A PRELIMINARY STUDY ON GREEN PRODUCTIVITY OPTIONS FOR THE TEXTILE INDUSTRY

By

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Declaration

The work described in this thesis was carried out by me at Ocean Lanka (Pvt) Ltd., Biyagama and Faculty of Applied Sciences under the supervision of Dr. B. F. A. Basnayake and Dr. R. Chandrajith. A report on this has not been submitted to any other university for another degree.

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DEDICATED TO

MY

BELOVED FATHER

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Abstract

The textile sector of the textile industry is a significant contributor to the Sri Lanka National Economy. Though it servers as a main contributor to industrial output, the impacts on the environment caused by this sector can be recognized in terms of the discharge of pollutants and of the consumption of water and energy which is a high cost to the industry and the environment.

This study was carried out in a textile manufacturing plant to formulate Green Productivity (GP) options in view of promoting GP in the textile industry. All the data relating to water consumption, energy consumption and waste generation of the plant were collected by undertaking a walk-through survey. The problems in those areas were encountered and causes for those problems were identified. Proper GP options were generated through numerous discussions and brain storming sessions with internal and external resource personnel.

Altogether twenty seven Green Productivity options were generated; nine options for waste reduction, eight for water conservation and ten options for energy conservation. The study highlights environmentally friendly chemical substitutions such as acetic acid by formic acid and sodium hydrosulphite by thiourea dioxide. It is estimated that COD reduction of 5000 kg/month could be achieved in the study plant with a saving of Rs. 200,000/month. In addition water savings options are dye bath reuse, bleach bath reuse, counter current washing, and final rinse reuse. Use of higher viscosity furnace oil, preheating of furnace oil by steam and insulation of jet machine surfaces are some of options to increase the efficiency of energy use.

It is very difficult to handle environmental problems relating to textile industry, which cause by the overuse of natural resources once it occurs. These problems can be eliminated by introducing "Green Productivity" approach to the textile industry.

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CHAPTER I - INTRODUCTION

The Textile and Garment sectors are considered as the most important industrial sectors in Sri Lanka. Industrial sector contributes to the Gross Domestic Production by more than 50%. Out of that, more than 47% is from the textile and garment sector. Textiles and garments contributed to 2/3 of the total industrial exports in the country and to 40% of the total exports(Central Bank, 1999).

The textile industry in Sri Lanka mainly comprises with textile processing sector including spinning, weaving, knitting, dyeing, finishing and the garment sector. Presently, there are about 191 textile processing units, employing about 40,000 people and producing approximately 223 million meters of finished fabric primarily for the domestic market. With the booming up of Export Processing Zones, large number of textile industries have come up to produce high quality fabric for the export market.

Although the Textile industry is not growing and it is in the decline, Board of Investment status companies dealing with textile seem to have a potential and the market is growing. The foreign earnings to the country is significant but it affects the environment in several ways. The processes of the textile production consume larger quantities of water and producing substantial volumes of effluent, which is a significant source of water pollution in Sri Lanka (CEA, 1992). Further, the knitting process in the textile industry consumes a major portion of electrical energy and a considerable amount of thermal oil is consumed for the dyeing and finishing processes(EPA, 1996). Because of these reasons, most of the textile industries in the country spend a large sum of money as their water and energy cost and the cost of end-of-pipe treatment of wastes. In some cases, it has been observed that some plants are not able to comply with the environmental regulations set up by local authorities creating some major environmental problems.

If these additional costs can be minimized, it will cause for the increase of profit in the production. On the other hand, environmental performance of the company can be improved through minimizing waste, minimizing the water and energy consumption. Further, the attitude of people towards green products will be much higher in the future globalize world. Therefore, it is better to focus on environmentally friendly textile products.

This study was carried out in a textile manufacturing plant where some of the practices have been improved. In addition to these improvements, the study was focused on applying Green Productivity(GP) practices in the textile industry in order to enhance its productivity and the environmental performance. The aim was fulfilled through finding out proper Green Productivity options for the problems encountered in terms of water, energy and waste in the selected plant.

1.1. Objectives of the study

Major Objectives

i. To study the process in a Textile Manufacturing Plant

ii. To apply Green Productivity practices in the Textile Industry

Minor Objectives

i. To suggest methods for reducing water consumption in the textile manufacturing plant

ii. To formulate improved energy management options in the Textile manufacturing plant

iii. To propose reduction methods for energy and waste in the textile industry to cut down the cost of "end-of- pipe treatment methods".

CHAPTER 2 – LITERATURE REVIEW

2.1 Concept of Green Productivity

Green Productivity is a strategy for enhancing productivity and environmental performance for overall socio-economic development . It is the application of appropriate techniques, technologies and management system to produce environmentally compatible goals and services (APO, 1996).

Before the 1950's the common business response to environmental pollution was to ignore such problems. It was possible when the problem was relatively small and the awareness of health and environmental impacts was not high. In 1960's the common practice was to disperse pollutants to the environment. But, it created some severe problems; some pollutants are toxic even in small concentrations, and some chemicals are persisting in the environment.

When industries and communities began to exceed the assimilative capacity of the environment by discharging their waste, there were some efforts to establish environmental standards to regulate the discharge of pollutants. In 1970's this resulted "end-of –pipe " treatment approach in order to meet stipulated environmental quality standards. But, with more stronger discharge standards, the cost of such "end-of-pipe" treatment of wastes became more expensive and affected the economic viability of some industries.

In the World, it has been estimated that over US $ 300 billion is being spent each year for environmental projects mainly for purchasing and maintaining end-of-pipe treatment technologies (APO resource persons, 1999).

Despite the high costs, the end of pipe treatment approach was found to be far from adequate as pollutants were not eliminated but merely transferred from one medium to another. The responses emerged form command and control regimes and slowly shifted to the voluntary systems emphasizing prevention of pollution at its source, cleaner production and environmental management systems such as ISO 14000 series.

These voluntary systems were found to be more cost-effective than using a command and control approach alone.

By considering pollution prevention separately from other manufacturing needs, such as productivity and quality improvements, most pollution prevention programs fail to develop the vital synergies and working relationships with manufacturers that are essential to drive both pollution prevention and manufacturing competitiveness.

Green Productivity is applicable not only to the manufacturing sector, but also to the agriculture and services sectors. It also addresses the interaction between economic activities and community development. Another dimension of Green Productivity is the role of the public sector in environmental protection and awareness.

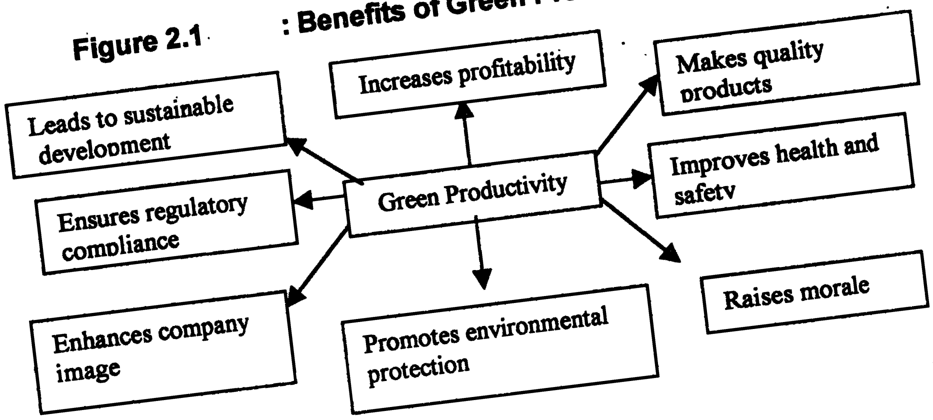
An attractive feature of GP is that it leads to gains in profitability through improvements in productivity and environmental performance. Green productivity pursues a strategy based on technical and managerial interventions. It is a process of continuous improvement.

2.2 The need for Green Productivity

The traditional "end-of-pipe" pollution control strategy, which is commonly employed in industries, is costly and ineffective. Other cost effective preventive strategies are not preferred by industries, as there are little or no effect to the productivity and quality, the main areas of concerning the industries.

Recognizing a new balance required between environmental protection and industrial activities (economic activities), the Asian Productivity Organization(APO) established the Green Productivity program in 1994 (APO, 1996).

Figure 2.1 : Benefits of Green Productivity



As a huge depletion of natural resources exists in this highly industrialized society, it is wise to employ Green Productivity practices in order to acquire the goal of Sustainable Development.

Increasing competition due to globalization and a heightening awareness of environmental deterioration have made the Green Productivity programs much important at present. There are several economic and environmental benefits derived from Green Productivity applications in industries.

- First and most important are monetary benefits due to lower energy costs, which are resulted from increased energy efficiency. Apart from energy, a reduced consumption of water and other raw materials can be achieved (Scholomer, 1998).

- Green Productivity promotes " eco-friendly products" in the industry. As the trend towards the environmentally friendly products is much stronger in this society, increase of demand can be observed.

- Increased labour productivity can be gained as a result of improved work ethics and corporate identity. As the Green Productivity programs are based on the commitment of all the staff, it enhances the integration of every single worker and motivates them to participate actively in pollution prevention practices.

- Increased sales resulting from positive marketing effects can be achieved by Green Productivity applications.

- Most recently, insurance companies have begun to exclude certain pollution incidents from their insurance coverage or place a surcharge on policies. In order to remove or reduce any increases in the insurance premiums, companies can use "GP" results to decrease the potential risk and also the possibility of environmental liabilities (Schlomer, 1998).

2.3 Green Productivity Tools and Techniques

Green Productivity persuades to lead to maximum feasible reduction of all pollutants generated at the production sites. It is a method of multi-pollution control and management that focuses on reducing the generation and discharge of pollutants at their sources in order to reduce subsequent handling, treatment, and disposal. It involves the sustainable use of resources through source reduction, energy conservation, reuse of input materials during production and reducing the water consumption. Green Productivity encourages industry to reduce pollutants at its source and to recycle pollutants on site rather than to treat and dispose them in to air, sewers, waterways, ground water and land. Within the preferred strategies for dealing with pollutants, the highest priority is assigned to preventing pollution through source reduction and source elimination. Recycling and reuse are considered as the next best way to handle pollutants. Effluent treatment (E.g. Biological degradation of toxic industrial wastewater, well controlled incineration of hazardous waste) is next most important. Finally, legally permitted disposal (e.g. Putting waste filled barrels in secured land fills or disposing of chemical waste in deep wells) is the least desirable waste management technique. This "environmental management options hierarchy" has been adopted by the United Nations, the U.S. Environmental Protection Agency , the U.S. congress, the Chemical manufacturers Association, Green peace International and many other organizations (APO, 1999).

2.3.1 Source Reduction

This includes practices that reduce the amount or toxicity of any waste, hazardous substance, pollutant or contaminant entering a waste stream prior to external recycling, treatment or disposal. Source reduction measures can be categorized in to two main areas;

2.3.1.1 Input material changes

Hazardous substances are introduced in to a process through input materials used to manufacture a product. These hazardous materials can be present in both the primary and secondary materials, which is used to manufacture a product. Input material changes can be done through two main ways; (a) material substitution and (b)material purification(Freeman et al., 1992)

a.) Material substitution

Environmental friendly raw materials can be used instead of toxic substances. (E.g. Water soluble cleaning agents can be used in place of organic solvents as the organic solvents have to be disposed of as hazardous wastes or recycled offsite after they are used).

b) Material purification

Higher purity raw material can be used to reduce the quantity of wastes generated. E.g. using an organic liquid or acid that is relatively free of metals or other impurities.

2.3.1.2 Process changes

Process changes include technology changes and improved operating practices. All such changes reduce worker exposure to pollutants during the manufacturing process. Modifying the technology used to produce a product is one of the most effective methods of preventing pollution generation. Manufacturing should be modified to make production more efficient through changes in the process, changes in equipment, lay out or piping, use of automation and changes in operating process conditions. A company can prevent pollution and increase production capacity and yield; improved product quality; and reduced costs for raw materials; utilities, handling etc.

Although some technology changes may apply only to specific processes, process changes can be implemented through several categories (EPA, 1996)

2.3.1.2.1 Process modifications

This involves developing an alternate process to obtain the same product specification, while generating less waste. Further, waste can be reduced by replacing inefficient or old processes with newer technologies. New processes, that generate less waste can be developed as new products are brought on line.

2.3.1.2.2 Operational adjustments

This is the easiest and least expensive way of minimizing pollution. Operational adjustments are changes in the way process equipment operates. If the process equipment are designed with optimal settings (e.g. Temperature, pressure, feed rate), it results for the highest efficiency of operation. Thus, less waste is generated.

2.3.1.2.3 Equipment modification

This involves reducing the pollutant generation by reducing equipment related inefficiencies. The equipment is modified while the process remains the same.

2.3.1.2.4 Automation improvements

An automated system monitors and adjusts process operating parameters to maintain the most efficient conditions. Automation can reduce human error and thereby reduce the likelihood of spills and process upsets that can increase waste. In addition, improved automation can generally increase product yields by maintaining small deviations from optimal set points.

