Design of a Cleaner Production Framework for Engineering Company: DrinkCo Beverages

Kumbi Mugwindiri[1], Ignatio Madanhire[2], Tapiwa Masiiwa[3]

[1]University of Zimbabwe, Department of Mechanical Engineering
P O Box MP169, Mount Pleasant, Harare, Zimbabwe
kmugwindiri@eng.uz.ac.zw

[2]University of Zimbabwe, Department of Mechanical Engineering
P O Box MP169, Mount Pleasant, Harare, Zimbabwe
imadanhire@eng.uz.ac.zw

[3]University of Zimbabwe, Department of Mechanical Engineering
P O Box MP169, Mount Pleasant, Harare, Zimbabwe
masiiwatapiwa@gmail.com

Abstract: ***This research work explores to improve the resource efficiency, reduction in waste water and to reduce losses of raw materials during manufacture in a beverage making industry. A series of advanced cleaner production technologies was proposed in this study. It was noted that cleaner production technology exercises are not only desirable from the environmental point of view, but they also make good economic sense, as they contribute to the bottom line by conserving resources like energy, raw materials and manpower, improving yield and reducing treatment/disposal costs. The study is a resource promoting widespread adopting and implementation of Cleaner production technologies in other industries to achieve sustainable development.***

Key words: resource efficiency, beverages, reduce losses, cleaner production, energy, yield

1. Introduction

Cleaner Production (CP) is an initiative to protect the environment by minimizing waste and emissions and maximize product output by analysis of materials and energy [1]. It is a continuous application of an integrated, preventative environmental strategy towards processes, products and services in order to increase overall efficiency and reduce damage and risk to humans and environment.

If CP is adopted it helps to [2]:

- Reduce and minimize the harm caused by waste like acidic water.
- Improve safety of the workers
- Reduce cost incurred in waste treatment and disposal hence reducing the cost the amount of fine paid to the municipal authority due to harmful waste
- Create a good image of the company at the same time it benefits both the environment and business.

2. Justification

Significant efforts by DrinkCo Beverages to implement a greener manufacturing strategy have been observed but however some areas still require a greater attention as end of pipe solutions are being implemented .Pollution, as an area of major concern, it is apparent the company is contributing to pollution to some extent. It involves noise, thermal and land pollution from the generators that run bottles run throughout the day respectively.

Waste in the form of acidic water containing solid is directed into the drain which is major threat to the surrounding land and ecosystem. Currently the company is contracting other companies for the collection and disposal of solid waste. After an audit at the site, cardboard, plastic containers and closers (bottle tops); labels and glue could be recycled together with electronic waste.

Power shortages have hit the manufacturing processes hence resulting in an increased level of expenditure and increased level of pollution. Electricity, being the major source of power, during power cuts the firm has resorted to the use of diesel powered generator which has intensively contributed to the high levels of noise in the plant.

DrinkCo Beverages is estimated to be consuming about 2, 5 to 3, 5 litres of water per litre of its products hence there is need for cleaner production implementation. With the current rise in the global population and the change in the climatic weather the demand for water has been seen to be increasing .The project will have to provide an alternative way of minimizing water consumption [3]. Meanwhile DrinkCo Beverages is using end of pipe solution where they have resorted to the treatment of their waste like acidic water with Sulphur dioxide and Citric acid being the main constituency of this waste water. This method of approach does have a great impact on the ecosystem and financially as still they would have to contract an external member to help them treat the waste water.

Power shortages have hit the town; DrinkCo Beverages has turned to using a diesel powered generator. The combination of the noise produced by the generator and the packaging machinery exceed the 80dB (A) level. Exposure to this high level to noise at work can cause irreversible hearing damage and is difficult to detect as the effects would gradually increase over time.

Energy consumption as an area of major concern, taking a tour around the plant it has been observed that little or no energy saving concepts are being implemented. The boiler, forty bar compressor and the shrink wrapper being the major consumers of energy in the production line. No monitoring has been done to take into account the amount of money that could be saved by an efficient management of these equipment hence this justifies the need for a cleaner production approach.

3. Cleaner production overview

Not caring for the wastes can work, when the quantity of wastes are small compared to the sink where they are disposed of and provided the waste can be biologically degraded within a reasonable time period. This situation remains true today only for very small remote communities who are also not large consumers of non biodegradable or toxic products [4].

However, as chemicals and industrial products have become more complex, less biodegradable, larger in volume and the wastes more dangerous and persistent, the old strategy of "out of sight-out of mind," stopped working well [6].

Problems of global warming, ozone depletion, soil depletion, toxic contamination of soils and water resources, loss of habitat and biological diversity all require a change of production techniques, a reduction in materials and energy throughputs, more efficient production, changes in the final products and also in the consumption ethic [1].

All of these concepts are embedded in the newer approach of cleaner production, pollution prevention and industrial ecology.

Cleaner production technologies provide a more fundamental and basic approach to dealing with environmental degradation from economic activities. Clean technologies also provide developing countries with the additional possibilities of "leap-forging" over the older, more polluting, growth path followed historically by the more industrialized countries [5].

3.1 Cleaner production definition

Cleaner production is defined as continuous application of an integrated preventative environmental strategy to processes, products and services to increase eco-efficiency and to reduce risk to humans and the environment [2]. It succeeds the pollution dispersion, control and recycling strategies by preventing or minimizing the creation of waste and pollutants. And it precedes the sustainable development strategy which emerged as an environmental management strategy but can no longer be regarded as strictly environmental given its focus on integrating rather than balancing objectives regarding economical growth, social equity and environmental protection and resource conservation example.

3.2 Elements of the complete Clean Production [7]

Clean Production must integrate four underlying principles:

- The precautionary principle: This requires that action should be taken as far as possible to avoid damage to the environment before it occurs and recognizes that there are limitations and uncertainties to scientific knowledge. For example, a company wishing to discharge an effluent that contains untested chemicals would have to acquire information and demonstrate the safety of that discharge, rather than require regulators or the surrounding community to prove that the discharge could be harmful.

- The preventive principle: It is cheaper and more effective to prevent environmental damage than to attempt to manage or “cure” it. Prevention involves using safer chemicals and eliminating hazardous chemicals, including though substitution, with effective non-hazardous alternatives. Where toxic chemicals are currently used, the elimination of spills, accidents and fugitive releases is required while safer alternatives are researched and implemented.

- The public participation principle: Public access to information about emissions and releases of hazardous chemicals from manufacturing facilities, the amounts and types of chemicals and materials used in production processes and the chemical ingredients in products is necessary to move to safer alternatives and can hasten the adoption of clean production.

- The holistic principle: Clean production is an integrated approach to production, constantly asking what happens throughout the life cycle of the chemical or product. It is necessary to think in terms of integrated systems, which is how the living world functions. Otherwise new problems may be created by trying to solve old ones, such as changing the manufacturing process to stop the direct discharge of hazardous chemicals in wastewaters by redirecting them to a waste water treatment plant which is unable to adequately treat many of the chemicals, wherein those chemicals are simply transferred to the sludge, thus generating a new hazardous waste stream

3.3 Cleaner production and pollution control [4]

Fundamentally cleaner production seeks to make the company more efficient and less polluting .The goal being to avoid pollution by using resources and raw materials are turned into valuable products instead of being wasted. Many cleaner production improvements require little or no initial investment or have a rapid pay back Cleaner production is a preventive business strategy designed to conserve resources, mitigate risks to humans and the environment, and promote greater overall efficiency through improved production techniques and technologies. Cleaner production methods may include:

- Substituting different materials
- Modifying processes

- Upgrading equipment
- Redesigning products

A carefully implemented cleaner production results in reduced long-term liabilities which companies can face many years after pollution has been generated or disposed at a given site and it usually increases profitability, lowers production cost, enhances productivity, provides a rapid return on any capital or operating investments require increases product yield, leads to the more efficient use of energy and raw materials.

3.4 Cleaner production and quality & safety [5]

Safety and quality are very important aspects of the food industry. While food safety has always been an important concern for the industry, it has received even greater attention over the past decade due to larger scales of production, more automated production processes and more stringent consumer expectations. A stronger emphasis is also being placed on quality due to the need for companies to be more efficient in an increasingly competitive industry.

