Study on Cleaner Production
Opportunities for the Sugar Industry in Belize.

Santos Chicas

Advisor: Professor Liao

Date: June 17, 2008

National Central University, Taiwan ROC
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摘要

貝里斯(Belize)製糖產業近年來面臨到兩個重要的危機，一項危機是人們逐漸意識到新河(New River)所受到的污染衝擊，另一項危機是優惠(關稅)市場的廢除。在嶄新的市場環境中，為了使製糖產業供應者依然保有成本的競爭力，並且能夠面對國際環境的難題，本篇論文建議貝里斯的製糖產業，整合清潔生產(Cleaner Production)的概念來解決以上的問題。我們將清潔生產的估計方式，巧妙的運用在工廠的磨粉廠，製程廠和鍋爐廠，藉此來證明清潔生產是可行的。將清潔生產技術，實際運作在工廠內和製程上，可以增進工廠的競爭水準，並且縮減環境所帶來的衝擊。再者，本研究指出在工廠的廢水處理設備之中，數據資料顯示一號池和三號池的化學需氧量(COD)( Chemical oxygen demand)移除效率需要改進。成功的運用清潔生產技術，提供貝里斯的製糖產業一個嶄新的舞台，並且藉由此技術，讓製糖產業面對危機能夠更有警覺性，更從容不迫的面對危機。這項技術也將不穩定傳統工廠產業(Conventional Industrial Production)逐漸轉變為穩定的清潔工廠產業(Cleaner Industrial Production)。
Abstract

The Belize Sugar Industry is facing two major problems, a growing awareness of the impacts of pollution on the New River and the abolition of its preferential markets. In order for the factory to remain as a cost competitive supplier in the new market environment and deal with its national environmental problems, this thesis suggests the integration of the concept of Cleaner Production (CP) in the Belize Sugar Industry. Using the Clean Production Assessment Methodology in the factory’s mill house, process house and boiler house, CP opportunities were identified. The implementation of the in-plant CP opportunities and production process CP opportunities identified will increase the factory’s level of competitiveness and reduce its environmental impact. Moreover, a study was conducted on the factory’s wastewater treatment plant. The data revealed that the Chemical Oxygen Demand (COD) removal efficiency of ponds #1 and #3 need improvement. The successful implementation of the CP opportunities identified will provide a stage for BSI to become more aware and comfortable with the concept of CP. This will initiate a gradual shift from unsustainable Conventional Industrial Production to sustainable Cleaner Industrial Production.
Acknowledgments

This paper was completed thanks to the information provided by BSI, DOE, and surveyed participants. To Professor Liao who advised me and provided me with sources where I was able to obtain useful information. Also to the assessing committee prof. Dyi-Hwa Tseng, prof. Shuh-Woei Yu and prof. Ching-Ju Chin for enhancing the thesis with their valuable recommendations. Moreover, thanks to all my professors and (International Cooperation Development Fund (ICDF) for all the support that I got. Thanks to Oxalis and my Parents who provided me with moral support to complete this paper. Finally, give thanks to all my classmates which in a way or the other helped me in the completion of this paper.
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Abbreviations

BSI………………………………….…..Belize Sugar Industry
Belize C.A……………………………..Belize Central America
BOD…………………………………… Biological Oxygen Demand
COD………………………………….....Chemical Oxygen Demand
CP………………………………….……Cleaner Production
CBI…………………………………...Caribbean Basin Initiative
CPC …………………………………….Cleaner Production Center
CARICOM………………….Caribbean Community and Common Market
EU……………………………………..European Union
FTAA………………………………….Free Trade Area if the Americas
HCMC…………………………………. Ho Chi Minh City
NORAD …………………….Norwegian Organization for Development
NEPS…………………………………..Environmental Protection Society
OECD………………………Organization for Economic Co-Operation and Development
U.S………………………………………United States
UNEP…………………………………United Nations Environment Program
SS…………………………………….. Suspended Solids
TC……………………………………….tonnes of cane
T…………………………………………Temperature
TCH…………………………………. Tonnes of Cane per Hour
WWTP…………………………………. Wastewater Treatment Plant
WTO…………………………………….World Trade Organization
1. INTRODUCTION

1.1 Overview

Belize is the smallest country in Central America and the less populated country comprising of a population of approximately 300,000. Even though, Belize is not an industrialized country there are still some industries present. The presences of these factories in Belizean territory are essential for the country’s economy and development. The Industries that operate in Belize are mostly food processing industries, since the country is heavily dependent on agriculture. These industries however have lead to environmental degradation in developing Belize. Environmental degradation in Belize occur due to the lack of proper legislations, enforcement of regulations, lack of infrastructure, outdated production approaches and the use of obsolete technologies. It is therefore, very crucial for the well-being of the country and its people that these sources of environmental degradation are identified and dealt with accordingly. If these problems are not addressed, the threat exist that these will continuously grow and will create more environmental problems at a local and national level.

In this case the problem is a problem of wastewater discharged into the New River system by the Belize Sugar Industry. Due to the 40 years of economical contributions that this factory has made and is currently making its existence is important for the country’s economy. On the other hand, the growing awareness of the impacts of pollution on the New River, coupled with the abolition of its preferential markets. Will demand BSI to take immediately actions in order to remain as a cost competitive supplier in the new market environment and deal with its national environmental problems.

In response, to the pollution problems that have occurred in the past BSI has built more wastewater treatment ponds. This approach or concept that the factory has used to deal with the problem is known as the end-of-pipe approach or Conventional Production Approach. This concept has made some relief but pollution problems are still arising.
Since, the inhabitants of the surrounding communities are still complaining of fish kills, increasingly browner river waters and bad odor. Taking the current situation in consideration, this research gives the factory a new perspective and idea of a more modern concept or approach that is currently being embraced by developed as well as some developing countries. The innovative concept that is suggested in this research is Cleaner Production. According to Centre for Professional Development Cleaner production is the continuous application of an integrated preventative environmental strategy to processes and products to reduce risks to humans and the environment. Its key feature promotes the switching of emphasis away from waste disposal to waste avoidance. Cleaner production includes conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes before they leave a process (CPD, 2001). This approach is also known for its ability to reduce water utilization, increase efficiency and competitiveness of industries and its inherent economic benefits.

This study provides the Belize Sugar Industry with useful data that is practical for the factory to become more competitive, efficient and able to comply with more stringent environmental regulation, if implemented in the near future. Based on the Cleaner Production opportunities and the wastewater treatment inefficiencies identified feasible recommendations are given to BSI. Moreover, due to the proximity of the factory to the residential areas, this study provides important data on how the residents benefit and are affected by the presence of BSI. In addition, it increases the awareness of the current river situation. In so doing it will persuade government officials to understand the implications that the degradation of the river system will have in the future, if actions are not taken immediately. The Belizean economy is dependent on the export of sugar for its foreign exchange; thus, sugar cane production is important. As a result, the study assist in providing information that can be utilized to make rightful decisions as to how sugar can be produced in a sustainable, efficient and competitive manner.
1.2 Study Objectives

The objectives of the thesis are to:

i) Introduce the concept of CP to BSI.

ii) Identify feasible CP opportunities in the Belize Sugar Industry facilities in order to reduce wastewater generation.

iii) Give recommendations for its wastewater treatment plant to improve COD removal efficiency.

iv) Survey community members living along the river side to have a more clear understanding about the pollution situation and what are the implications of this.

1.3 The difficulties in the study

The gathering of information to conduct this thesis resulted difficult since we were in Taiwan and the research was conducted on the Belize Sugar Industry. Also, the fact that BSI is located in developing Belize; thus, access to information was limited. Some of the information that existed was not in electronic form. As a result, someone was needed to type the information. This is because the only means to send the information from Belize to Taiwan was via e-mail. Moreover, some of the information that was requested was not sent or was not available. A visit was made to a Taiwanese sugar factory in order to collect information but time and language were two major limiting factor.

This research had to work with very limited data; thus, no in-depth analysis on the cost/benefits of the CP opportunities identified was made; when implemented on the BSI facilities.
2. BACKGROUND

2.1 General Characteristics

Belize is a small independent nation in Central America lying south of the Yucatan Peninsula, east of Guatemala and north of Honduras (Appendix B). Its territory is approximately 22,960 square kilometers, including 689 sq. km. of offshore islands. The area of the mainland and cayes is 8,866 square miles. The country's greatest length from north to south is 280 kilometers and its greatest width is 109 kilometers. The largest populations are in Belize City, Belmopan, and San Ignacio in the west of the country, Orange Walk Town and Corozal Town in the north, and the coastal town of Dangriga south of Belize City. The climate is sub-tropical, tempered by trade winds. Temperatures in coastal districts range from about 10*C (50*F) to about 35.6*C (96*F); inland the range is greater (Wikipedia). Rainfall varies from an average of 1,295 millimeters in the north to 4,445 millimeters in the extreme south. The dry season usually extends from February to May and there is sometimes a dry spell in August.

The main agriculture crop that is cultivated on the north and processed is sugarcane. Sugarcane plantations accounts for 38% of total agricultural land in Belize. The cultivation of this crop is done on both Corozal and Orange Walk districts. Sugar comprises of approximately 19% of total export earnings for the country (statistics office). The Belize sugar Industry directly or indirectly employs many Belizeans in the north part of the country. The industry produced nearly 100,232 tons of sugar during 1993 with an efficiency of 91.04. Well exceeding the estimated domestic demand. This is approximately 10,500 tons of Plantation White Sugar (BSI).

The processing of this agricultural crop is done on the Orange Walk district. Until 1985 Belize had two sugar mills. The Libertad factory in the Corozal District, opened in 1937, and the factory at Tower Hill near Orange Walk Town, opened in 1967 (Belize Sugar Industry Ltd). From the inception of the sugar factory in 1937 the cane farmers have been in associated with the industry. They are the growers of the cane that is supplied on a
daily quota basis for sugar manufacture. In 1937 there were only 5 registered cane farmers in Belize. In 1996 there were 7141 registered farmers.

In July 1985, the Libertad factory was closed, due to the continuing low world sugar prices and reduction of U.S. preferential market quota. Presently, all sugarcane in the country is milled by a single miller, Belize Sugar Industries. This factory is located approximately 4 km south of Orange Walk Town. The nearest settlement is the village of Tower Hill, approximately 1.3 km to the south of the site. The villages of Chan Pine Ridge and San Jose Palmar are located approximately 2.5 km south-east and 2.5 km north of the site respectively (Knight Piésold). To the east of the factory is the New River from where the factories extract fresh water for its manufacturing processes. The factory also uses the river to discharge its treated wastewater.