2.3.1.3 Improved Operating Procedures

Procedural aspects of a manufacturing operation include the management, organizational and personnel contributions for the production process. Improved operating practices can be implemented in all areas (E.g. Production, maintenance, raw material product and waste handling , and storage)

2.3.1.3.1 Material handling and storage

Possibility of spills, leaks, fire explosion or any other losses can be minimized by proper material handling, transfer and storage. Losses from improper handling and storage can often be curtailed without large investment.

2.3.1.3.2 Spill and leak prevention

Spills or leaks of chemicals, wash downs and mop-ups using absorbent materials create additional waste. In most cases, this kind of waste may require treatment prior to disposal. The best way to minimize waste from spills and leaks is to prevent them from occurring in the first place.

2.3.1.3.3 Waste Stream Segregation

Hazardous waste can often be considered as a combination of two or more waste stream types or one type of waste and water. Segregation at the source can reduce the quantity of disposal of hazardous wastes. Amount of hazardous waste disposal can be reduced by not allowing hazardous and non-hazardous waste to be mixed. Further, it yields substantial savings.

2.3.1.3.4 Personal practices

Green Productivity programs may vary form simple pollution awareness programs, where managers and employees are requested to identify ways of reducing the generation of waste, to complex programs that are carried out by corporate personnel and that extends to worldwide operations. An effective training program is a vital need in this regard. Employees should be trained to detect spills, leaks and releases of material. Process operators and maintenance personnel should be given additional training that stresses pollution prevention methods.

2.3.2 Recycle and Reuse

Recycling and Reuse is the next most preferable constructive approach to pollution prevention. This methodology conserves natural resources, avoids waste management options such as treatment or land disposal, reducing the raw materials thereby lowering production costs (Cheremisinoff, 1992).

Some recycling/reuse options are ranked in terms of generally decreasing preferability, based largely on risk or liability:

2.3.2.1 Reuse in the same process

Waste material generated in a manufacturing process in many cases can be reused in the original process with or without treatment to remove impurities. If the waste material cannot be reused in the same process due to its potential contamination, waste should be treated to remove contaminants. If reuse in the same process is not possible, an alternative use in the plant itself can be found. A single recovery operation may be less expensive from both a capital and operation labour standpoint. The disadvantage of this type of operation is the additional storage, segregation and handling requirements. These increase the possibility of environmental incidents and liability.

2.3.2.2 Off site recovery

Off site recovery can be employed when on-site recovery is not feasible. The recycled material could be either returned to generator for re-use at the generation site, or sold for use at other facilities. A waste stream must be characterized (composition and generation rate) before it can be sent off-site. A fairly constant composition and relatively high generation rates are two factors to which the attention is should be focused by the recovery firms.

Selling or giving away waste products for off-site reuse is sometimes possible. Routinely generated by-products or waste streams with consistent specifications may be sold through marketing organizations in many firms. These materials can be handled just like typical products.

2.3.2.3 Recovery of energy values

This involves salvaging energy from waste rather than raw materials. This option is preferable to destructive techniques such as incineration and land disposal. Some firms with their own power generation facilities may have the flexibility to co-fire moderated to high energy content wastes. Though the incineration reduce volume and generally toxicity, air pollutant generation and the final incinerator ash disposal must still be considered and may impact a generators' liability.

2.3.3 <u>Good Housekeeping</u>

Good Housekeeping involves keeping the work place clean, eliminating leaks and spills, resource efficient operational practices etc. It has been experimented that good housekeeping alone could lead to a reduction in waste generation up to 20 – 25%. Illustrations for good housekeeping practices are, preparation of recipes in right quantity to avoid surplus, efficient handling of materials, optimum storage procedures to avoid losses and material degradation during storage etc (EPA, 1996).

2.3.4 <u>Inventory management</u>

Proper control over raw materials, intermediate products, final products and the associated waste streams is recognized as an important waste reduction method. Inventory management involves controlling and handling of raw materials and controlling the type and quantities of materials in the plant inventory.

2.3.5 <u>End-of-pipe treatment technologies</u>

This is the least preferable strategy to combat waste. Waste, which cannot be eliminated, reduced, recycled or reduced, must be treated and disposed within all applicable environmental regulations. There are number of end-of-pipe pollution control measures that are applicable to treat and dispose of pollutants.

2.3.5.1 Waste treatment processes

This involves changing the form of composition of a waste stream through control reactions to reduce or eliminate the amount of pollutants.

2.3.5.2 Volume Reduction

These processes result in concentrating hazardous or toxic constituents. It is a useful approach to reduce volume of waste.

2.4. Energy conservation in industries

All round shortages of commercial energy, continuing problems of oil availability and present wasteful use of energy in different sectors has made energy conservation very important. Various kinds of energy conservation techniques have been applied in industries to conserve energy.

Energy conservation means that the efficient utilization of energy resources ensuring the same level of industrial activity with lesser inputs of energy. It also implies substitution of costly imported energy by cheaper and more plentiful indigenous sources to supplement conventional sources. Awareness campaigns and launching of demonstration projects, promoting energy efficiency projects, promoting energy efficiency technologies through activities related to organizing training programs and studies in the field of energy conservation is also taken up (Palaniappan et al., 1998)

2.4.1 Energy efficiency

Energy efficiency emphasizes higher production with limiting energy resources. Reducing waste in energy consumption will contribute to sustainable development.

Introduction of energy management in an organization does not require large investment. It is proved that the energy cost in the industry can be reduced by 10% - 15% through a proper energy management program. The savings thus accrued added to the profit line. It has been shown that 10% reduction in energy cost can increase the profit by 25%-50%. The dramatic increase in oil prices since 1973 has brought in to sharp focus the need to use energy efficiently. (Palniappan et al.,1998).

2.4.2 Energy Productivity

The ratio of energy consumption to production activities is called the "Energy Productivity" of an industry. It is the most important element when considering the industrial productivity. Measuring energy productivity involves establishing a baseline or reference point against which trial efforts can be judged or inter plant comparisons established. The cost of energy inputs for each section in the industry should be determined and ranked.

2.4.3 Energy Balance

Energy balance is an very important concept in the point of industry. Energy inputs in an industry should be balanced by Energy outputs. The difference of calorific value of these energy inputs and energy outputs is called as heat lost through evaporation.

2.4.4 Energy Management

Energy Management has emerged as a powerful tool for maintaining competitiveness and increasing profitability. Most efficient energy use will reduce emission losses in energy conversion process, reducing the consumption of fossil fuels. Therefore, energy –efficiency will improve the environmental performance of an industry.

Energy is basically used in two different forms in an industry; electricity and thermal energy. Combustion of fossil fuels in primary heat sources such as boilers or fired heaters provides a major source of industrial heat input. Normally, all energy used in process chain is produced through the use of heat inputs and it will generate pollutants which directly pollutes the environment. Any action that conserves energy would reduce the pollutants generating in the process while cutting down the additional expenses for waste handling and treatment.

There are lots of other advantages of energy efficiency programs are;

- Better performance of the plant as a result of improved operational and maintenance practices resulting higher productivity.

- Better quality products due to rigorous control of process parameters.

- Enhance the safety of operations

- Rational use of alternative fuels, including waste streams.

2.5 Environmental legislation related to Textile Industry.

As all the other countries, Sri Lanka is also subjected to rapid industrialization in the competitive world. The government of Sri Lanka promotes the industrial activities in order to increase the income level of people. While gaining much profits to the country, industrialization contributes to the deterioration of the environment to a significant extent.(CEA, 1992).

The government has, therefore, introduced environmental legislation to enhance environmental protection and pollution control. The National Environmental Act No. 47 of 1980, amended by Act No. 56 of 1988 is the main piece of legislation in this regard. The Central Environmental Authority (CEA) which was set up under the National Environmental Act is the leading agency in the implementation and enforcement of the environmental legislation. The industrial pollution control guide lines prepared by CEA describes the wastewater discharge quality standards which should be satisfied by Textile Processing industries (Table 2.1).

Table 2.1 :Tolerance limits for industrial effluent water discharged in to the common wastewater treatment plant

Parameters	Maximum tolerance limit
BOD_5 (at 20^0C)	200 mg/l
pH	1.0 – 8.5
Suspended Solids	500
Temperature (^0C)	40
Phenolic compounds	5 mg/l
Oil and grease	30 mg/l
Total Chromium	2 mg/l
Copper (as Cu)	3 mg/l
Lead (as Pb)	1 mg/l
Mercury (as Hg)	0.0005 mg/l
Nickel (as Ni)	3 mg/l
Zinc (as Zn)	10 mg/l
Arsenic (As As)	0.2 mg/l
Boron (as B)	2 mg/l
Sodium %	60 mg/l
Ammoniacal Nitrogen (as N)	50 mg/l
Sulphides (as S)	2 mg/l
Sulphates (as SO_4)	1000 mg/l
Chlorides (as Cl)	900 mg/l
Cyanides (as CN)	0.2 mg/l
Radioactive material Alpha emitters (μc/ ml) Beta emitters (μ c/ ml)	 10^{-7} 10^{-6}

Source: Industrial Pollution Control Guidelines, Textile Processing Industry, 1992

Table 2.2 :General standards for industrial effluent water discharged into inland surface waters (after treatment)

Parameter	Maximum Tolerance Limit
pH	6.0 – 8.5
Suspended Solids	50 mg/l
Temperature	$40^{0}C$
BOD_5 (at $20^{0}C$)	30 mg/l
COD	250 mg/l
Phenolic Compounds	1.0 mg/l
Cyanides	0.2 mg/l
Sulphides	2.0 mg/l
Fluorides	2.0 mg/l
Total residual chlorine	1.0 mg/l
Ammoniacal Nitrogen	50 mg/l
Arsenic (As As)	0.2 mg/l
Cadmium (as Cd)	0.1 mg/l
Chromium (as Cr)	0.1 mg/l
Copper (as Cu)	3.0 mg/l
Lead (as Pb)	0.1 mg/l
Mercury (as Hg)	0.0005 mg/l
Nickel (as Ni)	3.0 mg/l
Selenium (as Se)	0.05 mg/l
Zinc	5.0 mg/l
Pesticides	Nil
Oil and grease	10.0 mg/l
Radioactive materials	
Alpha emitters (μc /ml)	10^{-7}
Beta emitters (μc /ml)	10^{-6}

Source : Industrial pollution control guidelines, textile processing industry, 1992.

2.6 Previous work on Green Productivity in textile industry

Several studies have been carried out with the aim of applying Green Productivity practices in textile industry. United Nations Industrial Development Organization (UNIDO) plays a major role by sponsoring for these waste minimization activities in different countries.

The National Productivity Councils (NPC) of different countries with the collaboration of UNIDO, have conducted several projects for demonstrating the potential of waste minimization in small scale industries. Several examples for Green Productivity projects are given below;

(a) Novotex is a Dyeing factory which has been situated in Denmark. Industry had several problematic occasions to face with. They introduced the life cycle approach to the textile production. This effort has succeeded in many water and energy saving activities and in the necessary development of a mechanical, chemical and biological wastewater treatment facilities. Chlorine is not used for bleaching, no formaldehyde is used for post treatment, and no component of organic solvents are used in the detergents. To compile with the environmental standards set by the local authority the company decided to eliminate the use of heavy metals in the dyeing machines. The company's water and energy saving activities reduced the use of water and energy with 30%. Although, the cost of the dyeing process in the industry remains same as before, the sludge could be disposed to a farmland other than putting it as hazardous waste to a controlled land fill. At present the Novotex produces fabrics which meet long environmental requirements. The dyeing factory could reduce their heavy metal waste by 80%
(Chandak, 1994).

(b) Paradise prints is a large textile processing house situated in India. A programme was launched to carry out some major waste minimization efforts in this plant. Substitution of acetic acid by formic acid, Hydrosulphite by one sixth quantity of Thiourea Dioxide were some significant findings and replacing the conventional jet dyeing machines with more economical low liquor ratio machines could gain considerable reduction of water consumption in the plant (Desai, 1995).

(c) Another green productivity study was carried out at a Textile unit located in North Carolina, U.S.A. In this factory, dye bath reuse in jet dyeing was implemented in order to extend the use of raw materials. Replenishing dyes were added to the used dye liquor at the end of a cycle to prepare the dye bath for the next cycle. Dye bath reuse conserves dye and other specialty chemicals and conserves energy by avoiding the cost of re-heating. Economic benefits were resulted form the savings in water, chemicals and energy (Chandak, 1994).

(d) Dintex Dyechem Ltd., is an dye and dye-intermediate manufacturing industry situated in India. Annual sales turnover of Dintex Dyechem Ltd., is US$ 6.6 million. It had some main problems such as highly acidic wastewater from sulfonation process, wastewater with high level of salt form condensation process and dust emission from condensation process. Because of these problems, the company was ordered to be shut down by the High Court in India. There are economic and environmental benefits gaining by the implementation of Green Productivity program in this industry. Their savings was over US $ 1.0 million with an investment of US$ 450,000. The pay back period was 3-13 months. The company met with regulatory discharge limits after Green productivity implementation. As environmental benefits, 70% reduction in sulfonation water, 50% reduction in condensation water were achieved. Further, there were some reduction of sludge from wastewater treatment plant, reduction of hydrochloric acid, elimination of dust emission etc(Shah and Saxena, 1996).