In relation to food safety, Hazard Analysis Critical Control Point (HACCP) has become a widely use tool for managing food safety throughout the world. It is an approach based on preventing microbiological, chemical and physical hazards in food production processes by anticipating and preventing problems, rather than relying on inspection of the finished product [8].

Similarly, quality systems such as Total Quality Management (TQM) are based on a systematic and holistic approach to production processes and aim to improve product quality while lowering costs.

Cleaner Production should operate in partnership with quality and safety systems and should never be allowed to compromise them. As well, quality, safety and Cleaner Production systems can work synergistically to identify areas for improvement in all three areas [3].

3.5 Clean Production in practice

Without the mandatory requirement for companies to carry out toxic use reduction plans, and without the stimulus of public access to information about a company's hazardous emissions as well as legislation that makes wastes and hazardous emissions too costly to ignore, factories will continue to pollute.

Companies can achieve clean production by:

- Knowing all the chemicals used, and in what quantities, in their production system by doing a comprehensive materials audit
- Assessing the hazard of each chemical and material, and ensuring that the information on all releases of hazardous substances are publicly available for free

- Prioritizing all hazardous chemicals for elimination, through substitution with safer chemicals in processes or through product redesign
- Establishing reduction targets and timelines for complete elimination of current hazardous chemicals use through toxic use reduction and elimination plans

- Cleaner productions in relation to DrinkCo a beverage manufacturer will emphasize greatly on the following:
  - Use of materials
  - Energy consumption
  - Minimization of waste
  - Minimization of emissions
- Reduced risk to humans

3.5.1 Use of materials and resources

High consumption of good-quality water is characteristic of beverage manufacture [10]. Large quantities of good-quality water are needed for drinks. More than 90 percent of drink is water and an efficient process of beverage production will use between 4–7 liters (l) of water to produce one liter of drink In addition to water for the product, beverage manufactures use water for heating and cooling, cleaning packaging vessels, production machinery and process areas, cleaning vehicles, and sanitation.

Drink manufacture requires water in almost every stage of production, but certain production methods or machinery can lead to overuse. If well or pump water is used, excessive water use can deplete water sources for future production or community use.

It must be used in a sustainable way to prevent degradation of the environment or health and general well being. With an increasing population it is important that inefficient equipment and consumer behavior do not waste this valuable resource [12]. Reducing water consumption will not only reduce the purchase cost of water, it also reduces the heating cost and the waste water discharge.

3.5.2 Minimization of waste

Beverage manufacture generates large amounts of waste. Waste in the form of solid waste, acidic water, cardboard, plastic containers and closers (bottle tops); labels and glue. Many of these wastes contain valuable materials that can be reclaimed and re-used, reducing the need to exploit new supplies of a resource. Reclamation and recycling of scrap metal rather than mining new materials is an obvious example.

Sewage water and waste water from the cleaning processes of the toilets, floors, tanks and bottles has an acidic pH hence it under goes pH level monitoring before being discharged. Depending on the dilution available there may be significant increase in the in the dissolved and solid organic content, nutrients color and turbidity and these may give rise to undesirable changes in water quality particularly as downstream abstraction [12].

Techniques for treating industrial process wastewater in this sector include flow and load equalization, pH correction; sedimentation for suspended solids reduction using clarifiers; and biological treatment. Biological nutrient removal for reduction in nitrogen and phosphorus and disinfection by chlorination are sometimes required. Dewatering and disposal of residuals; in some instances composting or land application of wastewater treatment residuals of acceptable quality may be possible. Currently DrinkCo is using the pH correction method and has contracted another firm to process its solid waste away from its plant. Additional engineering controls may be required to contain and neutralize nuisance odors. Adoption of anaerobic biological treatment, followed by aeration is increasingly adopted by breweries worldwide. This technique has the benefits of much reduced footprint, substantial electricity savings and generation of biogas which can be used in boilers

3.5.3 Reduced risk to humans

Food and drink production results in hazardous working conditions, excessive heat caused by operating machines such as the Shrink Wrapper and the blow molder, lack of ventilation, skin irritants can cause damage to the workers. Certain working conditions such as exposure to chemicals in the air or in solution baths during the cleaning of tanks can be hazardous to workers. Beverage manufactures often have large refrigeration systems, typically using ammonia refrigerant which is toxic and can form explosive mixtures in air. Symptoms can include skin irritations, dizziness and breathing problems. An unhealthy workforce can lower productivity, cause excessive absences and contribute to potentially costly mistakes.

Physical hazards include exposure to same-level fall hazards due to slippery conditions, the use of machines and tools, the handling of glass bottles, and collisions with internal transport equipment, such as forklift trucks. Mills, mixers, grinders, augers and conveyors are potential hazards and may catch fingers, hair, and clothing. Eye injuries are a particular risk prevalent in bottling operations. Beverage manufacture activities that may expose workers to risk of injury typically arise from heavy manual lifting and carrying (for example, crates of bottles); repetitive work including packing and cleaning, and poor work postures caused by inadequate workstation and process activity design.

When products and packaging are designed, their influences on mankind and natural environments during their life-cycle must be considered and priority accorded to selecting toxin-free, non-hazardous, easily degraded and easily recycled options. Enterprises should package the products in a reasonable manner to reduce the overuse of packaging materials and reduce the generation of packaging wastes.

Unless properly managed, solid waste such as chemical containers, cardboard box have a potential to cause serious environmental and health impacts. It can lead to surface and groundwater contamination, land pollution and air quality deterioration [8]. Coal dust from the coal used in coal fired boiler and litter scattered by wind are responsible for deterioration of air quality in the vicinity of disposal sites.

3.5.4 Energy

The increasing demand for the energy to power industry, however, is also producing unwanted effects, including higher energy prices, increased air pollution and higher emissions of greenhouse gases linked to climate change. To protect both economic growth and environmental values, we need to rapidly increase energy efficiency and deploy less carbon-intensive energy sources [7].

Characterizing the local industry it covers an extremely diverse range of activities. In 2000, industry was responsible for 30% of the greenhouse gas (GHG) emissions and consumed 35% of the country's primary energy. Currently many opportunities exist to improve industrial energy efficiency and there is a large potential for future efficiency developments. Improving industrial energy efficiency and reducing energy-related GHG emissions can be accomplished through technological improvements as well as changes in the structure of the overall industrial sector (in reaction to economic and environmental drivers). In addition, further reductions in GHG emissions from industry can be realized through reduction of process-related emissions, fuel switching to lower carbon fuels, and integrated pollution prevention and material efficiency improvement. All of these opportunities are available on the near-term and many will continue to be available in the medium- and long-term.

Energy is used for a variety of purposes in the manufacturing industry; energy sources include electricity and the fossils fuels. DrinkCo Beverages manufacture consumes a large amount of energy, some of the energy source s used during manufacture include electricity which is used for lighting, heating, packaging etc .Coal among the fossil fuels used for heating in the boiler, sanitation that is the cleaning of tanks. Diesel consumed by the generator and the trucks, Petrol used by the cars. Taking an audit on the records it has proved the generator and the trucks consume much of the fuel.

Beverage processes are relatively intensive users of both electrical and thermal energy [10]. Thermal energy is used to raise steam in boilers, which is used largely for sanitation and water purification in the, and in the cleaning of bottles. The process refrigeration system is typically the largest single consumer of electrical energy, but the, bottling hall, and wastewater treatment plant can account for substantial electricity demand. The specific energy consumption of a beverage is heavily influenced by utility system and process design; however, site-specific variations can arise from differences in product recipe and packaging type and climatic variations.

Taking that as a major concern DrinkCo Beverages has little in progress at the mean time that has to do with the monitoring of the energy consumption. Currently the boiler has no measures which have been put in place to try and improve the efficiency of the boilers, that is the boilers have no economizers there is no use of the condensate recovery system which contributes to large consumption of coal.

3.5.5 Maintenance

Maintenance to most people is any activity carried out on an asset in order to ensure that the asset continues to perform its intended functions, or to repair any equipment that has failed, or to keep the equipment running, or to restore to its favorable operating condition. Predictive maintenance is a more condition-based approach to maintenance. The approach is based on measuring of the equipment condition in order to assess whether equipment will fail during some future period, and then taking action to avoid the consequences of that failures. This is where predictive technologies (i.e. vibration analysis, infrared thermographs, ultrasonic detection, etc.) are utilized to determine the condition of equipment, and to decide on any necessary repairs. Apart from the predictive technologies, statistical process control techniques, equipment performance monitoring or human senses are also adapted to monitor the equipment condition. This approach is more economically feasible strategy as labors, materials and production schedules are used much more efficiently.

