is loaded with 12 kg of pants (about 14 pants) and filled with about80-85 l of dyeing solution; that is equivalent to a LR of 6.67-7.1 l/kg.

4.2.1.1 Recipe

Dyeing (exhaustion) bath

- **Dye (**Sulphur Black BR 522, China) :

  50 g/kg of pants x 12 kg = 600g

  No extra dye is added to compensate losses due to oxidation during dyeing (which is opposite to the case of manual dyeing, where an extra of 25% is added).
- **Sodium sulphide :** 1.5 x amount of dye = 1.5 x 600 = 900 g
- **Caustic soda :** 500 g
- **Salt :** 8.5 kg

Oxidation bath

Oxidation is conducted in a separate container containing 30 –40 l of an aqueous solution of potassium dichromate (35g) and acetic acid (70 g) at 60°C.

4.2.1.2 Process Description (illustrated in Annex 6)

Each of the 14 pants are wrapped around itself from waist to legs, like a sandwich, before loading in the machine, then given a cold rinse. Dyeing begins with filling with fresh water and the machine turned on, where the dye solution (600 g of dye dissolved with 900 g sodium sulphide in about 3 l hot water) is added. Then 0.5 kg NaOH in about 2 l is added and the temperature is raised to 90-95ºC in about 30 min. where the salt is added. Dyeing continues for further 90 min. before discharging. A cold rise, a cold soaping and 2 other cold rinses are performed. Oxidation is performed outside the machine on 3 batches (5,5 and 4 pants), each batch continues for 5 min. under stirring with a wooden rod. Dichromate (25 g) and acetic acid (60 g) are first added to the container, and after oxidation of the first two batches, making up is made with 5 g dichromate and 10 g acetic acid as well as water to the specified limit of the container. The pants are then loaded into the machine and given a cold rinse, taken out, hanged and air dried.

4.2.1.3 Energy Consumption

One LPG pump (about 10 kg) is used to generate steam that can process 9 batches in winter and 11 batches in summer.

4.2.1.4 Material balance

Inputs (kg)

Pants	**12**
Water	590
Dye	0.6
Na_2S	0.9
NaCl	8.5
NaOH	0.5
Soap	0.1
Dichromate	0.035
Acetic acid	0.07
Total	612.705

Outputs (kg)

wet pants	**24**
wastewater	588.705
Total	612.705

4.2.1.5 Product quality

Quality	fastness			Depth of shade	Handle
	Wash	Rubbing (dry)	Rubbing (wet)		
Value	2-3	2-3	1-2	satisfactory	rough

4.2.1.6 Effluent quality

BOD (mg/l)	COD (mg/l)	TDS(mg/l)	S^{-2} (mg/l)	Cr (mg/l)
360	1560	44300	120	2.6

4.2.2 Substitution of sodium sulphide by glucose and dichromate by hydrogen peroxide

Based on previous experience in a similar project of SEAM 1, optimal dyeing quality can be achieved using the following ratios of chemicals:

Reduction:

Dye: glucose: caustic soda = 1: 2:1

Oxidation

Hydrogen peroxide (50%) : acetic acid = 1 : 1

These ratios were used, as a start, in the substitution, as shown in the following trials.

4.2.2.1 Feasibility of Substitution

Trial 1

Recipes:

Exhaustion: dye (600 g), glucose (1200 g), NaOH (600 g); salt 8.5 kg.

Oxidation :hydrogen peroxide (60 g), acetic acid (60 g), all in 30-35 l.

Procedure

In this trial, 14 pants are loaded in the machine and cold rinsed. The machine is filled with fresh water. In the mean time the dye is dissolved in 2 l of an aqueous solution containing 0.25 of the amount of NaOH (i.e. 150 g), and 5/6 the amount of glucose (i.e. 1 kg). This solution is added to the machine (while being running) and after 2-3 min. 1.5 l of an aqueous solution of NaOH (450 g) is added. The temperature is raised to 90-95ºC, then salt (8.5 kg) is added. After 30 min. 200 g of glucose (dissolved in 1 l hot water) are added. After 60 min. the dyeing bath is discharged. A cold rinse, a soaping and a further 2 cold rinses follow.

The pants are oxidized in the external container on at 50 ºC on 3 batches (5,5 and 4 pants). The container initially contains 2/3 of the chemicals (dichromate and acetic acid), and making up with the rest of chemicals is done after the 2nd batch.

A final cold rinse, hanging and air drying follow.

Results

A satisfactory shade was obtained, however, some white precipitates were found on the pants, which were removed by brushing. These were alike of those of soap precipitates.

Trial 2

Dyeing was performed the same manner as that of trial 1, with the exception that the soaping step was replaced by a cold rinse.

Results: Satisfactory depth of shade with no precipitates.

Trial 3

This was a confirmation trial, where trial 2 was repeated. The same results were obtained.

4.2.3 Dyeing optimization

4.2.3.1 Reduction Recipe

In the aforementioned trials, the shade (i.e. amount of dye per 100 g of pants) was 5%, that is 50 g dye per 1kg of pants. In the following trials the amount of dye was reduced to 45, 40 and 35 g/kg of pants. The proportion of dye/glucose/caustic soda (i.e. reduction recipe) was kept constant at 1/2/1. Dyeing and oxidation procedures were the same as described in trial 2. Monitoring was achieved by visual evaluation of depth of shade of dyeings as a function of exhaustion recipe. Given below is the depth of shade as a function of exhaustion recipe.

Reduction recipe (g) Dye : glucose : caustic soda	Depth of shade of dyeings
600 : 1200 : 600	satisfactory
540 : 1080 : 540	satisfactory
480 : 960 : 480	satisfactory
420 : 840 : 420	unsatisfactory

That is, a reduction recipe of 480 g of dye : 960 g glucose : 480 g of NaOH represents the optimal one per batch. This is equivalent to a shade of 4%.

4.2.3.2 Salt quantity

The effect of reducing the amount of salt on the depth of shade of dyeings is shown in the following table.

Salt (kg)	Depth of shade of dyeings
8.5	satisfactory
7	satisfactory
5.5	unsatisfactory

That is, optimal salt quantity is 7 kg per batch.