(e) Apallo Textile Mill is a demonstration textile processing plant situated in Bombay, India. This mill generates considerable quantities of solid waste materials during different stages of the operation. Willow dust is one of a waste generated from willow machines. A plant was installed at Apallo textile mill to convert this willow dust into bio gas. The average monthly production of willow dust is 12.5 tons. The investment cost of the project was Rs. 3.4 lakhs. Operational costs are about Rs. 18,000. Bio gas generation was 12,000m^3 /year resulting Rs. 63,412 of cost saving (Chandak, 1994).

(f) Another waste minimization study was carried out at a larger fabric manufacturing plant.in U.S.A. The firm had taken some very significant "in-plant" measures to reduce effluent volumes at source. The plant was modified with the low liquor ratio dyeing machines and counter current water flows resulting much higher fabric throughput for the same amount of water consumption. Conversion of one dyeing machine had reduced its water consumption by half and dye usage by 10% and the capital cost of the changeover had been recovered in 18 months. Another interesting and highly cost effective way of reducing water consumption had been the installation of orifice plates on valves so that when valves were fully turned on water was not wasted (Atkins and Lowe, 1985).

CHAPTER 3 - THE SELECTED TEXTILE MANUFACTURING PLANT

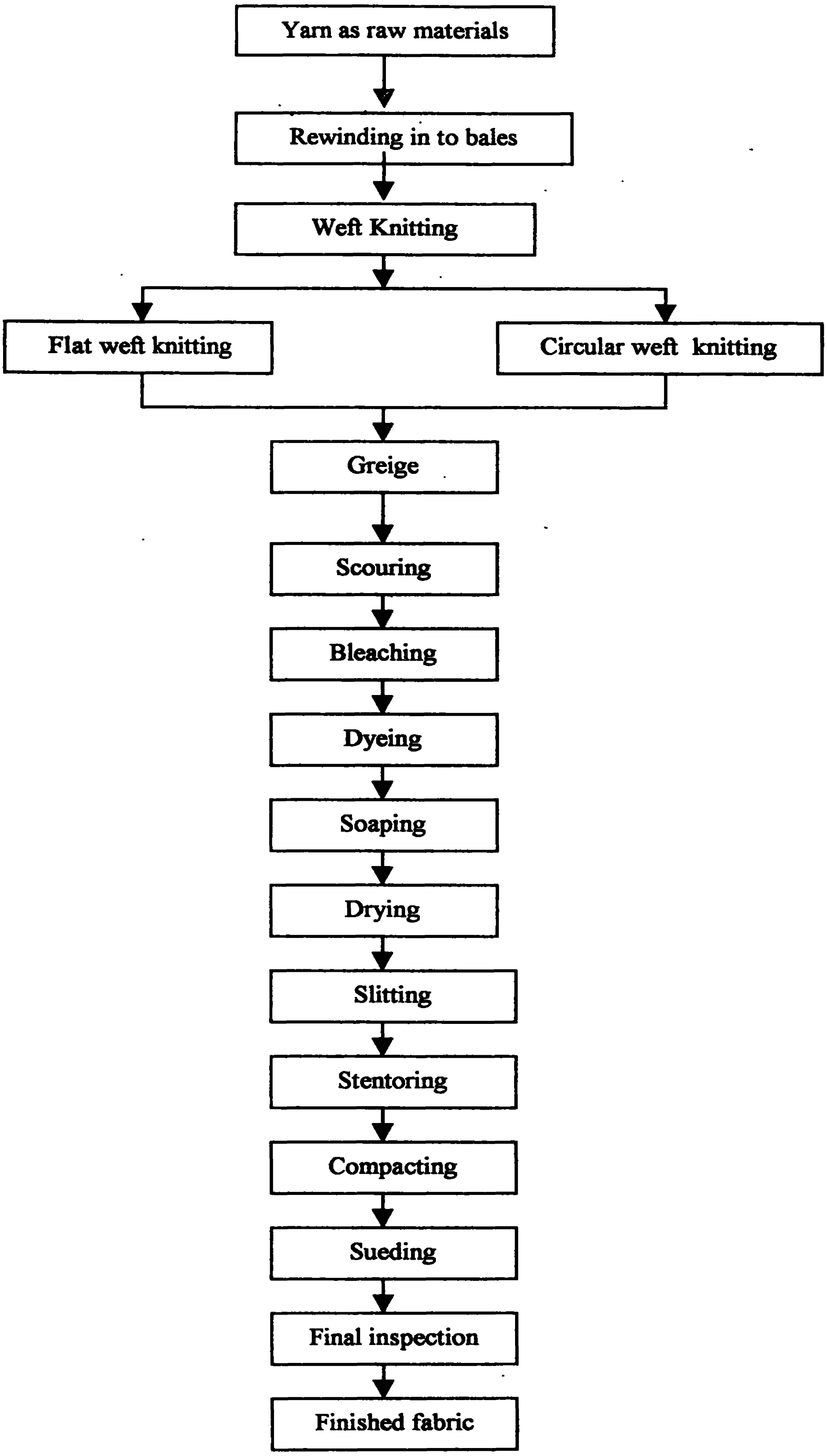
3.1. General Introduction of the plant

This study was carried out at Ocean Lanka (Pvt) Ltd, a well famous, textile industry situated at Biyagama Export Processing Zone, Walgama, Malwana. Ocean Lanka (Pvt) Ltd., is a larger BOI approved textile mill which produces export quality fabrics. It produces knit wears for most of export oriented garment industries in Sri Lanka. Further, their high quality fabrics are exported to some countries such as Moldives, Hongkong, Morrocco etc. It has a work force of 696 employees. Ocean Lanka is a main contributor to 20% of fabrics which are being exported to foreign countries. Approximately 40,000 pounds of fabric is being produced per day in the factory.

Production process in Ocean Lanka Textile industry mainly comprises with three sections.

- Knitting section
- Dyeing section
- Finishing section

Figure 3.1 Flow diagram for the production process in the plant



3.2. The production process of the plant

3.2.1 Knitting

Raw materials (Yarn) are brought from China, Hongkong, Bangladesh, Indonesia and Thailand. These are packed with cardboard or with polythene.

In the knitting section, yarn is rewound in to bales as to fit in to the machines. At this stage, yarn is sent through wax to remove the dust particles.

In knitting, the fabric is formed through interlocking of one or more sets of yarns through a set of loops. Knitting can be performed using either weft or warp processes. Only the weft process is employed in this factory. In weft knitting, one yarn is carried back and forth and under needles to form a fabric. Yarns run horizontally in the fabric and connections between loops are horizontal.

Weft knitting machines are mainly of two types;

- Flat bed knitting machines
- Circular knitting machines

Circular machines mainly produce fabric for T'shirts. Fabric used for collars are produced by flat knitting machines. Full garments are made by flat bed machines, and these machines will operate at much lower speeds. The simplest most common filling knit fabric is single jersey. The output from knitting is called as Greige or Gray cloth.

Dyeing Section

This mainly consists of major three steps

-Preparation

-Dyeing

-Drying

i.) Preparation

The fabric side is reversed at this stage. Scouring and bleaching processes are done in order to facilitate the dyeing.

3.2.2 Scouring

Greige (Gray fabric) is treated with NaOH or KOH at 95^0 C for 45 minutes. This will remove the natural and acquired impurities such as natural wax, pectine, grease, oil etc., It makes the fabric fitting for dyeing.

3.2.3 Bleaching

Fabric is treated with H_2O_2 (oxidative bleaching). WZB is added for reducing the H_2O_2 liberation. NaOCl also can be used instead of H_2O_2. But, as it gets yellow colour to the fabric, it is not used. This will remove the natural or acquired coloured impurities.

3.2.4 Dyeing

There are mainly three types of dyeing methods depending on the dye type

3.2.4.1 Direct dyeing

In direct dyeing, the fabric is treated with dyes at a temperature of 95^{0}C. Specific temperature and the salt concentration should be maintained in order to get the maximum fixation. Dye bath should be prepared according to the proper liquor-ratio. If the liquor-ratio is changed the absorbance efficiency will be lowered. Water and light fastness is low in direct dyeing and it is only used for cotton fabrics.

3.2.4.2 Reactive dyeing

The fabric is treated with reactive dyes at a temperature of 40^{0}C – 95^{0}C. As these reactive dyes are sodium salts of sulfonic acids, it dissolves in water fastly. Alkali medium is used for the reactive dyeing. Alkalis such as Na_2CO_3, NaOH, Na_3PO_4 can be used. 70% of these dyes will be absorbed to the fabric while other 20% - 30% portion is subjected to hydrolyzing or remain as unfix dyes. The water and light fastness is high in this dyeing.

3.2.4.3 Disperse dyeing

The disperse dyes are water insoluble. Therefore, dyeing of fabric is done at higher temperature and pressure such as 130^{0}C and 7 bar. Normally, Polyester or Polyester blend fabric are treated with disperse dyes.

3.2.5 Soaping

The unfix dyes remaining on the fabric are washed out by the soaping process. Soaping programs are different for different types of fabric produced. Depending on the programs, the temperature at which the fabric is treated will be different. Synthetic detergents such as CRL, AL are added in the soaping. Soaping process comprises with series of stages. In some cases, dye fixing agents are added depending on the fixation rate.

Eg: Soaping program No. 20.

Draining the dye bath —-> Filling water —->Running 10 minutes—->Draining—-> Filling water —-> add acetic acid—-> Run 10 minutes--> Draining—-> Filling water —-> adding soaping agent —-> Heat up to 80^{0}C – 95^{0}C —-> Run 10 minutes—-> Cool to 80^{0}C —-> Draining—-> Filling —-> Heat up to 95^{0}C —-> Keep 10 minutes—-> Cool to 80^{0}C—-> Draining—-> Filling water—-> Run 5 minutes—-> Draining—-> Filling

3.2.6 Softening

Softening is done to reduce the surface friction between individual fibers, thereby softening the fabric structure and improving its feel.. The fabric is treated with softening agents at a temperature of 60^{0}C for about 15 minutes.

3.2.7 Drying

If there is a special finishing is required for the fabric, it is dried using the drier at a temperature of 130^{0}C.

3.2.8 Slitting

Fabric is opened from the tubular form to flat form by slitting machines.

3.2.9 Stentering

Weight and width of the fabric is adjusted according to the customer requirement. This is done using a stenter at $200^{0}C$ temperature. Any special finishing on the fabric can be completed at this stage.

3.2.10 Compacting

Compacting includes the sanforizing process. Fabric structure is compressed to reduce stresses in the fabric. The potential for excessive shrinkage on laundering is reduced by the compacting.

3.2.11 Sueding

The fabric is brushed to decrease the luster of fabrics by roughening or raising the fiber surface.

3.2.12 Final Inspection

Final inspection is done in order to make sure that the fabric is satisfied the required conditions. Some damage fabric is rejected at this stage.

3.2.13 Finished Fabric

After the final inspection, the finished fabric is stored at the Warehouse till it will be dispatched to the customer's destination.

3.3 Water and Energy consumption in the plant

Water and energy consumption in the plant is considerably high resulting a large expense as the water and energy cost. The average water consumption in the plant is approximately 3000 m^3 per day. It is estimated that the average electricity consumption and the average fuel oil consumption in the plant are 32000 kWh per day and 13000 liters per day respectively.

