

Cleaner Production to Optimize Resource Consumption and Reduce Effluent Waste in a Beverage Plant

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Abstract - The study investigated the Cleaner Production (CP) concept in reducing waste generation, operating costs as well as resource consumption in a beverage manufacturing plant. CP assessments were done on respective key processes in the plant to optimize input resource and minimize waste at source. A number of implementable options were recommended for them to be effected in the beverage plant to improve on the cost effectiveness of the plan, and for environmental friendly complying operations.

Key words – waste; resources; cleaner production; manufacturing; beverage

I. INTRODUCTION

In a world of increasing demand for depleting natural resources, coming decades will see a focus on resource use efficiency. This thrust can be achieved through minimization and prevention of waste generation at source in a manufacturing set up. In Zimbabwe, manufacturing is the greatest source of pollution responsible for half the volume of all water pollution, as it uses fresh water to carry away industrial waste. Regulatory compliance is now mandatory for environmental preservation and product competitiveness. Inputs such as water, electricity, coal and process chemicals are to be used sparingly, to drastically reduce resource input consumption as well as minimize resulting waste in a carbonated soft drinks plant. High volume of water was used and there was no recycling of waste water in place for reuse. The cost of treating this water is about USD 47 384. Boiler efficiencies could as well be improved to cut on coal usage in the plant. The fusion of the prevailing environmental management system (EMS) and cleaner production practices were considered to eliminate unnecessary operational costs associated with waste and pollution mitigation.

II. CLEANER PRODUCTION (CP) OVERVIEW

A. CP Brief

UNEP defines Cleaner production as continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment [1]. CP reduces production costs through greater resource efficiency, recovery of valuable by-products and minimizes disposal challenges including charges for waste treatment. As well as reduce energy consumption and improve products quality and competitiveness. Thus CP is a broader commitment to pollution prevention, and it directs activities towards production aspects within any manufacturing sector. Unlike in the past when pollution was simply controlled, pollution prevention and cleaner production programs attempt to reduce or eliminate air, water, and land pollution in an efficient and sustainable manner to benefit both the environment and the society [2]. Also CP reduces resource use and pollution at source by using cleaner products and production methods, where as traditional end of pipe technologies curb pollution emissions by implementing add-on measures. In this regard, cleaner products and production technologies are seen as superior to end of pipe technologies for both the environment and economic reasons.

Any enterprise has the mandate to reduce waste and improve productivity, and in so doing it would save on energy (electricity, fuel), water (waste water) and input raw materials. At the same time the Occupational Health and Safety (OHS) situation is improved achieving a safer and better workplace [3].

B. CP Implementation

For successful CP implementation, an organization has to promote the involvement of employees. The employees on the shop floor have a good understanding of how and why waste is produced and they will be very key in coming up with ideas and suggestions. Accurate information on costs is very important to show everyone in the organization the benefits of cleaner production. Such costs are associated with end of pipe activities should be accounted for as they can be easily converted to profits. Table I below gives the organized approach to identify, evaluate and implement CP opportunities [4].

TABLE I. CP IMPLEMENTATION PROCESS

| | |
|------------------|--|
| Initially | Recognized Need for Cleaner Production |
| Step 1 | Planning and Organization |
| Step 2 | Pre-Assessment Phase |
| Step 3 | Assessment Phase |
| Step 4 | Feasibility Analysis Phase |
| Step 5 | Implementation and Continuation |
| Finally | Project Results Assessment |

If well implemented, the concept demonstrates that CP would provide management and employees with systematic tools to decrease the environmental impact and at the same time saving costs arising from inefficient use of materials and energy with the resulting effect of motivating the whole organization towards: productivity of materials, energy efficiency, material flow, environmental protection, sustainable use of materials, service orientation and legal compliance. A strong pollution prevention program forms makes the difficult task of implementing Environmental Management Program (EMS) easy. Employee training and awareness is critical, so are documentation, operating procedures, and setting up internal and external communication lines to review and monitor progress [5].