4.2.3.3 Dyeing time

As has already been mentioned in the dyeing procedure (trial 2), after reaching 90-95ºC , the salt is added and after 30 min. the rest of glucose is added, then dyeing continues for an extra time (i.e. 60 min.) before discharging. Trials were conducted to investigate the effect of shortening this extra time on the extent of depth of shade of dyeings. The results are listed in the following table.

Time after final glucose addition (min.)	Depth of shade of dyeings
60	satisfactory
45	satisfactory
30	satisfactory
15	unsatisfactory

It can be seen that, 30 min. represents the optimal time (after final glucose addition) needed to effect satisfactory depth of shade. That is, total time after reaching 90-95ºC is one hour.

4.2.3.4 Sequence of glucose addition

In the above trials, the amount of glucose was added on two portions. The first in the reduction recipe, and the second at 90-95ºC after 30 min. of salt addition. This was adopted to keep the dye in a reduced form during the course of dyeing. A mistake was made in one of the production batches, where all glucose was added in the reduction recipe. Surprisingly, no effect was noticed on the depth of shade of dyeings. This result was confirmed by repetitions. This can be attributed to the fact that the machine is closed which allows little air to enter and/ or that the amount of glucose used is enough to prevent any oxidation of the dye during the course of dyeing.

4.2.3.5 Replacing acetic acid by formic acid

Formic acid is of lower BOD and COD and price than acetic acid, and of higher strength. It is already used in many textile mills as a substitute of acetic acid. In our trials it was successfully used instead of acetic acid in the oxidation bath. That is 60 g formic acid (85%) were used instead of 60 g acetic acid (96%) to provide the acidic medium needed for hydrogen peroxide to effect dye oxidation and fixation.

4.2.4 Reduction of water and energy

4.2.4.1 Energy

It has been shown that exhaustion time was reduced from 90 min. to 60 min. This is reflected on heat reduction during exhaustion time, which can be calculated as follows:
% Energy reduction in exhaustion period =
100 (original exhaustion time – optimal exhaustion time) ÷ original exhaustion time
This amounts to 33% reduction.

Now, assuming that the total amount of heat energy consumed during dyeing process are divided according to the following percentages:

- 50% for raising the temperature to 90-95ºC in the machine.
- 25% for maintaining the temperature at 90-95ºC during exhaustion.
- 25% for performing fixation outside the machine.

Accordingly, % energy reduction in exhaustion period amounts to about 8% of total dyeing energy.

4.2.4.2 *Water and Energy*

The approach to reduce water and energy in this phase of the project was to increase the amount of pants per a batch, and to investigate its effect on the depth of shade of the dyeings. Trials were carried out using a shade of 4%. Readjusting of other chemicals to suit the increase in number of pants was done. Results obtained are listed below.

No.of pants	Reduction recipe			Oxidation recipe		Dyeings quality	
	dye	glucose	NaOH	Formic acid	H_2O_2	Depth of shade	uniformity
14	480	960	480	48	48	satisfactory	uniform
16	550	1100	550	55	55	satisfactory	uniform
18	620	1240	620	62	62	satisfactory	uniform
20	685	1370	685	69	69	satisfactory	Not uniform

It is clear that optimal number of pants per a batch is 18 pants, then
% reduction in water consumption = {(18-14) ÷ 14 } x 100 = 28 %
% reduction in energy consumption = {(18-14) ÷ 14 } x 100 = 28 %

4.2.5 Conclusions of Optimising Machine Sulphur Black Dyeing

4.2.5.1 *Optimal dyeing recipe*

No of pants per a batch = 18 (or about 15 kg)
Volume of dyeing liquor = 80 l

Exhaustion recipe:
Dye: glucose: caustic soda = 620 g : 1240 g : 620 g **Salt :** 7 kg
Oxidation recipe:
H_2O_2: formic acid = 80 g : 80 g
Volume of oxidation liquor = 30 – 35 l

4.2.5.2 *Procedure (illustrated in Annex 7)*

1 The pants are tuned inside out. Each pant is wrapped on its longitudinal axis around itself like a sandwich, then arranged in the machine beside each others. Then given a cold rinse and the wastewater is discharged.
2 The machine is filled with fresh water, and turned on.
3 In the mean time, a dye solution is prepared outside and added to the machine. It contains the dye , glucose and ¼ of NaOH in 2 l of hot water (80 –90 C).
4 After 2-3 min. the rest of NaOH in 1 – 2 l is added to the machine, then the temperature is raised to 90-95°C in about 30 min., where all the salt (7kg) is added.
5 Dyeing continues for an hour after salt addition before discharging, followed by 4 cold rinses, each for 5 min.
6 Oxidation is performed in a separate container outside the machine. It contains 55 g of each of H_2O_2 and formic acid in 30-35 l of water at 50°C . 2 batches, each of 5 pants , are separately immersed with stirring for 5 min. in the container. After the 2nd batch the rest of both H_2O_2 and formic acid are added and water is adjusted to the original level, where 2 other batches, each of 4 pants are treated separately in a similar manner.
7 The pants are given a cold rinse for 5 min. in the machine , hanged and air dried.

4.2.5.3 *Material balance*

Inputs (kg)	
Pants	15
Water	590
Dye	0.6
Glucose	1.24
NaOH	0.62
Salt	7
H_2O_2	0.08
Formic acid	0.08
Total	614.62

Outputs (kg)	
wet pants	30
wastewater	584.92
Total	614.92

4.2.5.4 *Conventional vs. Modified Sulphur Black Dyeing*

a- Cost and Time (based on a batch of 18 pants)

Item	Conventional		Modified	
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost(LE)
dye	0.75	7.5	0.62	6.2
Sodium sulphide	1.13	7.9	-	-
Caustic soda	0.625	1.37	0.62	1.36
glucose	-	-	1.24	3.1
salt	8.5	1.275	7	1.05
Acetic acid	0.09	0.54	-0	-
Formic acid	-	-	.08	0.4
dichromate	0.044	0.37	-	-
H_2O_2	-	-	0.08	0.2
water	737	0.37	590	0.295
Energy*		1.82		1.44
Total cost		**21.145**		**14.045**

(*)Assuming that cost of electricity is the same as that of steam, then
Energy cost of conventional = 2(2 pumps x LE 5/pump ÷ 11 batch) = LE 1.82/batch
Energy cost of modified = 2(2 pumps x LE 5/pump ÷ 14 batch) = LE 1.74/batch

Time of modified is 30 min. shorter than that of conventional.

b- Quality of Dyeings

Process	Fastness Dry rubbing	Fastness Wet rubbing	Fastness wash	Depth of shade	handle
Conventional	2-3	2-3	1-2	satisfactory	rough
Modified	2-3	2-3	1-2	satisfactory	soft

c- Effluent Quality

Process	BOD	COD	TDS	sulphide	chromium
Conventional (mg/l)	360	1560	44200	120	26

Modified (mg/l)	625	3720	36000	2.1	nil

5 PART V: COMPARATIVE STUDY BETWEEN MANUAL AND MACHINE DYEING

5.1 DIRECT DYEING

The following study pertains to dark blue dyeing because it is the dominant color in the establishment.

