CLEANER PRODUCTION: THEORY AND APPLICATIONS, CASE FOR ZIMBABWE

BY:

Kumbi Mugwindiri and Tawanda Mushiri

Cleaner Production: Theory and Application, Case for Zimbabwe

Kumbi Mugwindiri

&

Tawanda Mushiri

First Published in 2016 by
University of Zimbabwe Publications
P.O Box MP 167
Mount Pleasant
Harare
Zimbabwe

ISBN: 978-1-77920-114-0

Typeset by Dick Masala, University of Zimbabwe Publications

Printed by Print force Productions: 0773 357 277

Table of Contents

LIST OF CONTRIBUTORS ..... **VIII**

FOREWORD ..... **IX**

CHAPTER 1 ..... **1**

INTRODUCTION TO CLEANER PRODUCTION AND TRAINING IN CLEANER PRODUCTION **1**

1.1: Introduction 1
1.1.1: Definition of Cleaner Production 1
1.2: Why the Cleaner Production strategy? 1
1.3: Environmental Benefits 2
1.4: Methods to Achieve CP Technology 2
1.4.1: By-product Recovery 3
1.4.2: Process chemicals and raw materials recycling 3
1.4.3: Changing of production processes to reduce waste 3
1.4.4: Waste management 4
1.4.5: Raw and process material change 4
1.4.6: Fresh water management 4
1.5: Selected unit operations in CP technology options 5
1.5.1: Suspended solids removal 5
1.5.2: Dissolved solid removal 6
1.6: Application in selected industries 6
1.6.1: Pulp and paper mill industry 6
1.6.2: Sugar industry 7
1.6.3: Selected food industries 7
1.6.4: Pine apple industry 7
1.6.5: Cheese production 7
1.6.6: Poultry processing industry 7
1.6.7: Meat packing industry 7
1.6.8: Textile industry (Tanning) 7
1.6.7: Electroplating industry 8
1.6.8: Distillery industry 8
1.7: Origin and characteristics of waste 9
1.7.1: Treatment of wastes 9
1.7.2: Cleaner production (waste minimisation assessments) 9
1.8: Assessment Procedures 9
1.9: The training market for CP in Zimbabwe 10
1.9.1: Gaps in training 10
1.10: How best can these issues be addressed? 11
1.11: Conclusion 12

CHAPTER 2 ..... **13**

DEMONSTRATION OF THE CLEANER PRODUCTION METHODOLOGY **13**

2.1: Introduction 13
2.2: Planning and Organisation 13
2.3: Management Commitment 13
2.4: Project Team 13
2.5: Developing an Environmental Policy 13
2.6: Environment Policy for the Peanut Factory 15

2.6.1: Environmental Objectives for the Peanut Factory 15
2.6.2: Pre-assessment questions 15
2.6.3: Possible Environmental Targets for the Peanut Factory 16
2.6.4: Material and Energy Balance 16
2.6.5: Focus of the Audit 20
2.6.6: The CP Options solution generation, screening options 20
2.6.7: Implementation and continuation 24
2.7: Conclusion 25
CHAPTER 3 .... **26**
CLEANER PRODUCTION AT SWEETSUGAR **26**
3.1: Introduction 26
3.2: Company description 26
3.3: Cleaner production case for tertiary institutions 31
3.3.1: Overall learning objectives 31
3.3.2: Problem statement 31
3.3.3: Outline of case situation 31
3.3.4: Background - Description of the Sugar Process 32
3.4: Pre-assessment phase 33
3.4.1: Objectives of Pre-Assessment Phase 33
3.4.2: Assessment phase 33
3.5: Feasibility Study 33
3.5.1: Objectives of Feasibility Study 33
3.5.2: Implementation 34
3.6: Conclusion 34
CHAPTER 4 .... **35**
CLEANER PRODUCTION AT SWEETSUGAR – ANALYSIS **35**
4.1: Introduction 35
4.2: General Pre-assessment Observations 35
4.3: CP and Waste Reduction Opportunities 35
4.3.1: Water and Wastewater Management 35
4.4.: Energy Management 36
4.5: Factory Energy Design Attributes 36
4.6: Recommended CP Focus Areas 37
4.6.1: Water Usage 37
4.6.2: Waste Water 37
4.6.3: Energy Management 37
4.6.4: Operating Practices 37
4.6.5: Cleaner Production Assessment 37
4.6.6: Unit Operations in Sugar Production at Sweetsugar Ltd. 38
4.6.7: Receiving, Cane Handling and Preparation 38
4.7: Environmental Concerns 38
4.8: Extraction 39
4.9: Environmental Concerns 39
4.9.1: Concentration 40
4.9.2: Mud Filtration 40
4.9.3: Crystallisation and Centrifugation 41
4.9.4: Sugar Drying and Packing 42
4.9.5: Support Service Unit Operations 43
4.10: Best Practice Comparison 44
4.10.1: Sugarcane 44

4.10.2: Mixed Juice Purity ... 46
4.10.3: Water Consumption ... 47
4.10.4: Solid Waste ... 49
4.10.5: Energy Consumption ... 49
4.11: Conclusion ... 50
CHAPTER 5 ... 51
OPTION GENERATION, IMPLEMENTATION AND CONTINUATION ... 52
5.1: Introduction ... 52
5.2: Wastewater Recycling ... 52
5.3: Extraction Plant Wastewater ... 53
5.4: Upgrading of Extraction Technology ... 55
5.5: Sugar Spillage ... 57
5.6: Discharge Chute ... 57
5.7: Belt Scrappers ... 58
5.8: Power Generation and Supply ... 60
5.8.1: Power-Factor Correction ... 60
5.9: Feasibility Studies – Implementation and Continuation ... 61
5.9.1: Tools for economic evaluating options ... 61
5.9.2: Payback theory ... 61
5.9.3: Net Present Value theory ... 62
5.9.4: Internal Rate of Return Theory ... 62
5.10: Wastewater recycling assessments ... 62
5.10.1: Extraction Plant Cooling Water ... 62
5.10.2: Technical Evaluation ... 63
5.10.3: Economic Evaluation ... 63
5.11: Upgrading of extraction technology ... 64
5.11.1: New Diffuser ... 64
5.11.2: Technical Evaluation ... 64
5.11.3: Economical Evaluation ... 64
5.11.4: New Diffusser Payback ... 65
5.11.5: New Diffuser Net Present Value ... 65
5.12: Recommendations ... 65
5.13: Conclusion ... 66
BIBLIOGRAPHY ... 67
APPENDIX {SOURCE UNEP CP DOCUMENTS} ... 68
CP Assessment Worksheets ... 68
Material Balance Worksheet ... 69
Cost of Waste and Emissions Streams Worksheet ... 70
ENERGY LOSSES ... 70
Cause Assessment Worksheet ... 71
POSSIBLE WASTE SOURCES ... 71
SPECIFICATION ... 71
Cleaner Production Options Worksheet ... 72
CLEANER PRODUCTION APPROACH ... 72
TO EFFECT: ... 72
HOW: ... 72

Feasibility Study Worksheet Checklist 74
Technical Evaluation Worksheet: Cleaner Production Option........ 75
Economic Evaluation Option Worksheet........ 77
Environmental Evaluation Worksheet: Cleaner Production Option: 78
Implementation Worksheets 79

INDEX........**81**

List of contributors

Albert Chisadza
University of Zimbabwe, Department of Mechanical Engineering, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe

Wilford Karuwo
University of Zimbabwe, Department of Mechanical Engineering, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe

Kumbi Mugwindiri
University of Zimbabwe, Department of Mechanical Engineering, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe

Tawanda Mushiri
University of Zimbabwe, Department of Mechanical Engineering, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe; and Department of Mechanical Engineering, Faculty of Engineering and the Built Environment, University of Johannesburg, 2006, Auckland Park, Johannesburg, South Africa

Stanford Nyamuzihwa
University of Zimbabwe, Department of Mechanical Engineering, P.O Box MP167, Mt Pleasant, Harare, Zimbabwe

Foreword

Regardless of its size or nature, industry generates waste and is responsible for implementing the practices of pollution prevention and waste management in its day-to-day operations. Whether it is dirty water or toxic wastes, industrial pollution is all the same in one way: it reduces a business's profitability. Implementation of Cleaner Production (CP) urges environmental, health and safety department managers, industrial environmental consultants and personnel across all industries to employ a forward-thinking and tested technology of process improvements that will reduce waste generation, reduce the resources requirements to manufacture a product, and, most important to the life a business, increase revenues. Successful implementation of cleaner production improves their productivity, profitability, competitiveness, environmental compliance and working conditions of shop floor employees with minimum financial inputs.

This book starts by explaining CP concepts, techniques and strategies. It further gives CP methodologies and case studies of those industries in which CP was successfully implemented. The authors also usher you through all sorts of exercises to test your understanding.

I hope the book will encourage all stakeholders to think about what they can do to tackle the rising generation and inappropriate management of waste. Both producers and consumers of goods much work on the betterment of waste management. Every organization must strive to have the tools, technologies and financial resources to adopt CP. All sectors of society need to engage into an integrated life-cycle management of goods. The more efficient and less wasteful manufacturing and consumption processes will be, the less pressure there will be on essential resources and the better human health and the environmental will be protected.

As a fellow veteran production engineer, I encourage you to recognise that this field is changing and improvements are being made that empower today's business leader to minimize waste management generation.

This book can be used as a guide if you wish to adopt CP technologies in your organizations.

Enos Chaazi
Production Management Consultant

CHAPTER 1

Introduction to Cleaner Production and Training in Cleaner Production

Kumbi Mugwindiri, Tawanda Mushiri and Wilford Karuwo

1.1: Introduction

This chapter introduces Cleaner Production (CP) and shows how the introduction and development of CP can strengthen an industry's competitive position, maintain jobs, create new export opportunities and promote businesses to function in a clean and healthy environment, with particular focus on industries in Zimbabwe, a developing country in Africa. Once CP is implemented, the net return is always almost positive, considering that government subsidies and tax incentives could further strengthen this argument. This chapter further shows that after carrying out a CP audit, companies can choose from various options to implement, some of which can be classified into: profitable no-cost measures, low-cost measures and quick or long payback options. The final option for implementation is usually the one that takes into account the comparative advantages offered by new technologies, cost effectiveness, implementation efficiency and sustainable returns on investments. The chapter finally looks at the nature of the CP training market in Zimbabwe.

1.1.1: Definition of Cleaner Production

Cleaner Production is the continuous application of an integrated environmental management programme that seeks to minimise risks to humans and the environment. It applies to:

- **production processes**: conserving raw materials and energy, eliminating toxic raw materials and reducing the quantity and toxicity of all emissions and wastes;
- **products:** reducing negative impacts along the life cycle of a product, from raw material extraction to its ultimate disposal; and
- **Services:** incorporating environmental concerns into designing and delivering services.

1.2: Why the Cleaner Production strategy?

For manufacturing organisations seeking to adopt a structured and systematic environmental management approach, CP:

- Allows for compliance with legislation.
- Encourages continuous improvement of environmental performance.
- Is consistent with quality management systems.
- Improves overall company competitiveness.

- Allows for partial or complete discontinuation of existing waste treatment facilities and significant reduction in pollution control costs.
- Improves quality of treated waste products such as wastewater.
- Increases efficiency of the production process due to the incorporation of control systems which are necessary for heat and mass balances.

1.3: Environmental Benefits

The following environmental benefits have been achieved through the application of CP technology:

- Significant reduction of the volume of easily decomposable organic substances with the result that there is no significant reduction in dissolved oxygen content of natural water.
- Elimination of the pollution load of slowly decomposing or non-decomposable substances, particularly as a result of preventive measures taken by the paper and pulp industry.
- Decrease in the discharge of nitrogen and phosphorus compounds (nutritive compounds).
- Reduction of heavy metals such as mercury, cadmium, lead, zinc, nickel, copper, etc., discharged into the environment, chiefly due to improved recycling techniques.
- Promotion of economical use of water by industries (Meller, 1985).

The use of recycled wastes as resources in industrial processes and the society at large benefits the environment in the following ways:

- Recovery and re-utilisation of materials means less raw materials need to be mined.
- Use of recycled wastes as resources decreases the necessity of refuse disposal, thus decreasing the influence of refuse on the environment.
- Use of regenerated raw materials, instead of a brand new material in a production system, decreases the quantity of energy required and the quantity of materials discharged to pollute the environment (Clean Japan Centre, 1987).

1.4: Methods to Achieve CP Technology

CP technology is designed to prevent waste emission at the source of generation itself. This can be achieved by process modification, product modification, by-product recovery, substitution of raw materials and process materials which produce little waste. In an open production system, all the residues are emitted directly into the environment. In some cases, the residues can be released as secondary raw materials into the production process. If the waste stream consists of auxiliary materials only, it can be recycled to avoid waste.

The adoption of CP has helped to significantly reduce hazardous waste. Incorporation of valuable by-products recovery in industries like the sugar, brewery, dairy, oil refinery industries, etc., has reduced the pollution load. The use of alternative process chemicals (of comparable costs), which leads to less pollution, is beneficial.

1.4.1: By-product Recovery

From the environmental point of view, by-product recovery is an efficient method of waste reduction and may also lead to an economic gain. But in the past, only a low percentage of by-products were recovered from waste. This approach obviously reduces the waste disposal or pollution problem. There are many examples available with positive results from industries:

- Metal-plating industries recover metals like copper, nickel and chromium from plating solutions by using ion exchangers.
- The recovery of sulphite waste-liquor as a by-product from pulp and paper mills leads to a significant pollution reduction. This by-product is used in the production of road binders, cattle fodder and insulating compounds.
- Slaughterhouses recover waste blood for the manufacture of glue (Nemerow, 1978).

1.4.2: Process chemicals and raw materials recycling

From the point of view of sound management of non-renewable resources, recycling has always made sense. The major advantage of recycling and recovery is that it reduces the need for raw materials and, thereby, leads to a significant resource-saving. The significant reduction that results from recycling of used materials not only provides a cheaper product, but also benefits the environment through smaller energy demands and reduced pollution loads.

1.4.3: Changing of production processes to reduce waste

Changing the production process is an important technique for reducing waste volume and strength. Waste treatment from the source itself should be considered as an integral part of production. It is possible to reduce the volume of waste by:

- Improving process control.
- Improving equipment design.
- Using different or better quality of raw materials.
- Good house-keeping.
- Adopting preventive maintenance.
- Modifying equipment (Rocheleau, R. F. and Taylor, E F. , 1964).

Changes in equipment can lead to reductions in the toxicity of wastes. Slight changes are often made in the existing equipment set-up to reduce the waste such as putting traps at the discharge pipeline in poultry plants to prevent emission of feathers and pieces of fat.

1.4.4: Waste management

Classifying and segregating wastewater can considerably reduce the volume that requires intensive treatment. It may be classified as process wastewater, cooling water, wash water, etc. In some plants, the process water may be further classified into different types, depending on the pollution load of each wastewater. In many plants, it is possible to recycle the cooling/process water several times and treat it at the end of its usefulness.

This reduces the strength and /or the difficulty of treating final waste. It is easier and more economical to treat a small volume of concentrated waste than a large volume of diluted waste. Another type of segregation is the removal of one particular process waste from the other process wastes of an industrial plant which renders the major part of the waste more amenable for treatment.

Accidental discharge of significant process solutions represents one of the most severe pollution hazards. Preventive measures should be considered:

- Make sure that pipelines and valves in the plant are clearly defined.
- Allow only designated and knowledgeable persons to operate these valves.
- Install indicators and warning systems for leaks and spills.
- Provide a detection facility for spilled wastewater by having holding basins or lagoons (until proper waste treatment can be accomplished).
- Establish a regular maintenance programme of all pollution abatement equipment and production equipment which may result in a liquid discharge to the sewer.
- Install a proper storage facility for raw materials, products and by-products.
- Recycle accidental spillages, if any, within the process (Nemerow, 1978).

1.4.5: Raw and process material change

In some industries, change of raw and process materials results in less or no pollution being generated. For example, the substitution of chlorine, which is used for bleaching pulp in the paper industry by hydrogen peroxide or ozone, will reduce the pollution load by eliminating toxic chlorinated organic compounds.

1.4.6: Fresh water management

Better and economic use of water within industries can be achieved through the following ways:

- Regrouping industries in a particular place when combined (fastening and electroplating industries reduce the waste quantity).
- Rationing water use within the industry (each person uses defined quantity of water).
- Re-organising water use in different processes.

- Efficient washing processes (such as counter-current washing, high pressure air rinsing, cascade circuits, etc.).
- Re-use of bath water (i.e. plating bath in metal plating industry).

1.5: Selected unit operations in CP technology options

Cleaner production offers a very wide range of options for coming up with sustainable and environmental friendly and economically viable process operations. For example, the processes listed below are potential CP improvement options (Environmental Sanitation Information Center, 1988)

1.5.1: Suspended solids removal

1.5.1.1: Sedimentation

This process is used to remove suspended solids through gravitational settling. Kinds of sedimentation in use are plain sedimentation (settling without flocculation), sedimentation with prior flocculation and solid contact clarifier (sedimentation and flocculation in one unit) (Weber, 1972). The use of sedimentation is not as common in industrial waste treatment as it is in domestic waste treatment. If the industrial effluent contains a considerable amount of particulate matter, chemical flocs or precipitates, then the use of sedimentation process becomes essential. Some examples of industrial effluent treatment requiring sedimentation are in the cannery, paper, sand and gravel and coal washing industries.

1.5.1.2: Flocculation

The purpose is to destabilise and aggregate small particles to big ones such that they can be easily removed by subsequent solid-liquid separation processes. If industrial effluent contains micron-size particles, flocculation is used to make settleable flocs. Some examples of industrial effluent which require treatment by flocculation and sedimentation are beer, soft drinks and metal plating products.

1.5.1.3: Filtration

This is used for treating industrial effluent with or without pre-treatment by coagulation and sedimentation to remove solids or biological flocs present in the effluent. The structure of the filter for industrial wastewater treatment is almost the same as that used for potable water treatment. Some examples of industries where filtration is used are the steel-making, pulp and paper, beer, soft drinks, plating industry and research laboratories (Fujita, 1988).