Table 3.1 : Water and Energy consumption in the plant

	Water and Energy consumption with the production output				
	Production (Pounds)		Water	Energy consumption	
Month	Dyeing	Knitting	consumption	Electricity	Thermal
			(liters)	(Kwh)	(Liters)
August 99'	866,237.00	720,664.00	64,500,000	826,890	321930
Sep 99'	736,435.00	632,656.00	63,450,000	818,610	313950
Oct 99'	808,231.00	670,656,.00	58,500,000	785,460	303000
Nove 99'	834,131.00	703,384.00	63,600,000	785,850	302430
Dece 99'	681,782.00	624,276.00	69,300,000	816,450	386000
Jan 2000	950,049.00	777,294.00	78,000,000	908,700	352500
Feb 2000	976,000.00	786,300.00	80,000,000	950,000	360000
March 00'	1,125,907.00	889,962.00	86,400,000	997,530	388800
April 2000	846,305.00	791,298.00	73,900,000	994,110	384600
May 2000	1,019,715.00	839,082.00	84,600,000	994,230	390000
June2000	815,024.00	663,482.00	86,400,000	918,360	418500
July 2000	909,902.00	894,024.00	96,000,000	1,023,150	420000
Aug 2000'	910,900.00	897,000.00	96,809,000	1,025,200	425000

Table 3.2 : Fuel oil cost of the plant

Month	Consumption	Cost
	(in liters)	(in Rs.)
August 99'	321930	3,380,265
September	313950	3,296,475
October	303000	3,181,500
November	302430	3,175,515
December	386000	3,528,000
Jan 2000'	352500	3,701,250
February	360000	3,780,000
March 00'	388800	4,082,400
April 2000'	384600	4,038,300
May 2000'	390000	4,095,000
June2000'	418500	4,394,250
July 2000'	420000	4,410,000
August 00'	425000	4,462,500

Figure 3.2 : Graphical representation of the fuel oil consumption of the plant

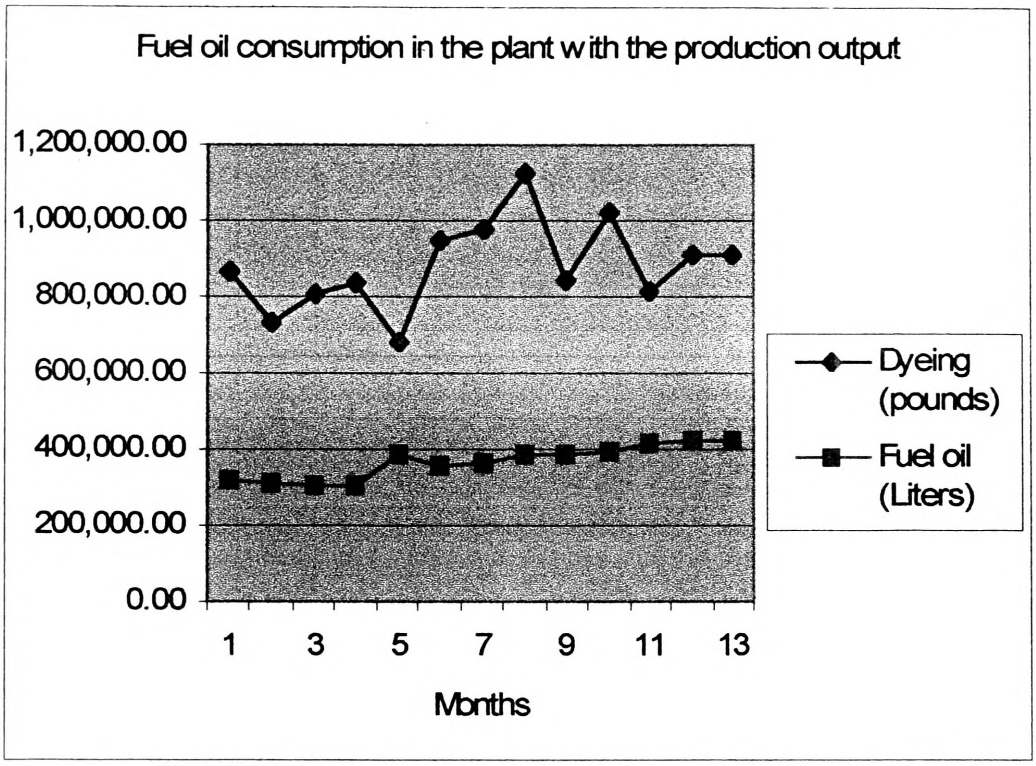


Table 3.3 : Electricity cost of the plant

Month	Consumption	Cost
	(in kWh)	(in Rs.)
August 99'	826,890	3,307,560
September 99'	818,610	3,274,440
October 99'	785,460	3,141,840
November 99'	785,850	3,143,400
December 99'	816,450	3,265,800
Jan 2000'	908,700	3,634,800
February 00'	950,000	3,800,000
March 00'	997,530	3,990,120
April 00'	994,110	3,976,440
May 00'	994,230	3,976,920
June 00'	918,360	3,673,440
July 00'	1,023,150	4,092,600
August 00'	1,025,200	4,100,800

Figure 3.3 : Graphical representation of the electricity consumption of the plant

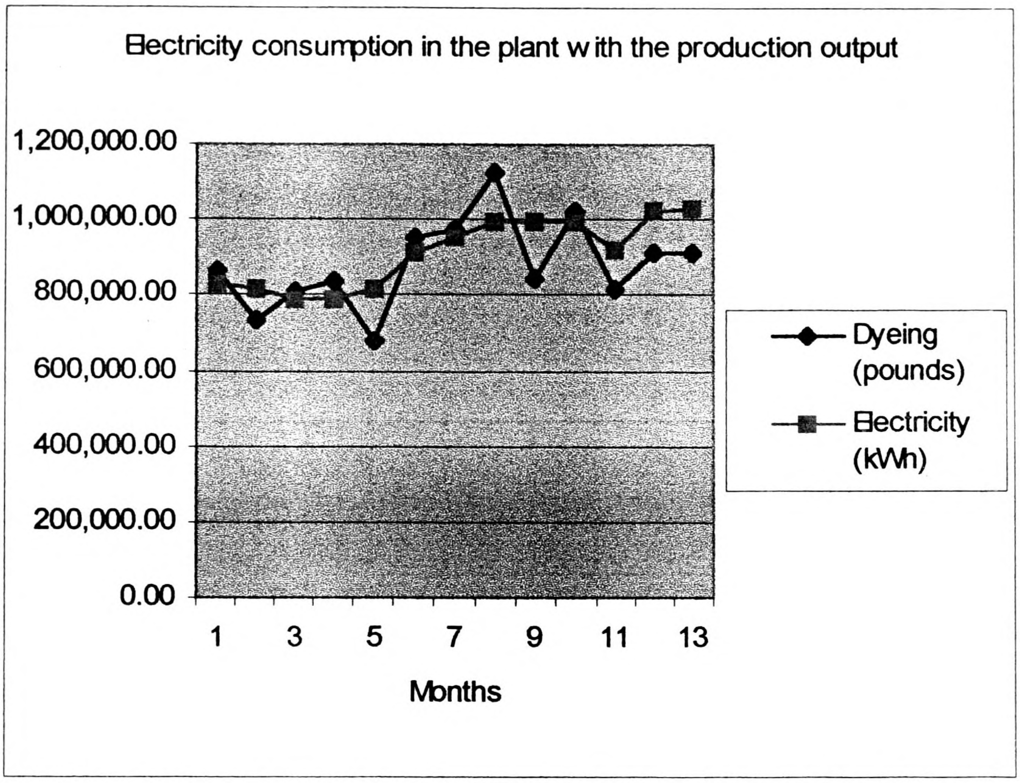
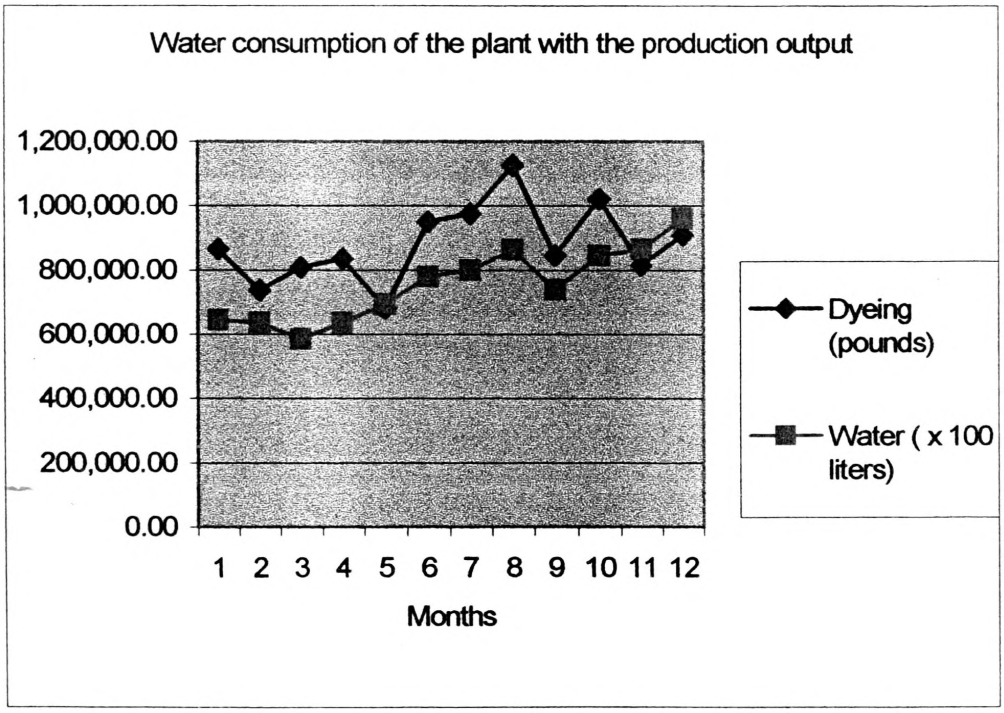


Figure 3.4 : Graphical representation of the water consumption of the plant



3.2 Wastewater generation of the plant

Table 3.4 : Generation of wastewater in the textile wet processes

Machine No.	Machine capacity (L)	No.of draining in scouring and bleaching	NO. of draining at dyeing	No. of draining at soaping	No. of draining at softening	Total water draining out (liters)
AK-3	800	4	1	5-6	1	9600
AK-4	1900	4	1	5-6	1	22800
AK-5	4900	4	1	5-6	1	58800
AK-6	2750	4	1	5-6	1	33000
AK-7	4900	4	1	5-6	1	58800
AK-8	9800	4	1	5-6	1	117600
AK-9	4900	4	1	5-6	1	58800
AK-10	9800	4	1	5-6	1	117600
TSF-11	8200	4	1	5-6	1	98400
TSF-12	8200	4	1	5-6	1	98400
TSF-13	8200	4	1	5-6	1	98400
TSF-14	8200	4	1	5-6	1	98400
TSF-15	2750	4	1	5-6	1	33000
TSF-16	2750	4	1	5-6	1	33000
TSF-17	4100	4	1	5-6	1	49200
TSF-18	4100	4	1	5-6	1	49200
TSF-19	4100	4	1	5-6	1	49200
AK-L-20	2750	4	1	5-6	1	33000
AKL-21	2750	4	1	5-6	1	33000
MK-22	1850	4	1	5-6	1	22000
GN-23	550	4	1	5-6	1	6600
WINCH-1	680	4	1	5-6	1	8160
WINCH-2	680	4	1	5-6	1	8160
WINCH-3	680	4	1	5-6	1	8160

WINCH-4	340	4	1	5-6	1	4080
WINCH-5	340	4	1	5-6	1	4080
WINCH-6	340	4	1	5-6	1	4080
WINCH-7	340	4	1	5-6	1	4080

Total wastewater generated by all machines in one cycle = 1219600 L

No. of cycles per day = 2

Total amount of wastewater draining per day = 2439200 L

= 2439 m^3

3.5 Solid waste generation of the plant

Table 3.5 : Types and quantity of solid waste in the plant

Type of waste generated	Source of Generation	Quantity Per day	Total quantity per day
Fabric (scraps)	Finishing Department (cut pieces) Quality Control Dept.(after inspection) Dyeing Testing (samples for testing) Fabric Preparation (cut pieces)	10 Kg 130 Kg 25 Kg 75 Kg	240 Kg
Finished Fabric (rejected)	Quality Control Dept. (after inspection)	100 Kg	100Kg
Greige Fabric (rejected)	Knitting Department (after inspection)	60 Kg	60 Kg
Polythene	Finishing Department (fabric covering) Quality Control Dept. (fabric in	5Kg 5Kg	

	roll cover) Greige fabric warehouse (fabric roll cover) Fabric Preparation (fabric roll cover) Chemical stores (empty chemical bags) Treatment Plant (empty chemical bags)	0.5 Kg 5 Kg 11.5 Kg 5 Kg	22 Kg
Plastic barrels	Finishing Department (Chemical usage) Chemical Stores (Chemical usage) Treatment Plant (Chemical usage)	2 Nos. 4Nos. 2Nos.	8 Nos.
Plastic cans	Chemical Stores (Chemical usage) Treatment Plant (Chemical usage)	15 Nos. 4 Nos.	19 Nos.
Boxes	Knitting Dept. (Raw material packing) Chemical Stores (Dyestuff packing)	250 Nos. 10 Nos.	260 Nos.
Yarn Cones	Knitting Dept (Raw material packing)	5000Nos.	50000Nos.
Fiber dust	Knitting Dept. Finishing Dept.(From raising machines0	20Kg 10Kg	30Kg
Sludge	Treatment Plant	2500Kg	2500Kg
Waste Oil	Maintenance Dept.(Removed from machines)	1 liter	1 liter

3.6 Wastewater Treatment facilities of the plant

The indoor wastewater treatment plant of Ocean Lanka Textile industry treats approximately 3000m^3 of wastewater per day. Treatment plant mainly comprises with 5 units.

3.6 Equalization tank

Mainly comprises of two inlets and two outlets. Two types of effluent enter through these two inlets.

a). Effluent below 50^{0}C temperature

This effluent is passed to the equalization tank through a bar screen which has been installed at the first inlet. All the larger solid particles are removed by the bar screen.

b). Effluent more than 50^{0}C temperature (Hot effluent)

The dye bath effluent, which has a higher temperature, is passed through a heat exchanger and the hot effluent outlet of the heat exchanger acts as the second inlet to the equalization tank.

The function of the equalization tank is, equalizing the different types of waste streams in order to treat them evenly.

A surface aerator has been installed in the middle of the equalization tank. It will reduce the temperature and the BOD level of the wastewater to a certain extent.

3.6.1 Cooling tower

The hot water of the equalization tank is passed through a cooling tower where the temperature of hot water is further lowered in order to meet the required BOI regulations. The water passed thorough the cooling tower is again flowed in to the equalization tank.