The New River is the main hydrological feature in the area it drains the majority of the east and central parts of the Orange Walk District. The water flow regime is characterized by the annual change from dry to rainy season. This river has a catchment area of approximately 1,400 km², rising in the Yalbac Hills and flows north via various swamps and lagoons, including the New River Lagoon which extends over 30 km from Hill Bank to Shipyard, to its final discharge to the Caribbean Sea at Corozal (Knight Piésold). Along its lower reaches the river flows across low lying flat lands and as a consequence the river has a very low hydraulic gradient. Within the vicinity of the development site the river is sluggish with very low velocities. Even during flood events, with high total discharge volumes, velocities only reach a maximum of approximately 0.3 m/s. For much of its length from Tower Hill to the sea the river is typically 20 m to 30 m wide, although occasional narrows occur (Knight Piésold). The limestone that underlies the site where BSI is located form a major aquifer. This groundwater is used extensively by the local population as a potable water supply.

BSI has a crushing capacity of 6,000 tons of cane per day and an operating season from end November to late June. The company has preferential quotas to exports
approximately 42,000 tonnes of raw sugar to EU, approximately 11,000 tonnes to US and 12,275 tonnes to CARICOM (Ministry of Foreign Trade 2004). The preferential quotas that the country enjoys account for approximately 2/3 of Belize’s sugar exports. The remaining 1/3 is exported at prices linked to the world market. However, the Belize sugar industry is currently coming under increasing economic and environmental pressure. To remain a viable sector it is recognized that a degree of restructuring is required. Belize is proactively addressing these economic and environmental issues. The foundations of the necessary industry restructuring have been laid already with the introduction of a new Sugar Act in 2001. In part the economic problems arise from the current low world price for sugar. To an extent Belize is protected from this by the Preferential Market Agreement. However, the World Trade Organization (WTO) has ruled that this and other such agreements are against free trade and the preferential arrangements are due to be phased out by 2008 (DOE).

2.2 Raw Sugar Cane and Plantation white sugar Production

In Belize when the harvest season starts the sugar cane fields that are going to be harvest, by the farmers, are set on fired. The following day farmers cut the cane which is loaded to trucks or tractors with trailers. The cut cane is delivered immediately to BSI to prevent the deterioration of the sucrose content on the sugar cane stem. When the trucks arrive to BSI they have to get on a line and waiting to deliver the cane. In the factory a system is in place where cane loads, before being weighed, are sampled and analyzed for maturity including staleness and excess extraneous matter (dirt, tops leaves etc.). Cane loads having a maturity index (purity) below 81 is penalized by being rejected. If the cane loads pass this quality control test, the cane is weighed on two road vehicle weigh- bridge computerized scales, one with 28 tons capacity the other of 100 tons. The cane is unloaded by overhead Cameco Side Tippers and gantry cranes. The cane is deposited directly on feeding tables that feed the cane carriers to the milling plant or stacked in loose piles for later feeding. Cane is received 24 hour daily.
The cane then travels through two sets of revolving knives that cut the cane into small pieces in order for the mill to extract as much cane juice as possible. The principal constituent in the cane juice other than water is "sucrose" which is a carbohydrate.

Figure 1: Cane sugar production. Source - Akbar, N. M., Khwaja, M. A. (2006)

MILLING

The mill utilized in BSI is a A & W Smith Mill which is made up of five units; each one with three mill rolls of 42” x 84” and a fourth mill roll 33” x 81”. The mill is activated by 1,000 HP Murray Steam Turbines. Steam generation is by three Babcock & Wilcox water tube boilers with a total capacity of 285,000 lbs. /hr. at 300 psi. The mill also has Donnelly
Chutes. Here the prepared cane successively passes through five units of four roller mills which extract the juice by crushing the canes between the rollers. To aid in the extraction, hot water (130øf – 150øF) is applied in front of the last mill unit to dilute the contained juice. This is known as imbibition. The residue of the milled cane after the last mill unit is called "Bagasse". This is fed to the Boilers to be used for the production of steam required to drive the mill units, and for the generation of electrical energy to supply the electrical needs of the factory. The juice extract forms the raw material from which sugar must be recovered with maximum efficiency. From the mills it is weighed, then clarified for processing into sugar.

CLARIFICATION

In this operation, Clarification is carried by two Rapidor Clarifiers. Impurities (non-sugars) that will interfere in the stages of sugar recovery are removed. Lime and heat are used as the clarifying agents. Lime in solution form is added to the juice with subsequent heating to 220øf followed by settlement of the impurities as mud in tanks called Clarifiers. Careful control of the temperature and pH levels (7.0 - 7.2) of the juice allows suspended matter to conglomerate and settle out as mud: to improve the settling rate, a small amount of flocculant solution (3 to 4 ppm) is added to the limed and heated juice immediately before it enters the Clarifiers (after the Flash tanks). The settled mud in the Clarifiers is pumped out and filtered on Five Oliver Rotary Vacuum Filters to de-sweeten it by washing and filtering under vacuum. The filtered juice circulates back to the Clarifiers for further clarification, and the filtered mud is scraped off the surface of the filter drum and discarded on mud carts to the fields for fertilizer or for land fill.

EVAPORATION

The clarified juice as it overflows from the Clarifiers contains about 80 percent of water and between 15 to 20 percent soluble solids. The crystallization of sugar does not occur in solution containing less than 70 to 80 percent solids; therefore, a considerable degree
of evaporation is necessary. In the evaporation station the clear juice is boiled in Multiple Effect Vessels arranged in series. Low pressure steam (18 to 30psi) is used to boil the juice in the first vessel. The subsequent evaporator vessels are each heated by the vapor (water boiled out of the juice) from the previous vessel. The concentration of the juice in each vessel is affected by the decreased pressure and temperature in each succeeding vessel. The increased temperature difference is due to the last vessel being operated under vacuum. At this point, the greater part of the excess water is removed to yield a concentrated juice called "Syrup", containing 60 to 65 percent solids. The concentrated syrup must be concentrated still further so that the sucrose in it will form crystals of sugar. The condensed vapor from the Evaporators are removed by the pumps and is used as feed water for the production of steam in the Boilers, for Imbibition at the mills, in the Vacuum Pans and in centrifugation of Massecuite.

CRystallization (Pan Boiling)

The resulting syrup from the evaporators is further concentrated and crystallized in several stages called "The Pan Boiling System. This involves five 1,800 FT³ Calandria vacuum pans each with a heating surface of 3,324 FT² and one continuous vacuum pan with a heating surface of Four pans operate on 15 psi first vapour and one operates on 30 psi exhaust steam. The continuous vacuum pan operates on second vapour. The Evaporator and Vacuum Pans are fitted with korting multi-jet barometric condensers with automatic vacuum control. The five batch pans operate. This is carried out in single effect Vacuum Pans resulting in a mixture of sugar crystals and molasses called "Massecuite". The Massecuite is discharged into a receiver then fed into centrifugal baskets revolving at high speed. The sugar crystals are retained in the inside of a perforated screen and the liquid molasses passes through the screen. The resulting sugar is weighed then stored in bulk. It is called Raw Sugar and is exported for further refining abroad. The molasses from which most of the available sugar has been extracted is called "Final Molasses". This product is also exported and a small amount is sold locally for the manufacture of rum or as cattle feed.
PLANTAION WHITE SUAR PROCESSING

The system of Plantation White sugar Production used at Tower Hill Sugar Factory eliminates the need for chemical products such as Sulfur and lime utilized in conventional clarification of sugar cane syrup for the direct production of Plantation White Sugar. A clean, clear syrup low in color is required for the production of Plantation White Sugar. High grade A Raw sugar is re-melted with condensate hot water. The melted sugar material is clarified with the use of a liquid decoulorizer and flocculant and the use of a continuous Rotary Syrup Clarifier for the removal of particulate matter. The scum removed is sent to the cane juice clarification stream and the clean product is sent to a storage unit from where it is fed to a batch Vacuum Pan and crystallized into a Plantation White Massecuite. The Massecuite, after centrifugation produces a Plantation White Sugar. Unlike Raw sugar, the white sugar is conveyed to a sugar Dryer before going on to the bagging station, where it is bagged into 112 pound sacks then stacked for marketing. This system is fully automatic and requires minimum supervision under normal operating conditions.

2.3 Chemicals Used

The Belize Sugar Industry uses many chemical to obtain the sucrose that is present in the sugar cane. The chemicals that are utilizes include those that are used in the process itself and those used in the laboratory for testing sucrose levels in the sugarcane. All of the chemicals that are used have a certain degree of degradation to the environment but there are some that are more toxic and persist in the environment for a long time. All of the chemicals utilized in the factory find their way into the wastewater stream. The wastewater stream leads to the factory wastewater treatment plant and subsequently into the New River system. Table 1 shows some of the chemicals used by BSI:
Table 1: Chemicals used in BSI

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Boiler water treatment chemicals</th>
<th>Cleaning agent chemicals</th>
<th>Laboratory chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium hydroxide</td>
<td>Anti foam GESSCO 1913</td>
<td>Rodine inhibitor 130</td>
<td>Silver sulfate</td>
</tr>
<tr>
<td>Isopropyl alcohol</td>
<td>Sodium sulfide GESSCO 1133</td>
<td>Sodium hydroxide</td>
<td>Mercury</td>
</tr>
<tr>
<td>Anionic polymer flocculant PCS300</td>
<td>Orthophosphate 1709</td>
<td>Hydrochloric acid</td>
<td>Barium chloride</td>
</tr>
<tr>
<td>Biocide PCS6001</td>
<td>Sodium hydroxide</td>
<td>Teepol</td>
<td>Mercuric sulphate</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>Sodium chloride</td>
<td>Thinner</td>
<td>Oxalic acid</td>
</tr>
</tbody>
</table>

Source: (DOE)

Before, BSI used lead sub acetate to analyze sugar but due to its toxicity and persistence in the environment this was replaced by Octapol a lead free reagent. Octapol is composed of 9 non toxic chemicals. Table 2 shows the amount of Octapol that is used in the factories laboratory.