1.5.1.4: Flotation

Flotation is used to separate solids or dispersed liquids from the liquid phase. The separation is effected by introducing fine gas or air bubbles into the system. The added fine bubbles either adhere to or are trapped in the particle's structure, thus imparting buoyancy to the particles and bringing them to the surface.

1.5.2: Dissolved solid removal

- **Adsorption**: This is used to remove taste, odour, colour, organic impurities, and non-degradable organic, heavy metals from industrial effluents. This process is commonly used if high effluent quality is required or recycling or re-use of the effluent is possible. In most cases, adsorption is used as a final treatment process following biological treatment. The most commonly used adsorbent is activated carbon, but other materials like peat, wood, charcoal, fly-ash and slag can also be used (De Ranzo, 1981).
- **Membrane processes:** membrane separation processes like reverse osmosis, electrodialysis and ultra-filtration, are found to have an extensive and economical usage in treating industrial wastes (Weber, 1972).
- **Ion exchange:** This is a process of exchanging certain cations and anions in the wastewater with sodium, hydrogen or other ions in the resinous material. In industrial waste treatment, it is used to recover valuable waste materials as by-products, particularly ionic forms of precious metals such as silver, gold and uranium.

1.6: Application in selected industries

There are quite a few industries in Zimbabwe which are in the process of setting up environmental management systems (EMS) or at least establishing some cleaner production activities. It should be noted, however, that most organisations are now quickly joining the CP/EMS bandwagon, albeit for interests like pollution-fee avoidance (such as the new Water Act) and also as a means of securing export markets and green financing. By looking at the industry sectors, it is possible to look at the areas where CP is applicable, as indicated below.

1.6.1: Pulp and paper mill industry

The paper mill uses the pulp as raw material, which is produced from different cellulosic materials like wood, rice straw, bamboo, etc. Various processes such as Kraft sulphate and alkali processes are used for paper-making. The major waste in the process is black liquor which is rich in lignin and unused chemicals. This black liquor waste comes out from leakages, spillage from digester, bleaching waste, brown stock washwater, caustic extraction waste, etc. Other toxic wastes produced from the digester include dimethyl sulphate, and methyl mercaptan. Small quantity of wood knots also comes as solid waste from the screening process.

Waste volume percentage from the digestion section is high in the case of a small mill since the entire quantity of black liquor is wasted. On the other hand, in the case of a large mill, only the leakages and spillage from the digester go as waste. It would be costly to have a waste treatment plant to treat these wastes directly. Therefore, it is cost-effective to adopt some CP techniques such as process materials change, and by-product recovery to reduce the strength and the quantity of waste, which will in turn lower the degree of wastewater treatment (Rao, M. N. & Datta, A. K., 1979).

1.6.2: Sugar industry

Because of the high volumes of wastewater produced in the sugar production, it is prudent to re-use the wastewater produced from the sugar-making process. A complementary CP technology for the sugar industry is by-product recovery, such as molasses can being used for steam-raising, alcohol manufacture, cattle feed and road surfacing.

1.6.3: Selected food industries

With the growing trend of food production and processing, a large quantity of effluent and residues is produced and this can be very damaging to the environment unless proper controls are instituted.

1.6.4: Pine apple industry

Pineapple processing produces 50% residue in terms of weight of original pineapple. This residue can be successfully converted into good quality protein by solid fermentation using fungi (Environmental Sanitation Information Center, 1988).

1.6.5: Cheese production

In cheese production, 90% of the milk is used in the form of lactoserum, which causes a serious pollution problem in the receiving waters if it is disposed without treatment. In most cases, it is either dried or separated into different components. The reduction of significant volumes of lactoserum by using evaporation and membrane processes is essential before its ultimate treatment and disposal.

1.6.6: Poultry processing industry

In the conventional poultry processing plant, excess water is used for transport of feathers, intestines and feet. Instead of using wash waters, one can use mechanical and pneumatic transport, thereby reducing the wastewater quantity (Overcash M.R. , 1986).

1.6.7: Meat packing industry

In the meat-packing industry, hot water is used for meat washing. After washing, the contains a fair amount of grease and oils, if it is allowed to go to a wastewater treatment unit (Overcash M.R. , 1986).

1.6.8: Textile industry (Tanning)

The fibres used in the textile industry may be classified into four types: cotton, wool, regenerated and synthetics. Characteristics of wastes depend on the type of fibre and the production procedures adopted. The entire liquid wastes come from the sizing (slashing), scouring and de-sizing, bleaching, mercerising, dyeing and finishing. The following are some of the suitable ways to reduce the waste load at different steps:

- Substitution of starch or other sizing substances like carboxyl methyl cellulose in the sizing step. This reduces the total bio-chemical oxygen demand (BOD) for a mill by 40-90%.
- In the scouring and de-sizing processes, the natural impurities and sizing compounds are removed using enzymes. This step itself contributes up to 50% of the total waste load, which can be reduced using low BOD detergents.
- During the mercerising process, sodium hydroxide (NaOH) is used to improve the strength, elasticity and dye affinity of cloth (Rao, M. N. & Datta, A. K., 1979).
- Recovery of NaOH using a membrane process like electro dialysis is not only economical but also helps to reduce the pollution problem.

1.6.7: Electroplating industry

The different streams of waste arising in the electroplating industry are:

- **Cleaning solution:** These are spilled out during drag out operation.
- **chromate wastes:** The chromium-bearing wastewater originates from chromium plating, anodising, electroplating solutions like passivating dips, bright dips and small portions which arise from rinsing operations of metals treated with chromate solutions. The main sources of chromium in wastewater are from drag out and washing operations.
- **spent alkaline and rinse waters:** They include all the spent alkaline solutions containing suspended solids, soap, grease and globules of oil. The pH of these wastewaters when discharged intermintently is very high.
- **acid pickling and rinse waters:** Strong spent acid solutions originate from stripping solutions in metal-cleaning vats. They contain mostly ferrous sulphate and residual acids, usually with pH below 2.5.
- **floor washes:** During plating operations, spilling and splashing may occur from baths and wash water, which possibly contain cyanide and other metals, which are used for plating. During floor washing, these pollutants go with the washed water (Environmental Sanitation Information Center, 1988).

1.6.8: Distillery industry

Products from the distillery industry include industrial alcohols, rectified spirit, silent spirit, absolute alcohol and beverage alcohol. All these are obtained by the biochemical process of fermentation with yeast, using carbohydrates as raw materials which contain different proportions of ethyl alcohol. Besides the products, unwanted residue is produced during the preparation of the medium. This contains high BOD, which requires treatment before discharging into the environment.

1.7: Origin and characteristics of waste

Different types of grains, malted barley and molasses are used as raw materials in the beverage alcohol industry. Industries producing industrial alcohol use molasses (black strap type) as raw materials. The spent wash, which has a volume of 10 to 15 times of the final product, is a major pollutant. Other pollutants include yeast, which is deposited at the bottom of the fermentation vats. In addition to these major wastes, floor washes, waste cooling water and waste from yeast or by-product recoveries also contribute to the volume of the wastes produced (Environmental Sanitation Information Center, 1988).

1.7.1: Treatment of wastes

The following methods can be used to treat distillery wastes:

- Anaerobic lagoon followed by aerated lagoon.
- Anaerobic lagoon followed by dilution and agricultural utilisation.
- Methane recovery by anaerobic digestion followed by activated sludge process.
- Potash recovery.
- Concentration to 60 % solids and disposal.
- Anaerobic contact filter or anaerobic activated sludge followed by aerobic treatment (Sastry, 1985).

1.7.2: Cleaner production (waste minimisation assessments)

The approach recommended herein is to arrest pollution in the design stage, e.g. the selection of raw materials that one can use. This approach is the environmentally friendly route in that it arrests pollution at source, rather treating it when the waste has been produced (end of pipe technologies). A thorough CP assessment will document the factories' activities. Such documentation should include:

- Changes in raw materials and processes.
- Changes in projected waste streams and disposal method.
- Technical specifications, claims and limitations on new equipment.
- Documentation of waste disposal such as receipts and manifests a cost-benefit analysis of waste minimization (UNEP, 1985).

1.8: Assessment Procedures

The size and type of business should help determine specific waste assessment procedures. Suggested general steps for assessing waste minimisation include:

- prepare background material for the assessment;
- identify waste streams;
- select waste streams for detailed analysis;
- conduct a detailed site inspection to collect data on selected waste streams and process data;
- develop a series of potential minimisation options;

- develop a series of potential minimisation options;
- evaluate preliminary options (including preliminary cost estimates);
- rank options by effectiveness in reducing waste, extent of current use in industry and potential for use at the facility;
- present preliminary results to plant personnel, along with ranking of options;
- prepare a final report, including recommendations, to plant management;
- develop an implementation plan and schedule; and
- conduct periodic reviews and updates of assessment.

1.9: The training market for CP in Zimbabwe

The training market for CP is rapidly expanding with quite a few companies and individuals offering training in CP. What is lacking is a co-ordinated approach to disseminate the benefits of CP and more demonstrated cases of the CP methodology itself. The list of organisations offering training in the field services is only a guide and is not exhaustive. The key to the abbreviations is given below:

EMS - Environmental Management Systems

TQM - Total Quality Management

EIA - Environmental Impact Assessment

Environmental standards (management, air, water, radioactive waste)

There is currently work being done within the National Pollution Control Project to enhance monitoring guidance and standards and organisations involved are: Cleaner Production Techniques

The CP market is wide and diverse, and as such, it is difficult to give a blanket CP module or course. What would be more beneficial is to look into what is being offered on the market and identify the needs and the gaps that need to be filled in.

Typical CP techniques include:

- waste minimisation
- energy minimisation
- by-product recovery
- process and/or raw material change
- raw material minimisation

1.9.1: Gaps in training

While it is true that CP awareness is generally rising in Zimbabwean industries, it is equally true to say that:

- there is need to close the cynicism gap among top management who merely regard CP as theoretically interesting (something which cannot be achieved practically).

- some factories and organisations seem to bemoan the lack of facilities, but to those who have the facilities, it seems that scepticism is high.
- laws on environmental pollution are not being enforced and, therefore, companies are not in a hurry to have their employees trained in CP.

In developing countries, the normal practice in manufacturing industries is to import technology as part of a turn-key project, thus widening the gap between the country's capabilities of technologies. This is detrimental to the actual local training and R&D efforts and identification of CP technologies. It is crucial to adopt the simultaneous or concurrent engineering approach right from the start. This way, scrap and rework are reduced to a minimum as consumers of products and services are taken into account at the design stage.

- lack of interdisciplinary approach involving co-operation between different engineering, natural and social scientific disciplines. This can been addressed through a concerted effort to link the various departments and institutions offering CP or other environmental management issues.
- lack of a close link between environmental management systems (EMSs) and CP. This is actually unfortunate as the two are complementary. However, this can be explained by not having a holistic approach to problem definition, solution and formulation.
- in some instances, courses offered are beyond the reach of many companies who are suffering from the economic hardships currently facing the country. Training is being regarded as a liability and not as an asset.

1.10: How best can these issues be addressed?

With regards to the development of CP technology and attendant courses in CP, aspects to be considered in the preparation of a possible training module should include:

- terms and goals of CP
- measures for realising the principle of CP
- principles of CP
- raw material selection
- developing technology processes
- developing manufacturing plants
- product development
- waste use
- responsible use of products and resources in terms of materials and energy consumption
- estimation of processes from the aspect of CP as the most efficient form of environmental protection

- establishment of punitive laws for environmental offenders
- audit preparation
- waste assessments
- synthesis
- feasibility studies
- implementation of options

1.11: Conclusion

Though industrial effluents are treated to comply with the imposed effluent standards, industries must be fully aware of the fact that the most effective way towards water, air and soil pollution control is to prevent the pollutants being discharged into the wastewater in the first place. In CP, effluent treatment begins at the production stage itself to prevent pollutants from entering into the waste streams. This not only reduces the pollution problem, but also leads to economic benefits. Ideally, pollution control measures should be effectively integrated into an industry's modernisation process ((Environmental Sanitation Information Center, 1988). In the long term, CP techniques designed to avoid most of the polluting substances at source will be beneficial to industry since they are more efficient and economical. These technologies may be based on:

- technically improving existing processes with the aim of low-pollution generating operations;
- integrating purification measures with production processes (recycling at plant levels);
- new manufacturing processes (concurrent and simultaneous engineering).

By implementing these changes in production technology, the pollution load to the environment can often be reduced to a mere fraction of its original value. Additionally, CP has another advantage over end-of-pipe technology in that it allows better utilisation of energy and raw materials. Environmentally safe raw materials and products can also contribute substantially towards environmental protection. This can be achieved by:

- using environmental safe materials instead of polluting ones; and
- eradicating polluting secondary materials.

On the other hand, it must be recognised that efficient CP technologies often involve intensive research and development efforts requiring considerable investments of money and time, often at some degree of market risk. Thus, considering competitive position of an industry, it may seem to be quite formidable to implement CPs which are technically feasible by all industries. This may imply that the development and implementation of CPs depends on a healthy economy (Meller, 1985).

CHAPTER 2

Demonstration of the Cleaner Production Methodology

Kumbi Mugwindiri, Tawanda Mushiri and Albert Chisadza

2.1: Introduction

Many organisations have been frightened by the seeming threat and distance posed by relatively new concepts such as Cleaner Production (CP) (World Commission). This chapter seeks to demystify that perceived threat by using a very simple, basic and logical approach to CP, in the hope that others will be encouraged to study and hopefully implement the concept. By using the classic United Nations Environmental Programme (UNEP) peanut factory, this chapter looks at the theory surrounding the concept of CP, going through the various stages from pre-assessment, focussing on the assessment phase up to option generation and implementation and continuation, and seeks as much as possible to proffer possible examples.

2.2: Planning and Organisation

From the broader cooperation planning process and agreement, CP objectives are established. Also the process must:

- plan for CP in a way which allows for investment analysis.
- document the CP plan properly.
- select and implement the most viable and effective CP plan.

2.3: Management Commitment

Without top management commitment, the CP implementation will fail. For it to work, top management has to be committed to it, otherwise instructions to subordinates will be contrary to the CP plans (Chandak, S. P. , 1999). Unfortunately, managers generally do not commit themselves to policies and strategies that are not of economic benefit: there is need for managers to fully appreciate the, economic and social benefits that CP would bring. This needs to be laid down in clear facts and figures.

2.4: Project Team

There is need to establish a CP champion, who should be enthusiastic about CP. After the champion, there is a need to come up with a project team. This team should represent the entire factory, from the bag dump to packaging, and to include management and administration. The team also needs to show some enthusiasm in CP, and also, they need to have enough process knowledge and understanding. It is preferable if they are well read in other similar processes elsewhere, so that they can come up with alternatives. Innovation would be a major positive for the team. This team should not suffer from an authority gap lacking the authority to implement.

2.5: Developing an Environmental Policy

The policy should be flexible and allow for continuous improvement. It is a guideline for assessment and directs the channelling of resources to where they are most appropriate.

An example of the peanut making plant was explained in great detail.

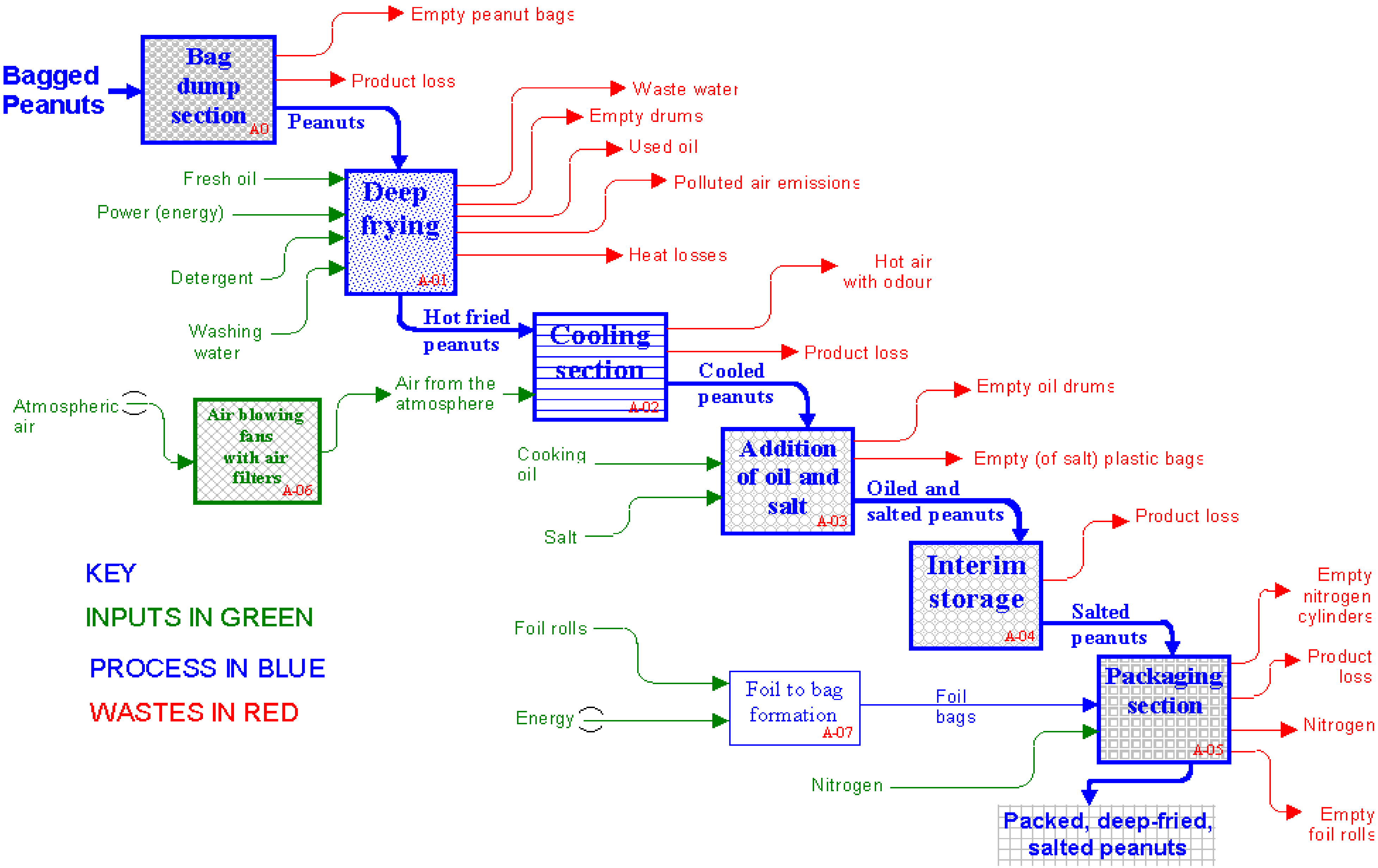


Figure 2.1: A process flow diagram for the factory, for a CP assessment.