3.6.2 Flash mixing tank

The wastewater from equalization tank is passed to chemical reaction tank where the wastewater is treated with chemicals such as $FeCl_3$, De-colourent, $NaOH/H_2SO_4$.

$FeCl_3$ is added as a coagulant(Instead of $FeCl_3$, Fe_2SO_4, $Al_2(SO_4)_3$, Poly Aluminium Chloride can be added. But as this is a continuous process, the Biological Oxygen Demand(BOD), Chemical Oxygen Demand(COD) values should be lowered using a high strength coagulant as $FeCl_3$. As a further improvement, $FeSO_4$ is also used as a coagulant at present.

Colour is removed by adding de-colourents. pH is adjusted by adding NaOH or H_2SO_4. Short chain polymer is added for the flocculation process prior to sending of wastewater to Dissolved Air Flotation Unit, as it is not advisable to settle down the particles in DAF.

3.6.3 Dissolved Air Flotation Unit

Raw wastewater from the flash mixing tank is fed in to this dissolved Air Flotation unit. This unit acts as a separation unit for sludge and clear water. The treated wastewater is passed to a pH adjustment tank, while the sludge is passed to the sludge tank.

This process uses compressed air and sometimes a coagulant to float the sludge to the surface where it is removed by a mechanically driven skimmer..

3.6.4 pH adjustment tank

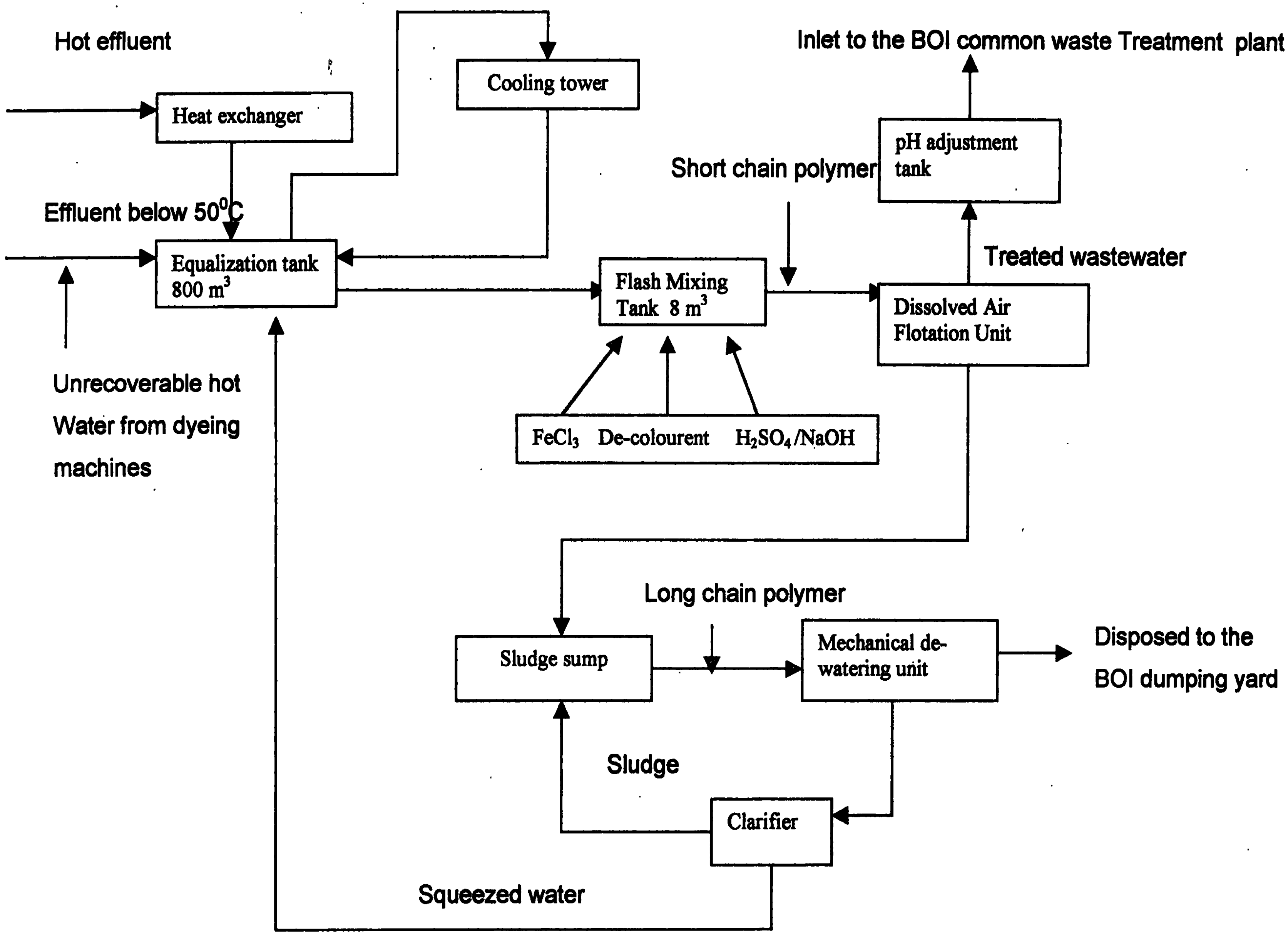
Treated wastewater is passed to a tank where the pH is adjusted to comply with the BOI regulations. After the pH is adjusted, clear water is discharged to the BOI outlet. The sludge which is separated from the Dissolved Air Flotation unit is passed to a Mechanical de-watering unit through a sludge sump.

3.6.5 Mechanical De-watering Unit (Filter Press)

The sludge is passed in to the filter press where approximately 25% of water is removed out. A long chain polymer is added at this stage to increase the particle size in order to increase the fastness of settling down.

The sludge is ultimately disposed to the BOI dumping yard while the belt wash water used in the filter press is passed to a clarifier. Rest of the solid particles are settled down in the clarifier. This settled down sludge is again passed in to the Mechanical De-watering unit while squeezed water is sent to the Equalization tank.

Figure 3.5 : Schematic diagram of the wastewater treatment plant of the industry



3.6 Solid waste disposal methods of the plant

Table 3.6 : Solid waste disposal of the plant

Type of waste material	Total Quantity	Storage place	Disposal method
Fabric scraps	215 Kg	Scrap ware House	Sold to local buyers
Finished fabric	100 Kg	Reject fabric Ware House	Sold to local buyers
Greige fabric (rejected)	60 Kg	Reject fabric Warehouse	Sold to local buyers
Polythene	33 Kg	Ware house	Sold to BOI recycling project
Plastic barrels	8 Nos.	Ware house	Sold to local buyers
Plastic cans	19 Nos.	Ware house	Sold to local buyers
Boxes	260 Nos.	Temporary yarn Warehouse	Sold to local buyers
Fiber dust	30 Kg	Day to day removal	Removed by scrap dealers Disposed to BOI dumping yard
Sludge (40% dry)	2500 Kg	Day to day removal	Disposed to BOI dumping yard
Waste oil	1 liter	Stored in drums	Reused as furnace oil

3.7 Wastewater characteristics of the plant

Collection point: Final discharge outlet of effluent treatment plant at above premises

Sampling method : Grab sampling

Table 3.6 : Wastewater characteristics of the plant

Period	Colour at 436nm^{-1}	Colour at 525 nm^{-1}	Colour at 620nm^{-1}	Temperature (°C)	pH at 30°C	BOD at 30°C	COD	TSS at 103°C-105°	TDS at 180°C (mg/l)
August 99'	19.7	15.4	11.5	36	6.1	95	160	60	2340
Oct 99'	17.2	9.6	5.9	36	5.4	130	380	280	1940
Nove 99'	11.4	11.2	10.7	35	6.5	100	220	40	2140
Dece 99'	9.7	6.2	5.0	43.5	5.2	140	350	315	3700
Feb 2000	19.3	14.6	11.4	39	5.1	145	325	135	3120
March 00'	21.7	12.9	7.9	40.5	6.6	290	435	200	3600
May 2000	9.7	6.2	5.0	41	5.2	140	350	315	3700
July 2000	6.9	2	1.0	40	6.8	100	170	90	2150

Source : CISIR reports

Other analyzed parameters

Parameter	**Mg/l**	**Parameter**	**Mg/l**
Oil and grease	<2	Total chromium	<0.1
Phenolic compounds	<0.1	Copper as Cu	0.06
Lead (as Pb)	<0.1	Sinc as Zn	0.3
Nickel (as Ni)	0.1	Boron as B	<0.002
Arsenic (as As)	<0.005	Cyanide as CN	0.001
Mercury as Hg	<0.001	Ammoniacal Nitrogen (N)	4.5
Sulphide (as S)	<0.1	Sulphate (SO_4)	21

The sludge which generates from the treatment of waste water is categorized as a hazardous waste.

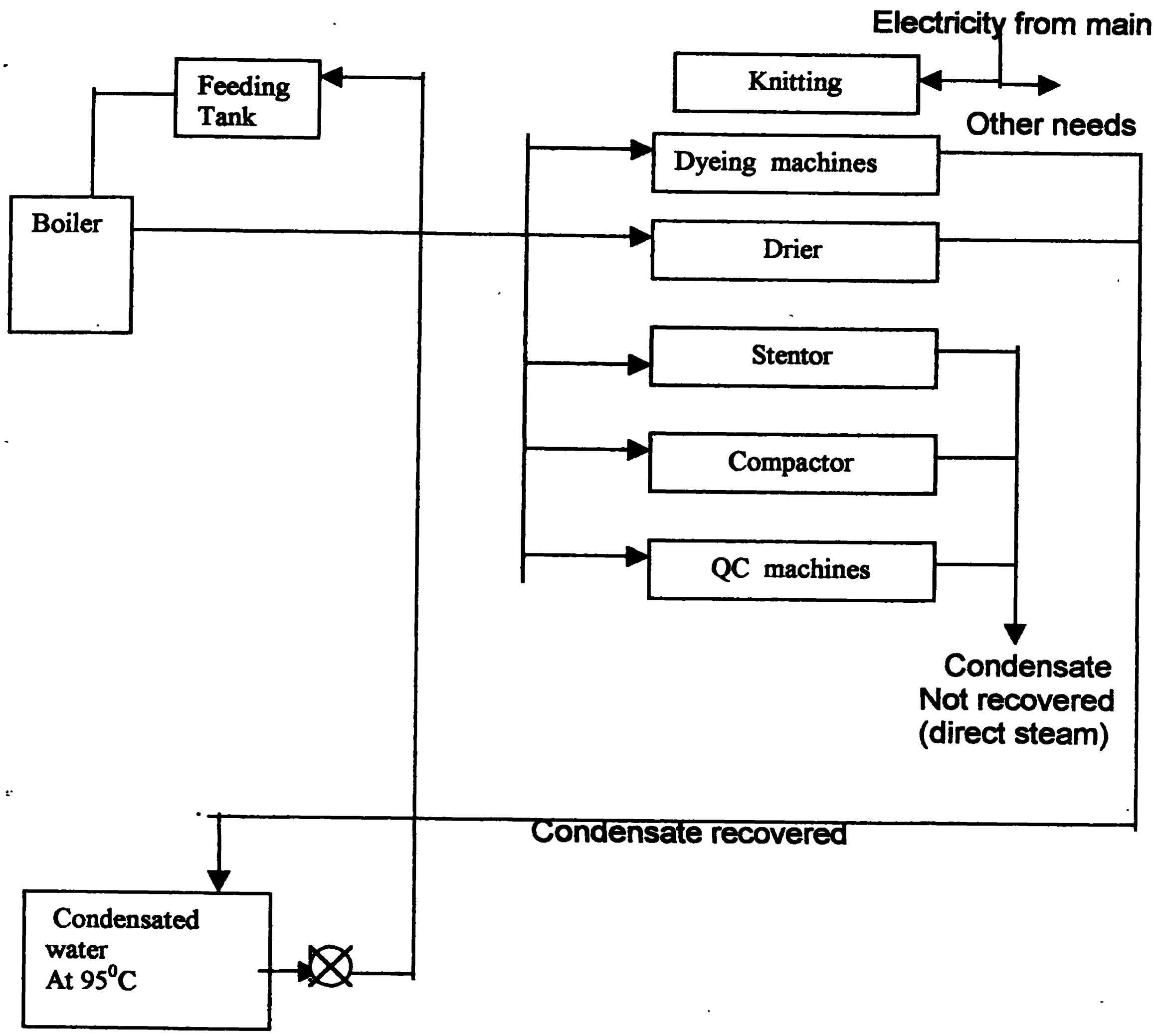
3.8 Existing energy conservation measures in the plant

- Power factor improvement through installation of fix capacitors (from 0.8 – 0.96).
- Heat recovery through the heat exchanger
  The hot effluent water at the temperature more than 50°C is passed through the heat exchanger and approximately 15°C temperature increment of the cold water can be obtained.
- Approximately 10% energy which is needed for boilers is recovered by using the flash steam
- The heat recovered from the heat exchanging process can be utilized for the soaping process, thus a considerable amount of fuel saving can be achieved.
- Reduction of fuel oil consumption by recycling the condensate water to the boilers.

