GUIDANCE MANUAL
CLEANER PRODUCTION FOR TEXTILES
SULPHUR BLACK DYEING

SEAM Project
Implemented by:

Egyptian Environmental Affairs Agency
Technical Cooperation Office for the Environment
and
Entec UK Limited

GUIDANCE MANUAL PRODUCED BY THE SEAM PROJECT

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The SEAM Project - An Introduction

Support for Environmental Assessment and Management (SEAM), is a multi-disciplinary environmental project being funded by Britains Department for International Development (DFID). This Project is being implemented by the Egyptian Environmental Affairs Agency (EEAA) through the Technical Cooperation Office for the Environment (TCOE) and *En*tec, a UK based engineering and environmental consultancy.

The SEAM Project is made up of 5 components, focusing on environmental management issues. These include Industrial Pollution Prevention/Cleaner Production, Environmental Impact Assessment, Solid Waste Management, Environmental Action Plans and development of an Environmental Database.

The main goal of the Industrial Pollution Prevention/Cleaner Production component is to show that significant financial savings and environmental improvements can be made by relatively low-cost and straightforward interventions. These consist of pollution prevention through good housekeeping, waste minimisation, process modification and technology changes. This approach has two benefits - valuable materials are recovered rather than wasted and factories are moved towards legislative compliance. This work is being undertaken in support of the National Industrial Pollution Prevention Programme (NIPPP) and has focused on three sectors: textiles, food and oil & soap.

Industrial auditing of 32 factories identified in excess of 200 low cost/no cost pollution prevention measures. Commonly occurring issues were then developed as demonstration projects for each sector, whose aims were to show the financial and environmental benefits of the pollution prevention approach.

Thirteen demonstration projects have been implemented in 21 sites as follows:

Textile Sector

- Eco-friendly Processing for Securing International Eco-label.
- Water and Energy Conservation.
- Combined Processing: Desize, Scour and Bleach.
- Bleach Clean-Up using Enzymes.
- Sulphide Reduction in Sulphur Dyeing.

Food Sector

- Installation of Milk Tank Level Controls and Valves.
- Water Conservation in Food Factories.
- Energy Conservation in Food Factories.
- Reducing Waste by Improved Quality Control.
- Recovery and Use of Whey as Animal Feed.

Oil and Soap Sector

- Waste Minimisation in an Edible Oil Factory.
- Oil and Fat Recovery.
- Improving Raw Water Quality to Reduce In-Plant Losses.

Outputs from these projects include industry workshops and seminars, demonstration projects with su Guidance Notes and Manuals (to enable other factories to implement similar projects themselves), cas incorporating cost-benefit analyses to demonstrate project feasibility, detailed Sector Reports and G describing how to carry out industrial audits.

The SEAM Demonstration Project Improving the Sulphur Black Dyeing Process

The demonstration project was designed to show how sulphur black dyeing can be carried out without using harmful reducing and oxidising agents, whilst maintaining or even improving the quality of the final fabric. It shows how pollution can be prevented through chemical substitution, rather than end of pipe treatment alone. The project was implemented in three factories in Egypt; El-Nasr Spinning & Weaving Co., Mahalla El-Kobra; Dakahleya Spinning & Weaving Co., Mansoura and AmirTex Company, Sadat City.

Using the information gained during project implementation in these factories, this Guidance Manual gives a step-by-step description of how other companies can make similar improvements. It also quantifies the benefits that were achieved at each factory as a result of project implementation.

Factories that participated in the SEAM Demonstration Project

The factories were selected for their different characteristics in terms of fabric type, type of manufacturing equipment used for sulphur black dyeing and the size of the operation. The following factories were involved:

2. *El-Nasr Spinning and Weaving Co., Mahalla El-Kobra* (El Nasr Spinning and Weaving)

The factory produces spun cotton yarns (70%) and polyester (30%), which are either bleached or dyed, woven as terry fabrics, then pre-treated, dyed, printed and finished. The company is also a commercial dyer and carries out wet processing as required by their customers. The products include white, dyed, and/or printed fabrics, terry fabrics, bed covers, sheets and upholstery fabrics. Approximately 52.5 million-metre of fabric was produced during 1996/1997.

2. Misr Beida Dyers Company (Misr Beida Dyers)

Misr Beida Dyers is a public sector company located at Kafr El-Dawar, Alexandria. It was established in 1938 and occupies a 264 feddan site.

The factory pre-treats, dyes, prints and finishes cotton fabrics and cotton/synthetic blends; processes yarns (pre-treatment, mercerising and dyeing); scours and dyes wool tops and produces absorbent cotton. During 1997/8, Misr Beida Dyers pre-treated about 1,182 tons of woven fabric on jiggers, of which about half were pre-treated using the separate processes (kamilase desizing, scouring and half bleaching). The remaining fabric was pre-treated using the combined process consisting of desizing/scouring, using Leonil EB, followed by half bleaching.

Part A

1. **What is Sulphur Black Dyeing?**
2. **Sulphur Black Dyeing in Egypt**
3. **Environmental Problems of Sulphur Black Dyeing**
4. **Improving the Sulphur Black Dyeing Process**

1 What is Sulphur Black Dyeing?

The sulphur dyes (of which sulphur black is one type) are mainly used for dyeing cotton, rayon and cotton-synthetic blends. The darker shades of the sulphur dyes are preferred by textile manufacturers for the deep colours they produce in the final fabric.

The solid dye is first converted into a water soluble form so that it can be absorbed by the fibre. This is achieved using an alkaline reducing agent in solution, traditionally sodium sulphide. Once absorbed, the dye is reconverted (by oxidation) to the insoluble form to fix it on the fabric and ensure that it will not wash out. This step is often carried out using acidified dichromate (usually sodium dichromate or potassium dichromate).

2 Sulphur Black Dyeing in Egypt

Sulphur black is widely used throughout Egypt. Amongst synthetic dyes, it is a low cost dye and exhibits excellent wash and good light fastness. The jet black shade of sulphur black colour cannot be produced in an economical manner by use of any other class of cotton dye. Further, sulphur black has good covering properties for dyeing immature cotton. The appeal of sulphur black colours results from its durability, flexibility of application and low cost.

Sulphur black can be applied on cellulose material by:

- Padding method on continuous dyeing ranges (where the fabric is saturated in a pre-mixed dyeing liquor and then passed through rollers);
- Exhaustion method on jiggers, winches, jets, etc. (where one batch of fabric is dyed at a time).

In Egypt, the padding method on continuous pad-steam dyeing range is not practiced. Generally, woven goods are dyed on jiggers and knitted goods are dyed on winches, or jet dyeing machines, by batching.

The adverse aspects of sulphur black dyeing result from the use of sodium sulphide and acidified dichromates, which are toxic and hazardous to health, both to factory staff and to end users. Consequently, many European countries have discontinued the use of sulphur colours. However, they continue to purchase a large volume of fabric dyed in sulphur black shade from developing countries.