2.6: Environment Policy for the Peanut Factory

The company should be dedicated to good and efficient operation of the factory processes and shall do better than just comply with environmental legislation. Continuous improvement shall be a guiding ethos. The company shall gain competitive advantage, not only from a green image, but also from the increased efficiency that results from cleaner production (UNEP/UNIDO, 1991). The company shall endeavour to protect the environment from its processes that have potential to damage the environment. It shall be fully committed to its environmental policy.

2.6.1: Environmental Objectives for the Peanut Factory

- Sustain the competitive profitability of the company without compromising the environment.
- Commitment to efficient use of energy and water.
- Maintain a clean and safe factory working environment, to maximise worker morale and minimise accidents. Make a habit of good house-keeping.
- Eliminate all toxic substances from the process.
- Minimise on the use of non-biodegradable materials that end up in waste streams.
- Identify areas where environmental and other legislation is being breached, even without getting caught, and put things right, for the sake of the environment.
- Conscientise the entire workforce on the cleaner production process in a way that leads to understanding and appreciation.
- Lessen waste streams on a continuous basis and eliminate where possible.

2.6.2: Pre-assessment questions

- Is the size of the raw material inventory appropriate to ensure that material-handling losses can be minimised? This needs to be considered at the bag dump.
- Transfer distances between storage and process or between unit operations - could these be reduced to minimise potential wastage? This could be leakage, dropping off of conveyers, etc. But in general, energy and wear and tear are greater with distance. Distances should be minimised. This agrees with other modern manufacturing concepts such as cellular manufacturing, which seeks to reduce the movement distance of products and materials.
- Is it possible to substitute harmful substances with less harmful one such as plastics, which are non-biodegradable, being substituted with recyclable and biodegradable ones?
- Is it possible to reduce the use of water and cleaning materials? Separation of raw materials will help in this regard and the use of newer and more efficient water jet technologies, such as a lance, instead of flooding in cleaning.
- Do the same tanks store different raw materials, depending on the batch product? Is there a risk of cross-contamination? Labelling of the tanks and the raw materials and training will assist in this regard.

- Are sacks of materials fully emptied or is some material wasted? Tipping technology could be such that the sack ends up in a vertical orientation which ensures that all material is emptied.

There are many other pre-assessment questions and the above listing is given as a guide to systematic tackling of those questions.

2.6.3: Possible Environmental Targets for the Peanut Factory

- Eliminate all legal liability and possible liability due to waste emissions.
- Aim for no accidents in the factory.
- Reduce oil losses by 20% in the next 12 months for example.
- Reduce the use of water by metering and notifying the relevant superintendents of water usage on a two weekly basis.
- Do an energy audit. Meter departmental electricity and gas consumption and make information available, "if you can't measure it, you can't manage it".

2.6.4: Material and Energy Balance

Material and energy balance is a very important source of information in data collection. It helps to identify *where*, *why* and *how much* of raw materials and other input mass are converted to final products, how much of the input mass is transformed to waste and how much energy is lost. Mass and energy balance should answer the following important questions:

- Where are pollutants generated?
- Where do energy losses occur?
- What are the causes *of* pollution and energy losses?

The simplest process flowchart characterises mass input and mass output from a unit industrial operation and demonstrates that each unit operation needs to be evaluated separately.

This is done for the peanut factory as shown below.

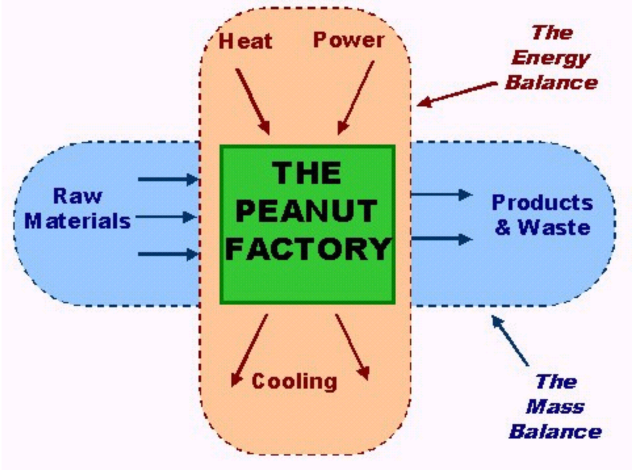


Figure 2.2 Inputs and Outputs for the Peanut Factory

The parent process flow chart for the peanut factory shows the inputs and output for the process. These are then used for the material and energy balance. This is shown in Figure 2.3.

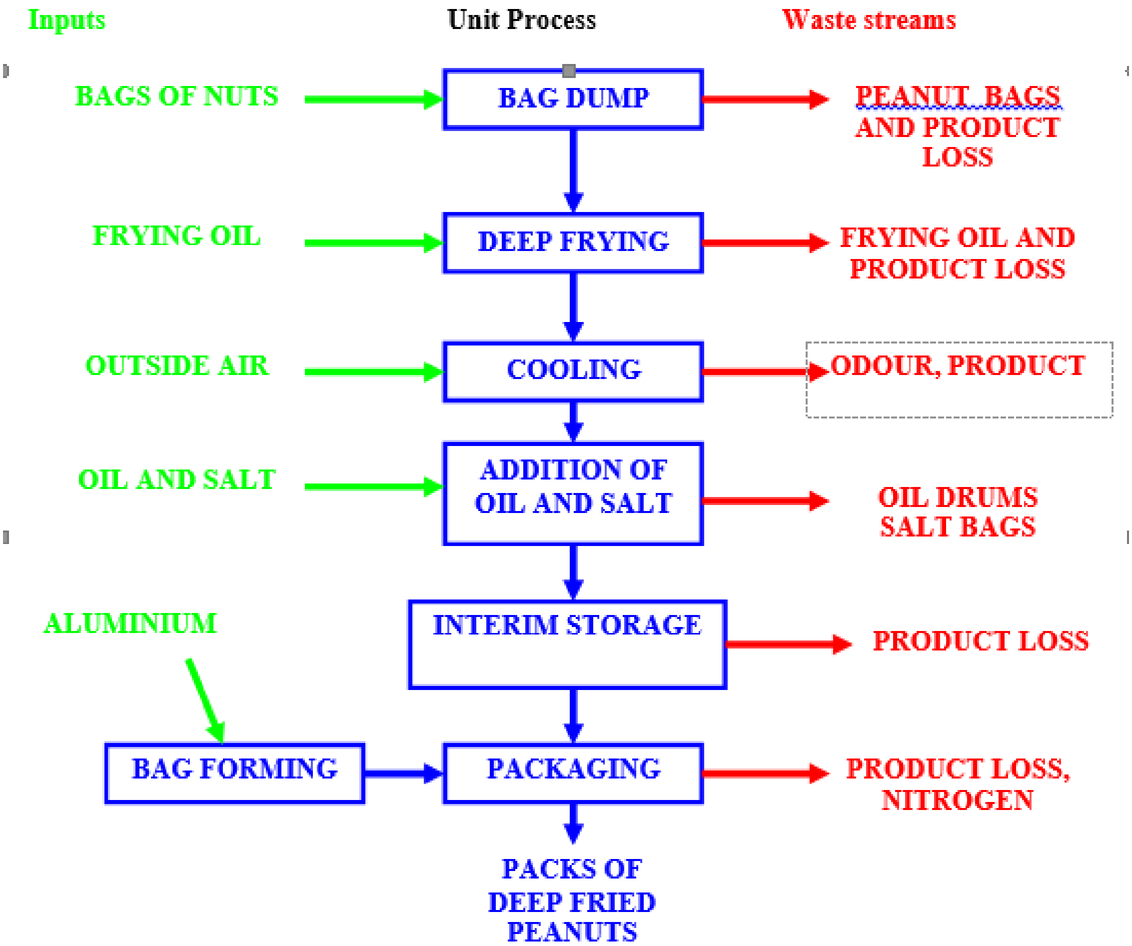


Figure 2.3 Unit Operations Chart

Importance of the material and energy balance:

- The material and energy balances are not only used to identify the inputs and outputs of mass and energy, but their economic significance is also related to costs, such as cost of:

- raw material in waste: this emanating from product loss at the bag dump.
- final product in waste: this emanating from the product loss towards the end of the process.
- energy losses: the peanuts have been heated during the deep-frying, they still need to be cooled.
- handling waste: transportation of waste to the bins and waiting areas.
- transporting waste: to the dump sites.
- solid wastes disposal: local authority charges for management of landfills.

Economic costs of waste can often be significant. Generally, “production of waste” is too expensive.

Listed below are, **sources of information** for a mass balance, but it will be necessary to get the input of managers and employees who are familiar with the processes:

- Existing flow measurements and analyses of raw materials, products and discharges/emissions/waste streams;

- Raw material purchase records: the rate at which bags of peanuts are delivered to the factory.
- Material inventories: the movement of inventory, the inventory levels etc.
- Product specifications: e.g the proportion of salt in the nuts.
- Waste manifests: mass and energy balances have their limitations and are only one tool to be used in the review process.

Cause diagnosis: The next step is to evaluate all material flows. It is desirable to try to quantify the volume and composition of all material flows, which could result in a mass balance for all individual unit operations or for the entire company (Berkel, R.V., 1993).
The principle of conservation of mass is used to come up with a material balance.

Mass of Inputs = Mass of Outputs + Mass of Accumulation within the Process.

Inputs are raw and other materials required for processing. Materials required for maintenance, including cleaning, are also included.

Outputs are the desired product, by-products of the process and wastes.

Accumulation is rare, but sometimes occurs. In our case, there is no long-term accumulation.

For input and output evaluation, the material balance shown in Table 2.2 is split into individual processes.

The outputs and waste streams are given a pollution rating shown in Table 2.1.

Rank	**Description**
9	Toxic/ Poisonous to humans, flora, fauna
7	Affects health, harmful and costly to eliminate
5	Costly to eliminate and undesirable
3	Undesirable and unpleasant, but easy to eliminate
1	Desirable but costly
0	Desirable and harmless and cost-free

Table 2.1 Pollution rating for the peanut factory

Inputs	Process	Outputs		Pollution rating
Bagged peanuts	Bag dump	Peanuts Loss of product Empty bags	Product is lost on emptying bag onto conveyor. Empty bags are a waste.	1 7
Fresh oil	Deep-frying	Absorbed oil in peanuts Oil traces in container Spillage Used oil oil in residue	Oil lost as a waste, the used oil. Oil decomposes with time, much faster in the process.	7 7
Peanuts		Product losses Accumulated residue Good product	Breakage is due to movement and agitation.	1
Energy		Air carries away heat Process absorbs heat	Energy is lost on heating peanuts first, then spending more energy cooling them.	3
Outside air	Cooling	Air	The air leaves with most of the heat energy into the atmosphere.	3
Salt	Salting & oiling	Empty plastic packs Salt losses Salt absorbed in oil and peanuts	Salt packs are a waste.	5
Oil		Traces of oil in drums Oil absorbed in nuts Empty drums	The empty oil drums are a waste.	5
Peanuts	Interim Storage	Peanuts to stage Product loss	Space wastage, Tied up capital, stored product is inventory.	3
Nitrogen	Packaging	Nitrogen containers	The nitrogen goes into the atmosphere & the bottles are returned to the supplier. Waste in only in non-value adding material movement.	3
Packaging foil		Used foil on packaged peanuts Foil off-cuts	Customer will throw the foil away. Empty foil roll are a waste.	5
Peanuts		Packed fried nuts product loss	Product loss is due to handling.	3

Water	Cleaning	Spillage waste vaporised water	Vaporisation of water, Waste water to be disposed.	3 7
Energy		Energy absorbed by equipment Energy absorbed by water Other losses to environment	Energy absorbed by the water during washing.	3

Table 2.2 Waste and Emissions Ranking

2.6.5: Focus of the Audit

Waste and emissions with a ranking of 5 and upwards are pollutants that will be targeted for cleaner production solutions, even though it helps to consider everything. Those processes that are harmless to the environment, but can be improved, are also to be considered.

Inputs	Processes	Output	Rank
Bagged peanuts	De-bagging	empty plastic bags	5
Fresh oil	Deep-frying	used oil	7
Raw peanuts	Deep-frying	gases	5
Hot water & detergent	cleaning frying oven	wastewater	7
Seasoning salt	adding salt	empty salt bags	5
Seasoning oil	adding seasoning oil	empty oil drums	5

Table 2.3 Peanut Factory Targeted Areas

2.6.6: The CP Options solution generation, screening options

1. Bag Dump

Peanuts should not be delivered in bags; they could be delivered in large re-usable containers. These containers can be coupled directly to a peanut feeding mechanism that feeds the peanuts directly onto the conveyor without losses.

2. Deep frying

The heat used to deep-fry should partially be obtained from a heat pump that pumps heat from the cooling section. The oil should be filtered faster. Also, the bottom oil contains delicious fried peanut residue. Before it deteriorates this oil with residue, should be sent to seasoning, to be used for oiling the nuts. This gives the peanuts a good flavour.

The correct frying conditions should result in a more efficient process, instead of dwelling too much on the actual nitty gritis, and waiting time and energy.

Insulation will prevent heat losses.

3. Cooling

There will be less need for atmospheric air if the heat pump mentioned before is used.

4. Seasoning

Salt should not be supplied in plastic bags; it should be supplied in re-usable containers that are sent back to the supplier. This will also reduce the costs. The containers should be able to couple directly to the salting process.

5. Interim Storage

The need for this should be reduced; this is a waste of space, also inventory management costs.

6. Packaging

Empty nitrogen containers should be sent back to the supplier periodically.

No leakage of nitrogen must be permitted. There are to be no off-cuts of foil, if there are any, the packaging process should be changed.

Here each option is analyzed in depth to check on feasibility. All options that require no capital input should be implemented immediately.

SECTION	**WASTE**	**CP OPTIONS**	**EXPECTED FEASIBILITY**			**RECOMMENDATIONS**
			Technical	**Economic**	**Environmental**	
BAG DUMP	Plastic bags	Re-useable bags or containers.	Highly feasible	Eliminates plastic disposal costs.	No plastic bags disposed of.	Implement
DEEP -FRYING	Used oil	Determination of optimum parameters, Conveyor speed monitoring and control. Regular removal of broken peanuts to minimise oil degeneration rate. Product change-use of peanuts that do not crumble easily.	Feasible	High investment but high ROI, IRR, low payback.	Reduction in oil usage & change periods.	Implement
COOLING	Energy losses	Use the heat for water-heating purposes.	Feasible & practical	Needs investment; expected IRR & ROI low	Savings in energy.	Implement
SEASONING	Oil drums	Oil delivered into tanks. Sell existing empty drums to public.	Feasible	Eliminates handling & disposal costs of drums.	Eliminates littering and improves space usage.	Implement
SEASONING	Salt packs	Large re-useable bags or containers.	Highly feasible	Packaging costs.	Eliminates littering. Improves good house-keeping.	Implement
PACKAGING	Nitrogen	Metering optimum quantities.	Feasible	Low investment- high returns	Little to no effect.	Implement
PACKAGING	Foil off-cuts	Process control.	Feasible - training	Feasible	Eliminates littering.	Implement
OVEN - CLEANING	Wastewater	Less detergent & higher wash water temp.	Feasible	Low cost	Less detergent released into the environment	Implement

Table 2.4 Feasible Cleaner Production Options

2.6.7: Implementation and continuation

This last stage of the CP assessment is to ensure that the selected options are implemented. The utilisation of resources resulting and the wastes generated are monitored continuously.

UNIT OPERATION	WASTE	CP SOLUTIONS	BUDGET	RESPONSIBLY	START DATE
BAG DUMP	Plastic bags	Re-useable bags	None	Supplier and Purchasing Dept.	Immediate
DEEP-FRYING	Used oil	1. Determination of optimum parameters, conveyor speed monitoring and control. 2. Regular removal of broken peanuts to minimise oil degeneration rate. 3. Product change-use of peanuts that do not crumble easily.	1. None 2. Minimal 3. None	1.Production Manager 2.Operator 3. Purchasing	Immediate Immediate Immediate
COOLING	Energy losses	Use the heat for water-heating purposes.	Minimal	Plant Engineer	
SEASONING	Oil drums	1.Oil delivered into tanks. 2. Sell existing empty drums to public.	1. None 2. None	1.Supllier 2. Stores	Immediate Immediate
SEASONING	Salt packs	Large Re-useable bags.	1. None	Supplier	Immediate
PACKAGING	Nitrogen	Metering optimum quantities.	Moderate	Plant Engineer/Production Mgr.	
PACKAGING	Foil off-cuts	Process control.	1. Moderate	Production Mgr.	
OVEN - CLEANING	Wastewater	Less detergent & higher temperature of wash water.	None	Operator	Immediate

Table 2.5 Feasible CP options to be implemented.

2.7: Conclusion

This analysis has demonstrated the application of simple and readily implementable solutions to the classic UNEP peanut factory in a step-by-step fashion. Each solution will have to be weighed against the pertinent and unique constraints of each company before it can be adopted for implementation.

CHAPTER 3

Cleaner Production at Sweetsugar

Kumbi Mugwindiri, Tawanda Mushiri and Stanford Nyamuzihwa

3.1: Introduction

It is the purpose of this chapter to ultimately assist tertiary institution students to understand the Cleaner Production (CP) concept by developing the core of a training module or course starting from a case in which a case study company is extensively described and studied with a view to exemplify the stages of CP. Students are encouraged to carry out the group exercises herein indicated in each of the CP stages.

Within CP, the objective of the initial plant survey is usually to assess the factory's physical and operational conditions for obvious waste reduction opportunities, quick assessment of the situation followed by corrective action which often brings considerable savings with minimum capital outlay (Joseph, T. and Raymond, A., 1988).