3.9 Existing water conservation measures in the plant

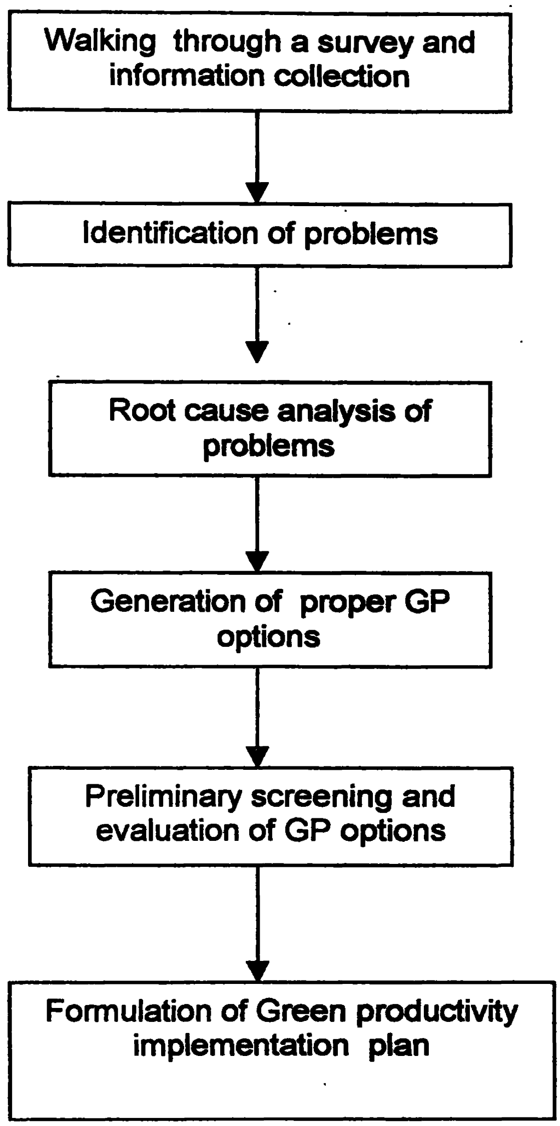
- Water conservation through the condensation of flash steam.
- Water conservation by using hot water recovered from the heat exchanger for the soaping process.
- Reduction of water consumption by feeding the condensate hot water to the boilers(steam from two boilers is condensated at 90°C and the condensated water is recycled in to boilers again).

Figure 3.6 : Schematic diagram of the energy utilization of the plant



CHAPTER 4 - MATERIALS AND METHODS

Figure 4.1 : Flow diagram for the methodology of the study



4.1 Methodology of the study

4.1.1 Walk through a survey and information collection

The manufacturing process of the industry was studied including utilities, waste treatment and disposal facilities. All process steps were listed. Process diagrams, initial layouts, drainage system and other material/energy loss area were prepared and identified. House keeping practices were observed and their obvious lapses were identified. Preliminary list of waste generating operations was prepared including a gross estimation of waste generated from different process steps. The possibility of waste prevention and control was noted.

Technical information needed for further evaluation such as water use, waste generated, energy use, raw material use, existing waste treatment facilities were collected. Existing methods that the industry has been adopted to conserve water and energy were identified. Special attention was focused on waste recycling and reusing. Existing waste treatment facilities were evaluated in order to ensure that they conform to legislative discharge limits and are operated within the designed conditions.

4.1.2 Identification of problems

Problems in each section of the industry were identified concerning process efficiency, waste generation and energy loss. Waste streams were characterized in terms of their constituents. Priority was assigned to waste streams in terms of quantity, toxicity, possibility of recovery/recycle etc. Energy loss areas were identified which are discrete, measurable and workable.

4.1.2 Root cause analysis of problems

This analysis involved locating and pinpointing causes of waste generation and energy loss. Cause and Effect (fish bone) diagrams were prepared to identify root cause of problems.

4.1.4 Generation of Green Productivity options

This step mainly focused on determining problems solving options. These options were generated from the root-cause analysis of problems carried out in the earlier stage. Possible methods of reducing waste were identified. Various views of resource personnel from the plant, trade associations, success cases tried elsewhere, specialist organizations including Research and Development institutions, equipment suppliers, consultants etc., were obtained. Techniques such as brainstorming and group discussions were helpful in generation better ideas. Information on the internet, books and other published literature were also sought in favor of generating proper solutions.

4.1.5 Preliminary screening of options

A list is prepared for all possible Green Productivity options that emerge in the brain storming or group discussion systems.

a) Assessment of technical feasibility

Technical evaluation was carried out in order to determine whether the proposed option is technically workable under the given conditions.

b) Assessment of economic viability

It was the key parameter for promoting of discussing implementation of waste prevention options. Options requiring small investment but involving more procedural changes like house keeping measures, operational improvements, process control measures etc., were not required intensive economic analysis and simple methods like "pay back period" was used. A cost/benefit analysis was carried out for some options on which the information is available. While undertaking the economic assessment the "cost" included fixed capital cost, shut down cost and operational and management cost. The savings included savings of input material/energy, profit due to higher production levels, lower operational and management cost, value of by products., reduction in environmental costs such as waste treatment, transportation and disposal costs etc.

c) Evaluation of Environmental aspects.

The waste prevention options were identified with respect to their impacts on the environment. The other impacts be improved treatability of waste. Changes in applicability of environmental regulations, applicability of simple end-of pipe pollution control systems etc.

4.1.6 Formulation of Green Productivity implementation plan

An implementation plan for the generated Green Productivity options was made in order to facilitate the implementation. It includes the location/point of application of the option, nature of option, required cost limit, time frame required, prioritization rank of the option etc.

4. 2. Materials of the study

Parameter monitoring	Instruments / Materials used
1. Total water consumption in the industry	Water meter
2. Water consumption in the wet process	Capacity of the dyeing machines/ Bath ratios of dyeing machines
3. Energy consumption in the industry	kWh meter , kVA meter, Monthly operational reports
4. Heat recovery measurement - Hot water outlet temperature - Hot water inlet temperature - Fresh water inlet temperature - Fresh water outlet temperature	 Temperature sensor Temperature sensor Temperature sensor Thermometer
5. Wastewater characteristics -pH of wastewater - Chemical Oxygen Demand	 pH sensor COD analyser
6. Moisture content of sludge	Watch glasses, Evon, Beaker, Electronic balance, Timer
7. Treated wastewater characteristics -pH -Temperature -COD -Colour	 pHsensor Temperature sensor COD analyser Lovi bond meter
8. Solid waste	Scale Views of the operators

CHAPTER 5 - RESULTS AND DISCUSSION

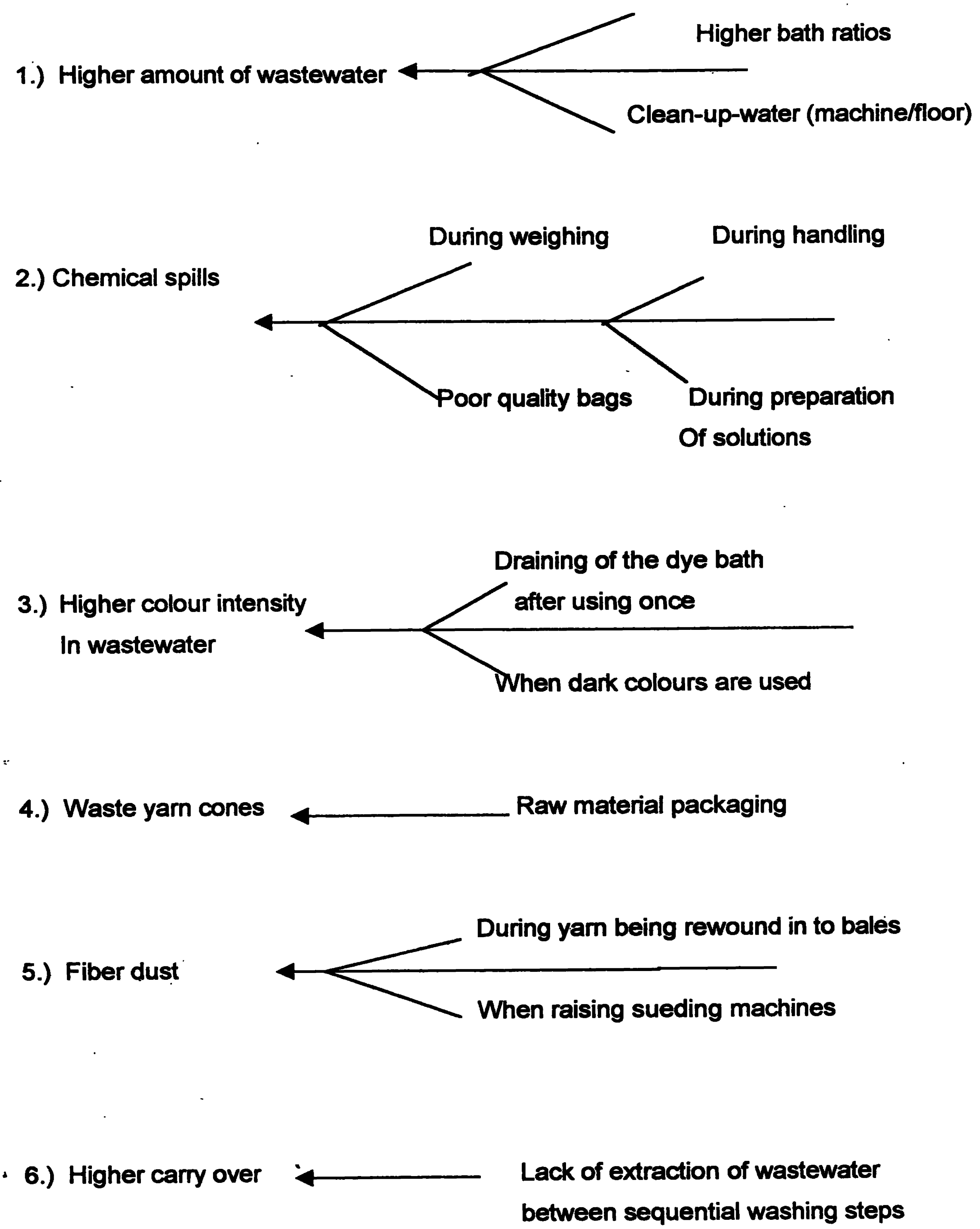
5.1 Identified problems of the plant

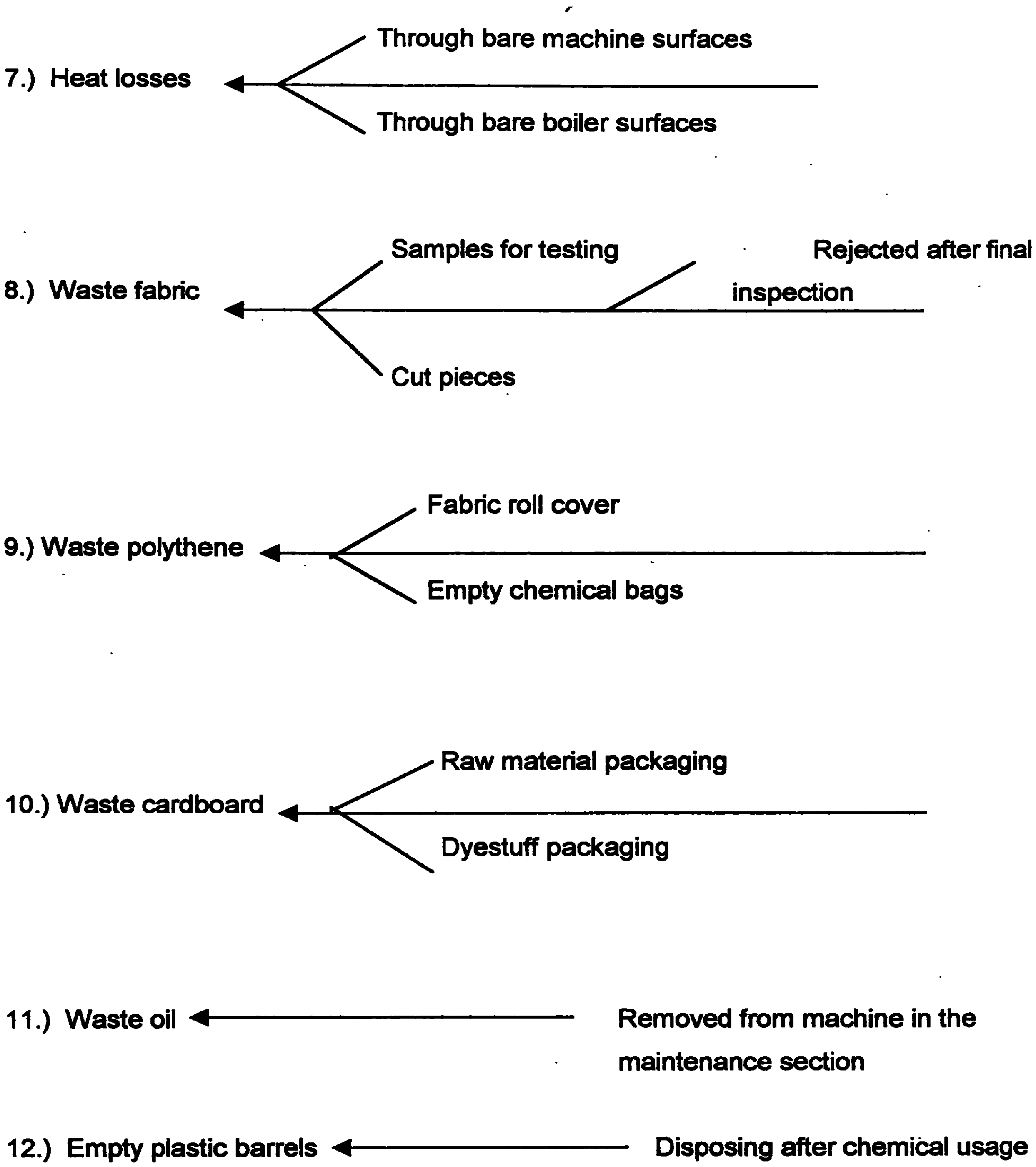
1.) Generation of higher amount of wastewater
2.) Higher colour intensity in wastewater
4.) Chemical spills
5.) Waste yarn cones in knitting section
6.) Fiber dust
7.) Higher carryover
8.) Heat losses
9.) Fabric (scraps) waste
10.) Waste Polythene
11.) Empty plastic barrels
12.) Waste cardboard
13.) Waste oil
14.) Sludge

5.2 Root cause analysis of problems

Causes were assigned to each identified problem. The causes ranged from simple lapses of housekeeping to technical reasons. Normally, the number of causes varies form one to five. The most important and predominant causes for identified problems are illustrated in figure 5.2.