Proactive maintenance can be considered as a new approach to maintenance strategy. Dissimilar to preventive maintenance that based on time intervals or predictive maintenance that based on condition monitoring, proactive maintenance concentrate on the monitoring and correction of root causes to equipment failures. The proactive maintenance strategy is also designed to extend the useful age of the equipment to reach the wear-out stage by adaptation a high mastery level of operating precision.

3.5.6 Overview of the Cleaner Production methodology

Table 1: Cleaner production stages [1]

Phase	*Stages*
I: Planning and organization	1. Obtain management commitment 2. Establish a project team 3. Develop policy, objectives and targets 4. Plan the Cleaner Production assessment
II: Pre-assessment (qualitative review)	1. Company description and flow chart 2. Walk-through inspection 3. Establish a focus
III: Assessment (quantitative review)	1. Collection of quantitative data 2. Material balance 3. Identify Cleaner Production opportunities 4. Record and sort options

4. Research Design

The researcher made some plant tours to the DrinkCo Beverages which exposed the researcher to the real life applications of cleaner production. The walk through inspection helped to observe other process involved in the drink manufacturing hence granting the researcher a chance to identify areas were cleaner production could be implemented. The tours granted the researcher a chance to discuss with the people involved in the process of manufacture. The researcher reviewed the company's processes and policies to see where cleaner production was being practiced and areas which required cleaner production opportunities.

5. DrinkCo Beverages Overview

DrinkCo Beverages produces bottled purified water, flavored drinks and canned juices. The company also, produces bottled and canned drinks', as part of manufacturing processes, water, carbon dioxide, sugar and other additives are involved. Water is a major component, making up to 50-70% of the drinks. Besides being a major component, water is also crucial in the cooling process during various manufacturing. Water is used for dilution, dissolving of the sugars, washing the bottles and cleaning of the floors. The process of manufacturing involves clarifying of water, filtering, mixing, carbonating and filling. For the above processes energy is obtained from coal, electricity, diesel and batteries. However coal is only used in the clarification of pure water .Electricity is used to drive the packaging machines and the mixers conveyor belts. Different losses occur during the manufacturing processes, waste from production line losses and this involves the spilled drinks and broken packages.

The DrinkCo Beverages Plant operates two beverages and a water bottling lines. The water bottling machine is also used for bottling fruit range of products. The need to increase productivity, maintain consistent quality of packaging material and guarantee total product quality of its products led to DrinkCo Beverages acquiring a pre-form making machine and two blow moulders.

DrinkCo Beverages produces bottled purified water, flavored drinks and canned juices. The company produces bottled and canned drinks, as part of manufacturing processes the process involves the use of water, carbon dioxide, sugar and other additives.

The plant is divided into the following branches of specialization;

- Water Treatment
- Manufacturing Services
- Packaging Operations
- Warehouse
- Engineering Quality Assurance

5.1 Manufacturing process

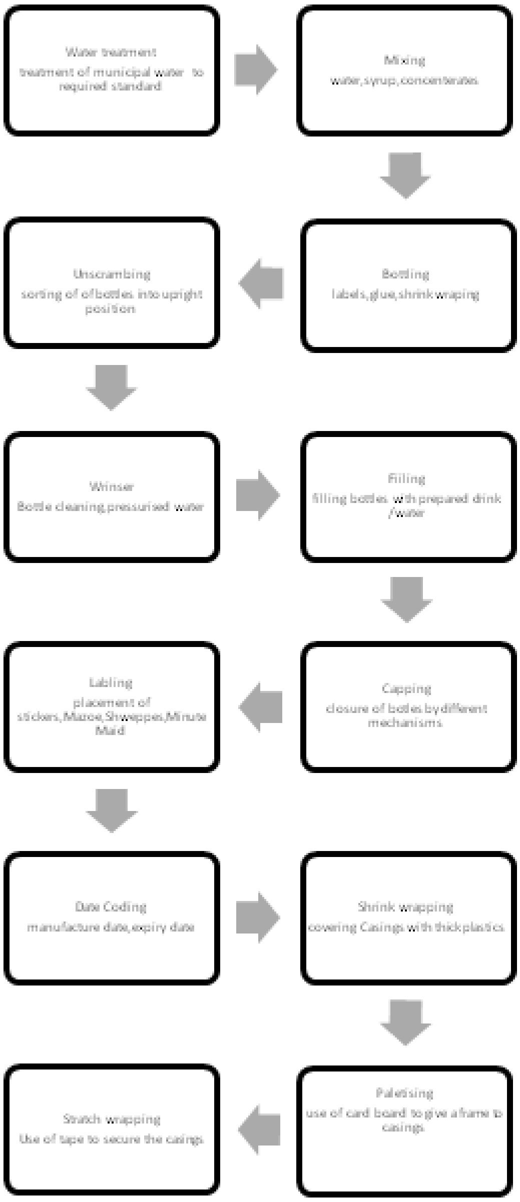

Figure 1: Manufacturing process sequence

5.2 Pre-Assessment

The objective of the pre-assessment is to obtain an overview of the company's production and environmental aspects. Production processes will be represented by a flow chart showing inputs, outputs and environmental problem areas. Qualitative review will also assist the Assessment and Evaluation stages of the Cleaner Production.

5.3 Cleaner Production assessment [2]

A detailed site inspection was performed at this step. During this task, processes were analyzed in detail to determine the inputs and outputs to be included in the mass balances which would be the basis for CP opportunities evaluation. The evaluation guidelines are as follows:

On-site inspection activities:

- Identify all wastewater discharges including leaks and spills.
- Monitor the process unit operations to identify unmeasured or undocumented releases of products and wastes.
- Make necessary measurements to identify flow rates of specific discharge sources.
- Make necessary experiments to characterize wastewater sources where there are obvious CP opportunities or high pollution loads to environment.
- Interview the operators in the targeted drink manufacturing processing areas to identify operating parameters, wastewater generation and spill reduction opportunities.
- Evaluate the general conditions of the processing equipment.
- Examine housekeeping practices throughout the facility.
- Check for spillage and leaks at the equipment
- Check waste storage area for proper waste segregation.

5.4 Environmental aspects

Liquid effluent: Like all beverage manufacturing plants, the company generates a warm, liquid effluent stream containing fruit juices, acids constituents and cleaning and sanitizing agents such as Metabisuphite and Caustic Soda used in cleaning of floors and product tanks. The quantity of effluent discharged per month is 730,000 L. The company is not connected to a wastewater treatment plant and therefore discharges treated effluent directly to a treatment site close to the Willovale plant were the pH levels of the water is reduced .

Emissions to air: Emissions to air principally result from the combustion of fossil fuels in the boiler for steam generation. Pollutants emitted include NOx, CO, CO_2, sugar dust and coal dust.

Solid wastes: Current operating practices generate a monthly average of 1420kg of solid waste comprising of ash, plastic containers and cardboard boxes and a little contribution from the electronic waste. By far the largest proportion of the company's solid waste stream is of packaging materials comprising, particularly the cardboard containers used to package drinks. Approximately 1200 containers are lost as waste per month, which represents approximately 10% of the total number of drinks ready for sale. Paper wastes are reused off site wherever possible and reject glass bottles are also recycled off site. The company generates its own steam in an on-site boiler for heating and processing, and other energy needs are met using electricity.

Energy: Company generates its own steam in an on-site boiler for heating and processing, and other energy needs are met using electricity.

5.5 Material balance

The purpose of undertaking a material balance is to account for the consumption of raw materials and services that are consumed by the process, and the losses, wastes and emissions resulting from the process. A material balance is based on the principle of 'what comes into a plant or process must equal what comes out.

Process inputs and outputs: The input and output information were collected in the plant simultaneously. During the process of collecting the input and output information the investigating team noted down any areas of inefficient operation and any opportunities for waste reduction. The information regarding to the inputs and outputs was noted down with respect to each section as shown below.

Some of the data used in the assessment were estimates calculated from the aggregated figures basing on the capacity of unit processes and usage while some of the data were calculated after taking measurements. The data collected was an average of the half year operation of the year from June 2012 to December 2012.