Table 2: Octapol used in BSI laboratory

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Average no. of samples</th>
<th>Octapol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane</td>
<td>200 samples/day</td>
<td>6 gr/sample</td>
</tr>
<tr>
<td>Sugar production</td>
<td>75 samples/day</td>
<td>8 gr/sample</td>
</tr>
<tr>
<td>Total</td>
<td>275 samples/day</td>
<td></td>
</tr>
</tbody>
</table>

Source: (BSI)

Some of the major chemicals utilized during the processing of sugarcane are: hydrated lime the amount of this chemical that is applied in the juice clarifier unites is 0.58 kg per ton of juice. Also a flocculant (water soluble polymer) is used the amount applied of this chemical is 0.013 kg per ton juice. In the Syrup clarifier 0.03 kg per ton thick juice of flocculant is used. 5 kg per ton thick juice of Phosphoric acid is used and 0.02 kg per ton thick juice of flocculant decolorizer. In the vacuum pans 0.004 kg per ton syrup of isoprophyal alcohol is used. Not all the chemicals that are used in the process are mention here.
2.4 Water utilization by the Belize Sugar industry.

The Belize Sugar Industry uses both ground water and river water for the production of sugar from sugarcane. River water is used for condensers and boiler ash wash water. The majority of water that is used for cooling is via a once through condensing system. The factory does not operate a second stage cooling tower system. Some condensate and well water (water softener used) is used for the processing. Table 3 shows the amount of water that is extracted from the ground well and table 4 shows the water that is extracted from the river.

Table 3: Water abstracted from the ground well

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Output</th>
<th>Destination of pumped water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15,000 – 18,000 gph</td>
<td>The water extracted from well No. 1 is used mainly in the Factory as domestic water, Industrial process, drinking water and also in the housing area for household use.</td>
</tr>
</tbody>
</table>

Source: BSI

Table 4: Water abstracted from the river

<table>
<thead>
<tr>
<th>River pump</th>
<th>Output</th>
<th>Destination of pumped water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four (4)</td>
<td>4 x 1,080,000 gph</td>
<td>Three pumps are used at one time. The water is mainly for condensers, other use is for Boiler ash washing.</td>
</tr>
</tbody>
</table>

One pump is always on standby

Source: BSI
The pumps that are used to extract the water from the river and ground well in BSI are electrically driven and are controlled by shift operating personnel during the crop period. According to BSI approximately 60,912,000 gallons of water are extracted from the wells per crop period and approximately 5,000,000,000 gallons are extracted from river per crop period. The water that is not used by the sugar plant process and excess condensate are discharged into the ash pit for cooling and settling.

Furthermore, Table 5 shows the detailed water consumption of BSI process streams. It illustrates that the most water-intensive operation is condensation feed. The water used during these operations accounts for 92.98% of the water inputs.

Table 5: Breakdown of water inputs of Tower Hill sugar Factory

<table>
<thead>
<tr>
<th>Process Stream</th>
<th>Flow rate (m³/tc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imbibitions water</td>
<td>0.25 m³/tc</td>
</tr>
<tr>
<td>Total Cooling water</td>
<td>0.30 m³/tc</td>
</tr>
<tr>
<td>Boiler makeup</td>
<td>0.43 m³/tc</td>
</tr>
<tr>
<td>Condenser Feed</td>
<td>13.00 m³/tc</td>
</tr>
<tr>
<td>Total</td>
<td>13.98 m³/tc</td>
</tr>
</tbody>
</table>

Source: BSI

Belize sugar factory, water intake are only monitored on a regular basis. This is in part due to the water rights law which allows fairly unrestricted access. As a result, it is quiet challenging to get accurate information concerning the whole fresh water consumption of the sugar cane factory.

2.5 Wastewater produced in the sugar manufacturing process

The Belize sugar industry main entities process different main inputs (materials). For instance, the mill house deals directly with the sugar cane that is brought from the cane fields. On the other hand, the main input of the processing house is the sugar cane juice that was extracted in the mill house. Due to this factor, the wastewater that is generated form each of the main entities differs in pollutant loads. Table 6 gives a brief summary of the different pollutants that are present in the wastewater, which are generated by the different entities that constitute the whole sugar manufacturing process.
Table 6: Waste produced in the different process stages

<table>
<thead>
<tr>
<th>Process Stage</th>
<th>Main Inputs</th>
<th>Wastes and By-Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill House</td>
<td>Sugarcane</td>
<td>Wastewater containing suspended solids and oil content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Washing from floor cleaning containing sugar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bagasse</td>
</tr>
<tr>
<td>Process House</td>
<td>Sugar Juice</td>
<td>• Washing of different components such as evaporator,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>juice heater, vacuum pan, clarifiers, etc., generates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aggressive effluents with high BOD5, COD and TDS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>concentrations</td>
</tr>
<tr>
<td>Boiler House</td>
<td>Bagasse and</td>
<td>• Wastewater from scrubbers</td>
</tr>
<tr>
<td></td>
<td>Furnace oil</td>
<td></td>
</tr>
<tr>
<td>Cooling Pond</td>
<td>Water &amp; Chemicals</td>
<td>• Wastewater</td>
</tr>
</tbody>
</table>

Source: Adapted from Akbar, N. M., Khwaja, M. A. (2006)

Moreover, pollutant loads also differ in the different streams of a factory’s manufacturing process. Table 7 shows a breakdown of the wastewater streams of the Belize Sugar Industry. It illustrates that thermal pollution is higher in the excess condensates and boiler blow down streams. Furthermore, it can be noted that all the streams have different pH levels ranging from acidic 4.46 to alkaline 9.68. The main sources of organic pollution are the boiler blow down and washing. This is as a result of the presence of dissolved sugar. It is very important to observe from table 7 that the washings constitutes of 43.45% of the total wastewater produced, while contributing to 99.7% of the organic pollutant load or COD of the wastewater.
Table 7: Pollutant loadings in wastewater streams from Belize Sugar Factory

<table>
<thead>
<tr>
<th>stream</th>
<th>Volume M$^3$/tc</th>
<th>Volume M$^3$/day</th>
<th>COD mg/L</th>
<th>COD mg/L</th>
<th>pH</th>
<th>Temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water</td>
<td>0.003</td>
<td>22</td>
<td>61</td>
<td>1,342,000</td>
<td>7.6</td>
<td>30</td>
</tr>
<tr>
<td>Washings</td>
<td>0.09</td>
<td>681</td>
<td>6,000</td>
<td>4,086,000,000</td>
<td>4.65</td>
<td>33</td>
</tr>
<tr>
<td>Excess condensate</td>
<td>0.11</td>
<td>814</td>
<td>7.0</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler blow down</td>
<td>0.008</td>
<td>50.38</td>
<td>194</td>
<td>9,773,720</td>
<td>9.68</td>
<td>95</td>
</tr>
<tr>
<td>Total</td>
<td>0.13</td>
<td>1567.38</td>
<td></td>
<td>4,097,115,720</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BSI

Since, washings contribution of COD of the wastewater is 99.7% it can be concluded that the most polluting discharges from the factories are actually generated outside of production times, at weekend wash downs and end-of-crop shutdown washings. During these periods the various equipments are scrubbed and hosed down creating large volumes of waste effluent, which have extremely high sugar content and suspended solid concentrations.

In addition, to the wastewater generated by the plants operation, wastewater is also generated from the industry’s sanitary and laboratory facilities. The factory is equipped with 4 toilet buildings with a total of 21 toilets which are used by the 275 workers.

2.6 Current wastewater treatment plant at Belize Sugar Factory

The purpose of the BSI wastewater treatment system is to treat the harmful content of the wastewater from the factory’s manufacturing process down to a level that the river can accept. The factory operates an Anti-pollution Waste Water Treatment Plant, using the process of Bio-Oxidation in open Lagoons. The Wastewater Treatment Program is mainly a Physical/ Mechanical Treatment Program consisting of:

- Manual skimming of Insoluble Matter
- Mechanical skimming of oil.
- Aeration with Surface Aerators
- Settling of solids
- Controlled Ditching of effluent with a controlled valve system

The wastewater that is discharge from the factory to the wastewater treatment plant is the water used for plant washing, processing, cooling purposes, cleaning of vessels and excess condensates (figure 2).

Figure 2: Sources of Waste Water in Cane Sugar Manufacturing. Source: Akbar, N. M., Khwaja, M. A. (2006)

The Belize Sugar Industry wastewater treatment plant, that treats the wastewater that is discharge by BSI’s sugar manufacturing process, is characterized by a series of wastewater treatment ponds. This wastewater treatment plant consists of seven ponds. Ponds 1 to 5 are used to treat the wastewater from the production process, laboratory and
sanitary facilities. Ponds No. 6&7 (ash pond and ash pond #2) are used specifically for the treatment of Boiler Ash wash water (Appendix C). Table 8 shows the capacity of the wastewater treatment ponds and the specific dimensions of the seven ponds that comprise the BSI treatment plant.

**Table 8: Wastewater treatment ponds capacities**

<table>
<thead>
<tr>
<th>L x W x H</th>
<th>Million Galls.</th>
<th>sq. ft.</th>
<th>M²</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 270x130x10</td>
<td>2.6</td>
<td>35,100</td>
<td>3260.79</td>
<td>0.806</td>
</tr>
<tr>
<td>2 270x130x10</td>
<td>2.3</td>
<td>35,100</td>
<td>3260.79</td>
<td>0.806</td>
</tr>
<tr>
<td>3 275x130x10</td>
<td>3.4</td>
<td>35,750</td>
<td>3321.175</td>
<td>0.821</td>
</tr>
<tr>
<td>4 250x142x8.5</td>
<td>2.2</td>
<td>35,500</td>
<td>3297.95</td>
<td>0.815</td>
</tr>
<tr>
<td>5 75x50x8</td>
<td>0.224</td>
<td>3,750</td>
<td>348.375</td>
<td>0.086</td>
</tr>
<tr>
<td>6 275x150x10</td>
<td>3.1</td>
<td>41,250</td>
<td>3832.125</td>
<td>0.947</td>
</tr>
<tr>
<td>7 40x20x7</td>
<td>0.04</td>
<td>800</td>
<td>74.32</td>
<td>0.018</td>
</tr>
<tr>
<td>total</td>
<td>13.864</td>
<td>187,250</td>
<td>17395.525</td>
<td>4.30</td>
</tr>
</tbody>
</table>

Source: BSI

**2.7 Wastewater treatment process of BSI**

During normal operations all wastewater streams are channeled to the Anti-pollution Treatment System which consists of an oil separator, one Buffer pond, one anaerobic pond, two Settling ponds and one aerobic pond (Appendix C). Oil is removed continuously with a mechanical skimmer, which is then disposed of in the bagasse pile for burning. The oil free wastewater then flows into the anaerobic pond where it starts to receive treatment. The Treatment System’s Buffer pond holds heavily polluted wastewater from the cleaning of vessels on service days. The wastewater in the Buffer pond is released in a controlled manner to the anaerobic pond to reduce the effects of shock loading.