5.1.1 Manual vs. machine conventional direct blue dyeing

There are two cases: single dye bath use and multiple dye baths reuse.

5.1.1.1 Single dyebath use

The following table shows cost and time comparison between a batch of conventional manual (with no dye bath reuse) and machine direct dyeing.

Item	Conventional Manual		Conventional Machine	
	Quantity	Cost (LE)	Quantity	Cost (LE)
No of pant/batch	3		14	
<u>Chemicals :</u> quantities in kg				
Direct Navy Blue	0.075	4.5	0.36	21.6
Direct Black FG Soda ash	0.0125	0.33	0.054	1.426
Soda ash	0.4	0.64	0.4	0.64
Salt	9.5	1.425	9.5	1.425
Acetic acid	0.2	1.2	0.2	1.2
Water	210	0.1575	430	0.3225
Energy*		.33		1.66
Total cost		8.5855		28.274
Time (min.)	195		125	

(*) Energy cost for manual = 1LPG pump x LE 5/pump ÷ 15= LE 0.333 /batch
Energy cost for machine = cost of LPG + cost of electricity
Assuming that cost of electricity is the same as that of LPG, then
Energy cost for machine = 2 cost of LPG = 2(2pump xLE 5/pump ÷ 12 batch) = LE 1.66

Dividing the total cost and time by the number of pant/batch, gives the cost and time needed to dye one pant. These are shown in the following table.

Process	Conventional Manual	Conventional Machine
Cost (LE/pant)	2.862	2.02
Time (min./pant)	65	9

It is clear that:

1. The cost of dyeing a pant by the manual method is about 1.4 that by the machine method
2. The time needed by the manual method is about 7 that by the machine method.

5.1.1.2 Dyebath reuse

In case dyebath reuse in manual dyeing, the situation is changed regarding to cost and time of dyeing (as described in item 3-2-1 of the report entitled "optimising the manual garment piece dyeing process at Cleopatra dyehouse, Sept. 2003"). That is, there are savings in cost and shortening in dyeing time. This is given as follows.

% saving in water = 30%
= LE 0.0473 /batch
% Saving in salt = 90 %
= LE 1.283 /batch
% Saving in energy = 41%
= LE 0.1365/batch
Dyeing time is shortened by 80 min., i.e. it becomes 115 min.

Accordingly, the following table shows a comparison between conventional manual (without or with dyebath reuse) and machine direct dyeing regarding to cost and time needed to dye a pant.

Process	Conventional Manual		Conventional Machine
	Without dyebath reuse	With dyebath reuse	
Cost (LE/pant)	2.862	2.373	2.02
Time (min./pant)	65	38	9

Dye bath reuse reduced the cost and time of manual dyeing, however both are still higher than their counterparts of machine dyeing.

5.1.1.3 Quality of Dyeings

Process	Depth of shade	Fastness		
		Dry rubbing	Wet rubbing	Wash
Manual	satisfactory	2	1-2	1-2
Machine	satisfactory	2	1-2	1-2

It is clear that dyeings qualities are the same in case of both processes. However, uniformity is much higher in case of machine than manual dyeing.

5.1.1.4 Effluent Quality

Process	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
Conventional Manual	1188	3265	101700
Conventional Machine	210	1333	77000

It is clear that the pollution load is much lower in case of manual than that in case of machine dyeing.

5.1.2 Manual vs. Machine Modified Direct Dyeing

Here also, there are two cases: single dye bath use and multiple dye bath reuse.

5.1.2.1 Single dyebath use

The following table shows cost and time comparison between a batch of modified manual (with no dye bath reuse) and machine direct dyeing.

Item	Modified Manual		Modified Machine	
	Quantity	Cost (LE)	Quantity	Cost (LE)
No of pant/batch	3		18	
Chemicals : quantities in kg				
Direct Navy Blue	.0425	2.55	.31	18.6
	.01	.2	.045	1.24
Direct Black FG Soda ash	.26	.416	.2	.32
Soda ash	6.8	1.0	6	.9
Salt	-	-	.06	.36
Magnesium chloride	-	-	.06	.3
Formic acid	210	.157	430	.125
Water				
Energy*		.265		1.32
Total cost		4.68		23.255
Time (min.)		155		110

(*) Energy cost for manual = 1LPG pump x LE 5/pump ÷ 18.86 batch = LE 0..265 /batch
Energy cost for machine = cost of LPG + cost of electricity
Assuming that cost of electricity is the same as that of LPG, then
Energy cost for machine = 2 cost of LPG = 2(2pump x LE 5/pump ÷ 15 batch) = LE 1.32/batch

Dividing the total cost and time by the number of pant/batch gives the cost and time needed to dye one pant. These are shown in the following table.

Process	Modified Manual	Modified Machine
Cost (LE/pant)	1.56	1.3
Time (min./pant)	52	7

It is clear that :

1. The cost of dyeing a pant by the manual method is about 1.2 that by the machine method
2. The time needed by the manual method is about 7.4 that by the machine method.

5.1.2.2 Dyebath reuse

In case dyebath reuse, there are savings in cost and shortening in dyeing time in case of manual dyeing. This is given as follows.

% Saving in water = 30%
= LE 0.0473 /batch
% Saving in salt = 90 %
= LE 0 .9/batch
% Saving in energy = 41%
= LE 0.109/batch

Total saving in modified manual dyeing = 0.0473 + 0.9 + 0.109
= LE 1.055/batch
Dyeing time is shortened by 60 min., i.e. it becomes 95 min.

Accordingly, the following table shows a comparison between modified manual (without or with dyebath reuse) and machine direct dyeing regarding to cost and time needed to dye a pant.