5.5.1 Steam generation and usage

Steam flow is shown in Figure 2 and the input output is given by the Table 2 below:

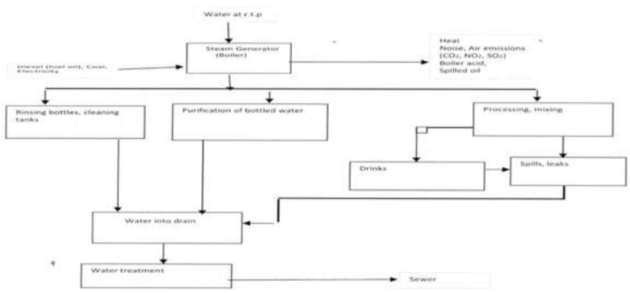

Figure 2: Steam generation flow process

Table 2: Steam process input/output

Inputs	*Outputs*
Diesel: 50L/hr~800L Fuel oil: 20L Coal: 0.013kg/L Electricity: 5000kwh Water at r.t.p: 758000L	Heat: 2000.27 GJ Noise: Not quantified Air emissions CO2,SO2: Not quantified

5.5.2 Compressed air generation and usage system

This is given by Figure 3.

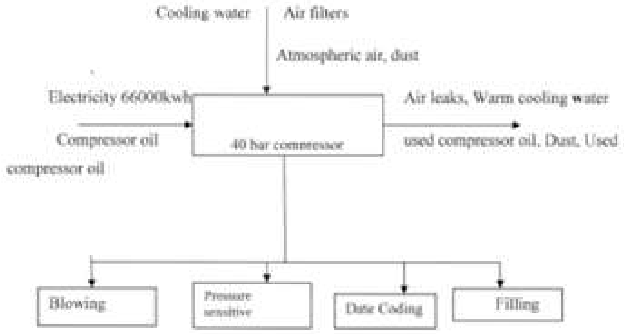

Figure 3: Compressed air process

5.5.3 Water Treatment

Water treatment process is also given by Figure 4

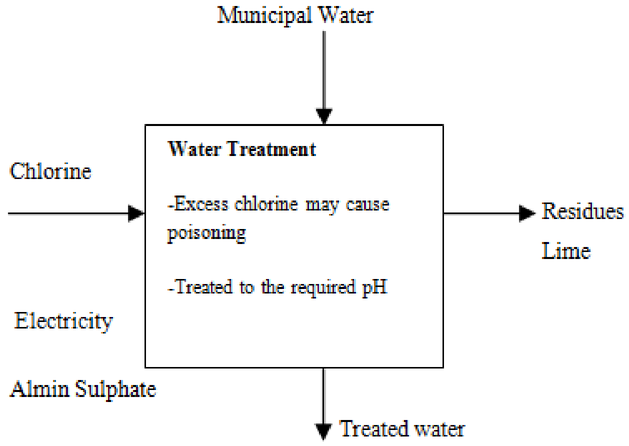

Figure 4: Water treatment process

Table 3: Water treatment inputs/outputs

Inputs	*Outputs*
Chlorine: 200kg Electricity: 36000kwh Municipal water: 7400000L Aluminum Sulphate: 25kg	Chlorine Spills: 500g Lime: Not quantified Treated water: 7400000L

The water is pre-treated on-site to meet product quality requirements before being used in the manufacturing process. The process of water treatment can be divided into two dies; a softened die produced softening water for bottle washing and for vapour production. The other produced treated water or (fresh water). This process is fed by municipal water.

The water input volume is measured by a flow meter. Then this water is stored in tanks to avoid any risk of water miss. For the production line of treated water, stored municipal water is pumped to the sand filter; a coagulation/flocculation can take place on line by adding aluminum sulfate according to the quality of municipal water. Then water passes through two decarbonator filters before stored. As this water is intended for the manufacture of simple and finished syrup, it must undergo a treatment by activated carbon with of two carbon filters.

5.5.4 Mixing of ingredients

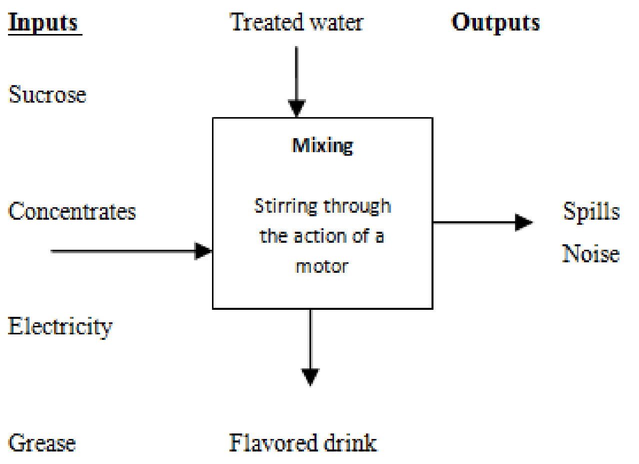

Figure 5: Ingredient mixing

Table 4: Mixing inputs/outputs table

Inputs	*Outputs*
Sucrose: 0,027kgs/L Electricity: 52000kwh Grease: 20kg's Concentrates: 0.0085kg/L Treated water: 6758000L	Noise approx: 76 dB (A) Flavored drink: 6757800L Spills: 200L

Raw sugar is dissolved in treated water. Sugar is dissolved in the sugar dissolving unit where it is stirred through the use of electric motor, when completely dissolved the solution is mixed with concentrates or pure juices depending on the type and flavor.

5.5.5 Unscrambling

This is the sorting out of the different containers preparing them for the filling process. The bottles are removed from a container and are placed on the production line. It involves ordering of the disordered bottles, the random bottles are tided and set in a good position to the conveyor belt. Disordered bottles are carried out into a storing bottle section with the help of a rotating disk. The bottles are ordered into a mouth up position and conveyed to the next by a conveying system.

5.5.6 Rinsing

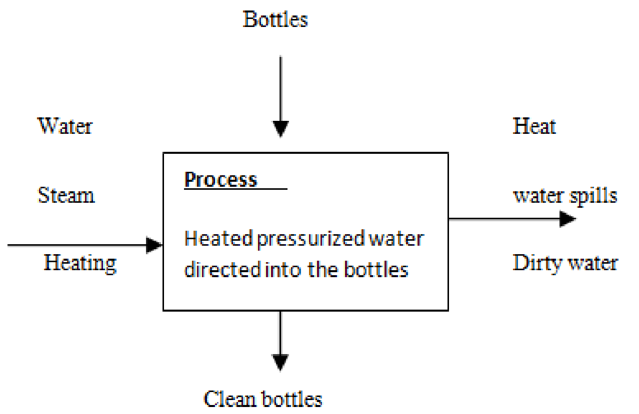

Figure 6: Container rinsing

Table 5: Rinsing input/output

Input	*Output*
Water: 320000L Steam Electricity: 42000kwh Bottles: 118 800	Heat water spills: 3200L Dirty water: 316 800L Clean bottles: 118800

The process involves the cleaning of the bottles using the highly pressurized water .Hot sanitation is used which involves the use of warm water. Besides the cleaning of the bottles the process also involve the cleaning of the tanks during product change. Caustic Soda (NaCO3) is used the cleaning of the tanks which is of great risk to the health of employees if not used as required. Product Change which is done on a daily basis during the early hours.

5.5.6 Container filling

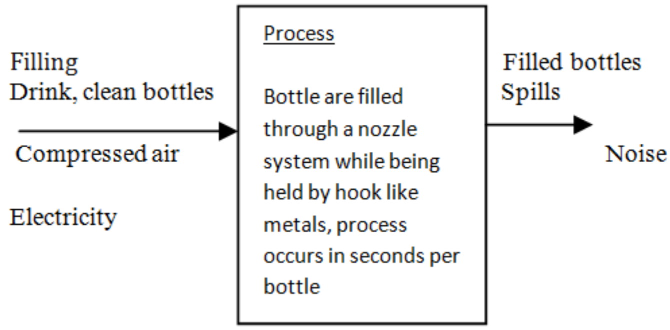

Figure 7: Filling process

Table 6: Container filing input /output

Inputs	*Outputs*
Drink: 675 800L Clean bottles: 118 800L Compressed air: Not quantified Electricity: 30000kwh	Filled bottles: 117612 Spills: 6758L Noise: Approx 95db(A)

The process involves the filling of the bottles, with the juices or beverage. The juice is pumped out of the tanks and allowed to fill the bottle through valves. The bottles are held in position by a wire on the bottle neck. The filing takes place in the different sizes of containers 500ml, 1L PET, 340 ml cans. Capacity of the filler ranges around 5L per minute per filling valve depending on the present conditions of this machine.