Wastewater from the anaerobic pond #1 flows to Settling pond #2 then to settling pond
#3 for further purification and settling of sludge. Water Lilies are also placed in pond #3 to serve as natural filtration media and to use up some of the nutrients in the wastewater. Growth control of the Lilies is exercised to avoid coloration of the water and choking. Water is allowed to overflow from settling pond #3 to the Main drain, which flows into the New River Stream. Wastewater then flows to pond #4 for anaerobic treatment where it is aerated with Surface and Submersible Aerators to increase bacterial growth to consume the organic matter that still remains. The water then is discharged to a swamp for further treatment and then it flows into the New River.

The efficiency of the Treatment system is monitored by analyzing the COD, pH, DO, and Temperature of the wastewaters. This information helps to follow the pattern of wastewater disposal and its effect on the purification process. The COD, pH and T of the BSI wastewater Treatment Facility average report for crop 2007 are shown in Table 9.

**Table 9: BSI Wastewater Treatment Facility report - crop 2007**

<table>
<thead>
<tr>
<th>Location</th>
<th>COD mg/l</th>
<th>DO MG/L</th>
<th>pH</th>
<th>Temp. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Oil Sump</td>
<td>20,108</td>
<td>6.28</td>
<td>34.3</td>
<td></td>
</tr>
<tr>
<td>2.Pond No.1 Inlet (anaerobic)</td>
<td>25,935</td>
<td>4.78</td>
<td>32.8</td>
<td></td>
</tr>
<tr>
<td>3.Pond No.1 outlet (anaerobic)</td>
<td>26,252</td>
<td>4.64</td>
<td>30.8</td>
<td></td>
</tr>
<tr>
<td>4.Pond No.2 outlet (settling)</td>
<td>14,008</td>
<td>7.00</td>
<td>28.8</td>
<td></td>
</tr>
<tr>
<td>5.Pond No.3 outlet (settling)</td>
<td>15,386</td>
<td>6.70</td>
<td>29.7</td>
<td></td>
</tr>
<tr>
<td>6.Pond No.4 outlet (aerobic)</td>
<td>7,393</td>
<td>7.36</td>
<td>28.0</td>
<td></td>
</tr>
<tr>
<td>7.Main drain Point #1</td>
<td>34</td>
<td>7.34</td>
<td>36.6</td>
<td></td>
</tr>
<tr>
<td>8.Main drain Point #2</td>
<td>32</td>
<td>7.31</td>
<td>34.9</td>
<td></td>
</tr>
<tr>
<td>Ash Pit outlet</td>
<td>169</td>
<td>10.47</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>Injection Pump area</td>
<td>31.4</td>
<td>7.25</td>
<td>26.6</td>
<td></td>
</tr>
<tr>
<td>Buffer Pond</td>
<td>81,653</td>
<td>4.21</td>
<td>41.5</td>
<td></td>
</tr>
</tbody>
</table>

Source: BSI

Note: The above are average figures for crop 2007.
2.8 Environmental Impact of Sugar Factory’s Wastewater.

Sugar cane industries are known to be water intensive industries; meaning that, they utilized a lot of fresh water for its production process. The wastewater generated by the sugar cane industries are characterized do to its high levels of BOD, COD, pH, SS, and T. Wastewaters with high BOD when disposed untreated or partially treated can result in aquatic pollution. The reason for this is because wastewater with high BOD contains high levels of organic matter, which serves as food for bacteria. This results in the increase of these microorganisms in the water. These increased number of bacteria then use up all the dissolved oxygen in the water. On complete exhaustion of the oxygen the bacteria begin to breakdown the chemicals in the water stream (sulfates) to get their oxygen. This leaves a foul smelling (hydrogen sulfide) gas, which in turn can precipitate iron and any dissolved salts, turning the water black and highly toxic for aquatic life. Another condition of concern caused by untreated wastewater is the increase of COD on the receiving water bodies. It has been documented that high levels of COD, which is a measure of the inorganic and partly organic non-biodegradable content of the effluents, has effects on the receiving water body similar to that of a high BOD (Akbar, N. M., Khwaja, M. A. 2006).

Sugar cane industrial wastewater is also known to contain considerable levels of Suspended Solids. Although not considered a human health hazard, suspended solids can lead to undesirable water quality conditions. Suspended solids can cloud or reduce light penetration. This in turn, has an adverse effect on fish and other aquatic life by reducing photosynthesis. Suspended solids may also contain contaminants, such as nutrients, organic matter, pesticides, and heavy metals (Devlin, D .L. and McVay, K. A. 2001).

Sugar cane effluent also increases the color, temperature and pH of aquatic environments resulting in pollution problems. Colored waters are responsible for the reduction of light penetration, resulting in the reduction of photosynthesis, which will decrease the dissolved oxygen in the water. Moreover, colored waters are aesthetically unpleasing. Effluents with high temperatures are responsible for depleting dissolved oxygen levels in
the water. Causing a significant increase above the ambient temperature range and destructing fish habitat if temperatures are too high. Industrial effluents generally change the natural pH level of the receiving water body to some extent. Such changes can tip the ecological balance of the aquatic system. Excessive acidity can result in the release of hydrogen sulfide to the air (Akbar, N. M., Khwaja, M. A. 2006).

Due to the potential environmental impact that sugar cane effluents can have on the aquatic environments where this are discharge, it is important for the BSI to monitor its wastewater treatment system continuously. BSI should also try preventing the generation of wastewater during the production process instead of trying to treat it later. To attain this it is proposed herewith that BSI should adopt the concept of CP, in order to become an efficient, competent and an environmentally friendly industry.
3. METHODOLOGY

The methodology for this thesis entails data collection from the Belize Sugar Industry and the Department of Environment. A letter to these parties was sent requesting the following information:

• The detailed manufacturing processes and the main manufacturing stages of the Belize Sugar Industry. The data collected on the manufacturing process was crucial in order to understand the factories unique process. Knowing BSI manufacturing process allowed for the identification of CP opportunities that exist within BSI. This data made it possible to pinpoint the areas where improvements need to be made in order to improve the factory’s efficiency and reduce environmental impact. The identification of the main manufacturing stages was important in order to determine at which stage the vast majority of wastewater is generated. With this knowledge feasible CP recommendations were made to BSI in order to reduce the wastewater that is generated.

• The breakdown of the water inputs and the pollutant loadings of the wastewater streams of the Belize Sugar Industry were also requested. This data was utilized to have a better understanding of which streams are responsible for the generation of the utmost quantities of wastewater and the concentration of pollutants present. With this in mind, it was easier to identify which streams generate wastewater that can be used in other processes with little or no treatment and which streams generate heavily polluted wastewater. Moreover, with this information it was possible to identify the streams that are water intensive and the streams with higher concentrations of pollutants. Based on the information, recommendations were given to reduce the pollution loads and wastewater that is generated.

• The list of chemicals used by the Belize Sugar Industry. This data was crucial to determine if the industry uses chemicals that are highly toxic, which can put in
danger the health of the nearby communities that utilized the New River waters.

- The total quantity of wastewater extracted by the industry from the ground well and river. Knowing the total amount of water that is extracted is important because it gives an idea of the rate at which water is utilized for the production process.

- The wastewater treatment plant process of BSI (in detail). Given the wastewater treatment process, its removal efficiency of COD was calculated. Based on the results, recommendations were given to improve the wastewater treatment plant’s COD removal efficiency.

The Cleaner Production opportunities that exist in the Belize Sugar Industry where systematically identified developed and evaluated using the Cleaner Production assessment methodology. The Cleaner Production assessment methodology used in these research involved five phases which are as follow:

1. **Planning and Organization:**
The concept of CP was proposed to the Belize Sugar Industry managers. Since, the company is committed to the protection of the environment. The manager became interested in this concept. The manager appointed individuals to collect information that was needed for this research. In the course of the Planning & Organization phase, the manager became the promoters of the necessity to adopt Cleaner Production. This facilitated the execution of the Cleaner Production assessment for this research.

2. **Pre-assessment:**
This research pre-assessment focus was on the Belize Sugar Industry Production Process, which is composed of mill house, process house and boiler house. An inspection of the factory’s production process was done in order to do a preliminary identification and evaluation of the Cleaner Production potential that exits. This provided the research with
a first inventory of the obvious options; as well as, a preliminary estimate of problems that needs to be addressed.

3. Assessment:
Water intensity operations, water utilization activities and wastewater generation streams were identified in BSI. The quantification of the volume and composition of the various wastewater streams; as well as, a detailed understanding of the causes of these wastewater streams was acquired. This lead to the development of a comprehensive set of alternate Cleaner Production options.

4. Feasibility Studies:
The CP opportunities or options identified in BSI can be classified in two areas in-plant CP opportunities and production process CP opportunities. The in-plant CP opportunities identified in this research are technically and economically feasible, as no measure investment and no retrofitting is required. The proper implementation of these options can reduce wastewater generation to significant amounts resulting in environmental and economical benefits. The production process CP opportunities required significant investment and retrofitting; thus, a much more in-depth study is needed in order to determine the feasibility of some of the CP opportunities. These opportunities will significantly minimize the amount of water used in the production process and the wastewater that requires treatment in the BSI’s wastewater treatment plant. In this research a general feasibility study is conducted on the CP opportunities identified. Considering general environmental benefits and its implementation is economically possible for the factory. An in-depth feasible evaluation for each of the CP opportunities is not conducted due to lack of information.