C. Waste minimization

These are efforts to resource and energy use in manufacturing processes. For the same commercial output, usually the fewer materials used, the less waste is produced. It requires knowledge of production process and a detailed knowledge of the composition the waste generated. Reasons for waste creation vary from supply chain requirements to inefficient production methods. In industries, that use more efficient manufacturing processes and better materials, less waste is generated. The application of waste minimization techniques has led to the development of innovative and commercially successful replacement products. And these are of great benefit to the industry and the wider environment [5].

D. Recycling of by products

Recycling seeks to process used materials(waste) into new products to prevent waste of potentially useful materials, reduce consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from land filling) by reducing the need for “conventional” waste disposal. Recycling is a key component of modern day waste reduction.

E. Eco-efficiency

It is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution. According to World Business Council for Sustainable (WBCSD) 1992, it is achieved through the delivery of competitively priced goods and services that satisfy human needs and improve quality of life, while reducing environmental impacts of goods and resource intensity to a level in with the Earth's estimated carrying capacity. Thus critical aspects of eco-efficiency are:

- Reduction in material intensity of goods and services
- Reduction in energy intensity of production
- Reduced dispersion of toxic materials
- Improved recyclability
- Maximum use of renewable resources

F. CP in food industry

In relation to food safety, hazard Analysis Critical Control Point (HACCP) has become a widely used tool for managing food safety throughout the world to enhance safety and quality. As well, Cleaner Production can take these two aspects to higher level of achievement in food industry production when the critical process steps are followed. A waste management plan is put in place to include inventory of waste produced and components of such waste as well as specific goals for reducing the quantities and pollution discharges through adaptation of CP methods, recycling of waste, safe transportation and disposal. Thus it is prohibited to discharge any waste in a manner that causes environmental pollution or ill health to persons. Due to biological nature of food products, if environmental regulations are not religiously enforced, massive damage and pollution occur to the environment.

III. METHODOLOGY

Pre-assessment was done by a walk through to get an overview of company operations in the plant and interact with operators. The objective was to do a work study of the production facilities, waste treatment and

disposal facilities to establish material balances of major polluter processes involved. Interviews were held to get insight into employees' experiences, opinions, attitudes and feelings on the subject matter. The actual assessment identified areas of inefficient use of resource and poor waste management in detail. The stage allowed collection of data to enable evaluation of environmental performance and generated waste during manufacturing of carbonated drinks. This allowed the generation of implementable CP options for the beverage plant against the assessed environmental indicators.

IV. RESULTS AND DISCUSSION

A. Organization overview

The case study company is an international and broad-based organization with interests in beverage manufacturing and distribution. It manufactures lager beers, soft drinks, juices and mineral water. The entity is focused on initiatives to reduce environmental footprint and promote inclusive work environment. The plant was both ISO 9001 and ISO 14001 certified as issues of quality are key to the beverage manufacturing industry.

B. Water usage

Enhancing water productivity i.e volume of production per unit of water is paramount to successful programs of water scarcity alleviation. Beverages have a water base and a lot of water is required in the manufacturing of products. Water is extensively used during bottle and crate cleaning process as shown by Table II below.

TABLE II. WATER CONSUMPTION FOR YEAR 2013

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-----------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Volume (liters) | 51 034 400 | 40 647 300 | 43 015 000 | 44 715 500 | 47 164 700 | 50 631 500 | 52 822 800 | 49 489 000 | 52 989 000 | 41 115 000 | 48 121 000 | 49 600 800 |

In year 2013, production was pegged at 8 776 300 liters. The rest of the water 562 569 700 liters (98%) was thrown away as effluent resulting from cleaning operations and process losses. Only one water meter is in place for total fresh water usage at the plant. Hence individual process water consumption was not known.

C. Solid waste

During the same period, a total of 755 080 kilograms of solid waste was produced of which 417 000 kg was glass, 34 090 kg of plastic was recycled. Then the rest 304 000kgs was taken to landfill dumpsite.