Process	Modified Manual		Modified Machine
	Without dyebath reuse	With dyebath reuse	
Cost (LE/pant)	2.862	1.208	1.3
Time (min./pant)	52	32	7

Dye bath reuse reduced the cost and time of dyeing a pant by the modified manual dyeing. However the new cost is about 7% less than that of modified machine dyeing. In the mean time, the time needed to dye a pant in case of dye bath reuse is about 7.5 that needed in case of machine dyeing..

5.1.2.3 Quality of Dyeings

Process	Depth of shade	Fastness		
		Dry rubbing	Wet rubbing	Wash
Manual	satisfactory	2	1-2	1-2
Machine	satisfactory	2-3	2	2

It is clear that fastness properties of dyeings in case of machine are slightly higher than those of manual dyeings. The uniformity is much higher in case of machine than manual dyeing.

5.1.2.4 Effluent Quality

Process	BOD (mg/l)	COD (mg/l)	TDS (mg/l)
Modified Manual	750	3062	82400
Modified Machine	140	633	57000

It is clear that the pollution load is much lower in case of manual than that in case of machine dyeing.

Conclusions
Machine direct dyeing is superior to manual direct dyeing, even in case of dyebath reuse, either by the conventional or modified method. This is due to the following reasons:
1. Cheaper cost for dyeing a piece
2. Much lower dyeing time per a piece.
3. Superior dyeing qualities.
4. Lower effluent pollution load.

5.2 SULPHUR BLACK DYEING

5.2.1 Manual vs. machine conventional sulphur black dyeing

5.2.1.1 Cost ant time(based on one batch)

Item	Conventional Manual		Conventional Machine	
	Quantity	Cost (LE)	Quantity	Cost (LE)
No of pant/batch	4		14	
Water	260	0.13	590	0.295
Dye	0.26	2	0.6	0.6
Sodium sulphide	0.2	2.8	0.9	9
Soap	-	-	0.1	0.1
Caustic soda	0.212	0.466	0.5	1.1
Salt	8.5	1.275	8.5	1.275
Potassium dichromate	0.035	0.298	0.035	0.298
Acetic acid	0.07	0.42	0.07	0.42
Energy*		0.385		1.82
Total cost		7.774		15.055
Time (min.)	140		170	

(*) Energy cost for manual = 1LPG pump x LE 5/pump ÷ 13= LE 0.385 /batch
Energy cost for machine = cost of LPG + cost of electricity
Assuming that cost of electricity is the same as that of LPG, then
Energy cost for machine = 2 cost of LPG = 2(2pump xLE 5/pump ÷ 11 batch) = LE 1.82/batch

The following table shows the cost and time needed to dye one pant. For both processes.

Process	Conventional Manual	Conventional Machine
Cost (LE/pant)	1.94	1.1
Time (min./pant)	35	13

It is clear that:

1. The cost of dyeing a pant by the manual method is about 1.7 that by the machine method
2. The time needed by the manual method is about 2.5 that by the machine method.

5.2.1.2 Quality of Dyeings

Process	Handle	Depth of shade	Fastness		
			Dry rubbing	Wet rubbing	Wash
Manual	rough	satisfactory	2-3	1-2	2-3
Machine	rough	satisfactory	2-3	1-2	2-3

It is clear that dyeings qualities are the same in case of both processes. However, uniformity is much higher in case of machine than manual dyeing.

5.2.1.3 Effluent Quality

Process	BOD (mg/l)	COD (mg/l)	TDS (mg/l)	Sulphide (mg/l)	Hexavalent chromium (mg/l)
Conventional Manual	410	2250	77000	172	34
Conventional Machine	360	1560	44200	120	26

It is clear that the pollution load is sensibly higher in case of manual than that in case of machine dyeing.

5.2.2 Manual vs. Machine Modified Sulphur Black Dyeing

Here also, there are two cases: single dye bath use and multiple dye bath reuse.

5.2.2.1 Cost and time

Item	Modified Manual		Modified Machine	
	Quantity	Cost (LE)	Quantity	Cost (LE)
No of pant/batch	4		18	
Water (Kg)	240	0.12	590	0.295
Dye (Kg)	0.2	2	0.62	6.2
Glucose (Kg)	0.4	1	1.24	3.1
Caustic soda (Kg)	0.2	0.44	0.62	11.36
Salt (Kg)	8.5	1.075	7	1.05
Hydrogen peroxide(Kg)	0.02	0.05	0.08	0.2
Acetic acid (Kg)	0.02	0.12	-	-0.4
Formic acid (Kg)	-	-	0.08	
Energy*		0.332		1.42
Total cost		5.137		14.05
Time (min.)		125		140

(*) Energy cost for manual = 1LPG pump x LE 5/pump ÷ 15 batch = LE 0.332 /batch
Energy cost for machine = cost of LPG + cost of electricity
Assuming that cost of electricity is the same as that of LPG, then
Energy cost for machine = 2 cost of LPG = 2(2pump x LE 5/pump ÷ 14 batch) = LE 1.42/batch

Here are the cost and time of dyeing one pant.

Process	Modified Manual	Modified Machine
Cost (LE/pant)	1.28	0.78
Time (min./pant)	31	8

It is clear that:

1. The cost of dyeing a pant by the manual method is about 1.6 that by the machine method
2. The time needed by the manual method is about 4 that by the machine method.

5.2.2.2 Quality of Dyeings

Process	Handle	Depth of shade	Fastness		
			Dry rubbing	Wet rubbing	Wash
Manual	soft	satisfactory	2-3	2-3	2-3
Machine	soft	satisfactory	2-3	2-3	2-3

It is clear that dyeings qualities are the same in case of both processes. However, uniformity is much higher in case of machine than manual dyeing.

5.2.2.3 Effluent Quality

Process	BOD (mg/l)	COD (mg/l)	TDS (mg/l)	Sulphide (mg/l)	Hexavalent chromium (mg/l)
Manual	1421	22750	77600	3.4	Nil
Machine	1625	3720	36000	2.1	Nil

It is clear that in machine dyeing both BOD and COD are higher and TDS is lower (due to lowering the amount of salt) than manual dyeing. Sulphide content is slightly higher in manual dyeing.

Conclusions

Machine sulphur black dyeing is superior than manual dyeing, either by the conventional or modified methods. This is due to the following reasons:

1. Cheaper cost for dyeing a piece
2. Much lower dyeing time per a piece.
3. Lower effluent pollution load, in case of conventional only.