5. Implementation & Continuation:
The feasible CP options identified by this research will be proposed to the manager of the Belize Sugar Industry. Since the concept of Cleaner Production is new for BSI it is recommended that the in-plant CP options are implemented first. For the successful
implementation of the first batches of the CP options a monitoring and evaluation system will be require. To measure the results achieved by the implementation of this feasible options. The successful application of the CP opportunities in BSI will initiate and assure the ongoing application of Cleaner Production.

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Figure 3: The clean production assessment methodology. Source- adopted from Berkel, R.V 1999.

In addition, to the information collected from the Department of Environment, the Belize Sugar industry and the CP assessment methodology used, this research involved the distribution of one hundred questionnaires to random community’s members that live downstream along the river side. The two major communities involved in this research were Palmar Village and Orange Walk Town. The questions asked in the questionnaires that were distributed ranged from the benefits obtained due to the presence of the factory in the vicinity, to the effects that the Belize Sugar Industry is causing on the New River
as a result from the discharge effluents.

The questionnaires were collected 3 weeks after they were distributed to the randomly selected participants. The data collected from the questionnaires served to strengthen the argument of the need for the Belize Sugar Industry to adopt Cleaner Production measures. This data also gave an idea of the major pollution problems that are affecting neighboring communities, which claimed that the pollution problems of New River are caused by the Belize Sugar Industry effluents. The data from the questionnaires also depict the many uses that some community members give to the New River water; for example, fishing, irrigation, swimming etc. This illustrates that the New River is an integral part of the communities and the utilization of this polluted water can cause severe health threats to individuals. The questionnaires were an essential part of the research as it provides a better understanding of how the affected community members’ view the New River pollution situation. In this context, the data give the research a better perspective to give recommendations to the Belize Sugar Industry to deal with the present situation.

Moreover, a Taiwanese sugar industry was visited (Appendix F & G) in order to get a better perception of wastewater treatment facility. Questions were asked about the wastewater treatment plant process. The information gathered during this visit was used in order to improve the BSI wastewater treatment facility pollutant removal efficiency.

Also, successful case studies in other countries were reviews about the economical and environmental benefits of the implementation of the Cleaner Production approach in manufacturing industries. These provide the research with a clear understanding about the Cleaner Production benefits, limitations and problems when implemented in an industry.
4. REASONS WHY BSI SHOULD ADOPT CLEANER PRODUCTION

4.1 The concept of Cleaner Production is innovative

In order for the Belize Sugar Industry to deal with its present and upcoming problems this research proposes the adoption of the concept of Cleaner Production. This concept emerged in 1990 to support the changes toward an industrial sustainable development. One of the principles of sustainable development is that economic growth has to be harmonic with the environment and that a rational and sustainable use of natural resources has to be implemented (Olguin, E.J. 2005). In correspondence to such principle, the Belize Sugar Industry has to change from its degradative production approach to a more sustainable production approach. In order to attain this change the concept of CP has to be embraced by the factory. CP is defined as a continuous application of an integrated preventive environmental strategy to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment (UNEP) Fig 4.

Figure 4: Cleaner Production. Source - Khoa, L. Van (2006)
From figure 4 it can be depicted that the proper implementation of this approach in BSI will definitely improve the factories current situation. The integration of this concept in BSI will require the participation of all individuals involved in the sugar production process from the managers to the laborers. This will ensure that production is carried out in a manner that is both cost-effective and environmentally sound. The concept of CP can be applied to different stages of the process according to a company’s needs and possibilities (Gumbo). In the case of BSI this concept needs to be implemented for the reduction of wastewater generation (resource conservation). Its implementation in the Belize Sugar Industry will involve a logical sequence of steps, known as the CP assessment methodology that will lead to the ultimate goal of wastewater reduction during the production process; thus, avoiding the difficulty of dealing with vast amounts of wastewater generated after the production process.

Separately, from the notable benefits in saving water, energy and other inputs, as well as the minimization of undesirable pollutants which are discharged into the environment. Two other driving factors that will serve as incentives for BSI to adopt CP are globalization and competitiveness. This is because BSI exports a significant amount of sugar to develop as well as developing countries around the globe.

Furthermore, in the innovative concept of CP waste is considered to have a negative economic value. As a result, every effort made by BSI to prevent or reduce the generation of wastewater and reduce the consumption of raw materials and energy, will increase productivity and bring financial benefits to the factory. It is obvious that the integration of CP will be beneficial to the Belize Sugar Industry as well as the environment. This is due to the significant influence of improvement it has on the production processes. CP can provide very useful short and mid-term approaches to innovation within a transition process towards sustainable development; thus, achieving more value with less use of natural resources and less waste production.

Over the year the concept of CP has been defined in many ways as a result controversy
has sometimes arise. In order for BSI to avoid arguments there are four elements that make up the concept of CP that need to be understood; these are The Four Principles of Cleaner Production (Thorpe, B. 1999):

**The Precautionary Principle**
When an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. Under this principle, BSI should understand that the lack of full scientific certainly shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

**The Preventive Principle**
It is cheaper and more effective to prevent environmental damage than to attempt to manage or “cure” it. This principle will require BSI to examining its entire production process, from raw-material input to its ultimate product. This will encourage the company to develop more environmental friendly alternatives and Cleaner Production opportunities to reduce its wastewater generation. This preventive principle will require BSI to avoid the use of toxic chemicals in its production process (Table 1). Also, it will urge the substitutions of these chemicals for nontoxic chemicals in order to avoid the degradation of the environment.

**The Democratic Principle**
Cleaner Production involves all those affected by industrial activities, including workers, consumers, and communities. BSI will need to provide access to information and involvement in decision-making, coupled with power and resources, to ensure a democratic control. Cleaner Production can only be implemented with the full involvement of all those involved in the production process.

**The Holistic Principle**
Society must adopt an integrated approach to environmental resource use and
consumption. Access to this information would help build alliances for sustainable production and consumption. We must also take a holistic approach so that we do not create new problems while addressing old ones or shift the risk from one sector to another.

The four principles aforesaid that comprise CP will require BSI to change attitudes, exercise responsible environmental management and promote technology change. It also calls for fundamental changes not only at the industrial level, but also at the legislation level. Accordingly, new incentives and policies should be promoted in the near future in order to facilitate the adoption of this emerging concept.

The embracement of CP within industries is becoming a trend in many developed as well as developing countries. This will lead to the ultimate goal of sustainable development and factories in return will benefit economically. On the other hand, if BSI doesn’t integrating this emerging concept it will result in the further degradation of the environment, loss of competitiveness and unsustainable use of natural resources. This can ultimately lead to the downfall of the industry. According to the UNEP CP does not deny growth, it merely insists that growth should be ecologically sustainable. It should not be considered only as an environmental strategy, but also related to economic benefits.

4.2 Cleaner Production is better than Conventional Production.

For approximately four decades the Belize Sugar Industry has been in operation in the Orange Walk District. During these years no major technological, restructuring or production approach (Conventional Production) change have occurred. As a result, aquatic pollution complains by nearby communities have arise. While this environmental concerns intensify and progress in the understanding of the phenomena of pollution and modifications to the eco-system has revealed that today's problems are the result of past decisions (Conventional Production) and that environmental impacts must be seen from a product and process design point of view and over the long term (Cleaner Production) ( Li. B. H 2005). In this context, conventional industrial production is seen as an
infeasible solution to deal with 21st century environmental challenges that BSI is facing. The innovative concept of Cleaner Production is the ultimate solution that will aid BSI to reduce risk to humans, environment and become more competitive in the global markets.

This is because Cleaner Production is recognized by many industries around the globe as the driving force that will certainly lead towards the goal of sustainable development of the 21st century. On the other hand, industries that still use Conventional Production Approach (like BIS) argues that because of the complexity of CP and the differences between the various industries its implementation may vary. Therefore, the risk of planning errors is higher than with end-of-pipe solutions or Conventional Production. As a result, techniques and practices that have been acquired in one project involving CP might be of little help in a next project. This is because the Industries needs might focus on the different area of CP. Generally speaking, CP techniques and practices cover areas such as (Environment Canada’s 2004).

- substances of concern
- efficient use and conservation of natural resources
- reuse and recycling on-site
- materials and feedstock substitution
- operating efficiencies
- purchasing techniques
- product design
- process changes
- product reformulation
- equipment modifications

In contrast, according to Zotter Conventional Production argues that end-of-pipe solutions in different companies often have similar qualitative and quantitative flows of
residual products. This can be treated in technically similar end-of-pipe solutions. As a result, system providers can build up a wealth of experience in the planning, implementation and operation of end-of-pipe solutions. This experience can then be applied when designing new plants. End-of-pipe solutions can therefore be standardized relatively well. This suggests that the planning risk for end-of-pipe solutions is low that of CP. Other arguments that are used to substantiate the advantages of end-of-pipe solutions are (Zotter, K. A.2004):

1. End-of-pipe solutions do not (or hardly) affect production because they are implemented after the production process and can be operated independently of the production process.
2. End-of-pipe technologies are “mature” technologies that have been used often in the past and have been continuously improved, and
3. End-of-pipe solutions have a high degree of legal security because they are suggested and recognized by the official authorities.

From these arguments it can be assumed that end-of-pipe solutions cause fewer and less serious problems in the planning, implementation and operating phases than CP solutions.

Despite the fact, of the advantageous arguments made by industries utilizing conventional industrial production, the Belize Sugar Industry should realized that there are much more pit falls than advantage on the concept of Conventional Production than there is in CP (Table 10). Moreover, with environmental regulation becoming increasing stringent in Belize and waste disposal becoming increasingly expensive, it will be far more cost-effective for BSI to reduce the wastewater generated at the source. Rather than provide treatment to the wastewater after it has been generated.
Table 10: Conventional Production V.S Cleaner Production

<table>
<thead>
<tr>
<th>Conventional Production</th>
<th>Clean Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expensive end-of-pipe pollution technology</td>
<td>Minimum impact on the environment</td>
</tr>
<tr>
<td>No use of by-products</td>
<td>Maximum use of by-products</td>
</tr>
<tr>
<td>Processes not designed for waste prevention</td>
<td>Processes designed for minimum waste</td>
</tr>
<tr>
<td>Expensive waste treatment, transport and disposal</td>
<td>Savings through reduced pollution control technology, and reduced waste treatment, transport and disposal</td>
</tr>
</tbody>
</table>

BSI should strongly consider the integration of this concept. In recent years the focus in environmental management has shifted from Conventional Industrial Production (reactive approach) to Cleaner Production (proactive approach). This is supported by a research conducted by Frondel covering seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway, and the U.S.). From his research it was found that 76.8% of the sampled facilities in these countries predominantly invest in Cleaner Production, which addresses environmental impact over a wider range of production activities including product design, procurement practices, and production processes. The key reason of this shift is to change from a "corrective" approach to a "preventive" one. Also, to try to transform what has traditionally been seen as a source of additional private costs– to meet environmental regulations – into a source of potential benefits, through environmentally friendly products or production processes (Chudnovsky, D).