3.2: Company description

Sweetsugar Ltd. Zimbabwe, is situated in the Zimbabwean low-veld, where the estate spans over 80 000 hectares with about 16% under cane and has, at times, more than 9 000 employees during the on-crop period. Sweetsugar is also engaged in ethanol production, animal feed manufacturing, cotton ginning and cattle ranching. Rail and road are used to ferry harvested cane from the fields to the sugar factory where it is processed into sugar (raw, sun-sweet, white). The process gives off bagasse, molasses, filter cake and Sweetsugar has put the environment at the centre of its strategic vision. It has formulated an Environmental Mission Statement and is keen to have in place an effective environmental management system. The following is an outline of the company profile:

It is estimated that the annual turnover is about 3 billion Zimbabwean dollars as at 30 September 1999. Sweetsugar's demographic details are shown below:

Permanent	**Contract**	**Total**
5 635	**3 180**	**8 815**

Table 3.1: Employment Statistics as at September 1999

Agricultural Division	236
Operations Division	46
Finance Division	16
Health & Community Affairs	14

Managing Director’s Division	22
Human Resources Division	1
Commercial Division	2
Total	**337**

Table 3.2: No of Volunteers Willing to be Trained in CP Broken Down per Division

All executive management, totalling 23 people, and some other 720 employees, have done some training in Environmental Management.

Details	Unit(s)	Totals)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Sugarcane	**t**	**2441453**	0	0	110584	363056	269410	273880	333473	234027	268822	315617	203762	68822
Main Product														
Raw Sugar	**t**	**214863**	0	0	7253	32670	25446	29779	35872	25071	22137	24689	10404	1542
Sunsweet	**t**	**77780**	0	0	0	5781	5589	4379	5402	5372	13611	16888	13984	6774
White Sugar	**t**	**34051**	0	0	0	2337	3681	3887	6582	3632	5170	6957	1805	0
Total	**t**	**325042**	0	0	7253	42224	35012	40896	45294	35405	42837	43418	24388	8316
By-products														
Ethanol	**t**	**2.7E+07**	2110485	1299267	998328	347512	5662660	1114555	3855886	2274383	1362155	3179114	2384060	1927015
Bagasse	**t**	**366218**	0	0	16588	54458	40412	41082	50021	35104	40323	47343	30564	10323
Molasses	**t**	**99977**	0	0	2805	18621	11469	11368	12643	7977	9501	12965	8013	4615
Filter Cake	**t**	**36621.8**	0	0	1659	5446	4041	4108	5002	3510	4032	4734	3056	1032
Stillage	**m^3**	**328643**	25494	15955	11615	40623	30191	12198	42747	28997	25045	44168	27581	24031
Aldehydes	**t**	**309291**	37390	16027	17289	65939	29382	7246	29020	25674	17903	27134	14313	21974
Fusel Oil	**t**	**86794**	238	10796	432	4383	2769	1323	19891	7668	4581	18681	8076	7956

Table 3.3: Sweetsugar Limited Production Figures 1998

Details	Unit(s)	Totals)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Peak Demand	**kVa**		13470	14414	14814	8670	2526	0	58	0	4256	2632	5488	8860
Month Peak Demand Charge	**$**	**10079149**	1727662	1848739	1900044	1112014	323985	0	7439	0	545875	405091	844658	1363643
Peak Energy	**kWh**	**11938234**	2270098	2290924	2570548	1506354	442160	163436	4260	57268	378520	339546	859968	1055152
Month Peak Energy Charge	**$**	**3147365**	529387	534243	599452	351282	103112	187951	993	65858	88271	150965	240619	295232
Off-Peak Energy	**kWh**	**8741170**	2885166	2400538	296888	416666	536444	78390	4826	38182	313456	472156	105232	1193226
Off-Peak Energy Charge	**$**	**2604305**	504616	419858	519259	306541	93824	90142	844	43909	54823	99106	220926	250458
Total ZESA Charge	**$**	**16595545**	2892482	2935601	3163088	1854553	546018	291218	10239	125184	721993	686696	1368448	2000026
Equivalent Energy	**GJ**	**74447**	18559	16889	10323	6923	3523	871	33	344	2491	2922	3475	8094
Total ZESA Charge	**$**	**16595545**	2892482	2935601	3163088	1854553	546018	291218	10239	125184	721993	686696	1368448	2000026
Mill & Factory Energy	**MWh**	**52968**	305	77	2538	7750	6097	5786	5971	5913	5944	5793	4844	1950
Equivalent Energy	**GJ**	**190685**	1099	279	9137	27901	21949	20831	21494	21285	21399	20856	17437	7018
Ethanol Consumption	**MWh**	**2059**	143	252	214	303	237	97	118	115	129	197	157	96
Equivalent Energy	**GJ**	**7414**	515	907	770	1093	855	351	425	415	465	708	565	346
Coal Consumption	**t**	**10441**	1088	259	958	2396	2676	652	745	389	265	371	393	249
Equivalent Energy	**GJ**	**84978850**	14293445	14424574	16185198	9484607	2784016	5074688	26823	1778171	2383313	4076050	6496713	7971251
Total Costs	**Z$**	**5220655**	544210	129335	479205	1198135	1337790	326185	372295	194510	132515	185500	196305	124670
Bagasse Consumption	**t**	**391169**	5291	3625	14308	47098	34916	40086	52155	37870	53086	44581	37778	20375
Equivalent Energy	**GJ**	**79563**	8294	1971	7303	18260	20388	4971	5674	2964	2020	2827	2992	1900
Total Costs	**Z$**	**0**	0	0	0	0	0	0	0	0	0	0	0	0
Total Energy Costs	**Z$**	**21816200**	3436692	3064936	3642293	3052688	1883808	617403	382534	319694	854508	872196	1564753	2124696

Table 3.4 : Sweetsugar Limited Energy Consumption 1998

The total energy is high, but constant during the on-crop, as opposed to the off-crop where energy demand is low. This can be explained by the fact that the plant will not be operating during the off-crop and irrigation demand is low since the off-crop coincides with the rainy season. The power station provides the bulk of the energy during the on-crop.

Details	Unit(s)	Totals)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Total Energy (Equiv)	**GJ**	**85132859**	14320298	14443434	16202824	9509790	2807927	5080530	32529	1781480	2387824	4081799	6503180	7981245
Specific Consumption														
Electricity per ton of Sugar	**GJ/t**		-	-	1.26	0.66	0.63	0.51	0.47	0.6	0.5	0.48	0.71	0.84
Electricity per ton of Ethanol	**MJ/t**		0.24	0.7	0.77	3.14	0.15	0.31	0.11	0.18	0.34	0.22	0.24	0.18
Sugarcane per ton of Sugar	**t/t**		-	-	15.247	8.598	7.695	6.697	7.362	6.61	6.275	7.269	8.355	8.276
Water Usage														
Consumption	**mega litres**	**2986**	215.7	292	303	220.4	251.3	276.7	304.7	394.6	308.6	230.1	57.1	131.9
Total Costs	**Z$**	**442186**	21570	29200	30300	36586	41716	45932	50580	65504	51228	38197	9479	21895

Table 3.5: Sweetsugar Limited CP Performance Indices (Intensities) 1998

The water consumed by the sugar factory cannot be determined without making a lot of assumptions that would invalidate the figures. From the figures for 1998, one can say that when one mega-litre of water was consumed, 2 986 tonnes sugar, 8 880 tonnes ethanol and 41 MWH were produced. Ingenio San Francisco Ameca, a Mexican sugar producer, was using 6.7 m^3 of water per tonne of sugar produced at the end of 1990.

3.3: Cleaner production case for tertiary institutions

3.3.1: Overall learning objectives

- Understand CP methodology and how to use it.
- Understand roles of various stakeholders in CP activities.
- Build capacity to perform CP assessment.

3.3.2: Problem statement

There is a need to understand how CP methodology can be used in real life situations to generate options of solving pollution problems in companies. Engineering students need to understand CP procedure methodology/stages. The case study in the sugar industry is intended to reinforce the theory of CP and its application in real industrial practices.

3.3.3: Outline of case situation

3.3.3.1: Planning and organisation

Sweetsugar is a company committed to a programme of ongoing development and improving sugar production. Its operations can be sustained through a healthy management of the environment. Sweetsugar seeks to:

- Maintain the storage capacity of dams through improved land use practices near water sources.
- Control quality on application of re-cycled water without damage to soils and controlled entry of water and other substances into streams as approved by the Water Act.
- Encourage responsible use and disposal of chemicals.
- Address firewood issue through proper veldt management and alternative sources of domestic energy.
- Control the release of gases into the air.
- Promote responsible practices by all employees, their families and surrounding communities through education.

3.3.3.2: Stakeholders

Stakeholders include both internal and external players (Beverley, T., 1999). These include:

- Management
- Employees
- Shareholders
- Labour representatives
- Government

- Community-based and non-governmental organisations.

Group Exercise:

Students role-play for management commitment/buy-in and setting up a CP team

3.3.4: Background - Description of the Sugar Process

3.3.4.1: Receiving and Conveying

The receiving process starts with the weighing of the sugarcane as it arrives from the estates. Sugarcane from the field comes to the weighbridge for the purposes of payment to the farmer. The farmer is paid on the basis of the sucrose content of the cane as analyzed in the laboratory. The weighing helps in control and mass balancing to identify loss areas during processing.

After weighing, the cane goes to the feeder tables, from where it either joins the 66-inch line or the diffuser line.

3.3.4.2: Extraction

For extraction purposes, there are two lines, the 66-inch line and the diffuser line. For the diffuser line, the cane is delivered from the tables by Conveyors 300 and 301. The diffuser line extracts the juice from the cane through unbroken cell walls. Large quantities of water (imbibition water) are added to the sugarcane bed to wash the sucrose out of the shredded cells. Lime is added to control the pH of shredded cane to between 5.5 to 6.0.

The juice, which drains from the shredded cane, is pumped to juice tanks where it is weighed and stored in juice tanks, ready for further processing. The fibre leaving the diffuser is saturated and has to be de-watered before it can be re-used.

The 66-inch line uses a different mechanism for extracting juice from the sugarcane. From the tables, the cane is conveyed to the primary knives where the cane is cut into shorter sections. The secondary knives further reduce the size of the cane before it can be passed on to the shredder. After shredding, the cane goes into the mills where it is pressed and juice from the first mill is collected. The fibre goes into the second mill where it is flowing counter to the imbibition water that is added from the last mill (sixth mill). The juice thus collected flows into the juice tank, and the fibre is collected out of mill six and passed on to the de-watering mills. The juice from this line is filtered and weighed before it joins the juice from the diffuser line in the mixed juice tanks.

3.3.4.3: Concentration

Sugar can only be made from the juices if the sucrose in the juice is concentrated enough to yield crystals. The concentration of the juice starts with the heating of the juice in the mixed juice heaters. The juice is heated up to 102°C. The heating helps to flush-off non-condensable gases. Lime and coagulants (Calcium hydroxide) are added to assist in the clarification process. Clarifiers allow the settling of the mud. The mud is pumped out and filtered. The filtrate is pumped back to the mixed juice tank. The mud residue, which contains phosphates, can be used as fertilizer. The juice goes through a series of evaporators (clear juice heaters) where it is heated up to 115°C before going to the separators. After the separators, the resulting raw syrup is sent to the pans.

3.3.4.4: Crystallisation

During the crystallisation process, seed crystals are fed into the continuous pans and massecuite discharges continuously into crystallisers where sugar crystals grow. It is left for about 24 hours. After this process, the mixture is sent to the centrifugals where the molasses and sugar are separated. At this stage, one gets A sugar and A molasses. The A sugar goes to the driers and the A molasses goes to B pans. The process is repeated two more times with sugar generated at the B and C processes re-melted and joining the process line. B molasses is used to generate C sugar and C molasses goes to the ethanol plant.

3.4: Pre-assessment phase

3.4.1: Objectives of Pre-Assessment Phase

These are mainly to:

- **a.** carry out a factory walk-through
- **b.** data collection and to select focus areas
- **c.** identify process inputs and outputs
- **d.** draw process flow diagram

Group Exercise:

At this point, students are required to draw a process flow diagram by carrying out a factory walk-through, use checklists, set criteria for selection of focus areas and process inputs and outputs. Identify no/low cost option, which can be implemented.

3.4.2: Assessment phase

Objectives of Assessment Phase are to come up with data required to do the following:

1. Derive material balance.
2. Generate CP options.
3. Identify sources and causes of the problem.
4. Prioritise CP options.

Group Exercise

At this stage, students are required to derive material balance by referring to CP data for unit operations.

3.5: Feasibility Study

3.5.1: Objectives of Feasibility Study

An evaluation of CP options derived from the Assessment Phase leads to an:

1. Economic evaluation.
2. Environmental evaluation.
3. Technical evaluation – availability and suitability.
4. Summary and recommendations leading to implementation.

Group Exercise

At this stage, students are required to use data to establish environmental and economic benefits and technical viability of the options arrived at.

3.5.2: Implementation

Objectives of Implementation include:

1. Identifying opportunities and constraints to implementation of options.
2. Preparing the CP implementation project plan.

Group Exercise

At this stage, students are required to prepare a CP project plan for presentation to management for financing.

3.6: Conclusion

From the description of Sweetsugar's process, it is expected that students will be able to carry out a pre-assessment of the company's operations. This will then lead to the assessment phase which is described in the next chapter. A Cleaner Production Pre-assessment report is usually then submitted to management, highlighting areas of focus for the full CP assessment, which would the be addressed in a full CP report (Noyes, R. , 1997).

Chapter 4

Cleaner Production at Sweetsugar – Analysis

Kumbi Mugwindiri, Tawanda Mushiri and Stanford Nyamuzihwa

4.1: Introduction

Within Cleaner Production (CP), raw data accuracy is of great importance as wrong conclusions can be derived from inaccurate data. Collected data will not be useful in its raw form. It is of paramount importance to synthesise the data, thus extracting important information. In this section, the data gathering was done in two phases: Pre-Assessment followed by the CP Assessment. Quick assessment of the situation followed by corrective action, often brings considerable savings with minimum capital outlay. The assessments point out operational procedures and systems that require more thorough analysis to properly identify the money saving opportunities

4.2: General Pre-assessment Observations

At the time of the pre-assessment, there were a number of pollution problems, typical in the in the sugar industry. The observed problems include:

- Cane and crushed cane fall-offs from the conveyors.
- Juice, steam and syrup leakage.
- Sugar and bagasse dust.
- Sugar spillages from the conveyors.
- Noise in the power plant.
- Wastewater disposal problems.

It was also observed that all the main by-products were being used. Areas of potential improvement, such as fresh and wastewater management, energy management and operating practices, were favoured areas of focus during the assessment phase. Several other CP related observations were made with regards to operational, housekeeping, maintenance and raw material usage issues.

4.3: CP and Waste Reduction Opportunities

4.3.1: Water and Wastewater Management

The sugar production process generates a lot of water from the sugarcane (Green H and Kramer A, 1979). However, most of the water used in the factory is abstracted from the local river catchment area, notably the Vesa River. In the factory itself, most of the water is used in the following areas:

- Boiler section for steam raising
- Cooling towers
- Process waters
- Wash waters

A large volume of wastewater is discharged into the local river and lagoon. The pollution load in the wastewater generated from the factory mainly comprises oils, sugars, suspended bagasse and the treatment chemicals such as lime (Sugar Research Institute, 1996). The purpose and the volumes of water used in these areas necessitate the need for an effective management of water in the plant.

4.4.: Energy Management

Sweetsugar Ltd's power demand is 21MW on average. Its power station can sustain this power requirement during the on-crop period with the power utility, the Zimbabwe electricity Supply Authory (ZESA), taking over during the off-crop.

The energy distribution system in the company is closely related to the complex sugar production process. An energy audit carried out by the Department of Mechanical Engineering, University of Zimbabwe in 1998 revealed that there is considerable potential for energy conservation at Sweetsugar Ltd by implementing an effective energy management programme. ZESA's power and coal bills were found to be too high for a company that generates its own electricity. Efficient utilisation of bagasse could see Sweetsugar Ltd. being self-sufficient in terms of energy.

4.5: Factory Energy Design Attributes

The sugar factory has the capacity for efficient energy usage. The major design attributes in this respect are:

- The exhaust from the turbines is used as process steam, thus maximising steam energy usage.
- Three drying mills and two feed-water pumps are steam-driven, hence avoiding double transformation and transmission of energy required by electric drive. Energy savings of about 20% are realised by using these drives.
- Bagasse, a by-product of sugarcane processing, is a true green fuel as some of the carbon dioxide released in its burning is absorbed in growing the cane.

4.6: Recommended CP Focus Areas

The CP assessment could focus on the areas of fresh and wastewater management, energy management and operating practices.

4.6.1: Water Usage

Due to the fact that most of Sweetsugar Ltd.'s water is drawn from their own dams, there seems to be no effective water management system. The main areas for improvement would be the cooling towers and in the boiler sections by reducing the amount of water lost. Another area for improvement is the reduction cleaning processes water in the factory (Helmer R and Hapanhol I, , 1997).

4.6.2: Waste Water

The main sources of water pollution at Sweetsugar Ltd. seem to be the discharge into the drainage system of sugar rich liqueurs. However, a number of steps can be taken to reduce the wastewater and, thus, pollution.

4.6.3: Energy Management

It would be necessary for further research to be carried out to address monitoring and energy conservation measures related to the following:

1. Economic viability of power factor correction.
2. Meters to be checked and calibrated regularly.
3. Steam pipes should be inspected for steam leaks and effective insulation and maintenance carried out regularly.
4. Bagasse should be temporarily stored to reduce moisture and increase combustion efficiency and boiler efficiency.

4.6.4: Operating Practices

This aspect needs further review especially in the management of the boiler house and steam distribution systems. Most of the issues deal with training and awareness. Spillage of bagasse, raw and dry sugar need to be reduced. This area would need to be addressed, as substantial savings can made from efficient conveying and storage.