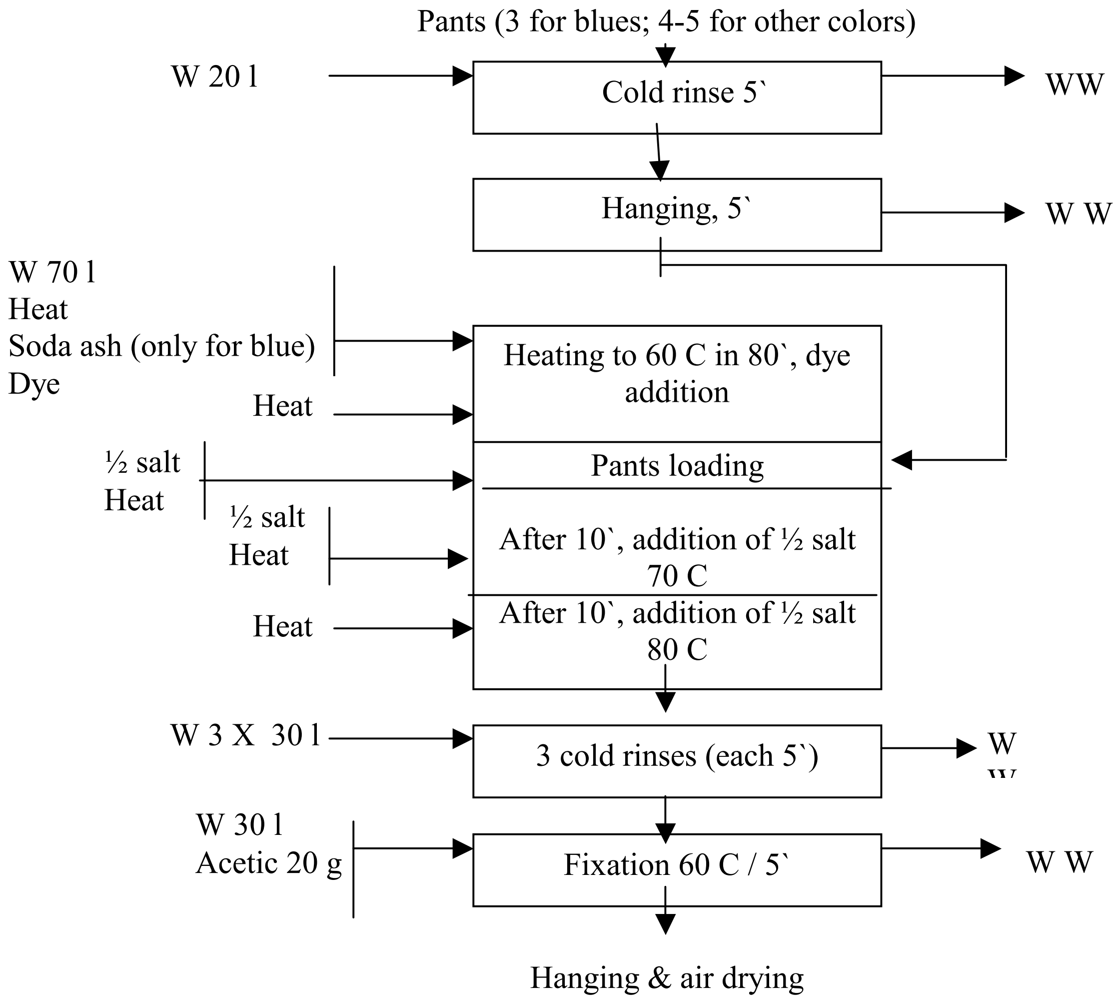
ANNEXES

ANNEX1: CLASSIFICATION OF TEXTILE FIBERS ACCORDING TO ORIGIN.

Textile Fibers

- **Natural**
  - **Vegetable**
    - Cotton
    - Linen
    - Jute
    - Hemp
    - Ramie
  - **Animal**
    - Wool
    - Silk
  - **Mineral**
    - Glass
    - Asbestos
    - Metal
- **Man-Made**
  - **Semi Synthetic**
    - Viscose Rayon
    - Cupra Rayon
    - Acetate Rayon
  - **100% Synthetic**
    - Nylon
    - Polyester
    - Acrylics

ANNEX 2: PROCESS FLOW DIAGRAM OF CONVENTIONAL MANUAL DIRECT DYEING AT CLEOPATRA GARMENT DYEHOUSE



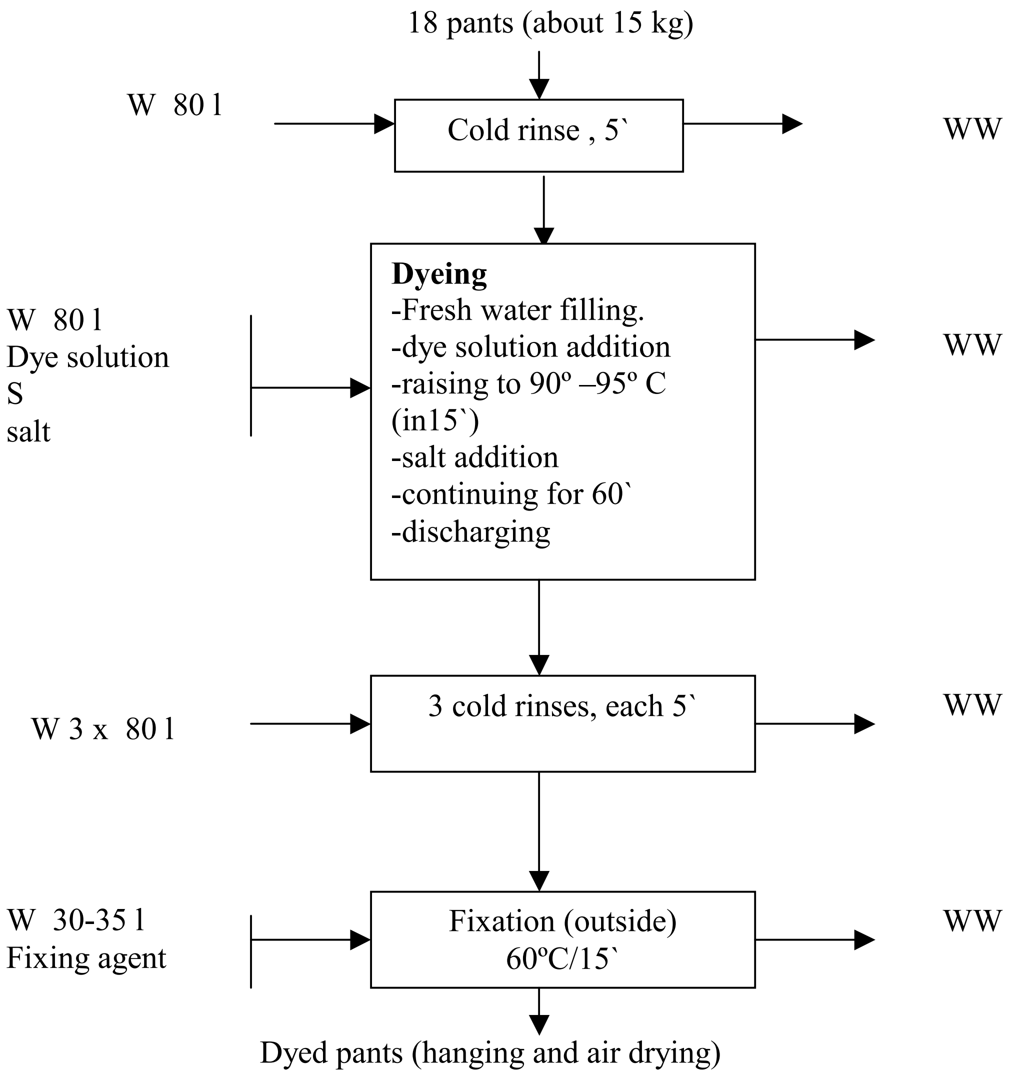
(W: water; w w: wastewater).