Additionally, fueling why BSI should shift from Conventional Production to CP is the fact that Conventional Industrial Production systems are linear; thus, this approach is seen as unsustainable (Fig 5). On the other hand, Cleaner Production systems are cyclical and are considered to be sustainable.
Figure 5 illustrates the linear nature of Conventional Production starting with non-renewable and unsustainable used of natural resources to end-of-pipe solutions. As it can be depicted from diagram 5 in conventional industrial production there aren’t any systems in place to recycle, reuse or prevent the generation of waste. This is one of the major reasons why the Belize Sugar Industry needs to shift from its Conventional Production approach to CP approach. The way BSI deal with the wastewater that is generated from its production process is an end-of-pipe solution. End-of-pipe solutions are understood to be control technologies, which are more or less stuck onto the end of the production system (Zotter, K. A. 2004). The purpose of end-of-pipe solution that the Belize Sugar Industry employs is to improve the quality of the wastewater that is generated by the production process, so it can be discharged to the environment. The level of treatment that the end-of-pipe solution provides to the wastewater depends on the discharge standards that the Belizean authorities imposed to BSI (Appendix A). The flaw of this method is that the treatment of the wastewater that is generated is an extra burden...
to BSI; this is because treating and disposing of the resulting wastewater require energy and raw materials, which costs money. This increases the company’s total consumption of materials and energy. On the other hand, if BSI shifts to the cyclical Cleaner production systems (Fig 5), the company will be able to decrease the wastewater that is generated by the production process through recycling and reuse. This will not only cover the reduction of wastewater produced but also reduce the amount of resources used by the company. This will ultimately result in an economical benefit for BSI and a reduction on environmental degradation.

From the aforementioned, it can be depicted that Cleaner Production is frequently seen as being superior to Conventional Industrial production or end-of-pipe solutions for both environmental and economic reasons. Even if this is the case, the total replacement of end-of-pipe solutions by Cleaner Production measures is certainly not possible. In practice, there will always be a mix of end-of-pipe solutions and Cleaner Production measures that depends on the underlying environmental targets, technology options, and related costs (Frondel, M.). Nevertheless, end-of-pipe should therefore be seen just as an aid to the concept of Cleaner Production.

4.3 Benefits of Cleaner Production

The Belize Sugar Industry has not realize how much resources they are losing in wasted materials, energy and water, or through handling, storing and disposing of waste materials. By adopting CP BSI would be able to increase its efficient; this will result in the conservation of resource, which will bring economical benefits to the factory. This economical gain will serve as an incentive to further encourage BSI to explore more CP opportunities in its production process. This approach also offers BSI with the opportunity to achieve their environmental goals in a way that is more effective and stimulates innovation and the ability to compete. Table 11 shows some of the industrial and environmental benefits that the incorporation of CP can bring to the industry.
Moreover, it is important for BSI to note that CP has acquired global attention over the past few years. This is because of its potential cost savings that accompanies pollution minimization measures such as increasing efficiency, recycling, minimizing resource consumption and utilizing by-products; thus, reducing the impact on the environment. In addition, there have been documented cases where industries that implement CP not only reduce the impact to the environment but also get economical benefits. For instance; the work of a Cleaner Production Center (CPC), funded by the Export Promotion Bureau and the Norwegian Organization for Development (NORAD) that guided 16 tanneries in Sialkot through the process of in-house modifications to minimize waste generation and

### Table 11: Industrial and environmental benefits of CP

<table>
<thead>
<tr>
<th><strong>Industrial Benefits</strong></th>
<th><strong>Pollution Prevention - Benefits</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Leads to improved products and processes</td>
<td>Minimize or avoids the creation of pollutants</td>
</tr>
<tr>
<td>Saves on raw materials and energy, reducing production costs</td>
<td>Avoids the transfer of pollutants from one medium to another</td>
</tr>
<tr>
<td>Increases competitiveness through the use of new and improved technologies</td>
<td>Accelerated the reduction and/or the elimination of pollutants</td>
</tr>
<tr>
<td>Reduces the need for more environmental regulation</td>
<td>Minimizes health risks</td>
</tr>
<tr>
<td>Improving worker’s health and safety by minimizing exposure to harmful substances</td>
<td>Promotes the development of pollution prevention technologies</td>
</tr>
<tr>
<td>Improves staff morale, leading to better productivity</td>
<td>Uses energy, materials and resources more efficiently</td>
</tr>
<tr>
<td>Improves a company’s public image</td>
<td>Minimize the need for costly enforcement</td>
</tr>
<tr>
<td>Reduces risk from on- and off-site treatment, storage and disposal of toxic wastes</td>
<td>Limits future liability with greater certainty</td>
</tr>
<tr>
<td>Reduces the cost of increasingly expensive end-of-pipe solutions</td>
<td>Avoids costly clean-up in the future</td>
</tr>
<tr>
<td>Fostering the reuse of process wastes and energy efficiency</td>
<td>Modifying current production processes to improve materials use and reduce waste generation;</td>
</tr>
<tr>
<td>Improving product quality by gaining a better understanding and control of the production processes</td>
<td>Facilitating compliance with environmental regulations</td>
</tr>
</tbody>
</table>

Source: Adopted from the Queensland and Canadian Council of the Environment

35
resource consumption. An initial review revealed combined annual savings of the 16 companies to amount to nearly Rs. 17 million, generating a profit of about 68% of what they invested for the improvements (Akbar, N. M 2006). Other exemplary example of the economical and environmental benefits, when implementing CP, was documented in the developing country of Vietnam in Ho Chi Minh City (HCMC). CP measures were carried out with applying strategies to minimize the generation of wastes and emissions. The CP project that was carried out in this city was to demonstrate the potential economical and environmental benefits of CP. For this project 6 industries (Thien Huong Noodle Company, Vissan Slaughter House, Xuan Duc Paper Company, Linh Xuan Paper Company, Phuoc Long Textile Company, Thuan Thien Bleaching and Dyeing Company) were involved and significant achievements were made (Table 12).

Table 12: Environmental impacts of CP measures

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of CP Options</th>
<th>% Reduction in Environmental impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wastewater (%)</td>
</tr>
<tr>
<td>Thien Huong</td>
<td>24</td>
<td>66</td>
</tr>
<tr>
<td>Vissan</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Xuan Duc</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Linh Xuan</td>
<td>19</td>
<td>45</td>
</tr>
<tr>
<td>Phuoc Long</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td>Thuan Thein</td>
<td>14</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>42% (Total measures available)</td>
<td></td>
</tr>
</tbody>
</table>

Source: DHAKA, S

Table 12 clearly illustrates that Thien Huong industry from a total of 24 Cleaner Production options that were identified, using the CP assessment methodology, the highest reduction on environmental impacts resulting from wastewater 66% and Pollution load 35% were obtain. The highest reduction on environmental impacts resulting from Gaseous emissions 70% was obtained by Thuan Thein. The reason why the Dyeing Company attained the highest reduction on Gaseous emissions is because in comparison to the other companies, gas emissions before the implementation of CP were higher than the other 5 industry. In short table 12 shows how the implementation of CP measures caused a significant reduction of environmental degradation by the companies. It can be
concluded that this enhancement will improve the environmental situation in the city. The industries will be able to comply with the countries environmental regulations more easily.

**Table 13: Economic benefits of implementing CP measures**

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of CP options</th>
<th>Investment US $</th>
<th>Savings US $</th>
<th>Pay back period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thien Huong</td>
<td>24</td>
<td>62,000</td>
<td>633,700</td>
<td>&lt; 2 months</td>
</tr>
<tr>
<td>Vissan</td>
<td>9</td>
<td>10,000</td>
<td>28,000</td>
<td>&lt; 5 months</td>
</tr>
<tr>
<td>Xuan Duc</td>
<td>21</td>
<td>15,000</td>
<td>96,000</td>
<td>&lt; 2 months</td>
</tr>
<tr>
<td>Linh Xuan</td>
<td>19</td>
<td>50,000</td>
<td>100,000</td>
<td>6 months</td>
</tr>
<tr>
<td>Phuoc Long</td>
<td>19</td>
<td>4,400</td>
<td>40,000</td>
<td>&lt; 2 months</td>
</tr>
<tr>
<td>Thuan Thein</td>
<td>14</td>
<td>100,000</td>
<td>75,000</td>
<td>&gt; 1.5 year</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>241,400</td>
<td>972,700</td>
<td>&lt; 4 months (average)</td>
</tr>
</tbody>
</table>

Source: DHAKA, S

Table 13 shows that the proper implementation of CP can yield impressive saving to companies with relatively short pay back periods. The Thuan Thein Industry invested the most in order to put into practice its CP options. As a result, the payback period is longer than the other 5 industries. The Phuoc Long industry is the one that invested the less. The investment made by these industries resulted in major economic gains for all the industries that underwent the CP project; thus, the companies can utilize the saving for the continuous improvement of the CP techniques.

From the two tables above it can be concluded that all the investments made by the 6 industries to implement their CP options prove to be worthwhile to both the environment and the industries.

The examples aforementioned clearly illustrate the economic and environmental benefits attained by the implementation of CP in industries. These further enforce why there is the need for BSI to integrate this approach in order to remain competitive and reduce its environmental impact.