4.6.5: Cleaner Production Assessment

The Cleaner Production Assessment was aimed at identifying the various environmental impacts associated with the production of sugar and the by-products from Sweetsugar Ltd.’s operation. This resulted in the identification of a number of recommendations that can be adopted and should result in a proactive, preventive approach for addressing the environmental concerns and also resulting in reducing production costs. The environmental concerns at Sweetsugar Ltd. relate mainly to energy and water usage. There is real and huge potential for significant improvements in energy and water usage at the plant. Of importance is that Sweetsugar Ltd. produces electricity for the plant and its entire community

4.6.6: Unit Operations in Sugar Production at Sweetsugar Ltd.

The sugar production process at Sweetsugar Ltd. can be divided into several stages or unit operations as described in the Sugar Production Process. These are:

1. Receiving, Cane Handling and preparation
2. Extraction
3. Concentration
4. Mud Filtration
5. Crystallisation
6. Centrifugation
7. Sugar Drying and Packing

Each of the seven stages was analyzed during the assessment phase. Material balancing and environmental concerns were identified for each of the seven stages. Possible CP methodologies were also suggested.

4.6.7: Receiving, Cane Handling and Preparation

Sugar processing starts with the receiving of sugarcane from the estates. The sugarcane is weighed and passed on to the receiving tables for each line. The diffuser line takes 300TCH whilst the 66” mill takes 190TCH. In both lines, electricity is used to drive the feeder tables, belts knives and the shredders, whilst cooling water is for cooling bearings and cooling oil.

After weighing, the cane goes to the feeder tables, from where it either joins the 66-inch line or the diffuser line. Cane is first prepared by knifing the stalks and then finely shredding the cane before extracting the juice as shown in Figure 4.1.

4.7: Environmental Concerns

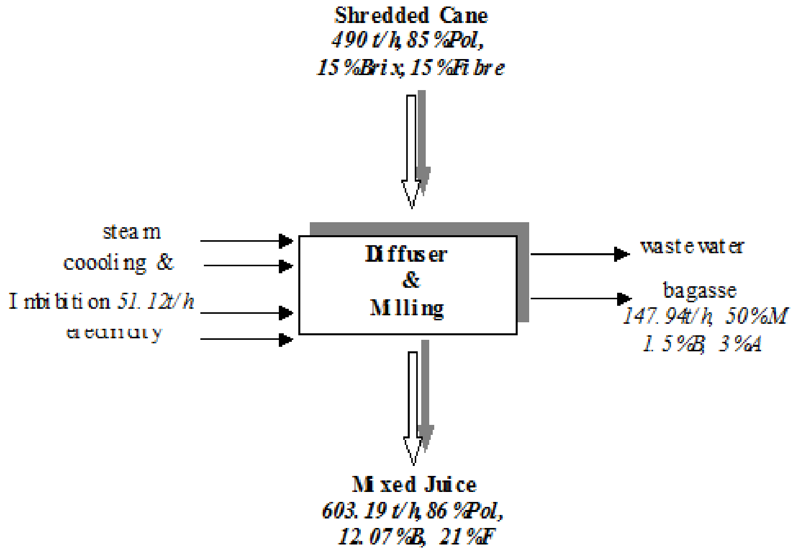
During the cane handling and preparation process, 0.06% trash is generated. This is mainly as a result of fall-offs during offloading onto the feeder tables. Fall-offs from the conveyor belts contribute to the trash (Kirov M, 1975). This trash is dumped at some landfill sites outside the factory area. Rain also washes some of the trash down the drains. Cooling water for the shredder oil coolers is not recycled but disposed of down the drain. There is noise pollution in the cane yard, resulting from the cane haulage trucks and the trains. During preparation of cane there, is also significant noise pollution emanating from the shredder and the cane knives motors.

The environmental effects caused by the harvesting and transport of the raw material are air pollution from the burning of sugarcane fields (flue ash) and contaminated access routes. The only advantage of burning sugarcane before harvesting is that it facilitates manual harvesting, as all the dry parts of the plants are removed by burning and the harvest volume is thereby considerably reduced.

The drawbacks are the adverse effect on cane quality due to damage to the cell tissue, destruction of organic matter, damage to the soil structure due to increased drying, increased soil erosion particularly on hilly sites and, finally, air pollution in the form of fumes and flue ash emissions. Sugarcane field burning would, therefore, seem to be contraindicated for biological and ecological reasons.

4.8: Extraction

The extraction of juice, by either the milling process or diffusion process, results in mixed juice and bagasse as the by-product as in Figure 4.1. Low-pressure steam (for diffuser only) and imbibition water are added directly to the shredded cane.



High-pressure steam is employed to drive de-watering mills in the diffuser line and the sixth mill in the 66” mill line with the other five mills being electrically driven. Cooling water is supplied to the roller bearings and to the 66” mill motors.

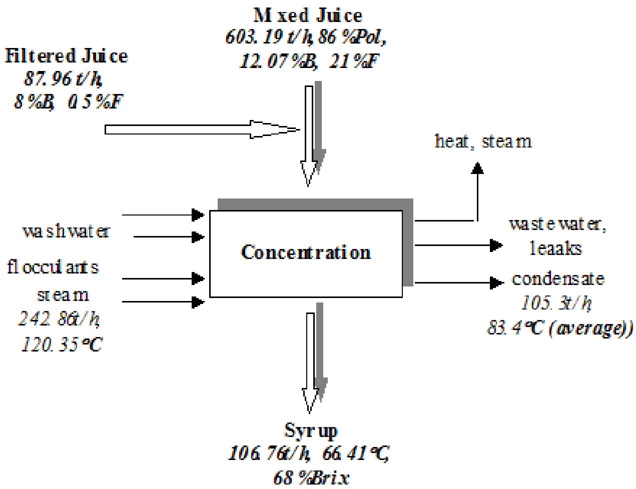
4.9: Environmental Concerns

Overflows from the diffuser and juice arising from the mills sometimes spills into drains, which, in turn, flow to Vesa River. Wash water, bearing-cooling water for the knives, shredder and mills wastewater also overflow into the same drain. Continuous welding on the mills to roughen surfaces during cane crushing, also presents a health hazard to the welders. Noise nuisance is produced in the whole area of mill extraction. Dust is generated with particular intensity in the area of sugarcane intake and transfer to the mill tandem.

The intermediate products of the sugar industry are ideal nutrient media for a large number of micro-organisms. The risk of microbial contamination is particularly high in this stage, where not even the most stringent technical hygiene measures and optimum process management can obviate the need to use disinfectants.

4.9.1: Concentration

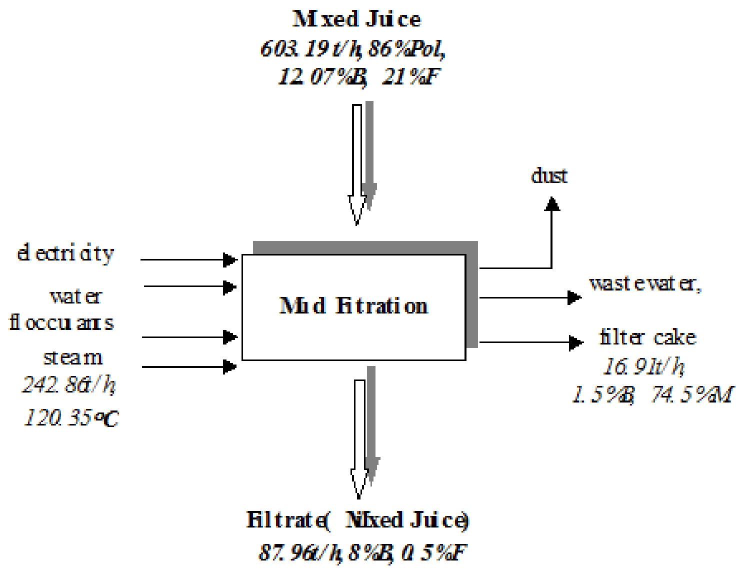
Figure 4.2 shows the concentration stage of the sugar production process. The process constitutes juice heating, clarification and then evaporation. Exhaust steam from the power station is employed during the concentration stage, that is, juice heating and evaporation. Flocculants are added to aid the clarification process.



The processes of heating the juice (in juice heaters) and evaporation of water (in evaporators), inevitably gives rise to scaling of the juice heaters and evaporators, thus necessitating cleaning. The cleaning process uses caustic soda that is washed away after it has been boiled. The wash waters drain into a sump, from where it is pumped to the Brown ponds (lagoons) for final treatment and disposal as irrigation water. Occasionally, the sump overflows to another set of lagoons. The use of the wastewater for irrigation purposes is of environmental concern as they contain high concentrations of sodium salts.

4.9.2: Mud Filtration

The objective of the process is to recover syrup, as shown in Figure 4.3 in the clarified mud. Fine bagasse (bagacillo) is added to aid the filtration. Mud leaves the filter station and is commonly called filter cake (used as fertilizer) and the juice is returned as filtrate to the mixed juice tank. The filter cake (milo) produced has a dry content of 50 to 60%, up to three quarters of which is in the form of calcium carbonate, the rest consisting of the most part of organic substances.

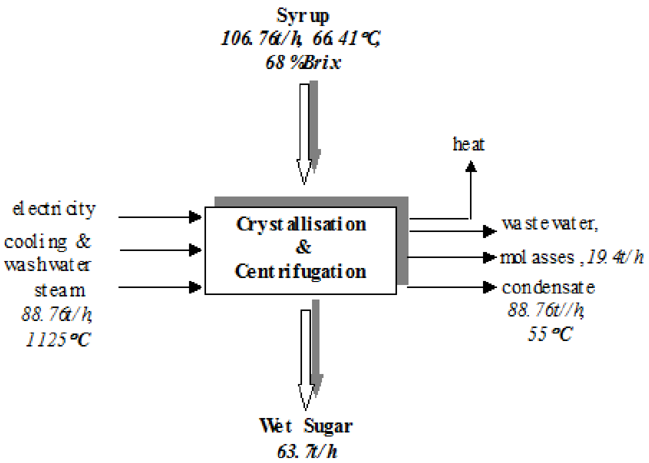


The filtration process requires bagasse particles (bagacillo). Extraction of the bagacillo from bagasse presents air pollution problems accompanied by health risks that can cause ***bagassiosis***.

4.9.3: Crystallisation and Centrifugation

The two process are different, with crystallisation involving the seeding and growth of crystals, whilst, on the other hand, centrifugation is the separation of the crystals from the molasses. However, at Sweetsugar Ltd, the two are inter-linked with an output from one process being an input to the other. During crystallisation, syrup is boiled in boiling (vacuum) pans as a way of growing sugar crystals and to maximise the amount strength (pol) of recovered from raw sugar. Massecuite leaving the boiling pans is not yet fully grown, hence the need to crystallise it further. The process takes place in crystallisers and, as opposed to the boiling pans, it is through cooling, rather than boiling.

Centrifugals are employed to separate the crystals from the molasses in the centrifugation process. The molasses passes out through a screen lining the centrifugal, leaving the crystals (raw sugar) inside. The more efficient this process is, the more sucrose is recovered in raw sugar and the fewer losses in molasses.

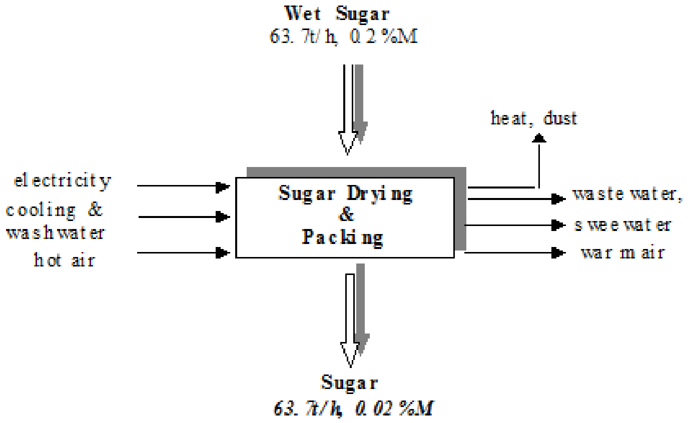


There were no environmental concerns identified for the crystallisation and centrifugation processes.

4.9.4: Sugar Drying and Packing

The sugar is dried to enhance its keeping and handling qualities. The sugar is dried in a rotary drum by passing heated air through the drier. The drying and packing unit process diagram is given in Figure 4.5.

A lot of sugar dust is generated during the weighing and packing. The dust gives rise to severe air pollution. This is not only a health hazard but, at a grain size of < 0.03 mm, is also highly explosive if the dust/air mixture concentration is within the explosion limit (approx. 20 to 300 g/m^3). A low dust level is 2 g/kg sugar. Floor wash waters discharged down the drain to the lagoons inevitably contains traces of sugar, which is of environmental concern.

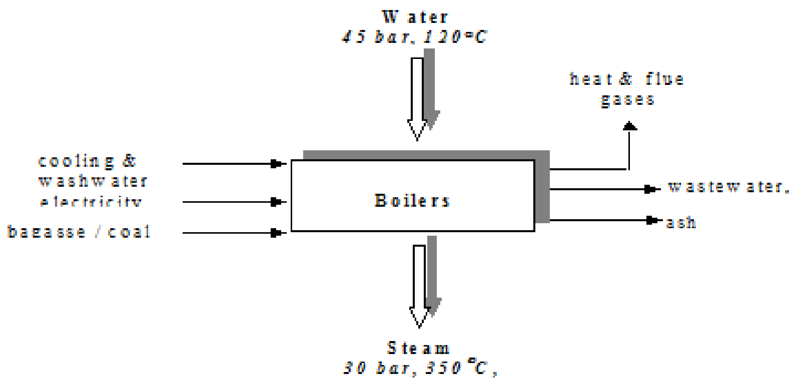


4.9.5: Support Service Unit Operations

4.9.5.1: Boiler Station

Sweetsugar Ltd. has nine boilers with only four most recent boilers: boiler 7, boiler 8, boiler 9, and boiler 10 being operational. The boilers have maximum capacity ratings of 45, 45, 100 and 150 tonnes of steam per hour, respectively, at 30 bar and 350°C. They are all water tube boilers which are both bagasse and coal-fired. Most of the high-pressure steam is expanded in the turbo-alternators during power generation while the other is used to drive turbines and, in the mills and diffuser section, as prime movers of some mills.

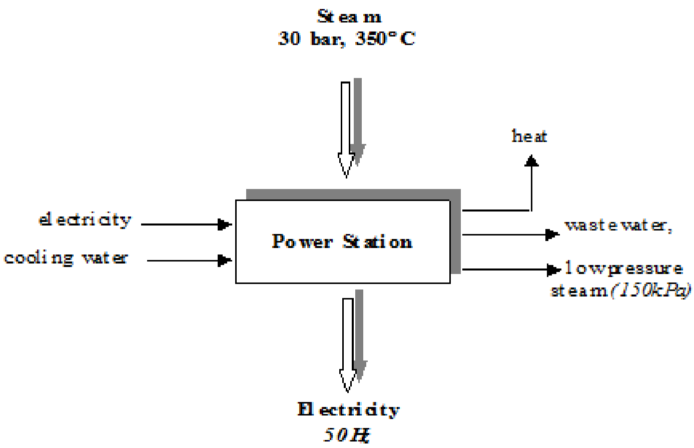
The steam output is a function of the number of boilers that will be operational and thus also determining the fuel required. However, one tonne steam requires 0.125 tonnes coal or 0.285 tonnes bagasse. The steam raising unit operation diagram is shown in Figure 4.6.



4.9.5.2: Power Station

The power station has six turbines coupled to the alternators, generating a combined maximum capacity of more than 30MW, but due to outage of the turbo alternators, only 21MW can be generated on average. There are five backpressure turbines which exhaust at 150 kPa, and the sixth being a condensing turbine exhausting at below atmospheric pressure. The exhaust steam is used in the factory before being returned to the boilers as the main water supply. One megawatt-hour requires 10-tonnes/hour steam supply.

The boiler station and the power station are jointly referred to as the Power Plant. Of major environmental concern is the flue gas emissions (Boubel, R. and Stern A, 1981), smuts waters (hoppers cleaning water) discharge into the main drain, noise pollution and also danger of burning employees due to ineffectively lagged steam pipe sections.



4.9.5.3: The Laboratory

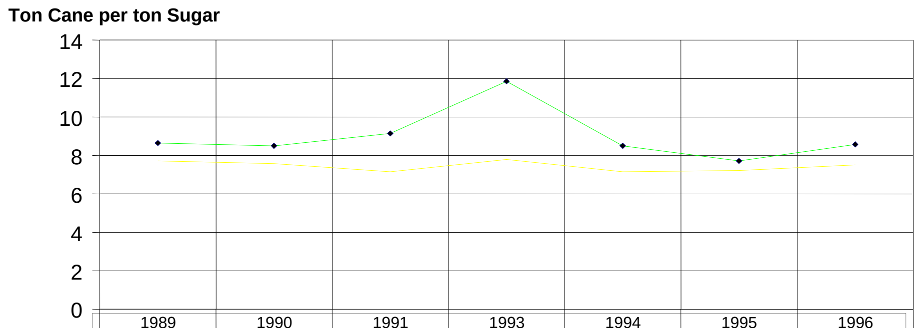
The laboratory does all the tests and analysis of all the plant's inputs, products, by-products and waste. The major environmental concern in this support service is the discharge of wash waters into the drain leading to Vesa River. Samples taken show that there are traces of some elements and characteristics of environmental concern.

4.10: Best Practice Comparison

The aim of the best practice comparison is to rate Sweetsugar Ltd.'s performance indices against the international standards. This would save to identify possible areas for improvement.

4.10.1: Sugarcane

The Maryborough Sugar Factory was one of the first cane growing areas in Queensland, Australia. The comparison between these two sugar production plants shows that



	1989	1990	1991	1993	1994	1995	1996
Maryborough Sugar Factory	7.68	7.6	7.15	7.78	7.15	7.23	7.49
Sweetsugar Limited	8.65	8.53	9.12	11.85	8.49	7.72	8.6

Table 4:1 Sugarcane per Ton Sugar Comparison

Sweetsugar Ltd needed more cane, that is, 10.72 tonnes/ton sugar whilst Maryborough Sugar Factory needed only 7.44 tonnes/ton sugar.

