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Project

Industrial Pollution Prevention

Case Study: Textile Sector

SULPHUR BLACK DYEING: A CLEANER PRODUCTION APPROACH

El Nasr for Spinning and Weaving Co., Mahalla El-Kobra, Egypt
Dakahleya Spinning and Weaving Co., Mansoura, Egypt
AmirTex Co., Sadat City, Egypt

THE SULPHUR BLACK DYEING PROCESS

Sulphur black dyes are widely used throughout Egypt, due to their low cost, excellent washing and light fastness properties. They are by far the most economical method of producing a jet-black colour in cotton fibres.

Sulphur dyes are water insoluble and must be first converted to a water soluble form, by adding a reducing agent, traditionally sodium sulphide, so that the dyes can be absorbed by the fibre. After dyeing the fabric, the dye is converted back to insoluble form with the addition of an oxidising agent, often acidified dichromates. This step prevents washing out of the dye from the fabric.

However, both sodium sulphide and acidified dichromate are toxic and hazardous to handle. Their usage may leave harmful residues in the finished fabric and generate effluents that are difficult to treat and damaging to the environment. Under Egyptian Laws 93/1962 and 48/1982 discharge limits for sulphur are a maximum 10mg/l into public sewers and 0.5 mg/l into canals and the Nile, and for hexavalent chromium a maximum of 10mg/l into public sewers and 0.05 mg/l to canals and the Nile (<50 m^3/day).

HOW CAN THE PROCESS BE IMPROVED?

The measures implemented by the SEAM project demonstrate how sodium sulphide and dichromate can be safely substituted without a decline in fabric quality. As a result the advantages of sulphur black dyeing can be retained, whilst eliminating the adverse environmental and health impacts.

This project was implemented at no capital cost and resulted in cost savings of 2-16% on consumable materials. Other benefits included the elimination of toxic and hazardous materials from the workplace and environment, reduced wastewater treatment costs, improved fabric quality and productivity. Due to reduction in the processing time and better fabric quality, the production of sulphur black dyed fabrics has more than doubled at one factory since implementation.

FACTORIES WHERE IMPLEMENTED

El-Nasr Spinning and Weaving is a large public sector factory built in 1963 and currently employing 7,000 staff. It processes an average of 8,000 tons of raw fabric per year, of which 20% are spun cotton yarns, 12% are polyester blend yarns, and 68% is grey fabric. The main products are cotton or blended yarns, white and dyed cotton and blended fabrics. Approximately 52.5 million metres of fabric were produced during 1996/7.

Dakahleya Spinning and Weaving is a public sector factory with annual production of 11,400 tons of spun yarns and ready made garments. The factory was built in 1965 and employs 4,000 workers. It comprises three spinning departments, an open end spinning unit and a tricot plant with a weaving unit, a dyehouse and a tailoring hall. The main products are cotton yarns, cotton knitted fabrics, polyester blended fabrics, and ready made knitted cotton garments.

AmirTex is privately owned company with around 100 employees. The factory was built in 1984 and comprises a weaving and knitting department, a printing unit and a dyehouse. The main products are cotton yarns, cotton knitted fabrics, polyester blended fabrics, and ready made knitted cotton garments. Average annual production is 720 tons of cotton, polyester and blended fabrics.

POLLUTION PREVENTION OPPORTUNITIES

The following pollution prevention opportunities were identified in the sulphur black dyeing process through an industrial audit at the 3 factories.

1. High sulphur content in dyehouse wastewater of 40-170 mg/l.
2. Acidified dichromate used at El Nasr, resulted in concentrations of hexavalent chromium of 27mg/l in the dyehouse wastewater.
3. Bad odour resulting from the use of sodium sulphide in the dyeing process.
4. Worker safety issues associated with the handling of toxic and hazardous chemicals.
5. High steam, energy and water consumption was noted during the sulphur black dyeing process.
6. Fabric losses resulting from the presence of excess sulphur on the material.

CLEANER PRODUCTION APPLICATION

Two options for reducing the problem of sodium sulphide and hexavalent chromium in the effluent are:

1. Provide adequate treatment facilities - this incurs capital cost for precipitation tanks and sludge management and ongoing operating costs. This option does not satisfactorily address the problem as pollutants are transferred to the sludge, which still requires disposal.
2. Implement chemical substitution that reduces the problem at source and provides a cleaner production approach to the problem. The cleaner production approach has the benefit of improving productivity and at the same time reduce the pollution load and costs of treatment.

The cleaner production approach was therefore preferred. The actions taken in this process are outlined below.