D. Energy consumption

Energy in the plant was used to run electric motors on process equipment, for heating and running compressors. The energy sources were grid electricity from the national power utility and combustion of coal for generating steam in the boilers. Table III gives the various energy uses. This area posed substantial savings without capital investment.

TABLE III. ENERGY USAGE FOR 2013

| Energy usage | Units |
|--------------|-------|
|--------------|-------|

| | |
|---------------|---------------|
| Electricity | 4 515 086 kWh |
| Fuel (diesel) | 73 500 liters |
| LPG | 63 701 kg |
| Coal | 1 329 300 kg |

E. Glass bottle recycling

Huge quantity of broken glass was sold to back to the bottle supplier. This is costly and unnecessary in terms of handling and transport involved. Two of the main filling lines are responsible for the 98% of bottle breakages experienced in the plant. These could be recommended for replacement in the long term to cut on unnecessary solid glass waste being generated in the plant.

F. Plastic and water reuse in PET section

Most of the plastic containers are reused. Water used for rinsing at the PET packaging line was relatively clean. This water could be recommended for reuse in conveyor lubrication and other laundry operations. Amount of water used in all processes could not be quantified. Hence it was suggested to install individual water meters at major water usage processes such as water treatment, syrup manufacture, bottle washing and packaging.

G. Resource consumptions

Table IV gives the various resource consumption per hectoliter (Hltr) (Hltr = 100 lt) for the organization against the best practice in the beverage plants.

TABLE IV. RESOURCE CONSUMPTION PER Hltr OF PRODUCT PRODUCED

| Resource | Actual / Hltr | Best Practice/ Hltr |
|-------------------|---------------|---------------------|
| Electricity (kWh) | 51.4 | 5.3 |
| Coal (kg) | 15.1 | 1.5 |
| Water (Hltr) | 65.1 | 5.7 |
| | | |

The consumption figures per Hltr of packaged for the organization in comparison to the best practice are way too high and this translates to a more expensive final product.

H. Syrup manufacturing

Fig .1 below gives the material balance for this cold process.

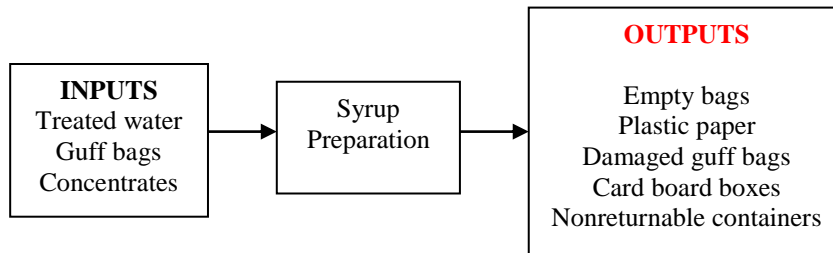


Fig. 1 Syrup material balance

Detergents and sanitizers were discharged into as effluent after cleaning. Also resulting are used packaging material and unwanted empty containers as solid waste overloading the equipment.

I. Bottle washing

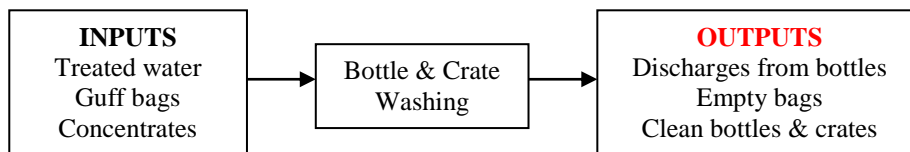


Fig. 2. Bottle washing material balance

Empty bottles and rates are received and presoaked in caustic tank steam at elevated temperatures. During rinsing, softened water, pH correction additive and chlorinated water is added. The discharged water with lots of caustic would go to effluent ready for treatment as shown by Fig. 2 above.