Pants: 3 pants in case of blues (2.4-2.6 kg)

: 4 pants for other colors (3.2-3-5 kg)

Amounts of dye and chemicals are shown in 3-1-1

ANNEX 3 PROCESS FLOW DIAGRAM OF CONVENTIONAL MACHINE DIRECT DYEING AT CLEOPATRA GARMENT DYEHOUSE

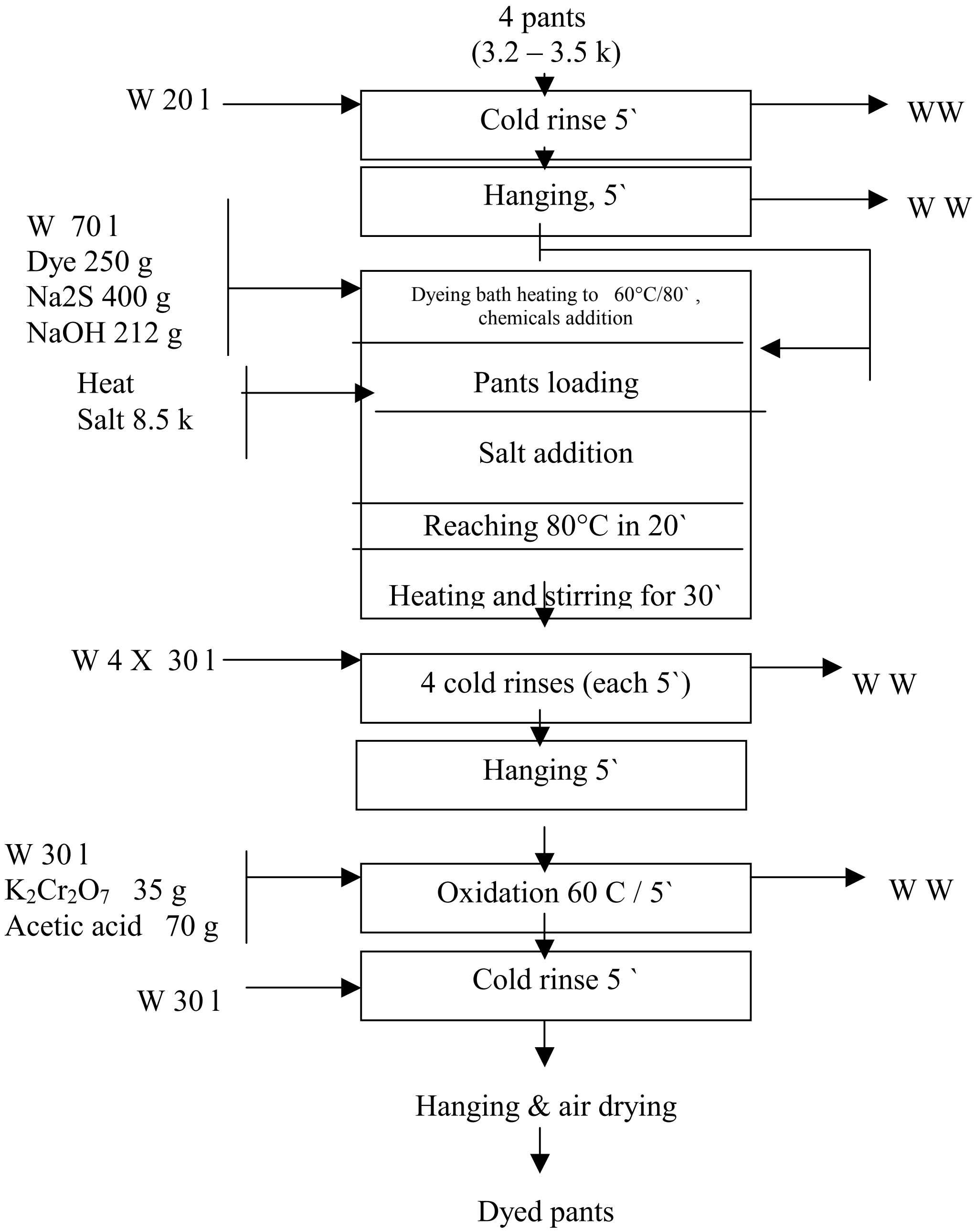


(W : water; S: steam; WW: wastewater)

N.B.