Possible Chemical Substitutes

An evaluation was undertaken to assess the viability, costs and quality of using various potential substitutes for sodium sulphide and acidified dichromates in Egypt. A summary of possible substitutes and costs are:

Substitute for Sodium Sulphide	**LE / ton**
▪ Glucose (75%)	1,580
▪ Dextrose	4,000
▪ Dextrine	1,500
▪ Hydrol (glucose waste)	0
Substitute for Acidified Dichromate	**LE / ton**
▪ Hydrogen peroxide	2,740
▪ Sodium perborate	3,200
▪ Ammonium persulphate	8,000
▪ Sodium bromate	8,000+
▪ Potassium iodate	8,000+

Selection of the Substitutes

Laboratory trials were initially used to determine the optimum combination of reducing sugars and alkali:

a) Substitution of Sodium Sulphide. In all 3 factories, dextrine and hydrol were rejected as they gave a poor depth of shade. Glucose and dextrose both gave good depths of shade when used with sodium hydroxide. Glucose was therefore preferred as a substitute to sodium sulphide because of its lower cost.

Sulphur Black dyed fabric using glucose as reducing agent

b) Substitution of Dichromate: In El Nasr Spinning and Weaving, sodium bromate and potassium iodate were rejected as these chemicals are corrosive, unsafe to handle and expensive. Hydrogen peroxide was also rejected, as it is not suitable for use with woven fabrics. Sodium perborate and ammonium persulphate were both acceptable, however sodium perborate was preferred due to its lower cost. In Dakahleya Spinning and Weaving and AmirTex, hydrogen peroxide was preferred as it is particularly suitable for processing knitted fabrics.

Pilot trials were then carried out to refine the preferred production scale. A summary of the final recipe and its effects on fabric quality, before and after, at Dakahleya Spinning and Weaving is summarised below. During the trials it was noted that when glucose is added in stages the depth of shade was significantly improved.

Recipe (for knitted fabric)		
Dyeing:	Shade 8%, liquor ratio 1/20, glucose-dye ratio 5g/2.5g, NaOH 5g/l, Hemactol 1g/l, NaCl 45g/l.	
Oxidation:	1-2g/l sodium perborate effectively replaced 3g/l potassium dichromate	
Fabric Quality		
	BEFORE (Conventional Process)	**AFTER (Modified Process)**
Washing fastness	2-3	3
Dry rubbing fastness	1-2	2
Wet rubbing fastness	2-3	1-2
Depth of shade	satisfactory	satisfactory

The successful recipes were then implemented at the production scale.

Process Optimisation

In association with the substitution, processing sequences could be optimised for greater productivity and financial savings as outlined below.

El Nasr Spinning and Weaving

- The desizing and scouring processes, normally carried out in 4 steps, were combined.
- Temperature in the soaping bath following oxidation was reduced.

Dakahleya Spinning and Weaving

- Cold washes were used between the dyeing and oxidation steps.
- One cold wash after oxidation was eliminated.
- One hot wash after the soaping bath was eliminated.

AmirTex:

- Two cold washing steps (after the overflow washing) were eliminated.

COSTS AND BENEFITS

Direct Financial Savings

No capital expenditure was necessary for implementation, as the benefits have been principally achieved through substitution and process optimisation.

Despite some increases in chemical costs, overall savings of 2-16% for all consumable materials have been achieved in the three factories for each ton of fabric processed. A breakdown of the savings is given below.

Savings in LE per ton of Fabric Processed				
Factory	**El Nasr**		**Dakahleya**	**AmirTex**
Shade	**Grey**	**Black**	**Black**	**Black**
Savings in:				
Chemical costs	12	(80)	(12)	60
Water use	6	6	59	17
Steam	14	14	135	120
Electricity	14	14	33	1
Labour	90	90	173	8
TOTAL (LE)	**136**	**44**	**388**	**206**

Note: Figures in brackets indicate an increase in cost.

El Nasr Spinning and Weaving

Chemical costs were reduced for grey shades but were much higher for black shades as larger volumes of glucose were required to produce acceptable results. Savings in steam (16%) and electricity (22%) resulted from combining the desizing and scouring process which also reduced the processing time by 2 hours thereby saving on labour costs.

General production of sulphur black dyeing is a small proportion of the total, however with improvements to the process it is likely to increase.

Dakahleya Spinning and Weaving

A slight increase in the chemical costs was more than offset by significant savings from process optimisation This included eliminating 2 hot washes after dyeing and optimising the number of cold and overflow washes carried out. As a result, steam, water and electricity costs were reduced by 38-39%. Processing time was reduced from 13 hours to 8 hours thereby increasing production capacity.

Around 24 tons of fabric per annum are dyed with sulphur black dyes.