Nonetheless, industries in developing countries, such as BSI, stick to the Conventional Production or end-of-pipe solutions, ignoring the economic and environmental benefits of
CP. This is because regulatory measures and the stringency of environmental policies are positively correlated with end-of-pipe technologies (Frondel, M.), meaning that the legislations in place force companies to stick to the concept of Conventional Production. Also, the lack of exposure to the concept of CP is the next reason why Conventional Production is Preferred. It is also important for BSI to be aware that although Cleaner Production offers opportunities for “win-win solutions,” where environmental improvements go hand-in-hand with economic benefits, its implementation will not happen overnight. Cleaner production is not simply a matter of applying new technologies but requires readjustment and rethinking throughout the firm, for which cooperation, involvement and commitment of management and employees are essential (Frijns, J. 1999). As a result, it is suggested that in order for BSI to successfully implement this CP approach exposure, leadership and direction are needed. The implementation of this concept is no an easy task but can be accomplished by enabling legislation within BSI that will sets the framework for responsive and pollution prevention programs. The Queensland Cleaner Production institute gives the following guide lines that the managers (on BSI) can follow for the effective implementation of CP in the Industry (Queensland Cleaner Production 2007).

- Develop and implement a comprehensive, corporate environment policy. This should be based on preventing pollution, minimizing waste and reducing environmental risk generated by all corporate activities.
- Develop regular pollution prevention and waste reduction audit procedures.
- Develop a plan containing specific environmental goals and timetables for achieving them.
- Educate and involve employees at all levels. Employees should be involved in identifying and solving environmental problems at their source. Often employees on the shop floor can develop better solutions to waste problems than executives not involved in day-to-day production.
- Allocate responsibility for achieving goals to specific employees. Management should allocate sufficient employee time and financial support to ensure that work
can be accomplished. The Cleaner Production Co-ordinator should be a senior management position.

- Gather the best management and technical information to help the business take advantage of waste reduction opportunities.
- Evaluate progress continually.
- Inform employees, shareholders and the public of the progress being made.
- Establish environmental award programs to foster and reward creative problem-solving.
- Review and update goals and timetables regularly.

If the abovementioned guidelines are followed and enforced effectively by the Belize Sugar Industry, the initiative made to adopt CP will be successful; thus, there will be a continuous improvement in the factory. This will slowly shift BSI from an inefficient Conventional Production Approach to an efficient Clean Production Approach.
5. THE IMMEDIATE NEED FOR CP IN BSI

5.1 Current situation of the Sugar Industry in Belize

Currently, the Belize Sugar Industry is using the Conventional Production Approach. The pollution control measure that the factory is implementing is known as end-of-pipe solutions, in order to comply with the Belizean authority’s environmental regulations. However, over recent years a new concept of reducing wastewater has emerged. This involves pollution prevention at the core of the industrial process. As mention in chapter 4, the concept of CP addresses the waste management problems by changing processes and working practices for achieving resource optimization, improving performance and overall reduction in the pollution load. This will result in the reduction of processing costs. Successful implementation of CP in an industrial has shown its significant economical and environmental benefits. Experts claim that hydraulic load could be reduced to 50% and pollution load could be reduced by 30% by adopting the CP path. International experience has revealed that this approach is more practical and cost effective.

The reason why there is an urgent need to adopt CP by BSI is because currently the factory is facing two serious problems.

i) External threats to preferential markets: BSI is soon going to lose its access to its preferential markets; this will have a negative economic impact on the industry. When the preferential markets are abolished BSI will need to compete with other sugar producing countries like Mexico and Brazil to gain access to sugar markets. With this in mind, it is important for BSI to adopt CP. This will determine the survival of the company in the liberalized markets, were efficiency, competitiveness and innovation are the key to survival (further discussed in section 5.2).

ii) Pollution complaints: Due to the proximity of the factory to populated areas, people are starting to complain of pollution problems in the New River and are blaming BSI. By
adopting CP BSI will be able to minimize its wastewater discharges to the New River; thus, decreasing its impact to the environment and comply with its environmental regulations (further discussed in section 5.3).

These national as well as international challenges that lie ahead will require BSI to shift from Conventional Industrial Production to Cleaner Industrial Production. If this shift is achieved successfully BSI will be able to address these two measure issues, which will result in a more efficient, competitive and environmental industry. It is important to note that the implementation of CP is not something that will happen over night. This is a process that will occur over time because workers at all levels need to be aware of this concept. With the due process being followed the implementation of CP is always a success.

5.2 External threats to BSI preferential markets

Belize sugar industry wills faces many challenges in the coming years. These challenges include from the increase in penalties by the local authority to the international level where export is of concern. For the past decades the Belize Sugar Industry has been exporting its sugar to four main markets the European Union [EU], the United States of America [USA], CARICOM and the world market. The first three markets provide preferential market access under various trading arrangements. Over the past few years several challenges threaten to erode the preferential market access upon which the Belizean Sugar Industry is dependent. Consequently, the effect on the long term viability of the industry is still unclear, though expected to seriously affect the industry. BSI will need to shift from a Conventional Production method which is constantly referred as inefficient, to a Cleaner Production method which will increase the efficiency and the competitiveness of the industry if it aims to survive in a free trade environment. The external threats to the BSI markets are mention below (Ministry of Foreign Trade 2004).
(1) The EU Market

The EU is the most profitable market for BSI because it guarantees 42,000 tonnes of raw sugar to be exported annually under the Cotonou Agreement. In 2003, income from the EU represented 66% of total revenues earned from sugar exports, as the weighted average price amounted to US 21.68 cents per pound.

Threats to the EU Market

Due to pressure from WTO and other countries, the EU has made public four possible ways in which the EU sugar market might be reorganized by 2009. These options each have significant implications for the future of Belize’s Sugar Industry. The options are:

1. Status Quo: EU raw sugar intervention price is cut by 17% for a future price of US$506.61 per tonne, with the same current quota allocation.

2. Fixed Quotas: EU sugar price decline as in the Status Quo and Belize receives the same level of access as today.

3. Price Cut - EU raw sugar intervention price is cut by 38% for a future price of US$380.25 per tonne. Under this option, two different access levels may be assumed; (i) unlimited access for Belize following the implementation of EPA’s; or (ii) limited access as in the two options above.

4. Full market liberalization: EU price support would be abolished and Belize would cease to benefit from prices above world market levels.

(2) The USA Market

Belize is allowed to export sugar on a duty-free basis to the United States under the CBI Agreement, which is expected to expire in 2008. The annual quota exported approximates to 11,000 tonnes. In 2003, this market represented about 14.3% of gross earnings with the
average price of US 20.27 cents per pound.

Threats to the US Market

Once the CIB Agreement expires it will be very difficult to renovate it. However, the CBI is expected to be succeeded by the FTAA agreement which is currently being negotiated. Although it is expected that the US will offer preferential market access under the FTAA there are a number of issues which will impact on the possible arrangements. First, the preferential arrangements must be WTO-compatible. Secondly, major sugar producers and exporters, for example Brazil and Mexico, are involved in the FTAA negotiations and expect to have better market access to the US market than they currently enjoy.

(3) The CARICOM Market

Belize has guaranteed preferential duty-free access treatment into CARICOM under the CSME. The price received in this market averages US 12.07 cents per pound. Exports to CARICOM increased dramatically in 2003, as volume exported to this market more than doubled from 5,809 tonnes in 2002 to 12,275 tonnes. This trend is expected to continue.

The CARICOM market is the most favorable for sugar exports in the long term, based on the contraction of production by other regional producers like Barbados, St. Kitts and Trinidad & Tobago.

Threats to the CARICOM Market

The only serious threat, if it can be so called, is the pending investment in the refurbishment of the Guyanese sugar industry. Guyana is the single biggest sugar producer in CARICOM and like Belize enjoys duty free access within the CARICOM. The investment in a refinery holds some likelihood of displacing our exports to the region.
(4) The World Market

The World market is the least favorable for Belize and is dominated by low cost producing countries such as Brazil, Australia and China. The volume of sugar exports sold on the world market in 2003 was 24,000 tons. The average price received in the market amounted to US 6.45 cents per pound.

As it can be noted from the aforementioned information due to the preferential Markets that BSI enjoyed for the last decades, the company didn’t have to compete with any other industry within or outside the country. This is one of the reasons why the company infrastructure and technology has become obsolete. This results in the use of the same outdated Conventional Production concept. During the research it was found that by the year 2009 Belize will loose its two major preferential markets this are the EU market and the US market. As a result, the company will experience severe money losses (Table 14). The only preferential market that will still be viable for BSI will be the CARICOM market. The loss of the two preferential markets will serves as an incentive for the company to improve and become more competitive in the new market environments, if no actions are taken BSI will not be able to compete.

Table 14: The Belize Sugar Industry Preferential markets

<table>
<thead>
<tr>
<th>Pricing</th>
<th>The EU Market</th>
<th>The USA Markets</th>
<th>The CARICOM Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferential Prices</td>
<td>US 21.68 cents per pound</td>
<td>US 20.27 cents per pound</td>
<td>US 12.07 cents per pound/</td>
</tr>
<tr>
<td></td>
<td>42,000 tonnes/ US 18,211,200</td>
<td>11,000 tonnes/ US 4,459,400</td>
<td>12,275 tonnes/US 2,963,185</td>
</tr>
<tr>
<td>Standard prices</td>
<td>US 6.45 cents per pound</td>
<td>US 6.45 cents per pound</td>
<td>US 12.07 cents per pound/</td>
</tr>
<tr>
<td></td>
<td>US 5,418,000</td>
<td>US 1419000</td>
<td>US 12,275 tonnes</td>
</tr>
<tr>
<td>Money loss expected</td>
<td>US 12,793,200</td>
<td>US 3,040,400</td>
<td>Only Treat for loss is the renovation of the Guyanese sugar industry.</td>
</tr>
</tbody>
</table>
In the case of the EU Market from the four options that were made public it is expected that option four will be selected, which is the full liberalization of markets. This will come into effect in November 2009, which means BSI will lose its price and quota supports. This will severely affect the sugar cane industry in Belize because EU price support would be abolished and Belize would cease to benefit from prices above world market levels. This means that the 42,000 tonnes US 18,211,200 dollars of raw sugar that was exported annually to the EU will no longer be certain because BSI has to compete with other sugar producing countries in order to sell its product to the EU. In the case that BSI manages to export the 42,000 tonnes of cane to the EU the selling price will be the same as the world market price. That means that for the 42,000 tonnes of sugar, BSI will be getting only US 5,418,000 dollars. BSI will be loosing a total US 12,793,200 dollars every year when the EU preferential Market is abolished (Table 14). To make things worse for BSI, the preferential market it enjoys from US is going to expire on 2008. This means that the company quota of 11000 tonnes US 4,459,400 dollars annually will no longer be certainly granted to BSI. The new agreement that is going to be sign will require BSI to compete with Brazil and Mexico sugar industries. The prices will almost be the same as the World Market. As a result BSI is expected to loose US 3,040,400 dollars for its 11000 tonnes of raw sugar. On the CARICOM market the only threat that exists is if the Guyanese sugar industry is renovated.