5.5.7 Capping

This is where closure of the filled bottles occurs. Bottles are brought by a conveyer system where each bottle is sealed. Depending on the design of the bottle different capping methods are used

5.5.8 Labeler

The process involves the use of glue, designed papers with the flavours written on them. The papers are stuck around the bottle using hot glue. The bottle containers are brought by a conveyor system a strip of the designed paper is unwrapped from the roll .Glue coming from a nozzle like structure is directed in circular motion to bottle were is used to stick the paper on the bottle

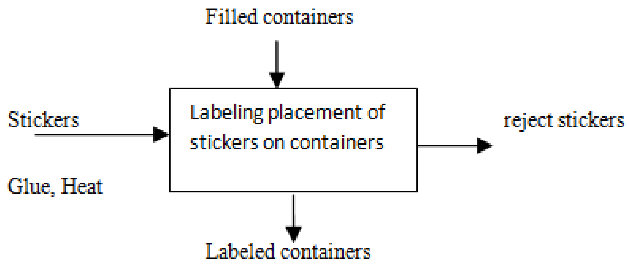

Figure 8: Labeling process

Table 7: Labeling input/output

Input	*Output*
Stickers: 118692 Glue: Not quantified Heat: Not quantified Filled containers: 117612	Reject stickers: 1080 Labeled containers: 117612

5.5.9 Date Coding

The labeled bottles are directed to date coding machine, the bottles are stamped on the bottle neck using ink. The manufacturing date and expiry dare are stamped onto the bottle neck .For products such as the Minute Maid the dates are placed on the cap. The permanent ink immediately dries once stamped on the bottle due to the warm environment created during the operation of the machine.

5.5.10 Shrink wrapping

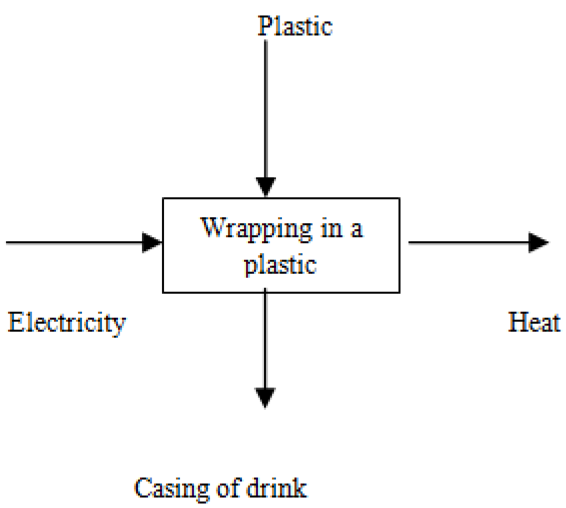

Figure 9: Wrapping process

The filled bottles are arranged in sets of six's and twenty-four's depending on the beverage type, for the 2 lt, 340ml they are wrapped in set of six, fruit and mineral water wrapped in 24's The sets are then wrapped in a plastic set of heated of elements are then used to shrink the 'casing'. The plastic then becomes tightening on the bottles .Great amount of heat is dissipated from the shrink wrapping machine such that there is need for an insulation measure to be put in place.

6. Cleaner productions options

Economic, technical and environmental evaluations were performed so as to select the best option for the cleaner production at the site. Ideally all unit operations should have been selected as a target for cleaner production but with the past experience it is common for Cleaner Production assessments to focus on those processes that:

- Generate a large quantity of waste and emissions;
- Need a lot of energy and raw material
- Use or produce hazardous chemicals and materials;
- Entail a high financial loss;
- Have numerous obvious Cleaner Production benefits

Environmental, Technical and Economic Concerns

Typical sources of problems at the site

Solid waste:	Plastic bottles
Soil pollution:	Spilled waste oil
	Dumped waste oil
Noise:	Engines and compressors
	Bottling hall
Air emissions:	Combustion gases from boilers

Occupational health and safety problems
Noise in the bottling hall
Handling of caustic soda

Unit operation - Water treatment

Volumes of water were lost in this first stage, water spills from the over spilling tanks .The tank were lately closed during other shifts of production hence resulting in the water wastage. Chlorine spills were simply allowed to be washed away with the water to the nearby grass hence killing the grass. Periodic cleaning of tanks resulted in the water being directed straight into the drains.

Unit operation –Mixing

The process produced sugar dust while the sugar was poured to the water; generally great economic losses were due to incorrect mixtures that were simply directed into the drain leading to a near water treatment site. Leaking solution and wrongly prepared solution if allowed to flow freely it may find itself infiltrating into the water sources close by this may result in an undesirable change in the water quality due to different pH levels and salts .Such an action led to the losses of the ingredients such as sugar and the concentrated juices. Energy used by the stirrer is wasted; no recovery measure can be implemented to recover such an energy loss. Analyzing closely the process it affects the fuel wasted by the forklifts in carrying the sugar the stir, syrup room.

Unit operation –Rinsing

Nozzles used in the process were a contributor to the water losses, highly pressurized water spills were created in the process. Water used in rinsing was simply discharged into the drain; no efforts of reclaiming the water were currently underway. A lot of water was used during this process and warm water was not recovered hence increased the time and heat energy required to heat the water causing bowing down to cost associated with the boiler. Wastewater containing dirt as a result of spills when cleaning the containers went straight into the drain.

6.1 Wastewater and energy problems

Characteristics of the waste water:

- High fluctuation in amount
- High pH caused by Caustic Soda
- High temperature caused by discharge of water from cleaning process.

During the study it was discovered that no condensate was returned to the boiler for re-heating. In the rinsing process, steam was directly used in heating water in steam/water mixers and was eventually discharged into the drainage system. All the steam except that lost due to leaks turned back into water and discharged into the wastewater treatment plant. Some of the pipes were not insulated. Steam leakage points were also noted. A total number of 4 steam leakage points were noticed. The boiler had no economizer or any mechanisms to reduce the consumption of coal.

6.2 Filling, Labeler, Shrink rapper Palletising

Spills mainly due to incorrect positioning of bottle containers during the filing process were measured .As a result of poor maintenance of the filling machine the solution in some instances is directed away from the opening of the bottles. The shrink wrapper consumes much of the electrical energy. Its operation of 22hours daily, simply because the elements on the wrapper require more time to heat up contributes to its large consumption of energy. Air compressors are often very noisy, and can be a nuisance for noise sensitive receptors in some circumstances. Since the air compressor is water cooled, water consumption is quite high. Small holes in the compressed air system (pipes, valves etc.), result in the loss of a large amount of compressed air continuously. This results in a waste of electricity because the compressor has to run more than is necessary .Card board left a shift of production is not reconsidered for the next shift it is simply discarded into the bins.

Table 8: Ranking of mixing options

Department: Mixing					
Process: Drink/juice preparation					
Responsibilities: Supervisor					
Activity Product	Aspect - normal - abnormal Operation	**Economic and Environmental effects**			
		Nature	Human	Raw Material	Energy
Process step	In normal use Accident or break down	Impacts to flora, fauna…	health and safety	Raw material and waste	Loss of heat, energy
Water Preparation	-Water spills - Chemical spills	1	2	3	1
Mixing	-Sugar dust -Syrup spills -wrongly prepared solution	1	2	3	2

Table 9: Ranking of bottling options

Department: Bottling
Process: Rinsing, Filling, Labeling
Responsibilities: Bottling manager

Activity Product	Aspect - normal - abnormal Operation	Economic and Environmental effects			
		Nature	Human	Raw Material	Energy
Process step	In normal use Accident or break down	Impacts to flora, fauna…	health and safety	Raw material and waste	Loss of heat, energy
Rinsing	-Water wastage	1	0	3	2
Filling	-Spills	0	1	3	1

Key

Rank	Description
3	Undesirable, immediate attention required
2	Undesirable, Significant impact
1	Desirable, little impact
0	Insignificant

Since the objectives of study carried out involved minimising waste, energy consumption the focus was selected on basis of the pollution and energy consumption. Using Berkel weighing method different process and stages are going to be analysed to establish a focus of control. The different processes were ranked on basis of their level of energy consumption and pollution.