Year	**Maryborough Sugar Factory**			**Sweetsugar Ltd. Limited**		
	Cane Crushed	**Sugar**	**Tonnes Cane per Tonne Sugar**	**Cane Crushed**	**Sugar**	**Tonnes Cane per Tonne Sugar**
	Tonnes	Tonnes		Tonnes	Tonnes	
1996	698,746	93,316	7.49	1508867	175543	8.6
1995	555,406	76,867	7.23	2006794	260060	7.72
1994	650,567	91,034	7.15	1926600	226816	8.49
1993	432,913	55,657	7.78	353737	29862	11.85
1992	468,625	62,802	7.46	66085	2895	22.83
1991	372,279	52,061	7.15	1244088	136474	9.12
1990	403,769	53,101	7.6	1738406	203861	8.53
1989	563,875	73,458	7.68	1905294	220153	8.65
	Average		**7.44**	**Average**		**10.72**

Table 4.2: Maryborough Sugar Factory and Sweetsugar Ltd. Production Statistics

Figure 4.8: Mixed Juice Purity Comparison

Although it can be concluded from Figure 4.8 that Sweetsugar Ltd.'s sugar production process was less efficient during the period under review, this is attributable to the drought period of 1992/1993 season and also other factors such as the cane quality have to be considered. However, in 1999, Sweetsugar Ltd. required 7.69 tonnes sugarcane per tonne sugar, a figure comparable to that of Maryborough and higher than 8.2 tonnes/tonne for Summitsugar (Zimbabwean Company) for the same year calculated from appendix A.

4.10.2: Mixed Juice Purity

The mixed juice purity of Sweetsugar Ltd. (1998) is comparable with the trend interpolated from the mixed juice purity graph for South African factories (1998) as shown in Figure 4.8. The average mixed juice purity between 1982 and 1997 is 83.85% and 84.91% for Sweetsugar Ltd. and South African mills, respectively. South African mills produce juice of high purity because most of them employ the diffusion process only during extraction, whereas Sweetsugar Ltd. has both a diffuser and the conventional method. The drop in the purity of the juice for the South African factories between 1992 and 1995 was attributed to the drought of 1992 and 1995.

The following were reported from the South African experience of the 1992 and 1995 droughts (Prosi, 1999)**:**

- High bagasse moisture due to higher pith/fibre ratio in drought stricken cane;
- Problem in clarification due to low P_2O_5 level in juice (addition of phosphoric acid may be necessary);
- Difficulty was encountered during crystallisation due to high non-sucrose and high gum content in drought cane;
- High viscosity of massecuite and molasses (sodium hydrosulphite can be added at 150-400 ppm on massecuites, with a 30-50% reduction in viscosity);
- Small grains found in C-massecuite;
- Increase in target purity difference of molasses (about 2 units);
- Bad sugar quality with low pol and high colour due to abnormally high juice colour; and

- Fouling of B and C-centrifugal screens with scale of mainly inorganic origin (>50%).

Sweetsugar Ltd, being in the same climatic region as South Africa, also experienced the same droughts. This explains the sharp fall in juice purity in 1992.

4.10.3: Water Consumption

The total water consumed on its own is not an overall performance indicator. The water consumed by Sweetsugar Ltd. between April and December 1998 averages to 7.5m^3 per tonne of sugar produced (see Figure 4.9)

This figure includes the water consumed in the power plant and ethanol plant, as figures there are no water lines devoted for the sugar production process only to the specific figures to be determined. However, the figure for sugar production remains around 7m^3 per tonne of sugar since the other water consumers take minimal quantities with the power plant boilers using water within the system under normal operating conditions. Ingenio San Francisco Ameca, a Mexican sugar producer, was using 6.75 m^3 per tonne of sugar produced after implementation of Cleaner Production programme at the end of 1990. The programme focussed on recycling wastewater, a process that Sweetsugar Ltd. does not do, hence the

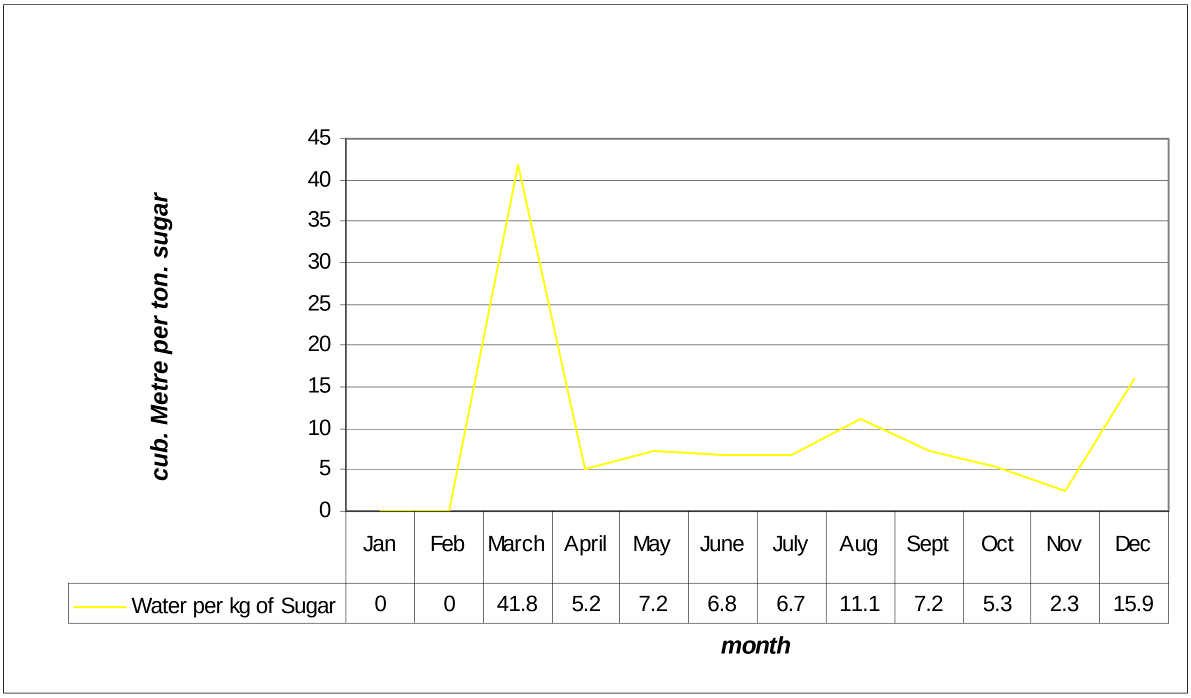


Figure 4.9: Sweetsugar Ltd. Water Consumed per Tonne of Sugar

higher figure.

Figure 4.10: Sweetsugar Ltd. Solid Waste in 1998

Figure 4.9 shows a sharp rise in March, marking the start of the on-crop and production will still be low although a significant amount of water will be consumed. During this period, a lot of water is used for cleaning.

There is no stage in sugar production where water in some quantity is not required. In sugarcane processing, large quantities of cane washing water (up to 10 m^3/t) and mixed condensate are produced during steam condensation and raw sugar-refining, which must be managed in a circuit system (large land areas required for evaporation lagoons, high investment costs for cooling towers). The purification water also includes wastewater required for cleaning the production areas and plant during and after the campaign, and for cleaning sugar transport vehicles. There are also juice and water overflows at plant breakdowns (clear juice, for example, has a BOD_5 of about 80,000 mg/l) so that values of up to 18,000 mg BOD_5/l can occur. Negligence is the main cause of excessive wastewater contamination. Low organic pollution and sugar losses in the mixed condensate (30 to 150 mg/l) can be achieved only by the installation of separators in the steam pipes (Sugar Research Institute).

The aim of establishing water management in a sugar factory must be to eject or treat as low a quantity of polluted water as possible. Water recycling heads the list of measures to be taken inside the factory. Water management must be such that once closed circuits are established, unpolluted or only slightly polluted water requiring no further treatment is discharged into the drains.

The treatment processes for wastewater that can be carried out in sugar factories are largely determined by local factors. The management of the wastewater and circuit conditions inside the plant have a major effect on plant size and the level of degradation, which can be achieved.

4.10.4: Solid Waste

Sweetsugar Ltd. Generated, on average, 0.14 tonnes of solid waste for every tonne of sugar produced in 1998, as shown in Figure 4.10. The solid waste comprises sugarcane trash, ash from boilers and filter cake from filtration plant. The figure for sugarcane trash is based on actual field measurements. The loads of trash produced were weighed on transportation from the plant. It was determined that on average 9 tonnes of trash are produced per day. Filter cake and ash were calculated from theoretical relations, that is, 1.5% of cane and 1.5% bagasse 8% of coal, respectively.

4.10.5: Energy Consumption

The energy consumption graph (Figure 4:11) shows that Sweetsugar Ltd. heavily relies on bagasse as its main source of energy. In

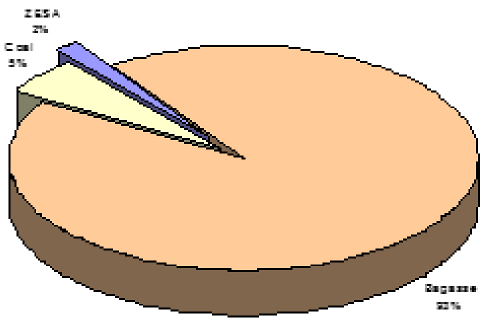


Figure 4.11: Energy sources at Sweetsugar Ltd.

1998 bagasse accounted for over 85 % of the energy to the factory.

Coal usage is significant at the start of year, as there is no bagasse since crushing would not have started.

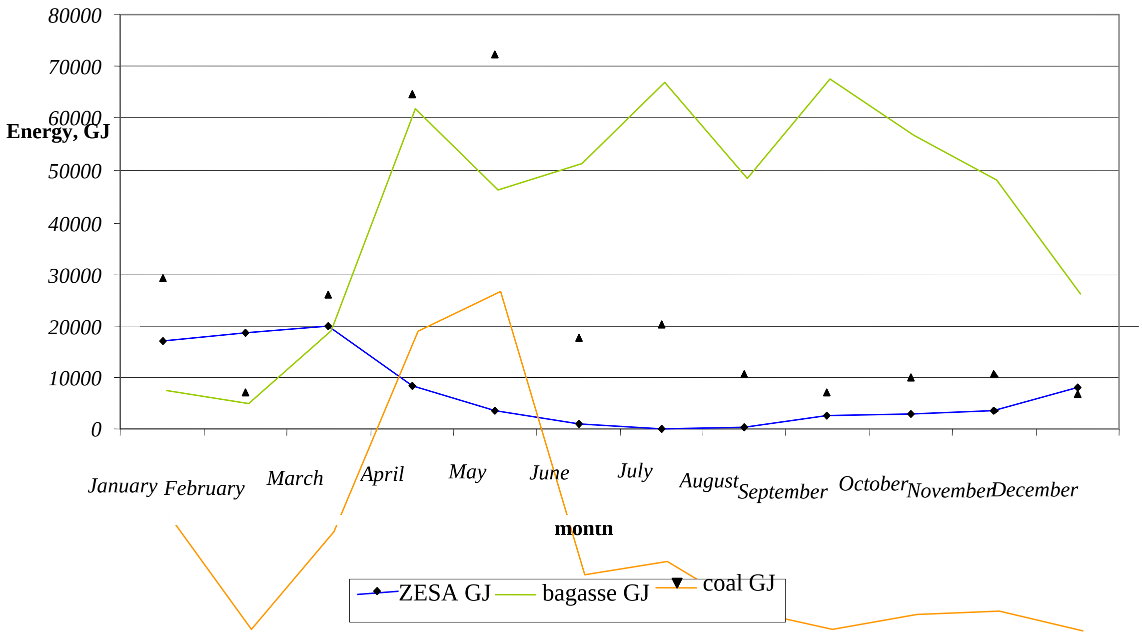


Figure 4.12: Sweetsugar Ltd. Energy Consumption 1998

Performance Parameter	For plant set up on the basis of 1973 standard specifications	Plant set up prior to 1973 standard specification	Sweetsugar Ltd. Limited 1998
Energy Consumption	25 – 30 kWh/ton cane	30 - 35 kWh/ton cane	21.70 kWh/ton Cane
Sugar Quality	Internationally marketable	Min. 30 colour series as per BSS	Internationally marketable

Table 4.3: Energy Intensity Comparison

Sweetsugar Ltd. limited energy consumption of 21.7 kWh/per tonne cane is less than the international standard given by Sugar Technology Mission as shown in Table 4:3. The energy per unit cane graph for 1998 (Figure 4.13) shows a peak at start of season. This could be due to the fact that the plant will still be operating below capacity and also that the cane will be having low sucrose content; hence more energy is expended to obtain unit sugar.

4.11: Conclusion

The bagasse produced is sufficient to cover the factory's energy requirements. Incomplete burning of bagasse (water content > 50%), increases the emission of flue ash and carbon particles. To start up the factory (start of campaign), other energy sources have to be used. If a refinery is also operated, it may also be necessary to back up the bagasse with other fuels. Maintenance firing is also essential where the plant is shut down for a prolonged period.

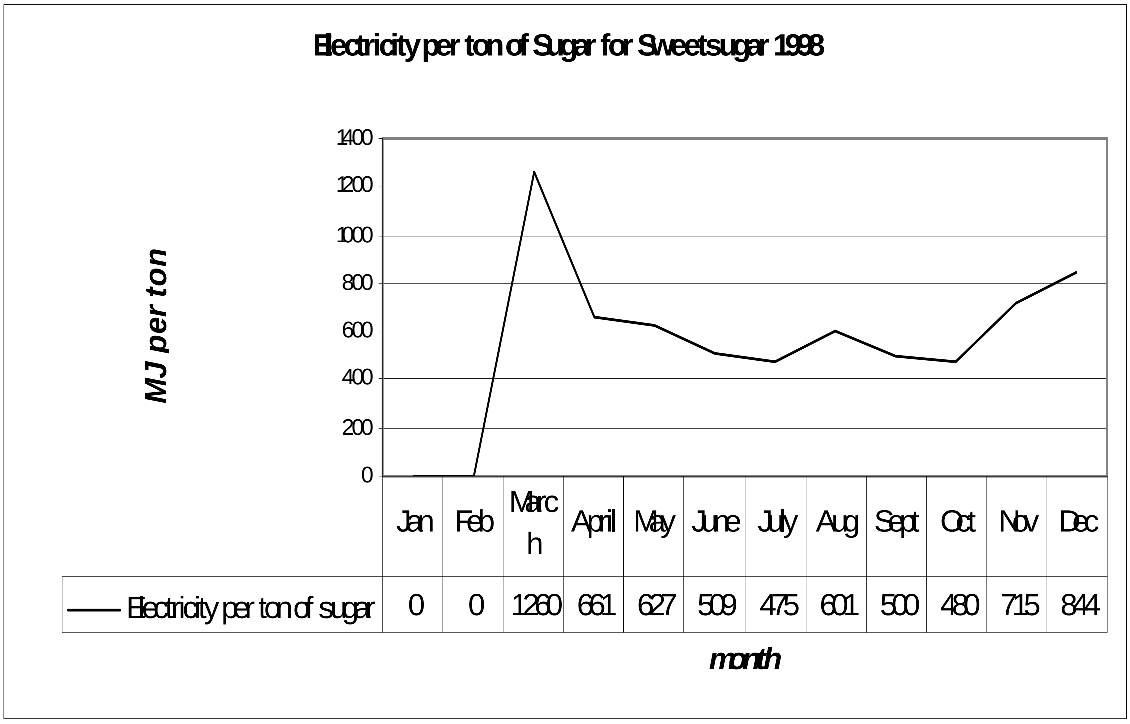


Figure 4.13: Sweetsugar Ltd. Electricity Consumption per Ton of Sugar

Chapter 5

Option Generation, Implementation and Continuation

Kumbi Mugwindiri, Tawanda Mushiri and Stanford Nyamuzihwa

5.1: Introduction

After completing the pre-assessment phase, and a material balance for each of the unit operations has been done in the assessment phase, the students are expected to conduct a cause assessment, generate CP options, and also screen the options mainly using standard checklists. The objective of the next stage, the evaluation and feasibility study phase, is to evaluate, mostly using checklists and evaluation sheets, the proposed Cleaner Production (CP) opportunities and to ensure that the selected options are implemented and the resulting resource consumption and waste generation are monitored continuously (Freeman). The opportunities selected during the assessment phase should all be evaluated according to their technical, economic and environmental merit, resulting in an implementation plan replete with performance indicators and a review mechanism with ways of initiating ongoing CP activities.

The CP Assessment gave rise to the identification of areas for improvement (Beverley, T., 1999). Possible options to these areas are proposed. In any business, it is necessary to ascertain if the policies or proposals are feasible technically, economically and in the case of CP they should be environmentally feasible as well. Technical and environmental evaluations do not have specific methods but, rather, depend on the business type, but generally checklists are employed. On the other hand, several tools can be used for the economical evaluation, but one has to weigh the merits and demerits of each method before using it.

5.2: Wastewater Recycling

Zimbabwe, for years has been using the Water Act of 1927. This Act was deficient in dealing with pollution. Environmental pressures have made it more important than ever to revise the Water Act to address the problem of pollution. It is against this background that [1]*"A Polluter Pays Principle"*, Water Act has been drafted. The Act will entail polluters being allowed to

---

[1] ***Mr Sibhekile Mtetwa***
(Principal Water Pollution Control Officer, Department of Water Resources, Zimbabwe)
"Zimbabwe Waste Water Regulations - How They Affect Local Authorities"

pay to pollute and any damage to the environment or third part will be the polluter's burden. Factories are classified under four different categories, namely blue, green, yellow and red, in accordance with pollution load that they discharge.

5.3: Extraction Plant Wastewater

Sweetsugar Ltd. wastewater from the diffuser line is discharged into the Vesa River. The wastewater comprises mainly cooling water for oil coolers and bearings. Added to this load are diffuser sump overflow and laboratory wash waters. It was noted that there was no drainage system devoted to a particular quality of wastewater. The same drains are also storm water drains. The wastewater was measured and chemically tested. The results of oils and greases, Total Dissolved Solids (T.D.S) and Total Suspended Solids (T.S.S), are given in Table 5.1. Also given in the table are limits for the red category as in the new Water Act.