J. Packaging

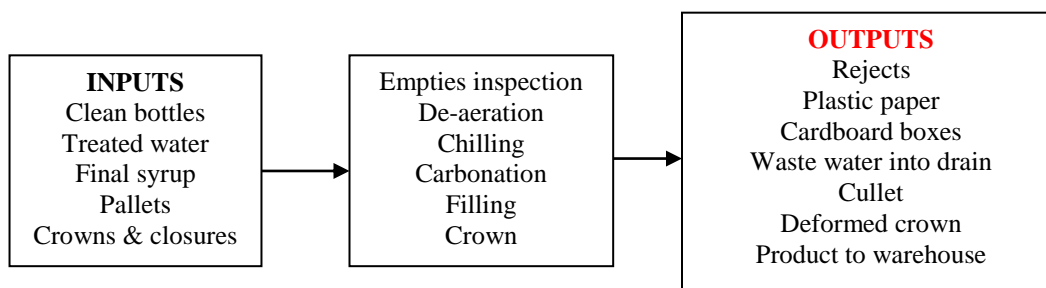


Fig. 3. Packaging material balance

The process involves empty inspection, de-aeration, chilling, filling and crowning as shown in Figure 3 above. The number of rejects was so huge and that it needed to be reduced. Also the amount of broken glass was responsible for the large amount of solid waste. So was the amount of waste water into the drain from this process.

K. Cleaner production opportunities

A number of observations were made with regards to operational issues, housekeeping and maintenance. Water management, energy usage, maintenance and operational practices were areas of potential improvement. Leaks and spillages needed special attention to achieve overall equipment effectiveness. CP options had to be generated to reduce resource consumption, increase production and reduce waste generation through improved operational practices. Equipment replacement, material conservation, energy and water usage reduction would result in major cost savings.

V. RECOMMENDATIONS

Syrup manufacturing: CP options are meant to reduce the amount of water used for cleaning operations. This can be done through reducing the frequency or flavor change over to minimize water used during cleaning. Rinsing water can also be used for other purposes like in laundry and toilets. There is also need to reduce spillages of concentrated syrups which requires a lot of water for cleaning.

Container preparation: This process is water intensive and water discharge has to be reduced through arresting water leaks by having proper maintenance and training of personnel. Recycling of rinse water to other processes, other than crates cleaning and pre-soaking. Installation of meters is required so that information on exact quantities of water used in each process is captured for evaluation purposes.

Electricity consumption: The plant consumes 51.4 kWh of electricity to produce a Hltr of product compared to best practice of 5.3 kWh per Hltr. Thus sub-metering has to be put in place to find the problem area among the processes. Grid power consumption could be reduced by reducing unnecessary lighting as well as sub-metering the various plant processes for close monitoring with view to reduce. Correcting load factors on electric motors can also complement this effort in the plant.

Coal usage: Again the plant used 15.1 kg per Hltr compared to 1.5kg per Hltr for best practice. For the boilers optimal combustion efficiencies have to be maintained on the steam boilers. Also elimination of visible steam leakages and lagging of pipes is key. High quality coal should be used by all means, and also avoid coal pulverization through per handling.

Water consumption: It was unbelievable to note that the plant uses more water to produce just 9% of saleable product. Over and above sub-metering various major water consumption sections, employees in different production centers can be asked to brainstorm to provide suggestion to save water in the plant as an interim quick fix initiative.

IV. CONCLUSION

The thrust of becoming competitive is in implementing environmental conscious manufacturing through CP as an effective tool. The CP assessment was done at a beverage plant, a number of low cost and high value action item options were generated to bring the operation close to the best practice targets. Major areas of potential improvement were identified as reduction of water and energy consumption. Material balances for various key processes were generated to reveal system losses and possible corrective action. Modernizing the plant operation by replacing some obsolete lines could also result in competitive products in terms of quality, cost and availability.

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BIOGRAPHY

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Charles Mbohwa is a Professor of Sustainability Engineering and currently Vice Dean Postgraduate Studies, Research and Innovation with the University of Johannesburg, SA. He is a keen researcher with interest in logistics, supply chain management, life cycle assessment and sustainability, operations management, project management and engineering/manufacturing systems management. He is a professional member of Zimbabwe Institution of Engineers(ZIE) and a fellow of American Society of Mechanical Engineers(ASME).