Table 10: Processes and their pollution rating

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 11: Waste and emissions ranking

Inputs	Process	Outputs	Description	Pollution rating
Municipal Water	Water Treatment	Spillage waste vaporised water	Vaporisation of water Rest of the water is stores in tanks	1
Chlorine	Water Treatment	Chlorine in purified water Spillage	Spilled Chlorine is swept and directed to the bin Some is washed away by running water	3
Almin Sulphate	Water Treatment	Almin Sulphate in purified water Spillage	Almin Sulphate is swept and directed to the bin	3
Electricity	Water Treatment	Pumping of water	Continuous process	1
Sucrose	Mixing	Diluted in water Sugar dust	Sugar lost as dust Dust settles on wall in the syrup room	3
Clean water	Mixing	A solute to the concentrates and sucrose	Dilution of concentrates and sugar	1
Energy	Mixing	Air carries away heat Process absorbs heat	Energy is lost on conduction with the pipes and vessel.	3
Concentrates	Mixing	Diluted in water		1
Steam	Rinsing	Steam leaks Condensing to flow as water	Small holes on the pipe section contributing to loss	7

Plastic bottles		Cleaned plastic bottles Losses due to some falling along the conveyor belt		3
Water		Spills, directed into the drain Water with small solid particles	Dirt is collected by the rinsing water under pressure	5
Energy		Energy used to carry the bottles on the conveyor system and the boiler	Other losses to the heat lost in the condensate that is simply disposed into drain	7
Drink	Filling & Capping	Product losses, product change Filled bottles with drink.	Product change some of the previous drink is discarded.	5
Clean bottles		Filled bottles with drink.	Customer will dispose container after use.	5
Energy		Used to pump the liquid into the containers.	Absorbed by the compressor	1
Compressed air		Air leaks Used in filling process	Left in the open air	7
Glue	Labeling	Placed on stickers Spillage	Permanent on the bottle, disposed together with container	3
Stickers		Are stuck on containers Rejects	Customer will dispose after use Rejects disposed in the bin	5
Heat		Absorbed by glue Dissipated into the air	Heats up the air in plant	3
Filled containers		Rejects Labeled containers	Customer disposes after use	3
Plastics	[illegible]	Plastics covering the bottles	Customer throws away the plastic	5
		Plastic wastage	Off cut plastic is waste	
Energy		Used in heating plastic for wrapping	Customer will throw the foil away. Empty foil roll are a waste.	5
Cardboard		Card board wastage	Loss is due to wet cardboard	3
Water	Cleaning	Spillage waste vaporised water	Vaporisation of water, Waste water to be disposed.	7
Energy		Energy absorbed by equipment energy absorbed by water	Energy absorbed by the water and cleaning machinery during washing.	3

Rank	Description
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

6.3 Selecting areas of focus

The selection of areas of focus was done with basis of the rankings given above. Ideally all process should have been selected for the focus but however to get an effective cleaner production implementation only areas that had a ranking of 5 and 7 were selected.

Table 12: Option ranking

Input	Processes	Output	Rank
Steam	Rinsing	Steam leaks, condensing to flow as water	7
Water	Rinsing	Spills, dirt water with solid particles	5
Compressed air	Filling	Leaks, air in filled plastic bottles	7
Stickers	Labeling	Rejects, stuck on containers	5
Plastic	Shrinking, wrapping and palletizing	Off cut, customers throw away plastic	5

6.4 Feasibility of options

6.4.1 Steam Supply System

Proper operation of the boiler requires proper training of employees. The efficiency of boiler depends on how well the boilers are operated. If the air/fuel ratio is wrongly adjusted the incineration will be poor, causing more pollution and/or poorer utilization of the fuel.

Steam leakage: Steam leaks should be repaired as soon as possible when identified.

Utilization of condensate: Steam condensate from the heater exchangers and by-products machine should be returned to the boiler. Utilisation of the condensate will help reduce the amount of energy required to heat the water to produce the required steam. The payback period for such a system would be short considering that 1m3 of lost condensate represents 8.7kg of oil at a condensate temperature of 100°C. There is also some saving in water consumption. Condensate is a valuable resource and even the recovery of small quantities is often economically justifiable. The discharge from a single steam trap is often worth recovering. Unrecovered condensate is replaced by cold make-up water with additional costs of water treatment and fuel to heat the water from a lower temperature.

Oil handling: It is very important to avoid oil spills, and if they occur, they need to be cleaned up properly. Oil spilling can cause serious pollution of soil and water. One litre of oil contaminates 100,000m3 of water, rendering it unfit for drinking.

6.4.2 Rinsing

Table 13: Options related to equipment rinsing

Type of prevention Practice	*Typical low/no cost examples*	*Typical medium/high cost examples*
Product Modification	Install nozzles on hoses to increase the effectiveness of spraying while decreasing water use.	Reduce the pumping cost by optimum pipe sizing since the power used to overcome the static head varies linearly with flow Replace the steel pipes with pvc (low coefficient of friction)
Technology Modification	Replacing the star-delta connection with a variable speed on the motor as is saves more energy	Monitoring the flow of the concentration mixture of the solution. Placing meters that measure density, temperature and concentrates of individual ingredients.
Good Housekeeping	Spot apply solvents instead of pouring; this helps avoid spills and stops excessive chemical use Turn off water between batches or while product change.	
On Site Recycling	use rinse water from the final stage of production for cleaning floors	

6.4.3 Labeling

Glue and labeled paper should not be used for labeling the plastic containers; stickers should be used for labeling since this reduces the loss of the glue and the heat required to heat the glue hence reducing the electricity consumption.

6.4.4 Filling

Shutting the system off when not in use and reducing the operating pressure of the system can also reduce the use of compressed air. A temperature-sensitive valve, ensuring the optimum cooling temperature and minimum use of water should regulate the consumption of cooling water. Furthermore, cooling water can be re-circulated via a cooling tower. Alternatively, the cooling water can be reused for other purposes such as cleaning, where hygiene requirements are low.

6.4.5. Plastic

There should be an initiative to bring back the empty containers to the plant so as to cater for the littering that is caused by these plastic bottles when disposed by the customer

6.5 Evaluation and feasibility

The suggested cleaner production options were evaluated in the different sectors that included technical, economic and environmental feasibility. The no or low cost options were suggested for implementation, housekeeping methods of cleaner production should be directly implemented without further investigation as they were rendered suitable for the site. Responsible authorities to where the implementation was to be applied were consulted to obtain the technical and economic feasibility.

Table 14: Option feasibility

Cleaner Production Option	*Expected feasibility*		
	Technical	*Economic*	*Environmental*
1.Utilization of condensate	Feasible	Reduces heating cost	Savings in energy and water
2.Using pressurized air for cleaning	Highly feasible	Saves water cost	Saves water
3.Replacing the star-delta connection with a variable speed on the motor, use of Variable Frequency Drives (VFDs) for use in pumps,	Feasible and practical	Moderate returns	Little or no effect
4. Placing meters that measure density, temperature and concentrates of individual ingredients.	Feasible	Low investment ,high returns	Reduction in chemicals discharged into the drain
5.Using rinse water from the final stage of production for cleaning floors	Feasible	Low cost	Savings in water
6.Using stickers for labeling	Feasible and practical	Eliminates glue costs	Savings in energy
7.Buying back the plastic containers	Highly feasible	Legal fines	Eliminates littering
8.Section metering	Feasible	Low returns	Little or no effect

6.6 Cost- benefit analysis

Cost Benefit Analysis is a relatively simple and widely used technique for deciding whether to make a change. It is basically to use the technique simply add up the value of the benefits of a course of action, and subtract the costs associated with it. In its simple form, cost-benefit analysis is carried out using only financial costs and financial benefits. The cost benefit analysis relies on the addition of positive factors and the subtraction of negative ones to determine a net result, it is also known as running the numbers.