Therefore, this demonstration project has been developed to retain the advantages of sulphur black dyeing, whilst reducing the hazards normally associated with it. This is achieved by substituting the hazardous reduction and oxidation chemicals with less harmful ones.

3 Environmental Problems of Sulphur Black Dyeing

Being fairly cheap, sodium sulphide is a widely used, traditional reducing agent for sulphur black dyeing. However during processing, sodium sulphide gives off foul smelling sulphide gas which is toxic by inhalation and can be fatal even at very low concentrations.

Its use also contributes to sulphide in the effluent which can have toxic effects (beyond permissible levels) on the aquatic life in the receiving water bodies.

Sulphide-bearing effluents are also corrosive and can accelerate corrosion of the equipment used for effluent treatment.

Acidified dichromate is commonly used as an oxidising agent in sulphur black dyeing. Sodium and potassium dichromate are examples of popularly used dichromate forms.

Dichromate can lead to severe injuries upon contact to the skin and is carcinogenic. Moreover, chromium left as a residue on the fabric, by forming complexes with the dye or via adsorption, can cause skin problems in some people. As a consequence most eco- -Tex 100 restricts the level to 1 ppm for baby clothing). Its use also contributes to hexavalent chromium in the effluent, which is both toxic and hazardous.

The Egyptian discharge regulations for sulphide and chromium are summarised in the following table.

Law	Sulphide (as ppm sulphur)	Chromium (Cr) (ppm)
Law 4/1994: Marine Environment	1	1 (max. allowable Cr)
Law 93/1962: Public Sewerage	10	10 (at 50m^3/day) 5 (above 50m^3/day)
Law 48/1982: Discharge to River Nile & waterways	0.5	0.05 (as Cr(VI))
Law 48/1982: Discharge to Nile branch, canals, underground reservoirs	0.5	0.05 (as Cr(VI))
Law 48/1982: Discharge to River Nile & waterways (for less than 100m^3/day)	0.5	0.01 (as Cr(VI))
Law 48/1982: Discharge to Nile branch, canals, underground reservoirs (for less than 100m^3/day)	0.5	0.01 (as Cr(VI))
Law 48/1982: Discharge to non-potable water	-	-

4 Improving the Sulphur Black Dyeing Process

There are two options to reduce or eliminate the occurrence of sulphide and chromium in the effluents. These are:

- **Option 1.** Continue to use traditional sodium sulphide and acidified dichromate, but provide adequate effluent treatment to meet the applicable sulphide and chromium standards.
- **Option 2.** Implement chemical substitution for sodium sulphide and dichromate by less harmful substances.

In the first option, referred as the end of the pipe approach, the sulphide and chromium in the effluent are precipitated. This requires additional investments such as the capital cost of the precipitation tanks and sludge management in addition to the operating costs. Therefore, the end of pipe approach does not solve the problem but merely transforms the pollutants from liquid phase to solid phase, in the form of sludge.

The second option focuses on reduction of pollutants at source and is referred as the Cleaner Production approach. Reduction or elimination of the pollutants at source is possible by carrying out process changes or by substituting the raw materials. In the case of sulphur black dyeing, substitution of sodium sulphide as well as sodium and potassium dichromate can be done as these are harmful substances to the environment. The substitutes can be chosen in a manner such that the process of sulphur black dyeing is unaffected and the environmental impacts are nil or minimal.

Specific benefits of eliminating sodium sulphide and acidified dichromate include:

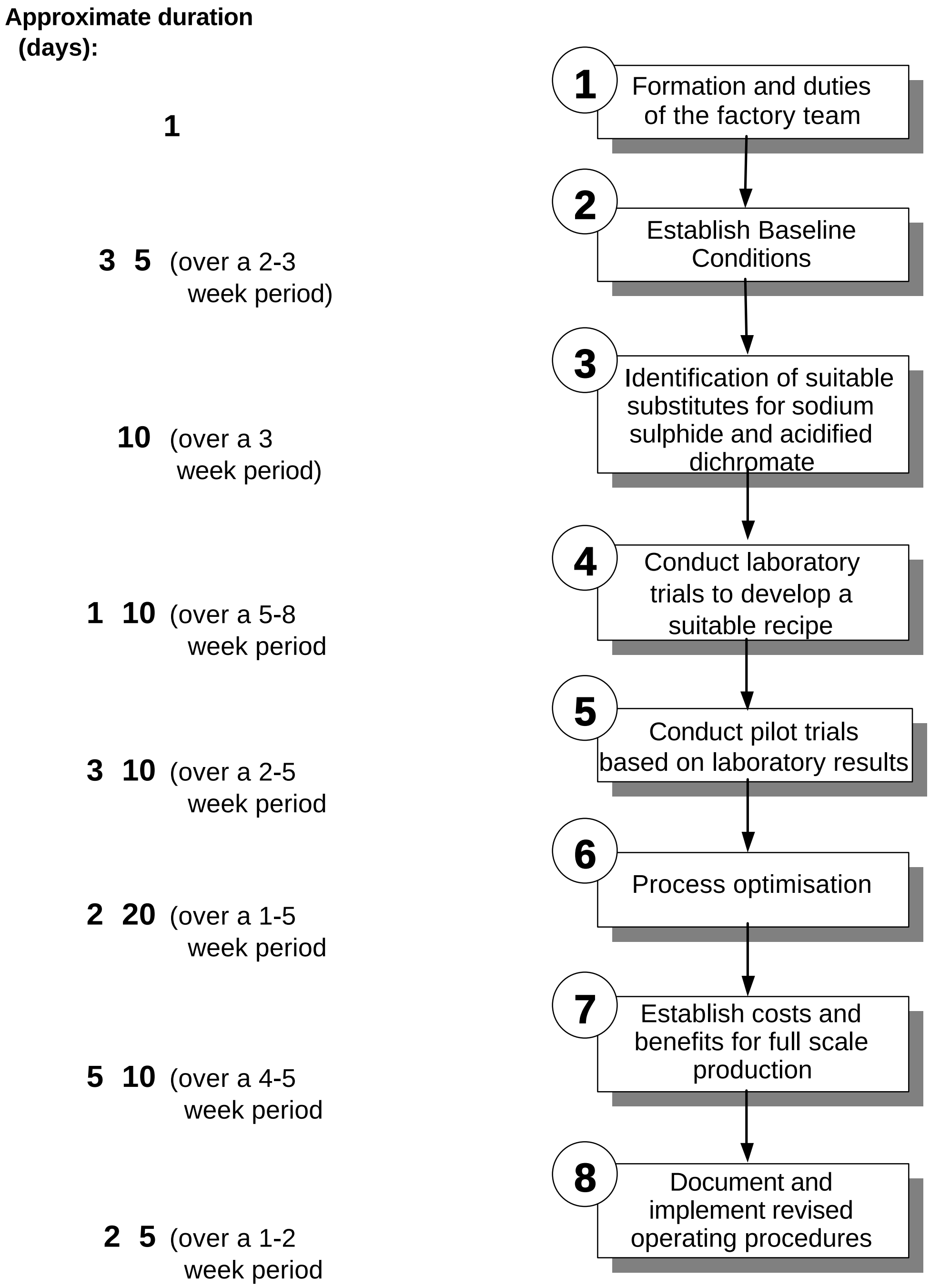
- Reduction in fabric damage caused by tendering (the oxidation of sulphur compounds, which can then attack the fabric).
- The required shade of dye can be obtained more consistently, increasing Right First Time and reducing the need for re-processing.
- Reduction in the corrosion potential of the effluent.
- Increased ability to meet legislative discharge standards for sulphide and chromium.
- Reduction in effluent sulphide and chromium levels, to minimise impacts on the aquatic environment.
- Improved chances of meeting eco-label requirements.
- Improved working conditions due to elimination of toxic and hazardous chemicals.
- Improvement in the atmosphere at the work place due to reduction of foul smell of hydrogen sulphide.