Figure 5:1 : Fish bone diagrams for root cause analysis




7.) Heat losses
Through bare machine surfaces
Through bare boiler surfaces
8.) Waste fabric
Samples for testing
Cut pieces
Rejected after final inspection
9.) Waste polythene
Fabric roll cover
Empty chemical bags
10.) Waste cardboard
Raw material packaging
Dyestuff packaging
11.) Waste oil
Removed from machine in the maintenance section
12.) Empty plastic barrels
Disposing after chemical usage

5.3 Green Productivity options for identified problems

Green Productivity options for water conservation, waste reduction and energy conservation were generated. Among these were, material related changes, process related changes, equipment related changes, reuse and recycling options

5.3.1 Green Productivity options for Water Conservation

5.3.1.1 Counter current washing

Least contaminated water form the final wash can be reused for the next to last wash and so on, until the water reaches the first wash stage (more suitable for washing after continuous dyeing, bleaching and scouring). Counter current washing configurations are mainly of two types which illustrates in figure 5.2 and 5.3.

Figure 5.2 : Horizontal washer configuration

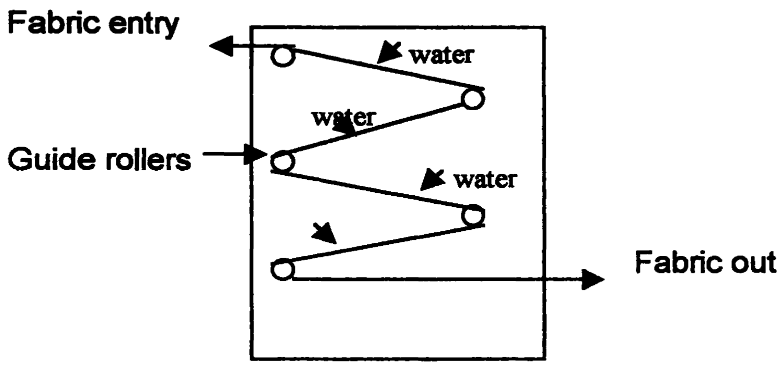
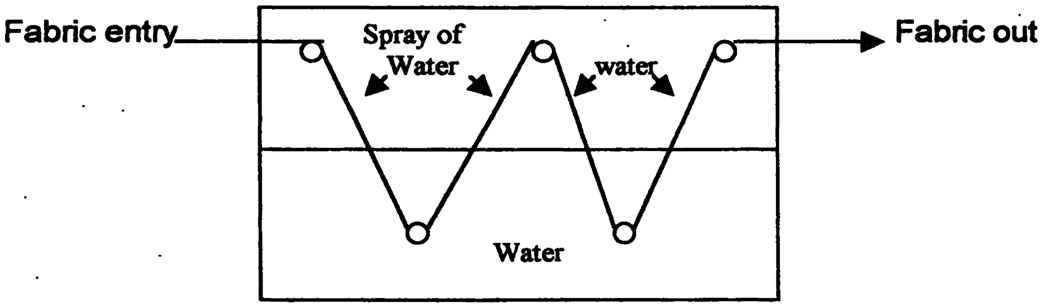


Figure 5.3 : Vertical washer configuration



If properly constructed and maintained, horizontal or inclined washers can produce high quality fabrics with much better washing efficiency and reduced water use.

5.3.1.2 Vertical counter flow washer

The water can be sprayed on to the fabric and rollers can be used to squeeze waste through the fabric in to a sump, where it is filtered and re-circulated. The filter can be made of loops of polyester fabric that rotate continuously and fresh water is sprayed at one end to clean off the filtrate. A considerable amount of water can be saved through this method.

5.3.1.3 Pad Batch Dyeing

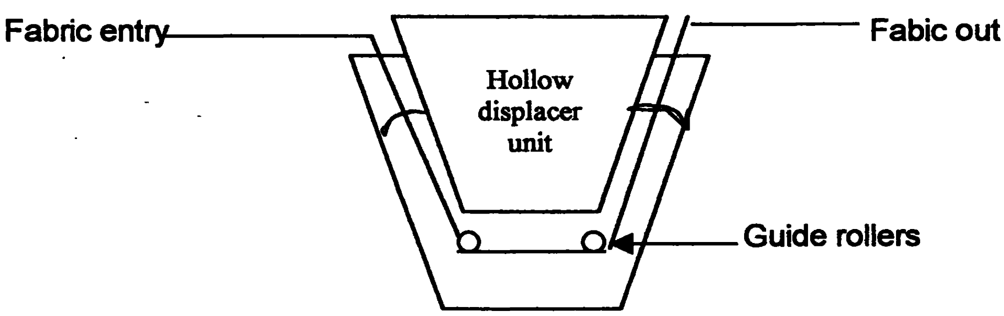
Prepared fabric is saturated with a solution of dyes and alkali, and the fabric is passed through a padder where the penetration of dyestuff to the fabric is forced while removing excess dye solution. Then fabric is stored on rolls or in boxes and covered with a plastic film to prevent evaporation of water and absorption of CO_2 from air. The fabric is then batched for 2-12 hours. This method offers several advantages over conventional dyeing processes:

- No salt or special chemical is required. This reduces waste as well as chemical and wastewater treatment cost.
- Due to the higher efficiency of dye fixation, the remaining colour in the wastewater is less and reduces water and energy consumption. (It has been experimented that the fixation ratio for pad-batch dyeing is about 92-97% compared with 42 – 80% for reactives at a 10:1 dyeing bath ratio).

5.3.1.4 Hollow displacer unit

The hollow displacer unit (Figure 5.4) will increase the path through which the fabric will be sent out with lower water amount. In this way, this method will lower down the chemical requirements for pH control as well as for lower water use.

Figure 5.4 : Pad with a displacer



5.3.1.5 Dye bath reuse

Almost 75% of dye exhaustion is taking place in polyester dyeing. Alternative to discharge of this exhausted bath is by collecting it in an overhead tank, analyse it for remaining dyes and chemicals and reconstitute the bath for reuse. In this manner, a single bath can be reused for 15 times for dark shades and four times for light shades. Dye bath reuse can only be employed for disperse and direct dyes but not for reactive dyes.

Further, this method can also reduce dyeing effluent with COD load by 85% and would yield 40% savings of energy and 80% saving of chemicals, water and treatment costs.

5.3.1.6 Bleach bath reuse

The spent bleach bath contains all of the alkali and heat necessary for the next bleaching operation. Peroxide and chelating compounds must be added to reconstitute the bath. This can save water and heat significantly.

5.3.1.7 Replacement of jet machines with advanced low liquor ratio machines

The average consumption of water in the industry is approximately 75 liters per one pound of fabric. Lowering down of liquor ratio brings down the volume of water used and waste generated. It has been shown that a change of liquor ratio from 1:10 to 1:5 brings about a decrease of pollution load by 40%.

5.3.1.8 Final rinse reuse as loading bath to the next batch

This technique works well in situations where the same shade is being repeated and the dyeing machines should be fairly clean when this method is applied. This option can save water and heat in to a considerable extent.

5.3.1.9 Wastage of water can be reduced by good house keeping practices such as restricting the number of hoses inside the plant.

5.3.2 Green Productivity options for Waste reduction

5.3.2.1 Low carry over

The purpose of washing is to reduce the amount of impurities in the substrate. It is imperative that as much water should be removed between sequential steps. Water that is not removed is "carry over" to the next step. Proper extraction between steps in the continuous washing process is important. In continuous washing operations, squeeze rolls or vacuum extractors can be employed to typically extract water between steps. Reduction of wastewater amount can be resulted by this method.

5.3.2.2 Application of chemical alternatives

Several chemical alternatives exist for various wet processing operations in the textile industry. These alternatives are selected based on following factors.

- Biodegradability / Bio eliminability
- Aquatic toxicity
- COD and BOD values
- Metal concentration

5.3.2.2.1 Substitution of acetic acid by formic acid

Acetic acid, which is used for the dyeing processes alone, can contribute to more than 20% of wastewater effluent COD and BOD loads. It can be substituted by formic acid resulting in 83% and 91% COD and BOD reductions respectively. A buffering system, which is free from drawbacks of formic acid, has been identified. It effectively maintains the pH of the dye-bath.

5.3.2.2.2 Substitution of Sodium Hydro Sulphite by Thiourea Dioxide

Hydros(Sodium Hydro sulphite $Na_2S_2O_4$) which has a COD of 333mg/g causes remarkable depletion of dissolved O_2 in water. Considerable reduction in COD can be achieved by replacing hydro with one sixth the quantity of Thiourea Dioxide(Disyn-HF) which has a COD of 208 mg/g , thus effectively reducing COD by 87% and costs by 43%.

Note: pH should be somewhat higher.

5.3.2.2.3 Substitution of Nonyl phenole ethoxylate by Alfa olefin sulfonate

A non ionic detergent based on Nonyl phenole ethoxylate is non – biodegradable, gives toxic metabolites which are highly poisonous to aquatic organisms. This can be substituted by Alfa Olefin Sulfonate which is biodegradable, non-toxic and even cheaper. Other biodegradable substitutes available are fatty alcohol ethoxylate.

5.3.2.2.4 Substitution of oxalic acid by hydrochloric acid

Oxalic acid used for removing rust stains is also quite toxic to aquatic organisms and also has high BOD and COD values. It can be partially replaced by hydrochloric acid.

5.3.2.2.5 Substitution of castor oil ethoxylate by hicoleveller BJD

The levelling agents also contribute heavily to plant's effluent load. The conventional levelling agent for polyester, based on Castor oil ethoxylate. It has COD and BOD value of 1947 mg/g and 537mg/g respectively. It can be replaced by hicoleveller BJD (Hico) having COD, BOD values of 588 and 150 mg/g respectively. Further, this turns out to be the most economical alternative.

5.3.2.2.6 Substitution of polyphosphate by phosphonates

High quantities of softening agents are used in textile industry to soften the water if the water is hard enough. Polyphosphates like Sodium Tri Poli Phosphate and Sodium Hexa meta phosphate can be replaced with phophonates. It has a higher chelating value than EDTA and hence very little quantities are required to soften the water. And that does not promote the algae growth in point of view of the environment.

5.3.2.3 Use of Intermediate Bulk Containers (IBC) for purchasing of chemicals.

Intermediate Bulk Containers can be used instead of smaller volume chemical bags and cans. Being IBC s are stackable and reusable, economical benefits can be gained by this and unloading costs can be reduced. Difficulties of handling these IBC should be tackled in an efficient way.

5.3.2.4 Replacing paper yarn cones with plastic yarn cones

Approximately 5000 Nos. yarn cones are wasted per day. This can be reduced by replacing paper yarn cones with plastic yarn cones if they can be reused. Purchasing specifications should be modified with the suppliers.

5.3.2.5 Biogas generation/ Viscose production from cotton fiber waste.

5.3.3 Green Productivity options for energy conservation.

5.3.3.1 Cost reduction by using higher viscosity furnace oil

At present, lower viscosity furnace oil is used in the plant. But, it can be replaced with much higher viscosity furnace oil. Approximately 15 cents reduction per one liter of furnace oil can be gained by the substitution with a cost saving of Rs. 1950.00 per day.

5.3.3.2 Preheating of furnace oil by steam

At present the plant uses electricity for the preheating of fuel oil. It is estimated that heating fuel oil by the steam is three times cheaper than heating by the electricity.