	Unit	Result	Red
Oils and Greases	*mg/l*	40	>7.5
T.D.S	*mg/l*	860	<1500
T.S.S	*mg/l*	660	>100

Table 5.1: Wastewater Chemical Analysis

The wastewater discharge was monitored for five days, twice per day. Each time three runs were done to enable the deduction of a somewhat true discharge figure. The volume flow was determined by timing a floater through five metres.

The average discharge figures are given in Table 5.2.

Day	**Time**	**Depth**	**Velocity**	**Area**	**Discharge**	**Discharge**
	Sec	m	ms^{-1}	m^2	m^3s^{-1}	m^3hr^{-1}
1	7.1	0.05	0.704	0.016	0.011	40.56
2	6.6	0.09	0.758	0.029	0.022	78.55
3	7.2	0.05	0.694	0.016	0.011	40.00
4	6.9	0.07	0.725	0.022	0.016	58.43
5	6.4	0.11	0.781	0.035	0.028	99.00

Average					0.018	63.31

Table 5.2: Wastewater Discharge Measurement

The average discharge figure includes wash water from the laboratory, diffuser sump overflow and washe water. Assuming 75% to be the actual diffuser line cooling water discharged into the Vesa River, then:

Diffuser Cooling Water = 47.48 m^3/h.

The 66" mill also uses a substantial amount of water that is discharged into the Brown ponds via the oil trap. Three wastewater streams emanate from the 66" mill and their quantities are given in Table 5.3.

Source	**Quantity / (m^3/h)**	
Mill Bearings	***20.6***	
Turbine Oil Coolers	***6.6***	
Mill Hagglands Drives	***7.3***	
66" mill Subtotal		**34.5**
Diffuser Cooling Water		**47.48**
Grand Cooling Water Total		**81.98**

Table 5.3: Extraction Plant Cooling Water Quantities

Discharging of wastewater into the Vesa River has some associated cost and environmental implications. The wastewater can be treated before final disposal to the river. This can be achieved by digging an oil trap that will trap the oils and the suspended matter. The simple physical treatment by flocculation can also be implemented to remove the suspended matter. Unfortunately, the dissolved solids will still find their way to the river. Aerobic treatment, followed by biomass separation of the wastewater, would then be required before final disposal to the river. This option is easy to implement and cheap, but it does not result in reduction of waste and emissions. Besides disposing of the water to the river, the water can be recycled within the system, that is, in the case of Sweetsugar Ltd, the water is cooled and re-used in the same process with makeup water added to make up for losses. This approach would involve some costs, but would bring about cost savings in the long run and also reduce the waste and emissions (Noyes, R. , 1997).

Treatment of wastewater before final disposal is an end-of-pipe method that is not prioritised in CP, as it does not reduce waste. It is against this background that the option of recycling water is chosen.

There already exist cooling towers in the plant. The composition of the extraction plant wastewater would not be desirable in the already existing cooling towers, hence there will be need for separate cooling towers for the cooling water.

It is proposed that:

1. The extraction plant cooling water should be retained within the system by employing cooling towers.
2. Wastewater from the laboratory should not be allowed into the same drain but, rather, discharged through the drain into a nearby pond (a lagoon) after treatment if need be.
3. Diffuser wash waters and overflows from the sump should be discharged through the oil trap located near the sugar shed.

5.4: Upgrading of Extraction Technology

The diffuser line crushing capacity is 300 tonnes cane per hour and that of the 66" mill line is 190 tonnes cane per hour. Comparison of the process parameters in Table 5.4 shows that the diffuser line is much more efficient and reliable than the 66" mill line. The low overall time efficiency of 75.56% in the 1999 for the latter line, suggests that the line is now very old and easily breaks down. The technology itself, which is referred to as the conventional method, is no longer efficient compared to other new technologies like in this case, the diffuser. The extraction efficiency for the 66" mill line of 96.05% in 1999 is lower than that of the diffuser line at Sweetsugar Ltd. and two diffuser lines at Summit sugar of 97.63 %, 97.41% and 97.32%, respectively.

More sucrose is lost in the 66" mill line through bagasse as evidenced by the high bagasse pol percentage of 1.88 and high bagasse moisture percentage of 51.71 %.

	Sweetsugar Ltd. Ltd. Diffuser Line	Sweetsugar Ltd. 66"Mill	Summitsugar Diffuser Line 1	Summitsugar Diffuser Line 2
Extraction Efficiency	97.63	96.05	97.41	97.32
Bagasse Pol %	1.13	1.88	1.25	1.3
Bagasse Moisture %	50.99	51.71	47.96	48.49
Overall Time Efficiency	88.25	75.56	88.27	87.25
Preparation Index	91	91	91	91

Imbibition % fibre	384	358	282	295
Mixed Juice % Cane	124.08	124.08	111.63	113.01
Mixed Juice Suspended Solids %	0.25	0.25	0.25	0.25
Mixed Juice Brix %	13.21	13.21	14.19	14.23
Mixed Juice Pol Purity	87.06	87.06	86.67	87.19
Lack of Cane	1.05	5.40	0.72	0.70
Foreign Matter	0.41	0.67	0	0

Table 5.4: Extraction Plant Performance Summary 1999

The Extraction Plant Stoppage Analysis for 1998 in Table 5.5 indicates that more stops were experienced in the 66” mill line, accounting for 78% of the stoppages whilst the diffuser line accounted for only 22%. However, it is apparent that management is fully aware of the shortcomings of the 66” mill line as supported by the unequal distribution of cane during the season in question. The diffuser line was prioritised as it had only 73.39 hours of no cane whilst the 66” mill had over 500 hours of no cane.

	Diffuser	66” Mill
	hours	hours
Electrical	46.48	124.1
Mechanical	127.6	274.37
Operations	104.67	301.32
No Cane	73.39	521.63
Planned	211.3	782.48
Foreign Matter	1.7	19.25
Total	**565.14**	**2023.15**

Table 5.5: Sweetsugar Ltd. Extraction Plant Stoppage Analysis 1998 Season

From the discussion, it can only be concluded that the existing 66” mill line is no longer the best juice extraction technology. It is clear that employing the diffuser is a better technology. However, a South African company claims that the 66" mill can be upgraded to increase its efficiency through the installation of its products. Two alternatives can thus be employed in the quest for extraction technology improvement. These are:

- Replace the six milling tandem with a diffuser and de-watering mills.
- Upgrade the 66” mill to new conventional technology.

The two options will not reduce waste and emissions but will bring about increased and improved production. The two technologies are applicable to Sweetsugar Ltd, with the diffuser option actually in use. The two will be evaluated to obtain the best option for implementation.

5.5: Sugar Spillage

Sugar coming from the driers is weighed using a batch scale before final packing and storage. Conveyors are employed to transfer the sugar from the driers to scale and from scale to packing and storage sheds. It was observed that a lot of sugar spillages were occurring between the centrifugals and the storage area. Further investigations revealed that ineffective belt scrappers and lack of skirting on discharge chutes were giving rise to these spillages. Sugar spillages have some associated costs that include the sugar value itself and hiring of labour to reclaim the sugar. Besides the costs, the spillages result in the general uncleanliness of the sugar floor.

The spilled sugar is reclaimed to the raw sugar storage shed. Reclaiming Sunsweet sugar to the raw sugar storage shed is tantamount to devaluing the Sunsweet sugar to raw sugar. The difference in value between Sunsweet and raw sugar is $3 805 per tonne. Raw sugar is sold at a price that is a function of the sugar quality. The sweeping of raw sugar onto the conveyor belts and sugar sheds compromises the quality of sugar sold to Zimbabwe Sugar Refinerie (ZSR), hence yielding less return which, from Sweetsugar Ltds. point of view, will be lost profit or loosely a loss. The deterioration in sugar quality could not be obtained. Assuming recovered sugar is devalued by 2.5%, the sugar loss per tonne is 2.5% of the cost of raw sugar per tonne ($7 610) giving $190.25 per tonne of recovered sugar.

5.6: Discharge Chute

After the weighing of sugar (raw or Sunsweet) in a batch scale, the sugar is discharged onto a conveyor belt (No. R6) through a discharge chute giving an effective freefall height of approximately 1.7 metres and hits sugar against the belt. For the 1999 season, the scale was weighing sugar batches of about 400 kg, therefore momentum on impact with the belt (assuming stationary belt) is given by,

Momentum, $M = mass \times \sqrt{2gs}$, where s is the distance of free fall.

$$= 400 \times \sqrt{2 \times 9.81 \times 1.7}$$

$$= 2310.12 \text{ kg ms}^{-1}$$

With this momentum on impact, the sugar splashes off the belt through the tolerance gap between belt and the discharge chute.

It was observed that the chute spills about 20 grams per batch (approximately 400 kg) which means that 0.005% of the sugar produced is lost to raw sugar through spillages at this discharge chute.

A rubber skirting can be installed on the chute to act as a seal, thus eliminating sugar spillages. This is easy to implement but with some associated cost. Since the sugar is falling directly onto the belt, a feeder can be installed on the mouth of the chute, which ensures an even and slow feed onto the belt. In both options, there would be some reduction, if not total elimination, of sugar dust health and safety hazards and the reduction of spillages, that is, less generation of waste. The feeder option requires total modification of the chute and installation of motor. Given the space limitation on site, this option will not be applicable. Also by implementing this option, electricity consumption will be increased. It is thus proposed to install rubber skirting on the chute. The drawing of the chute with the skirting positioned is given in Figure 5.1.

5.7: Belt Scrappers

There are numerous sugar belts in the plant, all being prone to sugar spillages. However, on some belts, sugar spillages are insignificant compared to that on others and also to the sugar production capacity of the plant. It is against this background that the Pareto Rule was applied. This is to say that the belts with the most significant sugar spillages were monitored. These belts are sugar conveyor R5 and conveyor R6. The floors were first swept clean before

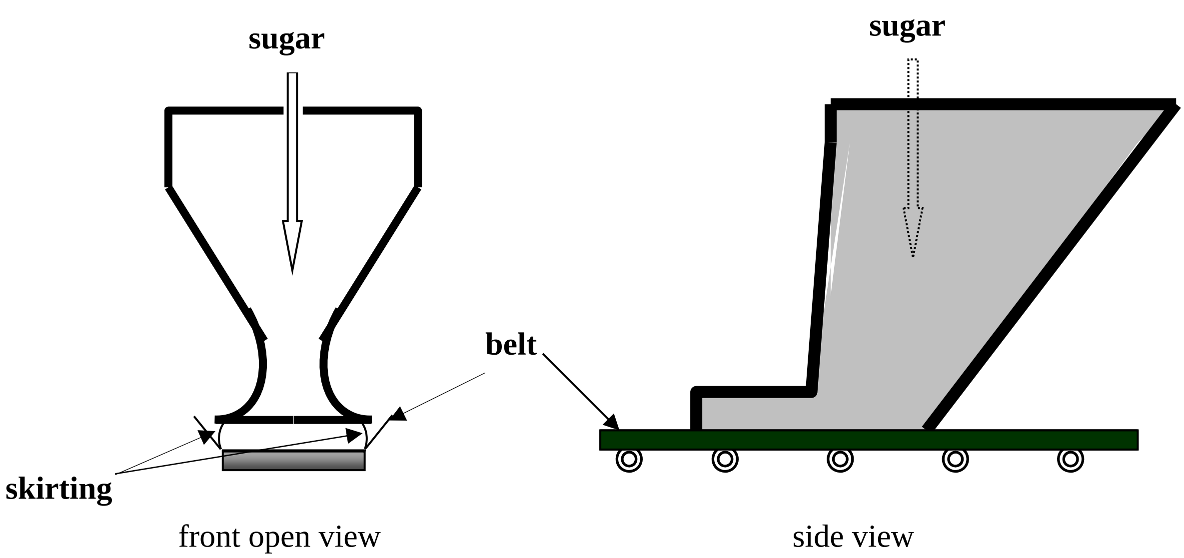


Figure 5.1: Sugar Discharge Chute

the exercise was undertaken. The process was monitored for four hours after which the spillages were swept and weighed. The sugar tonnage that went through the scale during that four-hour interval was also noted. The results are shown in the Table 5.6.

Conveyor	*kg*	R5	R6	Total
Spillage	*kg*	60.5	22.5	83

Table 5.6: Sugar Spillage Summary

During the four hours, 124 997.85 tonnes of raw sugar were produced. The sugar spillages for conveyor R6 include those due to the discharge chute. Prior investigations had revealed that the discharge chute spills approximately 20g per batch of 400 kg. This translates to 0.005% of the sugar produced spilling through the discharge chute. Thus, the actual sugar spillage figure attributable to conveyor R6 and R5 is 76.8 kg. The sugar spillage as percentage spillage of production is 0.0624%.

Conveyor R12 and R14 were observed to have minimal sugar spillages. Further investigations revealed that a nylon brush scrapper was being employed on both belts. This scrapper is very effective and does not give rise to wear of the belt. It is proposed to install the same scrapper on all the sugar belts. Here an appraisal is done for conveyors R5 and R6. The proposed set-up is shown in Figure 5.2.

The secondary and primary scrappers would be removed. The conveyors had recently been fitted with fine water sprays on the tail pulleys to enhance the scrapping effect of these existing sprays but it did not improve the situation. It has to be emphasised that the brush will rotate faster than the head pulley of the conveyor to enable effective scrapping and to avoid build-up of wet sugar or molasses that would render the scrapper ineffective.

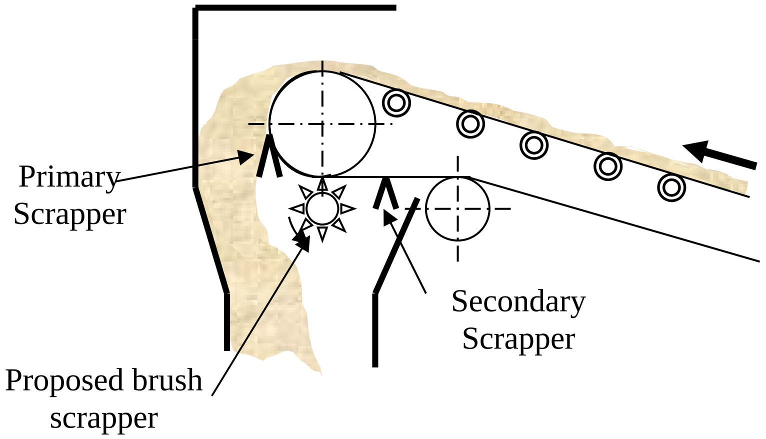


Figure 5.2: Proposed Scrapper Set-up

5.8: Power Generation and Supply

5.8.1: Power-Factor Correction

Power factor correction becomes important for Sweetsugar Ltd. when it is drawing power from ZESA since a low power-factor results in high demand costs. On the other hand, power factor correction gives rise to low transmission costs even in the case of transmitting locally generated power. The main irrigation lines were monitored in conjunction with ABB in October 1998. A summary of the results obtained is given in Table 7. The observed power-factor is actually better than what it is today.

This is because more reactive loads have been added onto these lines over the past year, implying that the power factor has deteriorated. ZESA's demand charge for 2000 was $580.21 per kVa.

Recalculation of the demand costs for the above figures result in Table 5.7.

Line	Maximum Demand, kVa	Power-Factor	Maximum Demand, kW	Monthly Demand Costs, $
Mutirikwe	5134	0.89	4569	922 887
P2	2494	0.89	2219	448 321
Christine	2836	0.81	2297	509 799
Column Ref.	A	B	C	D

Table 5.7: Summary of Power-factor Monitoring Results 1998

1. $C = A \times B$
2. $D = 179.76 \times A$, Where the maximum demand charge is $179.76 per kVa.

Line	Maximum Demand, kVa	Power-Factor	Maximum Demand, kW	Monthly Demand Costs, $
Mutirikwe	5134	0.89	4569	2978798
P2	2494	0.89	2219	1447044
Christine	2836	0.81	2297	1645476
Column Ref.	A	B	C	D

Table 5.8 : Recalculated Demand Costs

1. $C = A \times B$
2. $D = 580.21 \times A$, Where the maximum demand charge is $580.21 per kVa.

It is apparent from the figures in Table 5.8 that the demand charge has sky rocketed over the past year. If the power factor issue is left unchecked, Sweetsugar Ltd. would end up paying large electricity bills to ZESA.

It is important to note that Sweetsugar Ltd. will be charged for maximum demand regardless of the duration of ZESA supply within that month.

It is proposed to correct the three lines to a power-factor of 0.99. The power-factor correction can be implemented it two ways:

- Fixed Capacitor Bank
- Variable (Automatic) Capacitor Bank.

These options can be implemented on entire lines or on point loads, that is, say on each motor. The line loads for the three vary significantly, thus automatic capacitor banks would be appropriate for these lines. Power factor correction on point loads would not be favourable for these lines as there are numerous loads which would entail a big number of small capacitor banks. Power factor correction is proposed to be done for the entire lines using automatic capacitor banks.

5.9: Feasibility Studies – Implementation and Continuation

5.9.1: Tools for economic evaluating options

Sweetsugar Ltd.'s management employs mainly three tools in their evaluations. The three tools are namely:

i. Payback
ii. Net Present Value
iii. Internal Rate of Return

These same tools will be used in this project in line with what the decision-makers use in their evaluations. During this evaluation stage, the landing costs for materials to be bought from South Africa are based on Sweetsugar Projects Department rule of thumb ratio of R1 = Z$9. This ratio is based on the bank exchange rate and takes into account tax, transport and other charges.

5.9.2: Payback theory

It is the period, usually in years, that it takes for the project's net cash inflows to recoup the original investment.

$$\textbf{Payback} = \frac{\text{Total Investment}}{\text{Annual Net Cash Flow}}$$

5.9.3: Net Present Value theory

Net Present Value (NPV) is an appraisal method used to calculate the present values of expected cash inflows and outflows, and to find out whether in total the present value of cash inflows is greater than the present value of cash outflows.

$$NPV = \sum_{i=0}^{n} \frac{C_i}{(1+r)^i},$$

where C is the net cash flow in the period

i is the period number, and

r is the discount rate.

5.9.4: Internal Rate of Return Theory

Internal Rate of Return (IRR) is the interest rate or discount factor that gives zero net present value. IRR is found by linear interpolation. A project is favourable or accepted if the IRR is above the actual discount factor.