The substitution of sodium sulphide and dichromate by least harmful substitutes (such as glucose, peroxide, sodium perborate etc.) can thus make the sulphur black dyeing process eco-friendly. Such a modification maintains the price and quality advantage of the sulphur black dye and at the same time eliminates the adverse environmental impacts of sulphur black dyeing.

Part B

A Cleaner Production Approach to Sulphur Black Dyeing - A Step by Step Guide

Figure 1
Step-by-Step Flow Diagram for Sulphur Black Dyeing
As implemented by El Nasr Spinning and Weaving, Dakahleya Spinning and Weaving and AmirTex



A Cleaner Production Approach to Sulphur Black Dyeing - A Step by Step Guide

Introduction

This section gives a step-by-step description of how to improve the sulphur black dyeing process by eliminating sodium sulphide and sodium / potassium dichromate and using less harmful substitutes. These steps are summarised in Figure 1.

Step 1: Formation and Duties of the Factory Team

The composition and size of the Factory Team will vary from factory to factory depending mainly on factory size. As a general guide, the Team should be formed by top management and include:

- Head of the Dyeing Department.
- Dyemaster for sulphur black dyeing.
- Stores and Purchases Manager.
- Marketing Department representative (to ensure that buyers are kept informed of the beneficial changes that are being made).
- Head of the Laboratory Facilities and / or Head of Quality Control.
- Senior Operator on the sulphur black dyeing machine.

An external consultant with experience in modifying the sulphur black dyeing process may also be a useful Team member.

Once the Team has been formed, specific roles and responsibilities should be assigned. The Team Co-ordinator (possibly the Dyemaster of the sulphur black dyeing department), will then manage the various responsibilities and tasks.

Following is an example of Team composition and the responsibilities of each Team member at AmirTex.

Example of Team Composition and Roles, AmirTex

Team Member	Specific Responsibilities
Head of Dyehouse	■ Co-ordinator of activities and tasks
Processing Manager	■ Allocation of machines for modification ■ Approving orders of fabrics and chemicals ■ Monitoring the quality of dyeing
Process & Quality Control Manager	■ Providing quality information to the Processing Manager
Senior Dyeing Operator	■ Machine operation and fabric loading
Head of Stores	■ Preparation of all dyes and process chemicals required
Purchasing Manager	■ Providing information for cost-benefit analyses ■ Making contact with suppliers of suitable substitutes ■ Ensuring that the eliminated reduction and oxidation chemicals are no longer purchased.

Step 2: Establish Baseline Conditions

It is important that the baseline environmental conditions are established to enable later quantification of the incremental costs as well as benefits. The assessment should include the following:

1. **Fabric quality** - the following parameters should be assessed:
   - Washing fastness.
   - Rubbing fastness (dry and wet).
   - Depth of shade for the lots most commonly processed with sulphur black dyes.
   - The percentage of re-shading (if any).

These should be taken for the entire range and combination of fabric types, weights and counts that are dyed with sulphur black (a summary of the fabric characteristics from each factory is given as Appendix A).

2. **Cost issues** - the costs involved in processing 1 ton of sulphur black dyed fabric should be quantified (see Part C). These should include:
   - Processing time.
   - Consumption of individual process dyes and chemicals.
   - Water consumption.
   - Electricity and / or fuel consumption.
   - Steam consumption.
   - Amount of labour used.

   Note: Some of the above items may have to be estimated if actual records are not available.

3. **Environmental issues** - measurements to include:
   - Concentrations of Biochemical Oxygen Demand (BOD), sulphide and hexavalent chromium in the wastewater coming from the sulphur black dyeing unit(s).
   - Concentrations of hydrogen sulphide in working areas, particular those that are enclosed.

Sulphide and Chromium Measurements in the Sulphur Black Dyeing Wastewater

Concentrations of sulphide in the dyehouse effluents were measured at between 68 to117 mg / l at El Nasr, 40 mg / l at Dakahleya and 103-112 mg / l at AmirTex.

Chromium was not observed in the effluents of Dakahleya as peroxide is used as an oxidising agent instead of dichromate. In the case of El Nasr Spinning and Weaving and AmirTex, dichromate is used resulting in hexavalent chromium levels of 26- 27 mg / l and 8 mg / l respectively.

4. **Improved working conditions** - resulting from the elimination of sodium sulphide and dichromate. These may be quantified by:
   - reviewing incident records.
   - interviewing factory staff.

Step 3: Identify Suitable Substitutes for Sodium Sulphide and Acidified Dichromate

Probable Substitutes for Sodium Sulphide

Several alternatives for sodium sulphide were identified and can be classified in two categories:

- Sulphur containing reducing agents such as sodium bi-sulphite, sodium hydrosulphite, sodium sulphoxylate formaldehyde, sodium dithionate, sodium dithiodiglycolate and 2-Mercaptoethanol.
- Sulphur-free reducing agents such as hydroxyacetone, glucose, dextrose, dextrine etc. A successful substitution of sodium sulphide for sulphur black dyeing has been reported by a leading textile factory in India, through maize starch waste containing sugar alcohol - known as *hydrol.*

Obviously, using sulphur free reducing agents is preferable, so a survey was carried out to assess costs, availability in bulk and consistency of quality of reducing agents in Egypt. Of these, dextrine, glucose and dextrose were most easily available; a suitable source of hydrol was not found. The costs of these are summarised below:

Cost Data for Reducing Sugars Easily Available in Egypt

Chemical	Purchase Price (LE/ton)
Dextrine	1500
Glucose 75%	1580
Dextrose	4000
Hydrol (glucose waste)	0

Probable Substitutes for Acidified Dichromate

Oxidation of the leuco sulphur dye on fabric plays an important role in the development of correct shade and optimum fastness properties. Probable alternates to dichromate as oxidising agent are:

- hydrogen peroxide,
- sodium perborate,
- ammonium persulphate,
- sodium bromate and
- potassium iodate.