7. Research recommendations

7.1 Option One: Utilization of condensate

Any process that allows energy contained in Steam condensate to go unutilized, is losing money in terms of fuel costs. Steam condenses to water at saturated temperature and so, depending on the pressure during condensation, the temperature of water may be 100 oC or more. Heat content in condensate is about 20% of the fuel energy burnt in the boiler. This is usable heat energy; it would be waste of money and resources.

Cost of installing the condensate recovery system

Utilization the condensate would have involved installing a system to collect the condensate and return it to the boiler for reuse. The materials required included a plastic tank, pump and motor, heat exchange pipes, drain pipe, return pipe, valves and T-junctions, installation of a flow meter to measure total gallons recovered and directed to the cooling tower.

Total material cost @Cochrane	US$17 000
Installation cost (labour)	
@12% of the material cost	US$2 040
Running cost (for one year)	US$5 460
Total cost	US$24500

Cost Savings

The boilers are coal fired, assuming an average of coal fed into the boiler with a gross calorific value of 27,2MJ/kg.

Fuel savings based on the following average temperatures

Condensate return temperature = 60°C
Make-up water temperature = 25°C
Temperature difference = 35°C

Each kg of condensate not returned must be replaced by 1 kg of cold make-up water that will need heating to the same temperature.

Heat required in raising 1 kg of cold make-up water by 35°C:

1 kg x 35°C x 4.19 kJ/kg °C = 146.65 kJ/kg

Basing the calculations on an average of 10 000 kg/h evaporation rate, and where none of the condensate is presently returned, 7 hours a day, 7 days a week, 50 weeks of the year (2450 h/year), the net energy required to replace the heat in the make-up water is:

10 000 kg/h x 146.65 kJ/kg x 2450 h/year = 3592 GJ / per year

If the average boiler efficiency is 85 %, gross energy needed to heat the make-up water

$$=\frac{3592\text{GJ/year}}{0.85}$$

= 4,226GJ/year

With a calorific value of 27.2 MJ / kg, potential savings on fuel 4.226 GJ / year

$$=\frac{4.226\text{GJ/year}}{27.2\text{MJ/litre}}$$

= 155 367 litres / year

With fuel at \$0.25 / kg, cost savings = 155 368litres×\$0.25

Therefore, potential annual fuel savings = \$38 842

Water savings

Total amount of water required in one year to replace condensate which is not returned:

$$=\frac{\mathbf{010\ 000}\boldsymbol{h}\times\mathbf{2450}\boldsymbol{kg/hr}}{\mathbf{1000}\ \text{kg/m}^3}$$

=24 500 kg/m³

Quoted at \$0.60 per m³: = 24 500×0.60

Therefore potential annual water savings = \$14 700

Total savings = (US\$38 842+14 700)
= US\$53 542

$$\text{Payback period} = \frac{Cost\ of\ installation}{Total\ savings}$$

$$=\frac{24\ 500}{53\ 542}$$

=6 months

Waste measurement Index

Waste water generated per unit of production or output

$$\text{Before} \quad \frac{waste}{waste+by\ products+product}$$

Amount water used per liter of production 3,2L

$$=\frac{2.2}{3.2}$$

=0.68

Although the value of the waste index is less than 1, an improvement could be made so as to reduce the wastewater

Other benefits of effective condensate recovery

- Energy Recovered from condensate reduces boiler running costs.
- Re-using water reduces water treatment costs.
- Reduces effluent treatment and disposal costs.

7.2 Option Two: Replacing the convectional d/c drives with variable frequency drives

Currently the compressors and the water pump are running with the support of the 7.5kW, 5.5kW and the 4kW power motors. The pressure to cut cost and to apply the different improvements in technology has led to the suggestion of using variable frequency drives. The use of variable frequency drives on variable torque loads for the purpose of gaining energy savings is a common application in other bottling plants. Variable-frequency drives are enjoying rapidly increasing popularity at water and waste-water facilities, where the greatest energy draw comes from pumping and aeration—two applications particularly suited to variable-frequency drives. Variable-frequency drives enable pumps to accommodate fluctuating demand, running pumps at lower speeds and drawing less energy while still meeting pumping needs. The workings below are meant to convince the engineering section why they should opt for such a move.

Workings

Considering a 7.5kW motor that is driving the centrifugal pump Installation Cost. Prices quoted at (ICM) industries A 7.5kW, 460 volt drive with line reactor will cost about \$1 300. Installation time, materials and start-up will cost \$500 or more.

Savings

For justification we assume an average of (7days×50 weeks×10hrs/day) =3500hrs/year

When operating across-the-line, the cost of power consumption of the motor will be

(7.5kW x 3500 Hours x $ 0.13) =$3 412 when running at full speed

Assuming the Pump does not need to run at full speed all of the day since we encounter product changes, change in shift of workers:

Running- full speed (100%) for 25% of the day
-80% speed for 50% of the day
-60% speed for the remaining 25% of the day

Cost of running with an AC drive controlling the motor

7.5kW x 875hours x1(0.3) x $0.13/kWhr = $256 per year
7.5kW x (0.8x0.3) x 1750 hours x $0.13/kWhr = $410per year
7.5kWx (0.6x0.3) x 875 hours x $0.13/kWhr = $153 per year

Total = $ 819 per year

Placing a variable frequency drive that will, according to the affinity curve, save 50% energy by allowing a 20% reduction in flow. Savings will be

=Cost of running at full speed-Cost of running at varying speeds
=$3 412-$819= $2593

Since the affinity curve neglects the static head of the system as seen by the pump, according to (Elusive Energy Savings: Centrifugal Pumps and Variable Speed Drives).Most applications will save between 1/2 and 1/3 of what is determined by the affinity curve calculation. Thus, the savings on the present application will be $863 to $1297) per year.

With the higher system head and a savings of $863 per year,

Payback is

$$=\frac{\$863}{\$500}$$
= 1years 9months

On average the drive fails after eight years. The user has gained a savings of:

(8 years minus the 2years 9 months year payback period) x $863 per year = $4556

Additional benefits

Maintenance costs can be lower, since lower operating speeds result in longer life for bearings and motors.
Eliminating the throttling valves and dampers also does away with maintaining these devices and all associated controls.

7.3 Option Three: Section metering

Cost of meter quoted @ $ 65.00 (Kent)
Sections where meters are to be placed :(Mixing, Boiler, Rinsing, Cleaning) ×3
Total cost of metering = ($65× 3) =$195.00

NB: The cost of installation was not included since the general fittings could be carried out by the maintenance team at the plant.

Monitoring the cost will help reduce the consumption of water by 10%

Amount of water saved (0.1× 7 400 000) =740 000L

Cost of water /m^3 is $0.60

Savings in water consumption (0.60× 740) = $444/month

Annual savings (12× $444) =$5 328

Pay back = $\frac{\textit{Cost of meters}}{\textit{annual savings}} = \frac{\$195}{\$5\ 328}$ =14 days

Installation of meters has a small pay period of payback making it suitable for implementation as early as possible

7.4 Integrated assessment

In terms of technical level, the eight options only four are classed in advanced CP technologies. In terms of environment protection, all options reduce pollutant discharge and they are friendly to the environment. Among them, option 1 is the best choice since it has the largest amount of reduced pollutants. In terms of economic benefits, each of the eight options has strong points and can provide significant benefits but only from three we managed to make an economic analysis. In general, the eight options all satisfy the comprehensive requirements of technology, economy and environment. However, option four is not currently recommended for implementation because new equipment and worker training are needed and the investment is relatively high. Based on the systemic characterization and analysis, all the options except 4 were combined into an integrated cleaner production system, which was recommended for implementation.

Compared with individual option implementation, such an integrated CP system will generate more benefits, such as save more water and energy, and reduce more wastes. At the same time, the productivity and health and safety will be improved and more economic profits will be obtained.

7.5 Implementation of selected options

As for other investment projects, the implementation of Cleaner Production options involves modifications to operating procedures and/or processes and may require new equipment. Schweppes should, therefore, follow the same procedures as it uses for implementation of any other company projects. However, special attention should be paid to the need for training staff. The project could be a failure if not backed up by adequately trained employees. Training needs should have been identified during the technical evaluation.