5.3.3.3 Recovering energy from boiler blow down.

If the boiler blow down is continuous, part of heat lost through blow down can be recovered. The blow down can be passed through a suitable heat exchanger and a part of it's heat can be transferred to incoming cold feed water.

5.3.3.4 Recovering energy in boiler stacks.

A part of energy loosing through stacks can be recovered by using recuperators. This recovered energy can be transferred to boiler feed cold water.

5.3.3.5 Reduction of flash steam pressure.

The flash steam pressure can be reduced to 3-4 bars by using thermo compressor. This low pressure steam can be used in activities where the low pressure steam is required.

5.3.3.6 Minimizing the heat losses by insulating the jet machine surfaces.

Normally, the jet machine surfaces are so hot and considerable amount of heat is lost through the surfaces. Lagging the jet machine surfaces can minimize this heat loss. Through this method, significant amount of fuel oil can be saved.

5.3.3.7 Introduction of low humid air from out side for the drying process

Considerable amount of energy is required for the drying of fabric. This can be reduced by introducing low humid air from outside. Draw backs such as time consuming can be overcome with the continuous improvements.

5.3.3.8 Insulation of hot water tank.

Bare surfaces of the hot water tank can be insulated with glass wool and aluminium sheets in order to reduce heat losses. This method will be beneficial only when the maximum temperature of hot water tank is higher.

5.3.3.9 Installation of moisture meters to avoid over drying of fabric.

Excessive heat requirements can be avoided by this method.

5.3.3.10 Insulation of bare/poorly insulated steam lines.

Considerable amount of heat is lost through bare/ poor insulated steam lines. This loss of heat can be saved by lagging those.

5.4 Cost Benefit analysis of Green Productivity Options

A Cost / benefit analysis was carried out for some significant options.

Option : Substitution of Acetic acid by formic acid

	Rate (Rs/Kg)	COD (Kg/Kg)
Acetic acid	42	1.04
Formic acid	72	0.52

Average monthly consumption of Acetic acid = 5160 Kg

Substitution of formic acid required = 2580 Kg

Cost incurred for Acetic acid = Rs. 216,720.00

Cost incurred for Formic acid = Rs. 185,760.00

Cost saving from the substitution = **Rs. 30,960.00 /month**

Chemical Oxygen Demand reduction Which can be achieved = (5160 x 1.04) – (2580 x 0.52)Kg

= (5366.4 – 1341.6) Kg COD

= **4024.8 Kg COD**

Option : Substitution of Sodium Hydro Sulphite by Thiourea dioxide

	Rate (Rs/Kg)	COD (Kg/Kg)
Sodium Hydro Sulphite	90	0.33
Thiourea dioxide	190	0.33 x 0.15

Monthly consumption of Sodium Hydro Sulphite = 2980 Kg

Substitution of formic acid required = 496.6 Kg

Cost incurred for Sodium Hydro sulphite = Rs. 268,200.00

Cost incurred for Thiourea dioxide = Rs. 94,367.00

Cost saving from the substitution = **Rs. 173,833.00/ month**

COD incurred by Sodium Hydro Sulphite	= 2980 Kg x 0.33 Kg/Kg
	= 983.4 Kg COD
COD incurred by Thiourea Dioxide	= 2980/6 Kg x 0.33 x 0.15 Kg/Kg
	= 24.585 Kg COD
COD reduction which can be achieved	= 983.4 – 24.585 Kg COD
	= **958. 815 Kg COD**

Option : Condensate recovery and Reuse as boiler feed water

Steam generation per day	= 150 m^3
Total volume of condensate	= 50% of steam generation
	= 75 m^3
Average temperature of condensate	= 90^0C
Heat savings	= 75 x 1000 x 4.2 x (90 – 30)^{0}C
	= 189 x 105 KJ/day
Calorific value of fuel oil	= 40,500 KJ/l
Boiler efficiency	= 70%
Fuel saving	= (189 x 105/ 40,500) /0.7 l/day
	= 666.66 l /day
Fuel oil cost saving	= 666.66 l/day x Rs.10.50 / l
	= **Rs.7000/day**
Water cost saving	= 75 m^3 x Rs.26.50/m^3
	= **Rs.1987.50 /day**

5. 5 Green Productivity implementation plan

Green Productivity option	Location of application	Option category	Timing	Cost	Priority
1). Replacing Acetic acid with Formic acid.	Dyeing Dept.	SR, MRC	ST	M	2
2.Replacing Sodium Hydro Sulphite(Hydros) with Thiourea Dioxide.	Dyeing Dept.	SR, MRC	ST	M	2
3. Replacing Oxalic acid with Hydrochloric acid.	Dyeing Dept.	SR, MRC	ST	M	5
4. Replacing non-ionic detergent based on Nonyl Phenol ethoxylate by Alfa olefin sulfonate.	Dyeing Dept.	SR, MRC	ST	M	3
5. Replacing a conventional levelling agent based on Casto Oil ethoxylate with hicoleveller BJD.	Dyeing Dept.	SR, MRC	ST	M	5
6. Replacing polyphosphate (Sodium Tri Poli Phosphate or Sodium Hexa Meta phosphate) with phophonates.	Water treatment	SR, MRC	ST	M	3
7. Use of reusable, stackable In\termediate Bulk containers for purchasing of chemicals.	Chemical stores	Reuse, onsite MRO	MT	M	1
8. Replacing paper yarn cones with plastic yarn cones if they are reusable.	Knitting Dept.	Reuse, Onsite MRO	MT	L	4

Green Productivity option	Point of application	Option category	Timing	Cost	Priority
9. Bio gas generation from cotton fiber waste. Viscose production from cotton fiber waste	Knitting Dept.	Recycling, onsite, MRL	MT	M	4
10. Use of counter current washing	Dyeing Dept.	Reuse, PRC	MT	L	3
12. Using a hollow displacer unit.	Dyeing Dept.	SR, ERC	MT	L	4
13. Dye bath reuse(For direct and disperse dyes).	Dyeing Dept.	Reuse, PRC	ST	L	1
14. Bleach bath reuse.	Dyeing Dept.	Reuse, PRC	ST	L	2
15. Replacement of jet machines with advanced low liquor ratio machines.	Dyeing Dept.	SR, ERC	LT	H	4
16. Installing the water meters where the measurements are not available.	General	SR, ERC	LT	L	1
17. Use of pressure guns for container washing and floor washing etc.	Dyeing Dept.	SR, ERC	LT	L	3
18. Insulation of jet machine bodies to avoid heat losses.	Dyeing Dept.	SR, ERC	LT	M	2
19. Use of higher viscosity furnace oil	Boiler room	SR, MRC	LT	L	1
20. Insulation of bare/poorly insulated steam lines.	General	SR, MRC	MT	M	3
21. Close up of hot water tank to avoid heat losses.	Maintenance Dept.	SR, PRC	MT	L	6

22. Recovering energy in boiler stacks.	Boiler room	Reuse, onsite	LT	M	4
23. Introduction of low humid air from outside for the drying process	Dyeing Dept.	SR, ERC	MT	H	6
24. Installation of moisture meters to avoid over drying of fabric	Drying	SR, ERC	LT	M	3
25. Preheating of furnace oil by steam when the high viscous fuel oil is used.	Boiler room	CR	LT	L	1
26. Recovering energy from boiler blow down	Boiler room	Reuse, onsite	MT	M	5
27. Reducing the flash steam pressure by a thermo-compressor and use the low pressure steam.	Dyeing Dept.	Reuse, onsite	MT	M	2

SR - Source reduction
PRC -Process Related Change
ERC - Equipment Related Change
MRC - Material Related Change

MRO - Material reused for Original purpose
MRL - Material Reused for Lower purpose

ST - Small Time
MT - Medium Time
LT - Large Time

L - Lower cost
M - Medium cost
H - High cost

CHAPTER 6 - CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion and recommendations

There are significant problems, which have been identified during the study. The causes for each of these problems were identified through a root-cause analysis. A total of twenty-seven Green Productivity options were generated in order to eliminate these problematic causes. During this study seven Green Productivity options for water conservation, nine options for waste reduction, eight options for energy conservation have been identified. Among those there were eight source reduction – material related changes, six equipment related changes, four process related changes, five reuse options and one recycling option.

Out of the nine GP options for waste reduction, environmental friendly chemical substitutions play a significant role. It is estimated that a cost saving of Rs. 30,960/month and COD reduction of 4024.8 Kg can be achieved by the substitution of acetic acid by formic acid. Saving of Rs. 173,833/month and COD reduction of 958.82 Kg can be achieved through the substitution of Sodium Hydrosulphite by Thiourea Dioxide.

Among the Seven GP options for water conservation, Counter current washing, Dye bath reuse, Pad batch dyeing, proper house keeping measures can conserve a considerable amount of water resulting a lower volume of wastewater for final treatment and cost saving from the reduction of water consumption.

Use of higher viscosity fuel oil, preheating of fuel oil by steam, lagging of jet machine surfaces can be put as most significant for the conservation of energy.

It is concluded from this study that it is very difficult to handle the environmental problems, which cause by the overuse of natural resources once it occurs. These problems can be eliminated by introducing "Green Productivity" approach to the Textile Processing. Through the implementation of above Green Productivity options a substantial amount of raw material saving, cost saving through the reduction of water consumption, energy consumption and waste generation can be gained while improving the environmental performances of the plant.

6.2 Suggestions

Following suggestions can be made to improve the "Green Productivity" concept in the plant;

- Green Productivity needs more commitment from all the parties of the plant. This is not a individual work. Team work towards the "Green Productivity" can gain lot of benefits to the industry as well as to the environment.

- Research and Development work on Green productivity should be enhanced.

- Programs should be conducted to raise the awareness of "Green Productivity" practices among all workers, and the top management of the plant.

REFERENCES

- Anonymous. 1998. A top down strategy for promoting energy efficiency in industries. Asia Pacific Tech Monitor. 15(02) : 13 – 16

- Anonymous. 1999. Clean Technology Evaluation and Pricing. Asia Pacific Tech Monitor. 16(06) : 12 – 15

- Atkins, M.H. and Lowe, J.F. 1979. Case studies in pollution control measures in the Textile Dyeing and Finishing industries, A Hand book in non-technical language of essential information on the economics of control, the problems and the solutions. 1st ed.

- CEA. 1992. Industrial Pollution Control Guidelines –No.06; Textile Processing Industry, 1st ed. Central Environmental Authority, Colombo.

- Chandak, Surya Prakash. 1994. Desire to reduce waste; Project demonstrating Cleaner Production in SMEs of India. Asia Pacific Tech Monitor. 11(06) : 20-40

- Cheremisinoff, P. N., Ferrantge, L, M. 1992. Waste Reduction for Pollution prevention. 1st ed. Biddeles Ltd.

- De Oliveira, Marcos Antonio Lima. 1998. Documentation for environmental Act (Amended), No. 56. Publication Bureau, Sri Lanka.

- Desai, C. 1995. Reduce cost through waste minimization; Textile industry case study. Asia Pacific Tech Monitor. 12(01) : 14-17

- EPA. 1996. Best Management Practices for pollution prevention in the textile industry.

- Gurumurthy, G. 1999. Global market competition; Textile sector must adopt to Green Productivity, < URL :http: // www.apo-tokyo.com>

- ITC. 1986. Textiles and Clothing. An introduction to Quality requirements in selected markets. UNCTAD /GATT

- Lee, S. and Stephan, M. 1992. Energy Efficiency and Human Activity; Past Trends; future prospects. The International Energy Studies Group, University of California at Berkely

- Mahajan, S. P. 1996. Pollution control in process industries, 1st ed. Tata McGraw, Hill Publishing Company Limited.

- Olson, Edward, S. 1983. Textile wet Processes, Preparation of fibers and fabrics, Vol.01.

- Palaniappan, C., Kolar Ajit Kumar and Haridasan, T. M. 1998. Renewable Energy Applications to Industries. 1st ed. Narosha Publishing House, Inida.

- Ratna, Prabhu M. and Prarajia, J. S. Heat Economy in Textile mills. 2nd ed.

- Rudolfs, William. 1997. Industrial Wastes; Their disposal and treatment . 1st ed. Allied Sceientific Publishers, New Delhi.

- Schlomer, W. 1998. ISO 14001 in Developing countries; The Indian experience. Asia Pscific Tech Monitor. 15(5) : 30-37

- Shah, Dinesh S. and Saxena, A. K. 1996. Dintex Dyechem Ltd., Textiles dyes and dye intermediates. In *Green Productivity in pursuit of Better quality of life,* APO (Ed) p. 93-103

- UNEP. 1985. Cleaner production techniques and processes in the textile industry and the environment. Technical Report No. 16

- UNIDO.1979. Textile monographs; Water Conservation in the textile industry.

- Vaidayanathan, T., Joshi, S. B. and Pai, K. P. 1998. Environmental aspects of textile colouration. Asia Pacific Tech Monitor. 15 (06) : 9-16

- Villannueva, Eduardo, P., De Guzman, Zenaida, I., Cuchon, Caridad M. 1998. Pollution free dyes for textile industries. Asia Pacific Tech Monitor. 15(06) : 18-21

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