Amongst the above substitutes, sodium bromate and potassium iodate are very expensive, corrosive and unsafe to handle. Ammonium persulphate is also costly in comparison to hydrogen peroxide and sodium perborate. Hydrogen peroxide is not used for woven fabrics, as it results in reduced washing fastness. However, the use of hydrogen peroxide has been already practiced by some Egyptian textile mills for knitted fabrics. For the laboratory studies, therefore, only hydrogen peroxide, sodium perborate and ammonium persulphate were considered as substitutes for potassium dichromate.

Decision Matrix for Substituting Dichromate

Substitute	Costs (LE/kg)	Occupational Hazard	Restrictions	Decision
Hydrogen peroxide	2.74 (Med.)	Medium	Not used for woven fabrics	✓
Sodium perborate	3.2 (Med.)	Low	None	✓
Ammonium persulphate	8.0 (High)	Low	None	✓
Sodium bromate	Very high	High	Corrosive, unsafe to handle	x
Potassium iodate	Very high	High	Corrosive, unsafe to handle	x

Dichromate substitutes used in the SEAM Project

El Nasr Spinning and Weaving Both sodium perborate and ammonium persulphate were found to be suitable oxidising agents for woven fabrics. Sodium perborate was selected for further work as it was the cheaper of the two.

Dakahleya Spinning and Weaving Hydrogen peroxide was confirmed as being the cheapest suitable oxidising agent for knitted fabrics.

AmirTex Both hydrogen peroxide and dichromate were routinely used according to availability. Therefore, a complete changeover to hydrogen peroxide was easily achieved, particularly as it was the cheaper of the two.

Step 4: Conduct Laboratory Trials to develop a Suitable Recipe

The trials should be conducted by in-house research and development staff with the Factory Team. These trials are used to try out a number of recipes, the most successful of which can be scaled up to the pilot scale. If possible, laboratory trials should be carried out on laboratory jiggers for woven fabrics and laboratory winches for knitted fabrics.

The laboratory trials should consist of 3 steps:

1. A recipe is designed and the trial carried out.
2. Fabric quality is tested for washing fastness, rubbing fastness and depth of colour.
3. Once all proposed trials have been completed, the fabric samples are assessed to determine which are of an acceptable quality. The most successful recipe is then implemented at the pilot scale.

Substitution of Sodium Sulphide with Reducing Sugar at El Nasr Spinning and Weaving

(a) Summary of Results

- Initial trials were carried out using sodium carbonate (Na_2CO_3) as the alkali agent. With each of the reducing sugars (dextrine, glucose, dextrose and glucose manufacturing waste), this gave inferior depth of shade, regardless of the concentration used.
- Further trials used sodium hydroxide (NaOH) as the alkali agent, to increase dye solubility in the presence of the reducing sugar. With this modification, glucose and dextrose gave an acceptable depth of shade; dextrine and the glucose manufacturing waste did not. On the basis of cost, glucose was selected for use in the pilot trials as the reducing agent (glucose LE2,420 / ton cheaper than dextrose).
- Experiments were carried out with 3 different sulphur black dyes, to see which gave best depth of shade. Regardless of the reducing agent used, the best results were obtained using Isma Kabrit Black Tex 200, followed by Hydrosol Black B, followed by Sulphur Black WT 166.

(b) Summary of Fabric Analyses

(fastness tests carried out using AATC methods, depth of colour by visual examination)

Conventional Process		Modified Process	
Washing fastness:	3-4	Washing fastness:	4
Dry Rubbing Fastness:	2	Dry Rubbing Fastness:	3
Wet Rubbing Fastness:	2	Wet Rubbing Fastness:	2-3
Depth of Shade:	satisfactory	Depth of Shade:	80% of conventional

A key part of the experiment is determining the most effective type of alkali to be used (eg Na_2CO_3, NaOH) and its ratio to the reducing sugar (e.g. glucose).

For each experiment, the fabric samples need to be analysed for washing fastness, rubbing fastness (wet and dry) and depth of colour.

Step 5: Conduct Pilot Trials based on Laboratory Results

The pilot trials assess the reproducibility of the laboratory experiments at the production scale. This work must be planned to cause minimal disruption to production schedules. The pilot scale experiments at each of the three factories are summarised in Appendix B.

Pilot trials are carried out in 3 steps:

1. Scale-up the recipe developed in the laboratory and implement at the pilot scale.
2. Assess the results (as with the laboratory trials, fabric samples to be analysed for washing fastness, rubbing fastness and depth of colour).
3. Refine the original recipe to improve the results and re-analyse fabric samples.

In all three factories, the samples from the pilot scale experiments showed that fabric quality was similar to those that had been conventionally dyed. This was true for both woven and knitted fabrics. The samples were also free from bronziness, an undesirable characteristic often observed in traditional sulphur black dyeing. In addition, elimination of dichromate in El Nasr Spinning and Weaving resulted in a fabric with a brighter shade and softer feel. An example of adapting laboratory results to the pilot scale follows:

Adaptation of the Laboratory Results to the Pilot Scale: Dakahleya Spinning and Weaving

(a) Summary of Successful Recipes

- part of sodium sulphide (solid) was replaced by with 2 parts of liquid glucose (75 %) and 2 parts of

I Laboratory Scale:	
(a) Dyeing - Shade 8%, liquor ratio (LR) 1/20; glucose-dye ratio 4 g/1.6g, NaOH 4 g/l, Hemactol 1 g/l, NaCl 45 g/l.	(b) Oxidation - H_2O_2 1 ml/l, acetic acid 1ml/l.
II Pilot Scale:	
(a) Dyeing - Shade 8%, LR 1/20, glucose-dye ratio 5g/2.5g, NaOH 5g/l, Hemactol 1g/l, NaCl 45 g/l.	

(b) Summary of Fabric Analyses at the Pilot Scale

(fastness tests carried out using AATC methods, depth of colour by visual examination)

Conventional Process		**Modified Process**	
Washing fastness:	2-3	Washing fastness:	3
Dry Rubbing Fastness:	1-2	Dry Rubbing Fastness:	2
Wet Rubbing Fastness:	2-3	Wet Rubbing Fastness:	1-2
Depth of Shade:	satisfactory	Depth of Shade:	comparable to conventional process

During these trials it was shown that if glucose were added in stages, the depth of shade was significantly improved. This is because the glucose keeps the dye in the form that is taken up by the fabric being dyed (i.e. the reduced form). Results of the trials carried out at Amirtex are given below.