5.10: Wastewater recycling assessments

5.10.1: Extraction Plant Cooling Water

About 81.98 m^3 of water is discharged per hour from the extraction plant. Assuming an average season of 38 weeks (taking into effect production stoppages), the annual discharge is about 523 370m^3. The costs of discharging cooling water are given in Table 5.9. They are in three categories: water charge, monitoring charge and environmental charge.

	Cost
Annual Cost of Water @ Z$166.87 per mega litre	$87 402
Monitoring Charge @ Z$15 000 p.a.	$15 000
Annual Environmental Charge @ Z$80 per mega litre	$41 869
Annual Gross Total Costs for discharging the wastewater	**$144 272**

Table 5.9: Costs of Discharging Cooling Water

A quotation for the cooling towers was obtained from Industrial Water Cooling Co. of South Africa. The quotation was based on cooling towers with a capacity of 80 m^3hr^{-1}. This figure was taken after considering that not all the water discharged into the Vesa River was cooling water or could be recycled within the system.

This includes laboratory and diffuser line washwater, of which the quantities cannot be measured or calculated, However, in this case, they have been estimated at about 25%. The 66” cooling water will also be pumped to the cooling towers.

The calculated cost of cooling towers is $353 941 and the calculated cost of cooling tower spares is $125 473.

The total cost of the cooling towers and spares is $479 441, excluding transport and tax. The spares are optional and will not be considered in the project appraisal. Assuming a 10% factor for auxiliaries such as pipe work and installation costs, the project costs will be $389 335.

Industrial Water Cooling Co. experts say the cooling towers have a useful life of over 30 years with an expected maintenance costs of not more than R100 (= Z$650 @ *R1 = Z$6.5 R/E 6.1288 plus 6% 17/02/2000*), depending on the operation conditions, such as water pH.

5.10.2: Technical Evaluation

The option was technically evaluated with the aim of establishing the effects of the project on the operations of the plant and its attributes. The proposed option does not bring any changes to the process, product, by-products or inputs. The space for the installation of the cooling towers and the manpower is available. It is clear from the checklist that, technically, the option is feasible.

5.10.3: Economic Evaluation

The total project investment is Z$527 385 and the annual net cash flow is Z$144 272.

5.10.3.1: Payback value

$$\text{Payback} = \frac{389\ 335}{144\ 272}$$

This gives a payback period of 2.7 years.

5.10.3.2: Net Present Value figure

The net present value (NPV) of the project is $21 852.18 at 35% discount factor. Since the NPV is positive, the project should be accepted.

5.10.3.3: Internal Rate of Return value

$$IRR = \left(\frac{0-21852}{-100877.05-21852)}\right)(50-35)+35$$

IRR = 37 %

The payback is 2.7 years, which is within the average 4-5 years payback period considered by the company. The NPV is positive and the IRR is marginally greater than the discount factor used for the NPV. It can thus be concluded that the project is economically feasible.

5.10.3.4: Environmental Evaluation

The cooling tower is environmentally friendly as it produces minimum noise pollution and air pollution in the form of vapour since the fans are driven by electric motors. The cooling towers do not generate any waste. If proper operational procedures are adhered to, no effluent will result due to overflow.

Implementing the project has a number of environmental benefits. These are:

1. Oils and grease (40mg/l) will not be discharged into the river;
2. C.O.D and B.O.D in the Vesa River will be reduced; and
3. The pollution load from Sweetsugar will be reduced.

5.11: Upgrading of extraction technology

5.11.1: New Diffuser

In 2000, Sweetsugar Ltd. had plans to expand the mill from the present capacity of 490 tonnes cane per hour to 740 tonnes cane per hour by adding a second diffuser line. The estimates are used in evaluating the alternative of replacing the 66” milling tandem with a diffuser. The total cost of installing the diffuser and the de-watering mills was calculated to be $475.68 million. The 66” mill is over 30 years old. Equipment has been replaced over the past three decades. Taking a pessimistic approach, the line can be said to have surpassed its useful life. It is against this background that the depreciated value of $10 207 000 will be used as its present value.

5.11.2: Technical Evaluation

The installation of the diffuser to replace the existing 66” mill line would be a big project. Whilst the project would, in the end, improve product quality and quantity, reduce waste through juice spillages and reduce energy consumption, it has some associated drawbacks. It is an automated technology and will thus require training of personnel. Production will be affected during the implementation stage, as the whole line will not be operating.

5.11.3: Economical Evaluation

In 1999, mixed juice percentage cane of the diffuser and 66” mill lines were 124.08% and 118.56%, respectively. This means that 5.52 % cane of juice could have been extracted the diffusion process had been employed.

From the mixed juice percentage cane ratios, it can be calculated that 1.24 tonnes of mixed juice are produced in the diffuser and 66” mill line, respectively, per tonne of cane. During this season, the 66” mill crushed 768 640 tonnes cane, hence 42 429 tonnes of mixed juice was lost in the bagasse because of inefficiency of the technology.

The cost of mixed juice, an intermediate product, could not be obtained, as it is sensitive information. Now, considering the whole sugar production process, that is, equipment, labour and the process itself, it can be estimated that the value added to the product up to extraction is about 30 % or costing $2 283 per tonne. Therefore, the total cost of mixed juice lost is $96.865 million.

The total maintenance cost for the 66” mill tandem line is estimated at $13 million. The diffuser maintenance costs are estimated at $7.6 million The figure is calculated from the fact that maintenance costs for 66” mill tandem is 70% higher than that of the diffuser. Therefore, the extra cost for maintaining the mill line is about $5.4 million. The total net cash flow is $102.268 million.

5.11.4: New Diffusser Payback

$$\text{Payback} = \frac{475\ 683\ 000}{102\ 268\ 000}$$

This gives a payback period of 4.7 years.

5.11.5: New Diffuser Net Present Value

The diffuser project is a big project, thus we use a lower discount rate of 20%. The net present value of the project is $30.297 million at 20% discount factor.

5.12: Recommendations

The initiated CP programme should be continued by further investigations, implementation and monitoring the CP alternatives. This demands the active support of management and all the employees at all levels.

From the project investigations, the following are recommended:

- All employees should be actively involved in the Environmental Management System programme initiated in 1997. Awareness campaigns should also be conducted within the Sweetsugar Ltd community and the workplace to ensure the success of the project.
- The extraction plant cooling water should be recycled. This will be achieved by installing a small a cooling tower within the extraction plant. The wastewater that cannot be recycled or reused within the plant should be monitored in terms of its pollution load and volumes. The volume can be monitored by reading the existing flow meter.
- A diffuser should replace the 66" mill tandem with the mills from the tandem used as diffuser de-watering mills.

- Sugar spillages should be minimised by installing nylon brush scrappers on all the sugar conveyors. Discharge chutes should be skirted to avoid spillages.
- While power factor correction feasibility studies were done for three lines, it should be extended to other lines. If found to be feasible, it should be implemented.

5.13: Conclusion

A well designed and properly run Cleaner Production project will increase profits by employing effective technology and housekeeping, keeping waste related costs at controlled minimum and gaining of goodwill from environmentally conscious customers. Potential savings exist even in well-run plants, but it takes effort to realise them. The Cleaner Production related cost savings identified during the project amount to $102.6 million per annum, for $476.3 million investment. Apart from the cost savings, water consumption will be reduced by about 2 m^3 per tonne of sugar produced. Some of the recommendations have been discussed with management to confirm their compatibility with the process operation but further engineering design input will be required in the case of the capital cost retrofits.

The project at Sweetsugar Ltd. revealed that at times, management does not involve employees in issues that affect them as seen by the lack of active participation of employees in the EMS programme. Management is also aware of some areas of environmental concern and even health hazards, but is more concerned with keeping the plant running to maintain production levels, unaware that corrective action can actually improve on production. Discussions with the operators in plant indicate that these people are aware that there are areas of environmental concern and waste generation but it is also apparent that they are more concerned with the day-to-day problems of keeping equipment and maintaining production levels under adverse conditions. Although these people are highly capable individuals, their current duties and responsibilities would preclude them from the additional responsibility of implementing and co-ordinating cleaner production programme.

The way forward for Sweet sugar Ltd. is a holistic approach to environmental issues, coupled with a comprehensive Cleaner Production programme.

Bibliography

Berkel, R.V. (1993). Improving Cleaner Production in China. *Environmental Research, Amsterdam.*, 50-62.

Beverley, T. (1999). *Citizen's Guide to Clean Production.*

Boubel, R. and Stern A. (1981). *Fundamentals of Air Pollution.* Academic Press,.

Chandak, S. P. . (1999). *Application of CP & Global Experience. Seminar on How to Increase Profits and Save the Environment through the application of CP.* Colombo Sri Lanka.

Clean Japan Centre. (1987). *Recycling '87 Turning waste into resources.* . Japan: Clean Energy Research Centre.

De Ranzo. (1981). *Pollution control technology for industrial wastewater. Pollution Technology Review,.* New Jersey, USA.: Noyes Data Corporation.

Environmental Sanitation Information Center. (1988). *Environmental sanitation reviews.* Thailand: Asian Institute of Technology.

Fujita. (1988). *Deep bed filtration in industrial waste water treatment.* Japan: Nagoya University. Graduate School of Environmental Studies.

Green H and Kramer A. (1979). *Food Processing Waste Management.* AVI Publ. Co.,.

Helmer R and Hapanhol I, . (1997). *Water Pollution Control.* E and FN Spon,.

Joseph, T. and Raymond, A. (1988). *Introduction to Business.* USA: McGraw-Hill Publ. Inc.

Kirov M. (1975). *Waste Management, Control, Recovery and Reuse.* Aan Arbor Science Publishers Inc.,.

Meller. (1985). Industry experience in implementation of clean technologies in Federal Republic of Germany.

Nemerow. (1978). *Industrial water pollution: Origins, characteristics and treatment.* . USA: Wesley Publishing Company Inc.

Noyes, R. . (1997). *Pollution Prevention Technology.* E and FN Spon Publ. Co.

Overcash M.R. . (1986). *Techniques for industrial pollution prevention. A compendium for hazardous and non-hazardous waste minimization.*

Prosi. (1999, June 21). Productivity Press. *Prosi Magazine*, p. 30.

Rao, M. N. & Datta, A. K. (1979). *Wastewater treatment.*

Rocheleau, R. F. and Taylor, E F. . (1964). *An industry approach to pollution abatement.*

Sastry. (1985). *Effluent treatment in textile, leather and alcohol industries.*

Sugar Research Institute. (1996). *Annual Review 1995.* SRI Publ.,.

UNEP. (1985). *Industrial and environmental information tranfer series, Low and non-waste technologies.*

UNEP/UNIDO. (1991). *Audit and Reduction Manual for Industrial Emissions and Wastes.* Paris.

Weber. (1972). *Physico-chemical processes for water quality control.* John Wiley & Sons Inc. New York.: UK.

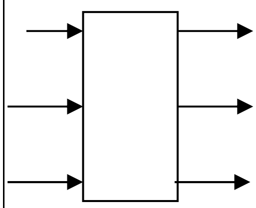
Appendix {Source Unep CP Documents}

CP Assessment Worksheets

Material Balance possible inputs

- Purchase records
- Material inventories
- Batch composition records
- Product information of supplies
- Product specifications
- Operating logs
- Standard operating procedures and operating manuals
- Samples, analyses and measurements of raw materials, input materials, products and waste and emissions
- Energy bills
- Energy inventories
- Equipment cleaning and validation procedures
- Waste and emissions forms
- Literature, consultants
- Interviews with work floor employees to check if operations are really done according to prescription.

Material Balance Worksheet

In				Out		
Costs (per year)	Quantity (per year)	Raw materials, auxilaries, energy	Unit Operation 	Product, by-product, energy, waste	Quantity (per year)	Costs (per year)

Cost of Waste and Emissions Streams Worksheet

Unit Operation: **Date:**

Waste and emission stream	**Cost of product loss (per year)**	**Cost of raw material loss (per year)**	**Environmental cost**	**Total cost (per year)**
Solid waste stream				
1				
2				
3				
Wastewater stream				
1				
2				
3				
Gaseous emissions				
1				
2				
3				
Energy losses				
1				
2				
3				

Cause Assessment Worksheet

Unit Operation:

Possible Waste Sources	**Specification**
Raw material 1. 2. 3. 4.	
Technology 1. 2. 3. 4.	
Good housekeeping 1. 2. 3. 4.	
Products 1. 2. 3. 4.	
Waste 1. 2. 3. 4.	

Cleaner Production Options Worksheet

Unit Operation:

Cleaner Production Approach	**To effect:**	**How:**
Change in input materials 1. 2. 3. 4.		
Technological change 1. 2. 3. 4.		
Good housekeeping 1. 2. 3. 4.		
Product changes 1. 2. 3. 4.		

On-site re-use 1. 2. 3. 4.		

Feasibility Study Worksheet Checklist

Availability	**Suitability**
♦ Is the cleaner production option available? ♦ Can you find a supplier who can supply you with the necessary equipment or input material? ♦ Do you know an advisor who can help you develop an alternative? ♦ Has the cleaner production option already been applied elsewhere? ♦ If so, what are the results and experiences?	♦ Does the option fit in with the way your company is run? ♦ Is the option in line with your company's product? ♦ What are the consequences of the options for your internal logistics, throughout time and production planning ♦ Does the option require adjustments in other parts of the company? ♦ If so, what adjustments? ♦ Does the change require additional training of staff and employees?
Environmental Effect	**Economic Feasibility**
♦ What is the anticipated environmental effect of the option? ♦ How big is the estimated reduction in the waste stream or emission? ♦ Will the option affect public or worker health? ♦ If so, what is the magnitude of these effects in terms of toxicity and quantity (positive/negative)	♦ What are the anticipated costs and benefits from implementing the option? ♦ Can you estimate the required investment? ♦ Can you make an estimate of the benefits, such as reduction of environmental costs, reduction in wastage and/or improving the quality of the product?

Technical Evaluation Worksheet: Cleaner Production Option

	Yes	No	Not relevant
1. Have you determined whether other companies already have experience with this?			
2. Will this option maintain product quality?			
3. Will this option adversely affect production?			
4. Will this option require additional staff?			
5. Will workers be able to run the process with the implemented option?			
6. Is extra training of workers required?			
7. Are you certain that this option will create less waste?			
8. Are you certain that this option will not simply move waste problems from one medium into the other (eg from solid waste to air emission)?			
9. Is your plant layout and design capable of incorporating this option?			
10. Will the vendor guarantee this option?			
11. Have you determined that this option will improve or maintain worker safety and health?			
12. Does this option reduce wastes at their source?			
13. Are materials and parts readily available?			
14. Can this option be easily serviced?			

15. Does this option promote recycling?			

Economic Evaluation Option Worksheet

	Yes	No	Not sure
1. Does this option reduce your raw material cost?			
2. Does this option reduce your utility costs?			
3. Does this option reduce material and waste storage costs?			
4. Does this option reduce regulatory compliance costs?			
5. Will this option reduce the costs associated with worker injury or illness?			
6. Will this option reduce your insurance premiums?			
7. Will this option reduce your waste disposal costs?			
8. Does this option have an acceptable payback period?			
9. Is this option within your price range (consider both capital and ongoing operations)?			

Environmental Evaluation Worksheet: Cleaner Production Option:

	Yes	No	Not sure
1. Does this option reduce the toxicity and volume of your solid waste and sludge?			
2. Does this option reduce the toxicity and volume of your wastewater?			
3. Does this option reduce the toxicity and volume of your gaseous emissions?			
4. Does this option improve the health and safety condition at the workfloor?			
5. Does this option reduce the use of raw materials (per product)?			
6. Does this option reduce the use of auxiliaries (per product)?			
7. Does this option reduce the energy consumption (per product)?			
8. Does this option reduce create new environmental impacts?			
9. Does the option increase the possibilities of recycling the waste streams?			
10. Does this option increase the possibilities of recycling the product?			

Implementation Worksheets

Worksheet I

Before-and-After Comparison

	Item	Price per unit (P)	Rate before implementation (A)	Rate after implementation (B)	Incremental benefits (B-A)*P
Materials 1. 2. 3. *Energy* Electricity Steam *Utilities* Water *Labour* Operation Maintenance Supervision *Others*					
Product 1. 2. 3. *By-product* 1. 2. 3. *Solid wastes* 1. 2.					

3. *Wastewater* 1. 2. 3. *Gaseous Emissions* 1. 2.					

Index

***Assessment*, 14, 15, 18, 37, 38, 39, 41, 56, 72, 75**
Availability, 38, 78
Before-and-After Comparison, 83
Cause diagnosis, 23
Cleaner Production, 6, 12, 15, 18, 30, 35, 38, 39, 40, 41, 51, 56, 58, 70, 76, 79, 82
***Company description*, 30**
CP, 6, 7, 10, 11, 14, 15, 16, 17, 18, 19, 25, 27, 28, 30, 34, 35, 36, 37, 38, 39, 40, 56, 69, 71, 72
***CP Focus*, 40**
CP options, 28
***Economic Evaluation*, 67, 81**
Economic Feasibility, 78
***Energy Balance*, 21**
***Energy management*, 40**
***Environment Policy*, 20**
Environmental Effect, 78
***Environmental Objectives*, 20**
***Environmental Targets*, 21**
***Feasibility studies*, 65**
***Feasibility Study*, 37, 78**
***Implementation and continuation*, 28**
Inputs, 23, 24, 25
Internal Rate of Return, 65, 66, 67
material balance, 22, 23, 37, 56
***material change*, 9, 15**
Net Present Value, 65, 66, 67, 69
Option Generation, 56
Payback, 27, 65, 66, 67, 69
***Pre-assessment*, 20, 37, 38, 39**
***Project Team*, 18**
recycled wastes, 7
recycling, 7, 8, 11, 17, 51, 52, 58, 66, 80, 82
Suitability, 38, 78
***Technical Evaluation*, 67, 68, 79**
training, 6, 15, 16, 20, 27, 30, 31, 41, 68, 78, 79
***waste*, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 30, 48, 53, 56, 58, 61, 62, 68, 70, 72, 73, 74, 78, 79, 81, 82**