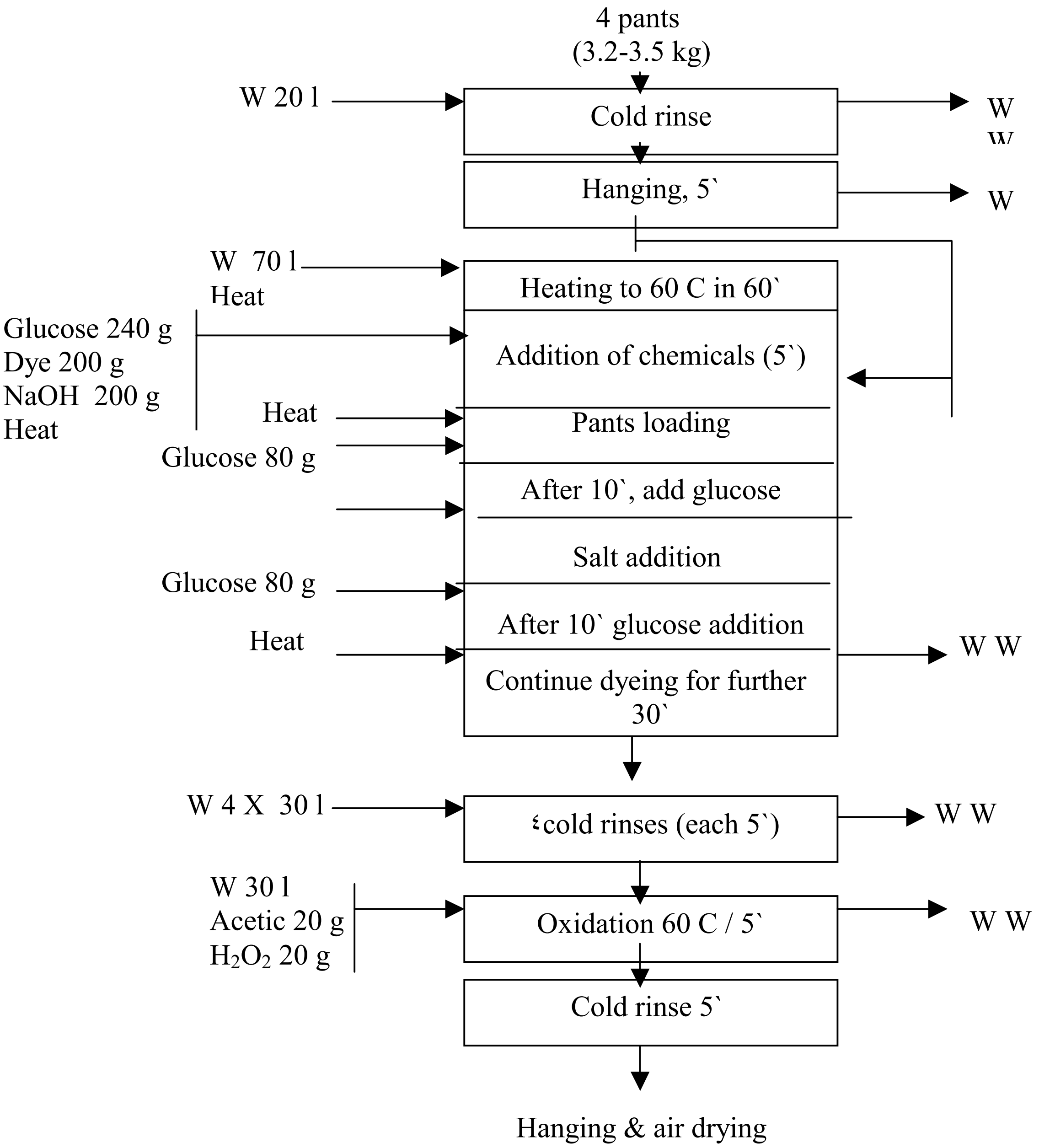
- In case of blues and gray colors, an extra 15` is given after reaching 90º–95ºC, before salt addition.
- 400 g of soda ash are dissolved in water taken from the machine and added before dye solution addition in case of blues.
- Fixing agent is 10 g/l NaCl.(for Brown color) or 200 g acetic acid (for blues).

ANNEX 4 PROCESS FLOW DIAGRAM OF CONVENTIONAL MANUAL SULPHUR BLACK DYEING AT CLEOPATRA GARMENT DYEHOUSE



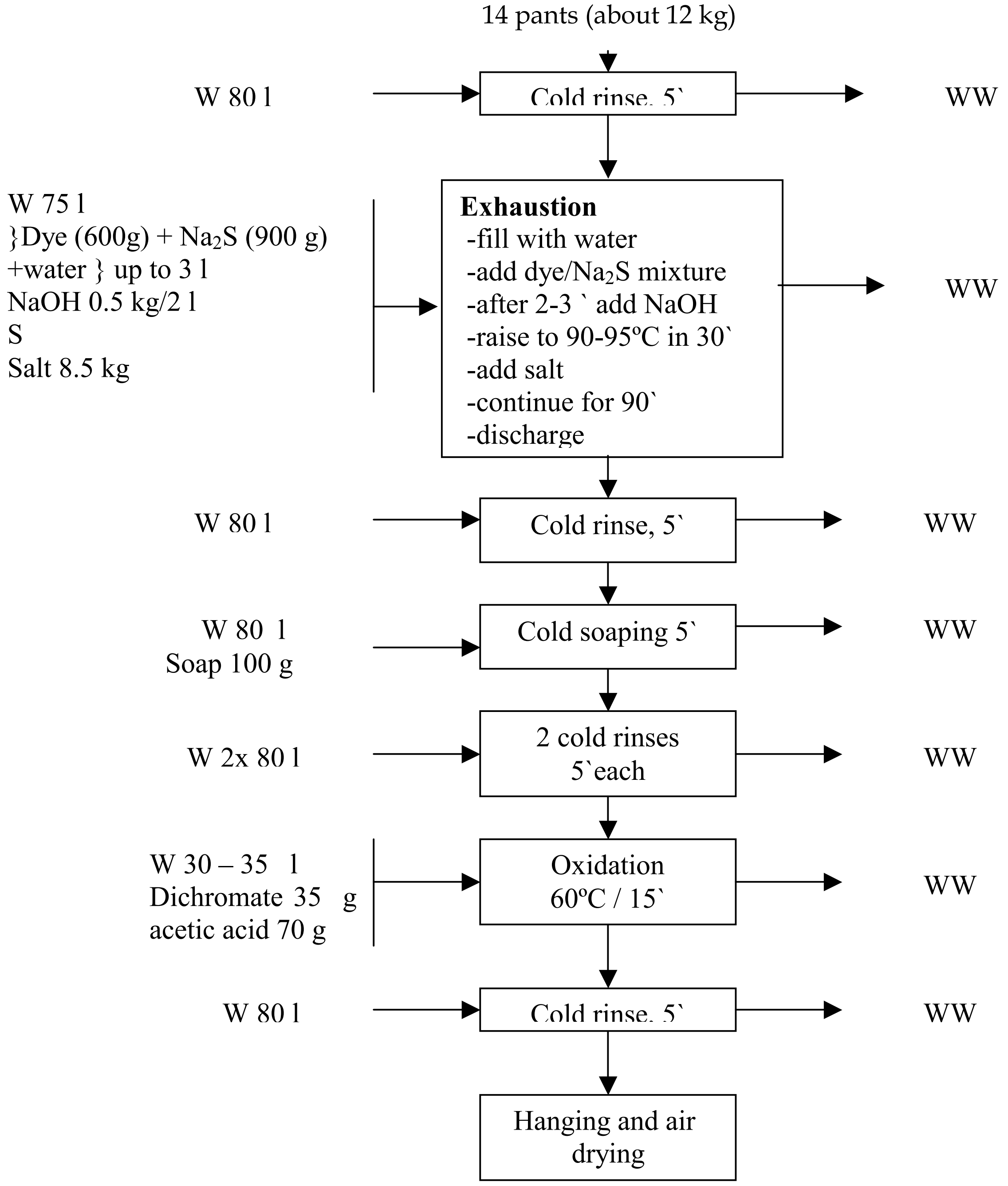
(ww : wastewater; w : water).