Optimising the Addition of Glucose to the Dyebath: AmirTex

(fastness tests carried out using AATC methods, depth of colour by visual examination)

Dyeing method	Sequence of Addition	Depth of shade	Washing fastness	Rubbing fastness	
				Dry	Wet
Conventional	(Using hydrogen peroxide)	Good	4	2-3	2
	(Using acidified dichromate)	Excellent	4	2-3	2
Modified: Trial 1	▪ All glucose added when dyebath	Excellent - good	4	2-3	2
Modified: Trial 2	▪ 50% of glucose added when dyebath ▪ 50% of glucose added after 15 minutes,	Excellent - good	4	2-3	2
Modified: Trial 3	▪ 75% of glucose added when dyebath ▪ 15% of glucose added after 15 minutes, ▪ 10% of glucose added 10 minutes	Excellent	4	3	2

The time taken to complete the trials and move to full production will depend largely on the size of the line being modified. In El Nasr Spinning and Weaving, 13 weeks were required and in Dakahleya 8 weeks. Only 2 weeks work was required at AmirTex, as laboratory results from the other factories were used to develop pilot scale recipes.

Step 6: Process Optimisation

In many cases, substitution can lead to an increase in the operating costs. This cost can often be eliminated and savings sometimes made, by optimising the modified process. This is done by reviewing the process and identifying those steps that can either be reduced or eliminated entirely. Optimisation can include interventions such as:

- Elimination of a washing stage.
- Recycle and reuse of a wash or dyebath.
- Recovery of process chemicals.

Optimisation carried out at El Nasr, Dakahleya and AmirTex Factories

- **El Nasr Spinning and Weaving -** optimisation consisted of combining the desizing and scouring steps. This saved time, electricity, steam, labour and water.
- **Dakahleya Spinning and Weaving -** optimisation consisted of the elimination of hot and cold washes and a reduction in temperature of a hot wash after soaping. This saved time, electricity, steam, labour and water.
- **AmirTex -** optimisation consisted of the elimination of 2 cold washing steps (after the overflow washing) and a reduction in the temperature and duration of the oxidation bath. These changes saved time, electricity, steam, labour and water.

These changes are summarised as flow diagrams in Appendix C.

Step 7: Establish Costs and Benefits for Full Scale Production

Once substitution has been successfully achieved, the overall benefits need to be determined. The parameters initially assessed in Step 2 (fabric quality, production costs and environmental benefits) will need to be reassessed and the two sets of results compared.

Part C of the Manual describes the benefits realised at each of the three factories.

Step 8: Document and Implement Revised Operating Procedures

Any changes that have been made must be formalised by:

- Issuing revised instructions (manufacturing as well as purchasing).
- Carrying out re-training for staff in areas where modifications have been made.
- Where necessary, updating the existing quality assurance programme.

These actions will ensure that the substitution is fully incorporated into the manufacturing process.

Part C

The Costs and Benefits of Implementation

1. Introduction
2. Chemical Substitution and Process Optimisation
3. Fabric Quality and Productivity
4. Marketing the Fabric
5. Environmental Benefits

1 Introduction

No capital expenditure is necessary for implementation as the benefits have been achieved through substitution and process optimisation. Overall savings of 2-16% for all consumable materials have been achieved in the three factories for each ton of fabric processed.

A summary of the costs and benefits at the three factories are:

Increased cost of chemicals:	up to 6%
Reduction in electricity consumption:	8-38%
Reduction in steam consumption:	16-39%
Reduction in water consumption:	13-39%
Reduction in processing time:	6-38%

The main cost increase in chemicals was due to the use of glucose which is 17% more expensive than sodium sulphide. Sodium perborate, when used, is about 80% cheaper than potassium dichromate.

Other benefits included:

- Improved in fabric quality.
- Improved production efficiency by decreasing processing time.
- Improved Right First Time (RFT).
- Improved working conditions.
- Reduced levels of pollution with the phasing out of toxic and hazardous substances.
- Reduce the cost of waste water treatment to remove sulphur and hexavalent chromium.

Buyer reaction to the quality of the fabric now produced has also been favourable. At AmirTex alone, production of sulphur black dyed fabric has more than doubled since implementation from 2.5 tons per month to 6 tons per month (whilst improved fabric quality has no doubt helped achieve this, it may not ,however, be only factor).

2 Chemical Substitution and Process Optimisation

2.1 The Costs and Benefits at El Nasr Spinning and Weaving

At El Nasr Spinning and Weaving, sodium sulphide and potassium dichromate were substituted in both grey and black shades. A summary of the savings made is presented as follows:

**Conventional and Modified Processing costs (LE)
for 1 Ton of Fabric**

Item	Grey shade		Black shade	
	Conventional (sodium sulphide & potassium dichromate)	**Modified** (glucose & sodium perborate)	**Conventional** (sodium sulphide & sodium dichromate)	**Modified** (glucose & hydrogen peroxide)
Chemicals	850	838	1200	1280
Water	46	40	46	40
Steam	88	74	88	74
Electricity	63	49	63	49
Labour	400	310	400	310
Total (LE)	**1,447**	**1,311**	**1,797**	**1,753**
Difference (LE)		**136**		**44**
% Savings	**9.4%**		**2.4%**	

In El Nasr Spinning and Weaving, the greatest savings were made in the grey shade dyeing, where LE136 was saved per ton. In the black shade, savings totalled LE44 per ton. The most significant savings for both shades came from a 16% reduction in steam consumption and a 22% reduction in electricity consumption. These savings primarily resulted from combining the preparatory processes (desizing and scouring carried out at the same time).

In the grey shade, a small saving was made in terms of reduced chemicals consumption. A slightly increased cost was noted in black shade dyeing, due to larger volumes of glucose being needed to produce acceptable results.

In addition, the modifications made to the line reduced processing time by almost 2 hours for both shades.

These results are presented in more detail in Appendix D, Tables D1 and D2.

2.2 The Costs and Benefits at Dakahleya Spinning and Weaving

At Dakahleya Spinning and Weaving, sodium sulphide was substituted in the black shade only. A summary of the savings made is presented in the following tables.

Conventional and Modified Processing Costs (LE) for 216kg of Fabric

Item	Black shade	
	Conventional Process (sodium sulphide & potassium dichromate)	**Modified Process** (glucose & hydrogen peroxide)
Chemicals	298.4	301
Water	32.8	20
Steam	75.6	46.3
Electricity	18.5	11.4
Labour	97.5	60
Total (LE)	**522.8**	**438.7**
Difference (LE)	**84.1**	
% Savings	**16.1%**	

Implementation of the project at this factory made an overall saving of LE84 for a 216kg batch of fabric. Particularly high savings were made in water and steam, valued at LE12.8 per 216kg (LE59 per 1,000kg) and LE29.3 per 216kg (LE135 per 1,000kg) respectively. These steam and water savings were made as a result of eliminating 2 hot washes after dyeing and optimising the number of cold and overflow washes carried out. As with El Nasr Spinning and Weaving, there was a slight increase in the cost of chemicals in the modified method. These results are presented in more detail in Appendix D, table D3.