Annual savings on current production: LE9,312
Annual benefits from increased production capacity: LE21,000

Jet machines at Dakahleya used in Sulphur Black dyeing

AmirTex

Savings of LE206 per ton were achieved however where hydrogen peroxide was already used as the oxidant the savings reduced to LE 46 per ton. AmirTex processes 21.6 tons per year using sulphur black dyes. Due to improved fabric quality AmirTex has increased production to 70 tons per year and reduced the use of more expenses reactive dyes, a saving of approximately LE490 per ton.

Annual savings on existing production: LE 2,386.
Annual savings by reducing use of reactive dyes: LE 23,716.

Improved Fabric Quality

Elimination of free sulphur now avoids the past problem

residual sulphur on the fabric progressively oxidised to form sulphuric acid, which then attacks and may eventually destroy the fabric.

At El Nasr factory, fabric strength was improved by 5% by using glucose instead of sodium sulphide

Improved Productivity

The modified process not only improved product quality but also reduced wastage by an improvement in getting it

achieved at AmirTex. In all factories, the modified process was shorter than the conventional process, thereby saving on time and labour costs.

Environmental Benefits

Concentrations of both hexavalent chromium and sulphur were significantly reduced in the effluent coming from the dyeing line at the three factories. BOD levels increased due to the use of glucose, however it is not likely to significantly increase either wastewater treatment costs or the characteristics of the final effluent.

Effluent Characteristics Before and After Implementation (from the end of the dyeing line)					
		El-Nasr		Dakahleya	AmirTex
Concentrat(mg/l)		Grey	Black	Black	Black
Sulphide	*Before*	68	117	40	103
	After	1	2.5	0.7	1.5
Hexavalent chromium	*Before*	26	27	n/a	Nil
	After	Nil	Nil	n/a	Nil
BOD	*Before*	360	540	347	660
	After	1275	2150	1233	1070
TDS	*Before*	3385	3900	1510	-
	After	2690	3450	1950	-

Savings on Effluent Treatment Requirements

Elimination of sodium sulphide and acidified dichromate made the final effluent easier to treat, as it became less toxic and corrosive. At AmirTex savings on wastewater treatment requirements, were estimated to be around LE60 per ton of fabric processed.

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.

BENEFITS AND ACHIEVEMENTS

	El Nasr	Dakah-leya	Amir-Tex
Electricity consumption reduced by:	22%	38%	8%
Steam consumption reduced by:	16%	39%	21%
Chemical costs reduced (increased) by:	2%	(6%)	4%
Water consumption reduced by:	13%	39%	15%
Labour costs reduced by:	23%	57%	6%
Processing time reduced by:	22%	38%	6%

- Improved productivity
- Improved working conditions
- Phasing out of toxic sodium sulphide and acidified dichromate

CONTACTS

More information on this project and the SEAM Project, are available from:

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The SEAM Project

Support for Environmental Assessment and Management (SEAM), is a multi-disciplinary

Department for International Development (DFID). This project is being implemented by the Egyptian Environmental Affairs Agency (EEAA) through the Technical Co-operation Office for the Environment (TCOE) and *En*tec, a UK engineering and environmental consultancy.

SEAM: Pollution Prevention

This is being implemented under the National Industrial Pollution Prevention Programme (NIPPP). NIPPP focuses on the introduction and promotion of low-cost improvement measures, which can be easily and quickly implemented by factories. It also emphasises the importance of economic benefits of any such intervention, particularly those with short pay-back periods.

Methodology - A Description

Pollution prevention opportunities can be identified through an industrial audit[1]. This

and processes, focusing on reducing waste, improving efficiency and alleviating pollution. This aims to identify and prevent losses from occurring in the first place, rather than resorting immediately to a treatment facility.

The SEAM Project has carried out audits in 32 factories in the food, textile and oil and soap sectors, which identified a wide range of low-cost pollution prevention opportunities, including water and energy conservation, the importance of good housekeeping, in-process modification and hazardous materials substitution. The SEAM Project is presently implementing 23 of these opportunities as demonstration projects.

Benefits of Pollution Prevention

It can ***REDUCE :***

- production costs;
- losses of valuable raw materials;
- on site treatment costs;
- energy and water costs;
- the volume of solid and liquid wastes generated;
- the risk of spills and accidents.

. . . and ***IMPROVE :***

- overall operating efficiency;
- generation of income through reuse and recycling of wastes;
- this approach can be easily replicated in sister factories to achieve similar savings;
- safety of employees;
- legislative compliance;
- company image.

1 Guidelines for Industrial Audits have been prepared by the SEAM Project.