7.6 Proposed framework for plastic bottles

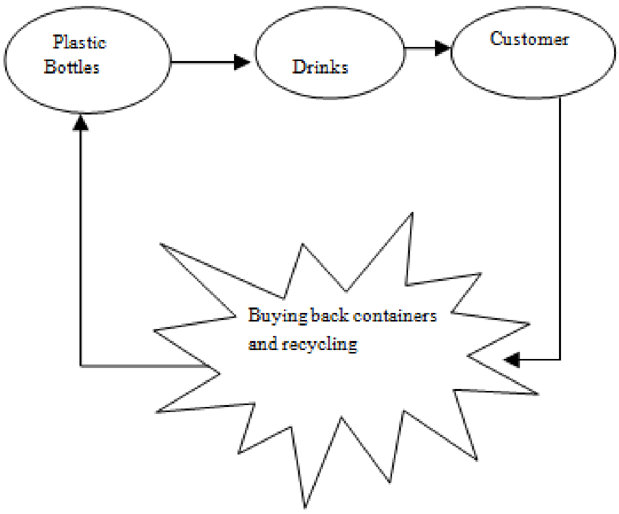

Figure 10: Plastic bottle re-cycling

7.7 Proposed framework for water

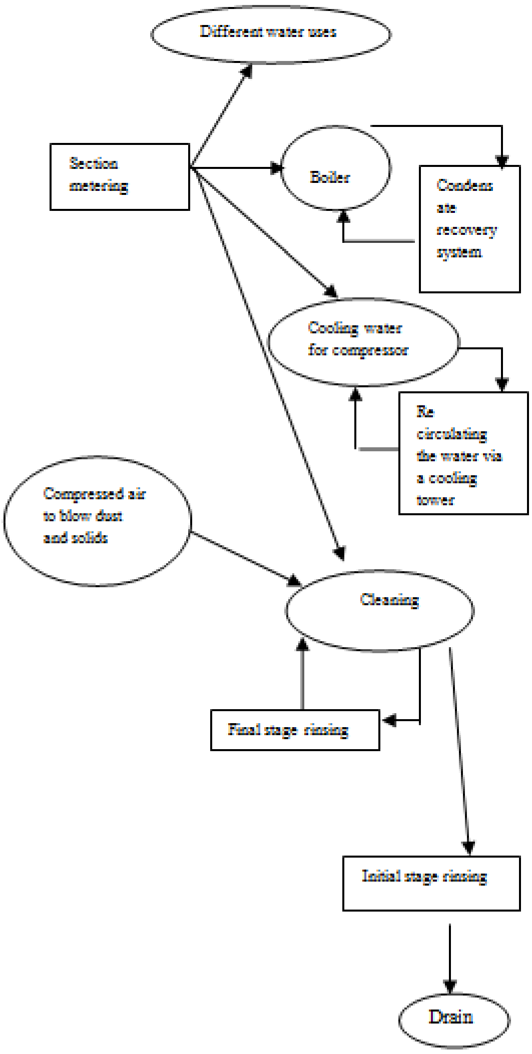

Figure 11: Water re-cycling system

8. Conclusion

To improve the resource efficiency, reduction in waste water and to reduce losses of raw materials during manufacture, an integrated system combined with a series of advanced cleaner production technologies was proposed in this study. After the consideration of environmental impacts and economic efficiency, seven cleaner production options integrated with various advanced technologies were proposed. For option seven a further study that is beyond the grounds of this project have to be conducted to see if a method in which the company can buy back the plastic containers.

While summing up, it is heartening to note that cleaner production technologies exercises are not only desirable from the environmental point of view as a preemptive strategy, but also make good economic sense. As has been seen in many cases, such exercises have added to the bottom line by conserving resources like energy, raw materials and manpower, improving yield and reducing treatment/disposal costs. The study should go a long way in promoting widespread adopting and implementation of Cleaner production technologies in other industries so that tangible progress is made in the direction of sustainable development. It is also observed that there are significant gains accruing from the merit goods viewpoint as well.

It is encouraging to note that in most cases where cleaner production technologies were implemented, the cost benefit analysis shows that the firms have benefited by and large, both quantitatively and qualitatively. The quantitative benefits are reflected in the short pay back periods; in some cases even as short as a few days to few months. In the implementation process of these options interruptions should be expected, however if implemented well they should not cause a drawback. In all the cases, firms have implemented Cleaner Technologies exercises during shutdown periods.

9. Further research

Cleaner Production options savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance. The environmental benefits of Cleaner Production can be translated into market opportunities for 'greener' products. Further work can be done on energy management options available to DrinkCo Beverages as the company still uses a lot of coal, steam and grid electrical energy, the aspect which remains a source of system inefficiency.

References

[1] UNEP Working Group for Cleaner Production 2006, Eco-efficiency in the Food Retail Industry Project: Coles Supermarket — Broadbeach
[2] UNEP Working Group for Cleaner Production 2007, Eco-efficiency Project for the Kawana Water Industrial Estate: Fortuna
[3] Mhazo. J, 2007: Air Pollution from gases O3, NOX , SO2 , and NH3 BSc Honors dissertation, University of Zimbabwe
[4] Tasmanian Department of Primary Industry, Water & Environment 2003, Information on biosolids, viewed

12 February 2004 http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/JMUY-5AJ4GM?open

[5] Tripax Engineering Co. Pty Ltd 2011, Tarn-pure, the proven cost-effective solution, Jorgensen Engineering Australia, viewed 11 November 2003, http://www.ferret.com.au/articles/e6/0c00f0e6.asp

[6] UNEP Working Group for Cleaner Production 2009, Eco-efficiency in the Queensland Food Processing Industry: Harvest FreshCuts UNEP Working Group for Cleaner Production 2003a, Eco-efficiency in the Queensland Food Processing Industry Project: Bundaberg Brewed Drinks

[7] South Australian Environmental Protection Agency 2008, Cleaner production case study — Port Lincoln Tuna Processors, viewed 31 July 2009, www.environment.sa.gov.au/epa/cp_tuna.html

[8] US DOE 2001, Office of Industrial Technologies, Energy efficiency and Renewable Energy: energy tips: Sheet 7: Clean boiler waterside heat transfer surface, US Department of Energy, Washington, 2010

[9] US DOE 2008, Energy tips: Insulate steam distribution and condensate return lines, Washington, Office of Industrial Technologies, Energy Efficiency and Renewable Energy, viewed May 2002, www.oit.doe.gov/bestpractices/steam/pdfs/insulate.pdf

[10] US DOE 2006, Office of Industrial Technologies Energy Efficiency and Renewable Energy, Compressed air system renovation project improves production at a food processing facility

[11] Washington State University Energy Program, Washington State University Energy Program Energy Audit Workbook, viewed 7 November 2003, http://www.energy.wsu.edu/ftp-ep/pubs/rem/energyaudit/audit1.pdf

[12] WBCSD (World Business Council for Sustainable Development) 2002, Eco-efficiency, creating more with less impact, viewed 19 March 2007, http://www.wbcsd.org/DocRoot/02w8IK14V8E3HMIiFYue/eco_efficiency_creating_more_value.pdf

[13] Western Australia Water Corporation 2008, Biosolids, viewed 14 November 2003, http://www.watercorporation.com.au/business/wastewater_biosolids.cfm

Authors' Profiles

Kumbi Mugwindiri did Bsc Mechanical Engineering Honors at the University of Zimbabwe, and Masters in Manufacturing Systems at Cranfield University, England. Currently, lecturing Engineering Management at the University of Zimbabwe. He worked as Workshops Engineer for Zimbabwe Phosphates Industries responsible for heavy maintenance of process plant equipment. In 1993 carried out a project with the Ford Motor Company to determine ways of improving working patterns and practices, this was a European Union wide project. In 2000, he undertook collaborative research in Clean Technologies at Tulane University in New Orleans. Has worked with many organizations researching/and or consulting in Maintenance Engineering and Cleaner Production.

Ignatio Madanhire, graduated with a BSc Mechanical (Hon) Engineering and MSc in Manufacturing Systems and Operations Management in 1993 and 2010 respectively from the University of Zimbabwe. He has been a mechanical engineer with Department of Water – Large Dam Designs, and also worked as a Senior Lubrication Engineer with Mobil Oil Zimbabwe as well as Castrol International dealing with blending plants and lubricants end users. Currently, he is a lecturer with the University of Zimbabwe in the Mechanical Department lecturing in Engineering Drawing and Design. He has published a number of works on cleaner production in number of journals.