2.3 The Costs and Benefits at Amirtex

At AmirTex, sodium sulphide and sodium dichromate were substituted in the black shade. A summary of the savings made is presented below:

Conventional and Modified Processing Costs (LE) for 1 ton of Fabric

Item	Sodium sulphide		Glucose
	Sodium dichromate	Hydrogen peroxide	Hydrogen peroxide
Chemicals	1,440	1,400	1,380
Water	110	110	93
Steam	570	450	450
Electricity	13	13	12
Labour	143	143	135
Total (LE)	**2,276**	**2,116**	**2,070**
Difference (LE)		**160**	**206**
% Savings		**7.0%**	**9.1%**

Three sets of trials were carried out at AmirTex, as the factory routinely used both hydrogen peroxide and sodium dichromate as oxidants. These trials show that highest costs were incurred when sodium sulphide and sodium dichromate were used. Substituting hydrogen peroxide for the dichromate produced 7% savings which were increased to 9% by using glucose as the reducing agent. Consequently, savings of LE206/ton were achieved. When hydrogen peroxide was used as the oxidising agent, the temperature and duration of the oxidation bath could be reduced (from 70°C for 50 minutes to 30°C for 40 minutes), resulting in significant energy savings. As a part of the optimisation process, 2 cold washes were also eliminated.

If the factory had a wastewater treatment plant, it is estimated that implementation of this project would result in savings of around LE60 per 1 ton of fabric.

2.4 Summary of Savings Made

A Comparison between the Operating Costs of the 3 Demonstration Projects

(on the basis of 1ton of fabric, black shade and sodium perborate/hydrogen peroxide)

	El-Nasr (Jigger)	Dakahleya (Jet)	AmirTex (Winch)
Conventional Process	1,797	2,420	2,276
Modified Process	1,753	2,031	2,070
Percent Savings	2.4%	16.1%	9.1%

In all three cases, it is financially feasible to eliminate sodium sulphide and acidified dichromate from the sulphur black dyeing process.

3 Fabric Quality and Productivity

3.1 Improved Right First Time (RFT) and Increased Productivity

The modified process was found to improve the dyeing process. At AmirTex for instance, an improvement of 10% was noticed in the Right First Time (RFT). Improvement in RFT implies increased productivity, reduction in the pollution load and profitability.

In all factories, the modified process was shorter than the conventional process, thereby saving on time. This is expected to provide a benefit of increased productivity at no additional cost, only requiring careful rescheduling.

3.2 Reduction in Tendering

Tendering occurs when sulphur-containing substances progressively oxidise and form sulphuric acid, which then attacks and progressively weakens the fabric until it is completely destroyed. Sulphur-black dyed fabrics are particularly prone to tendering during storage, especially in a hot humid atmosphere and where sodium sulphide has been used as the reducing agent. This effect can be worsened if the sodium sulphide contains iron impurities; these are often present in commercial sodium sulphide.

The reduction of tendering as a result of project implementation was quantified at El Nasr Spinning and Weaving, by conducting the accelerated ageing test developed by the American Association of Textile Chemists and Colourists (AATCC Test

Methods 122), as shown in the following table. In this test, dyed fabric is subjected to

Tensile Strength (TS) of Sulphur Black Dyed Woven Fabric
(using AATCC Test Method 122)

Reducing agent used	TS before Accelerated Ageing		TS after Accelerated Ageing	
	Warp	Filling	Warp	Filling
Sodium Sulphide	67	50	57	43
Glucose	69	52	62	47
None - undyed fabric	73	54	70	50

The undyed fabric showed some reduction in strength when subjected to moisture and heating. The fabric samples dyed using sodium sulphide were up to 6% weaker than the undyed fabric, even before ageing, whereas the samples dyed using glucose were up to 4% weaker. Following the accelerated ageing test, the fabric samples dyed using sodium sulphide had weakened by 105% and the samples dyed using glucose by up to 7%. The rate of ageing was also greatest for those samples processed with sodium sulphide.

4 Marketing the Fabric

Customers may well perceive these modifications as a distinct improvement over the original process. This is due to the higher tensile strength of the fabric and minimisation of hazardous chemicals present in the final fabric.

Once these modifications are made, it will also be much easier for the factory to obtain an eco-label, (see SEAM Guidance Manual Ecolabelling for Textiles). This is a certificate that guarantees that there are no harmful substances in the final fabric and is becoming a requirement in a number of countries, particularly in Europe.

5 Environmental Benefits

5.1 Improved Effluent Quality

Wastewater quality before and after project implementation at the three factories is summarised below.

Effluent Characteristics Before and After Implementation
(from the end of the dyeing line)

Factory	Process	BOD (mg/l)		Total Dissolved Solids (mg/l)		Sulphides (mg/l)		Hexavalent chromium (mg/l)	
		Before	*After*	*Before*	*After*	*Before*	*After*	*Before*	*After*
El-Nasr	Grey	360	1275	3385	2690	68	1	26	Nil
	Black	540	2150	3900	3450	117	2.5	27	Nil
Dakahleya		347	1233	1510	1950	40	0.7	NA	NA
AmirTex	Peroxide	660	1070	-	-	103	1.5	Nil	Nil
	Dichromate	530	-	-	-	112	-	8	-

This table illustrates that levels of both hexavalent chromium and sulphides have been significantly reduced in wastewater from the dyehouse. The rise in the concentration of BOD is caused by the use of glucose in the modified process. This is unlikely to significantly increase either treatment costs or the characteristics of the final effluent.

5.2 Improved Working Conditions

Workers interviewed at the factory were very positive on the improvement to working conditions. The bad odours and inhalation of sulphur fumes have been removed and the substitute chemicals are much safer to handle.

Part D

Helpful Hints

1. **Dos and Donts**
2. **Considerations for Implementation**

1. Dos and Donts

The recipes provided in this Manual are factory-specific and are presented for guidance only. However, they are a good starting point for any other factory interested in modifying their sulphur black dyeing process and will reduce the amount of experiments needed to identify the optimum recipe.

To optimise the dyeing process and ensure an even colour:

Do . . .

☺ Check that the pre-treatment is efficient and uniform to ensure even dyeing.

☺ Ensure that the number of turns (ends) (jigger dyeing) are even in each step (i.e. in pre-treatment, dyeing, oxidation, and washing.)

☺ Wash the fabric thoroughly after dyeing, to remove as much alkali as possible.

Dont . . .

☹ Do not buy loose dyes and chemicals, as these can be contaminated very easily. Chemicals and dyestuffs should be purchased in sealed packages only.