ANNEX 5 PROCESS FLOW DIAGRAM OF MODIFIED MANUAL SULPHUR BLACK DYEING AT CLEOPATRA GARMENT DYEHOUSE)



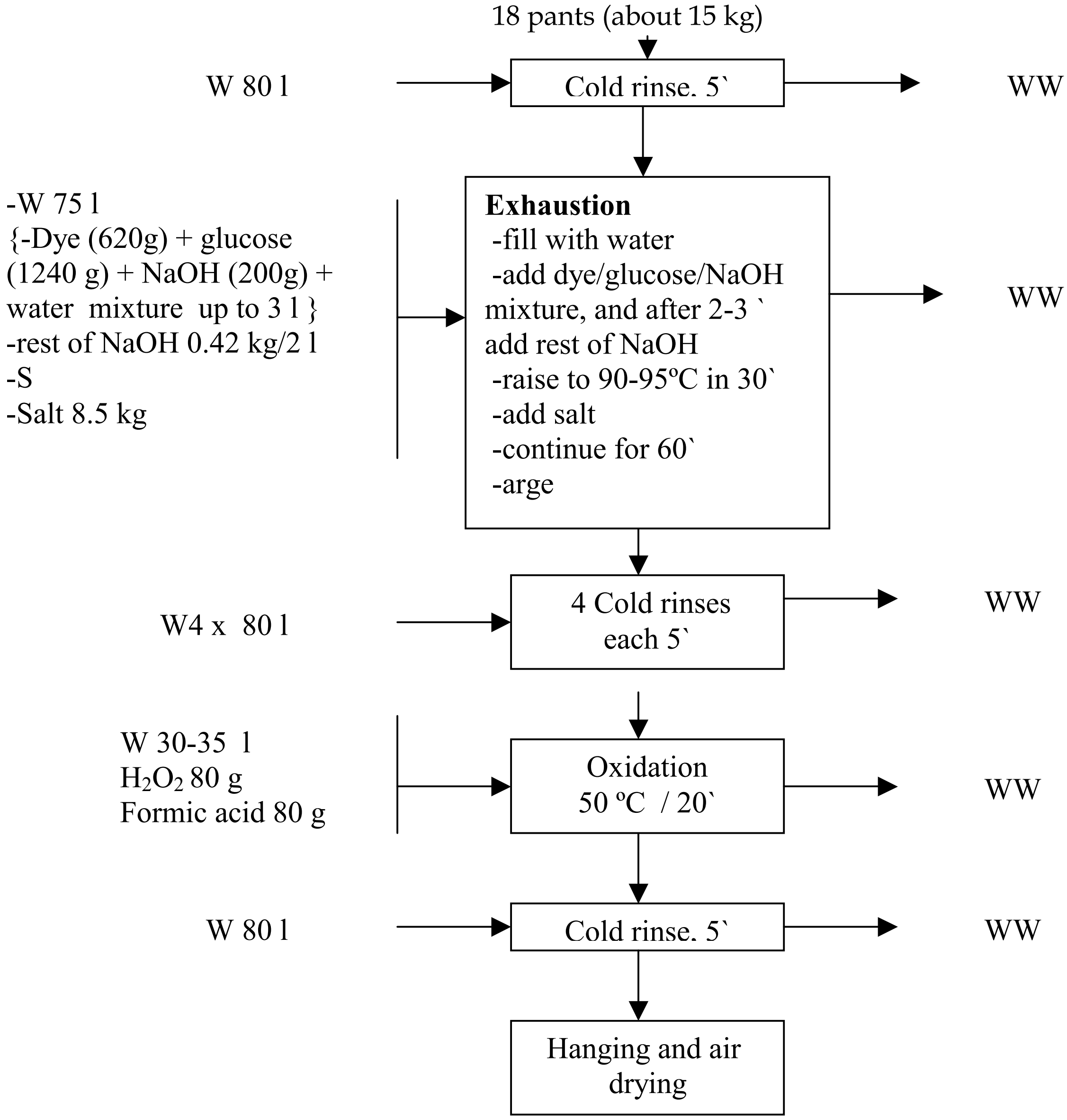
(ww : wastewater; w : water).

ANNEX 6 PROCESS FLOW DIAGRAM OF CONVENTIONAL MACHINE SULPHUR BLACK DYEING AT CLEOPATRA GARMENT DYEHOUSE



(W : water, S : steam, WW : wastewater)

ANNEX 7 PROCESS FLOW DIAGRAM OF MODIFIED MACHINE SULPHUR BLACK DYEING AT CLEOPATRA GARMENT DYEHOUSE



(W : water, S : steam, WW : wastewater)