☹ Do not add oxidising agents to an alkaline bath. Oxidising agents should be added only after making sure that the bath is acidic (pH ~ 4).

☹ Do not raise the temperature of any unit suddenly - good practice dictates that it should be raised gradually.

2. Considerations for Implementation

The washing fastness of fabrics dyed with sulphur black and oxidised with hydrogen peroxide or perborate, can be improved by:

- Adding para-nitroaniline (1% weight of fabric) to the oxidisation bath or
- After-treating the dyed fabric under acidic conditions with a aromatic amine (such as para-nitroaniline, p-phenylene-diamine and m-toluene diamine).

Appendices

A. Fabric Specifications for each of the Demonstration Project Factories

B. Summary of Results from Pilot Scale Experiments at Each of the Three Factories

C. Process Flow Diagrams of the Conventional and Optimised Processes at the Three Demonstration Factories

D. Cost Analyses of Implementation at El Nasr, Dakahleya and AmirTex Factories

Appendix A

Fabric Specifications for each of the Demonstration Project Factories

1. Dakahleya Spinning and Weaving - Knitted Fabric Specifications

- Single Jersey 30/1 - Giza 75 Combed 120gm/m^2
- Single Jersey 30/1 - Giza 80 Combed 110gm/m^2
- Melton 24/1 - Giza 80 Combed 220gm/m^2
- Single Jersey 24/1 - Giza 75 Combed 160gm/m^2
- Rip 20/1 - Giza 75 Combed 193gm/m^2
- Fine Rip 22/1 - Giza 75 Combed

2. El Nasr Spinning and Weaving - Woven Fabric Specifications

The fabric tested at El Nasr Spinning and Weaving had a weight of 208 gm/metre with count 20/1.

3. Amirtex - Knitted Fabric Specifications

Type	Weight g/metre	Counts
Melton	190 220	40/1, 30/1
Prasulla	160 180	40/1, 30/1
Fine Rib	140 - 150	24/1, 20/1
Interlock	180 190	40/1
Rib Lycra	200	(100% cotton)

Appendix B

Summary of Results from Pilot Scale Experiments at Each of the Three Factories

Work carried out at El Nasr Spinning and Weaving on Jiggers for woven fabric

The dye was dissolved at 50°C in a mixture of sodium hydroxide and half amount of glucose. In the mean time, the jigger was filled with water, and the temperature raised to 70°C. Half the dye mixture was added during first end and half at the second. The temperature was then raised to 90-95°C, where salt is added in two portions in two ends. Then a quarter of the amount of glucose was added at the fifth end and the next quarter at the six end. Dyeing was then continued over next 4 ends. The total dyeing time was thus 90 minutes. The oxidation was carried out at 60-65°C for six ends, corresponding to 55 minutes.

Work carried out at Dakahleya Spinning and Weaving on jets for knitted fabric

The fabric was loaded in the jet, the jet being half filled with water. Then hemactol, NaOH and one half amount of glucose were added. The temperature was raised to 60°C. The dye was added in 3 equal portions for a total time of 25 minutes. Then the second half of the glucose was added. The temperature was then raised to 90-95°C where dyeing was continued for 75 minutes. In the oxidation step, acetic acid was added to cold fresh water and the fabric was run through the same for 5 minutes. Hydrogen peroxide was then added to the cold water, without circulation to the dosing tank. Then the temperature was raised to 60-65°C where oxidation is achieved for 30 minutes. Softening was modified by introducing acetic acid first, to ensure acidity of the bath and after 5 minutes the softener was introduced.

Work carried out at AmirTex on winches for knitted fabric

Scoured knitted fabric was loaded on the winch with the winch 75% full with water. The motor was then started. The Na-HMP (previously dissolved in 20 litres of water) was added in 4 equal portions for a total time of 5 minutes. Next, NaOH (previously prepared in 20 litres of water) in 4 portions was added in a total time of 5 minutes. The temperature was raised to 40°C and glucose (previously prepared in 20 litres of water) was added. After 10 minutes, dye was added in 4 equal portions in 20 litres of boiling water for a total time of 10 minutes. The water level in the winch was checked, as now it was expected to be near full. The temperature was raised to 80°C and dyeing was allowed to proceed for 50 minutes. This was followed by overflow washing and separate cold washing until clear water is discharged.

Appendix C

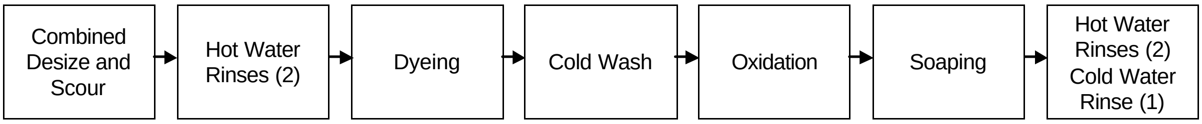
Process Flow Diagrams of the Conventional and Optimised Processes at the Three Demonstration Factories

Simplified Flow Diagrams Showing Where Modifications Were Implemented and the Associated Savings Made

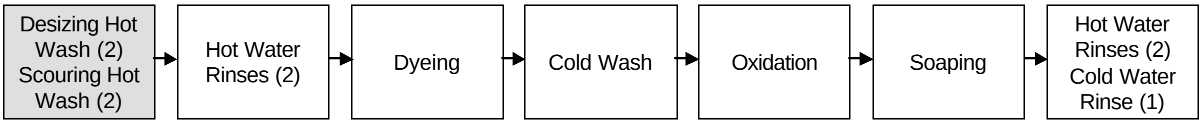
(modified process indicated by shading)

(a) El Nasr Factory combining the desizing and scouring stages

Modified Process

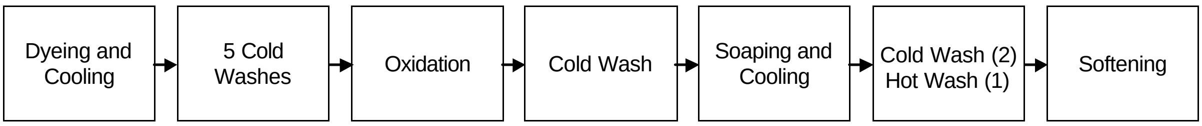


Conventional Process:

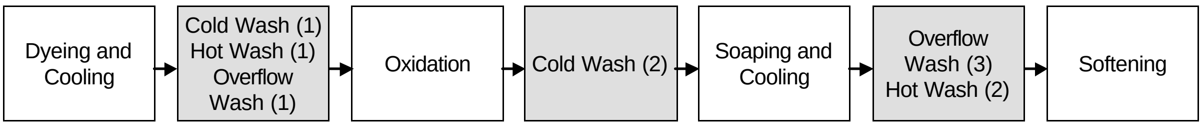


(b) Dakahleya Factory elimination of hot, cold and overflow washes

Modified Process:

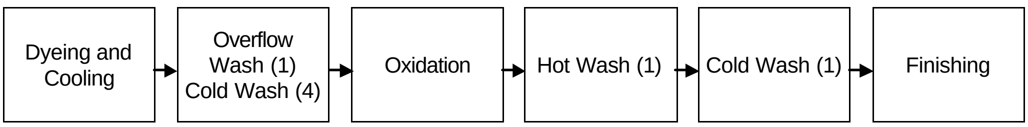


Conventional Process:

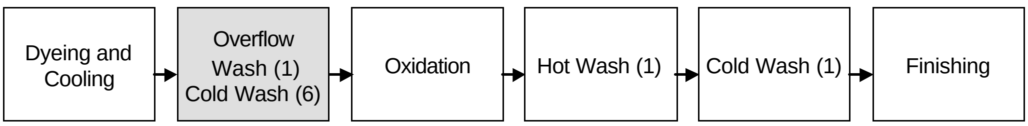


(c) AmirTex Factory elimination of hot, cold and overflow washes

Modified Process:



Conventional Process:



Appendix D

Cost Analyses of Implementation at El Nasr, Dakahleya and AmirTex Factories

Table D1
Costs Associated with Sodium Sulphide and Potassium Dichromate Substitution at El Nasr Spinning and Weaving for 100 kg of Grey Shade
(woven fabric, dyed in Jiggers)

Chemicals	Conventional Process		Modified Process		Cost Difference (LE)
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)	
Beta-amylase	1.5	5.2	-	-	- 5.2
Ammonium persulphate	-	-	0.25	2	+ 2
Espycon 1030	2	4.3	1.5	3.2	- 1.1
NaOH (38 Be)	35	38.5	43	47.3	+ 8.8
Dye	0.81	5.6	0.81	5.6	0
Na_2S	4	6	-	-	- 6
Na_2CO_3	2	1.3	-	-	- 1.3
Glucose	-	-	5	7.3	+ 7.3
NaCl	15	6	15	6	0
Acetic Acid	3	10.8	3	10.8	0
Potassium Dichromate	1.5	7.3	-	-	- 7.3
Sodium perborate	-	-	0.5	1.6	+ 1.6
Water (m^3)	9,200	4.6	8,000	4	- 0.6
Steam	700	8.8	590	7.4	- 1.4
Electricity (kWh)	33	6.3	25.6	4.9	- 1.4
Labour		40		31	- 9
Time (h)	8		6.2		--
Total	**--**	**144.7**	**--**	**131.1**	**- 13.6**

Table D2
Costs Associated with Sodium Sulphide and Potassium Dichromate Substitution at El Nasr Spinning and Weaving for 100 kg of Black Shade
(woven fabric, dyed in Jiggers)

Chemicals	Conventional		Modified		Cost Difference (LE)
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)	
Beta-amylase	1.5	5.2	-	-	- 5.2
Ammonium persulphate	-	-	0.25	2	+ 2
Espycon 1030	2	4.3	1.5	3.2	- 1.1
NaOH (38 Be)	35	38.5	43	47.3	+ 8.8
Dye	5	33.1	5	33.1	0
Na_2S	8	12	-	-	- 12
Na_2CO_3	4	2.9	-	-	- 2.9
Glucose	-	-	17	24	+ 24
NaCl	15	6	15	6	0
Acetic Acid	3	10.8	3	10.8	0
Potassium Dichromate	1.5	7.2	-	-	- 7.2
Sodium perborate	-	-	0.5	1.6	+ 1.6
Water	9,200	4.6	8,000	4	- 0.6
Steam	700	8.8	590	7.4	- 1.4
Electricity (kWh)	33	6.3	25.6	4.9	- 1.4
Labour		40		31	- 9
Time (h)	8		6.2		--
Total	**-**	**179.7**	**-**	**175.3**	**- 4.4**

Table D3
Costs Associated with Sodium Sulphide Substitution at Dakahleya Spinning and Weaving for 216 kg of Black Shade
(knitted fabric, dyed in Jets)

Chemicals	Conventional		Modified		Cost Difference (LE)
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)	
Hostapal sfk	2	14.5	1.1	8	- 6.5
Organic Stabiliser	2	11.3	2	11.3	0
Hemactol	1.6	13.2	1.6	13.2	0
NaOH	5	5.5	13	14.3	+ 8.8
Dye	16	110.4	16	110.4	0
Na_2S	19	28.5	-	-	- 28.5
Na_2CO_3	10	7.3	0.5	0.3	- 7.0
Glucose	-	-	30	43.5	+ 43.5
NaCl	75	30	75	30	0
H_2O_2	11.6	30.2	11.6	30.2	0
Acetic Acid	4.6	16.6	2.6	9.4	- 7.2
Softazine	6.1	30.9	6	30.4	- 0.5
Water	65,500	32.8	40,000	20	- 12.8
Steam	3150	75.6	1930	46.3	- 29.3
Electricity (kWh)	97.5	18.5	60	11.4	- 7.1
Labour		97.5		60	- 37.5
Time (h)	13		8		--
Total		**522.8**		**438.7**	**- 84.1**

Table D4
Costs Associated with Sodium Sulphide and Sodium Dichromate Substitution at AmirTex for 1 Ton of Black Shade
(and Hydrogen Peroxide as the Oxidant)

(knitted fabric, dyed in winches)

Chemicals	Conventional (sodium sulphide and hydrogen peroxide)		Conventional (sodium sulphide and sodium dichromate)		Modified		Cost Difference (LE)
	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)	Quantity (kg)	Cost (LE)	
Na_2CO_3	0.056	0.051	0.056	0.051	0.033	0.003	- 0.048
Na-HMP	0.027	0.111	0.027	0.111	0.027	0.111	0
Na_2S	0.167	0.367	0.167	0.367	-	-	- 0.367
NaOH	-	-	-	-	0.077	0.15	+ 0.15
Sodium dichromate	-	-	0.01	0.058	-	-	- 0.058
Glucose	-	-	-	-	0.167	0.242	+ 0.242
Dye	0.09	0.72	0.09	0.72	0.09	0.72	0
NaCl	0.33	0.036	0.33	0.036	0.33	0.036	0
Acetic Acid	0.013	0.046	0.013	0.046	0.013	0.046	0
H_2O_2	0.013	0.025	-	-	0.013	0.025	0
Detergent	0.016	0.048	0.016	0.048	0.016	0.048	0
Water	141	0.11	141	0.11	121	0.093	- 0.017
Steam	2.9	0.448	3.7	0.573	2	0.448	0
Electricity (kWh)	0.071	0.0127	0.071	0.013	0.067	0.012	- 0.001
Labour		0.143		0.143		0.135	- 0.008
Time (min)	2.86		2.86		2.7		
Total		**2.1177**		**2.276**		**2.069**	**- 0.107**