It is clear that if BSI doesn’t do any thing to tackle the eminent challenges that are ahead it will not be able to survive in a liberalized Market conditions. In order to tackle the problem, the company needs to refurbish its obsolete technology and implement the concept of Cleaner Production, which will certainly improve the company competitiveness and efficiency. Furthermore, the proposed CP concept could be a useful tool to attaining accessibility to new markets. This is possible because there is an international interest that industries adopt this concept as it is seen as the driving force of a new and sustainable industrial development style.

The World Trade Organization may have stripped Belize’s sugar industries of their preferential trade agreements with the European Union, but the E.U. is attempting to
compensate with technical assistance to make this industry more competitive on world markets. On March 03, 2008 the government of Belize and E.U. signed two agreements that will provide approximately seventeen point five million dollars for improvement of infrastructure in BSI (Channel5news). This is a great opportunity that the EU is giving to BSI. This money can be used by the company to retrofit technologies that will aid in the incorporation of CP in the production process.

5.3 Pollution complaints by nearby communities

As it has been established sugar cane factories are considered to be the most organic pollutants around the globe. This is due to the vast quantities of water they utilize for there production process. This is often true for sugar cane industries that operate in developing counties like Belize. The reason for this is because in many cases government officials lack to enforce environmental legislations, the penalties for the industries that violate the environmental legislations are lenient and the lack of incentives that will guide the industry to adopt environmental friendly approaches, such as CP. As a result, industries operating in developing counties often lost competitiveness and causes severe environmental degradation.

The Belize Sugar Industry has been in operation in Belize for the past 40 years. On the factory first years of operation neighboring communities were far and sparsely populated. The company’s production was low and little treatment was required to treat the wastewater that resulted from the production process but as BSI sugar production increased this resulted in more stress for the New River. As a result, environmental problems started to arise and nearby communities started to complained that the New River was being polluted.

To verified the allegedly complains and to further find support to pressure BSI to shift to the concept of CP, this research conducted a questionnaire survey of 100 randomly selected individuals living in Orange Walk Town and Palmar Village. The randomly
selected individuals live along the river side. The two communities mentioned are located down stream from BSI. Form the 100 questionnaires that were distributed 98 were returned, 2 were not completed and 1 of the questionnaires was not answered by the participant. The two uncompleted questionnaires were discarded because the information they contained was not enough. The uncompleted questionnaires and the unanswered questionnaire were rated as invalid. The 95 (valid) questionnaires that were completed were used to analyzed and study the situation of the New River from the affected individual’s perspective (Table15).

Table 15: Questionnaire survey results

<table>
<thead>
<tr>
<th>Number of questionnaires send</th>
<th>Questionnaires returned</th>
<th>Valid</th>
<th>Invalid</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>98</td>
<td>95</td>
<td>3</td>
</tr>
</tbody>
</table>

Questions asked in the questioners range from benefits to negatives due to the presence of BSI. The data collected from the questionnaire shows that when the 95 participants were asked if the New River in their community is polluted 35% of the participants strongly agree, 45% agreed and the other 20% was distributed between neutral, disagree, and strongly disagree (Fig 6).
Figure 6: The area of the new river in your community is polluted?

From the results it can safely be said that 80% are sure that the New River is polluted only 4% said it is not the case. This data clearly demonstrate that the New River is indeed polluted and something needs to be done in order to prevent the further degradation of the New River System.

In order to find the degradation state of the river questions concerning the odor, coloration and aquatic life of the river were asked (Figure 7). In diagram A it could be seen that 73% of the participants said yes the New River have bad odor. In diagram B when asked if the new river has unusual dark coloration 85% said yes and 15% answered no; in diagram C according to 62 participants, in the survey, they have been witnesses of fish kills in the river as a result of pollution. Moreover, cases of fish kills, as a result of pollution problems have been reported by the media many times in the past decade. For example, on June 15, 2007 The Independent Reformer news paper reported that The Environmental Protection Society, NEPS, which is a non-governmental organization, reported a fish kill in the New River between the Orange Walk Toll Bridge and Orange Walk Town. This organization also made mention that they believed that the pollution from the sugar processing plant BSI is responsible.
Figure 7: A) Does the New River have bad odor?  
   B) Does the New River have unusual dark coloration?  
   C) Have you witnessed plant life and animal life dying in the New River?

On the other hand, BSI claims that they are complying with environmental regulations set by the government; thus, they are not responsible for the pollution problems that arise in the river which cause the fish kills. This happens because along the river there are many possible sources that might be responsible for the polluting of the river. These sources are an Alcohol producing Factory, Leaching from farms and households. As a result, none of them what to take the blame for the environmental degradation that is happening in the New River. On this context, when asked in the questionnaire to the participants if they think that BSI is the main source of pollution to the New River 22% strongly agrees, 49% agree and 29% of the responds were distributed between neutral, disagree and strongly disagree (Fig 8). From the 76 participants that said the New River was polluted 9 answered that BSI is not responsible and 67 answered that it is.

![Figure 8: The Belize Sugar Industry is the main source of pollution?](image)

From figure 8 it can be depicted that 71% of the participants think that BSI is responsible for all the pollution problems that are affecting their communities, and 11% don’t think so. The New River for the communities is considered an important recreational area for 66 participants. The other 20 don’t consider it as an important recreation area (Figure 9).
When asked if in any point in time they have become unpleasant as a result of leaving too close to the river 59% answered yes and 41% answer no. The 59% that answer yes they stated the unpleasantness was because of the pollution problem that the river is recently in.

Figure 9: A) Is the New river and important recreational area in your community? B) Have you ever felt unpleasant as a result of living too close to the river?

Additionally, growing environmental degradation is already having some effects on human health in the area; according to 67% of the participants they know someone that has become ill as a result of swimming in the New River and 17% stated that they have suffered illness and they think it is because of the New River current situation (Fig. 10).

Figure 10: A) Do you know of anyone who has become ill while swimming in the New River? B) Have you ever suffered any illness and thought it was because of the river?
The reason why some of the participants are getting sick as a result of the polluted New River is because some of this people give different uses to the river water (Fig 11). 62% of the participants said that they give uses to the New River. It is important to note that individuals that are in direct contact with the river waters are more prone of getting sick. In this case swimming and fishing which account for a 26% of the participants. The 38% that doesn’t give any use to the river stated that this is because the river has foul smell. Also, the unpleasant color of the water has made the river an unwelcoming area for possible use and the fear of getting sick.

Figure 11: Do you utilize the River water?

The last question of the questionnaire asked the participants if they think actions need to be taken immediately to improve the New River current situation and 97% stated yes (Fig. 12).
Figure 12: Do you think actions need to be made immediately to improve the New River current situation?

On the other hand, the questionnaire also found out that BSI is very important for the communities nearby, as well as for the whole country. When asked about the benefits of the industry, 71% of the participants answered that BSI has brought economic benefits to their communities, and 21 said they are economically dependent on BSI (Fig 13).

Figure 13: A) Has the sugar cane industry brought about any benefits to your community? B) Do you directly benefit from the sugar cane industry?

From the 67 participants who said BSI brought benefits to their community, 21 benefit directly and 46 have an indirect benefit.

From all the data gathered, it is clear that the New River is polluted and the individuals affected believe that BSI is the major pollutant contributor. The data also illustrates that the presence of BSI is important for the nearby communities as individuals benefit directly or indirectly from the industry.

In this context, it is clear that the Belize Sugar Industry needs to shift to a more environmentally friendly production approach and work hand in hand with nearby communities. The industry should know what are the neighboring communities’ attitudes...
towards the industry and in what ways they are being affected by the presence of the industry. Moreover, the company needs to inform the affected communities what measures they are taking to improve the state of the environment and their production process. If this is done the people will have a positive attitude towards the industry because they will realize that the BSI is committed to care for the environment. To solve these and other environmental problems, it is proposed herewith that a pollution prevention strategy based on the promotion of Cleaner Production and environmentally sound decisions could be adopted in the Belize Sugar Industry. The adoption of this emerging concept will help the industry to reduce the wastewater that is discharge in the New river; thus, reducing cost, increasing efficiency and competitiveness and reduce the impact to the environment. The proposed concept of CP will be a useful tool for attaining sustainable development and overcome the challenges that BSI is facing.
6. CLEANER PRODUCTION OPPORTUNITIES FOR WASTEWATER REDUCTION IN BSI

6.1 Identify Cleaner Production opportunities in BSI

In order to identify the Cleaner Production opportunities that exist within BSI to reduce the wastewater that result from the production process. A Cleaner Production assessment methodology was carried out (Chapter 3). This assessment was made possible thanks to the collaboration of the factory manager, laborers and the factory chemist. Also from information provided from the Department of the Environment. The information collected was analyzed and CP opportunities were identified. The assessment of the Cleaner Production opportunities that exist was done following the Cleaner Production assessment procedure, which is described in the methodology of this research. In the sugar cane factory there are many Cleaner Production opportunities. This research only focuses on the feasible opportunities that exist to reduce the wastewater generated by BSI.

6.2 Phase I: Planning and organization

The Belize Sugar Industry is committed to develop and implement an environmental management system; that set out the company’s structure of possibilities and policies for protecting the environment and managing organizational environmental issues, in conformity with the company and the Environmental Protection Act. It also declares its commitment where practical to install and/or modify existing infrastructure and facilities to treat and manage effectively all forms of pollution emanating from the company’s operation to minimize detrimental effects on the environment. BSI agreed to provide information for this research because they want to minimize the wastewater generated by their production process.

The personnel that were contacted to collect the data for the CP assessment involved the factory manager (Mr. Tillet), Chemist (Mr. Leiva) and bottom level workers. The data that was requested was collected and sent via e-mail. Moreover, a compliance monitor site
visit report made by the DOE was also used for the CP assessment.

The collection of data for the project was facilitated because the company has its formal environmental policy. This states that the industry should act responsible towards the environment in which they operate by ensuring the conservation and preservation of the natural environment and supporting national polices on the environment. As a result, by reducing the wastewater produced they will be further complying with their own policy.

The Cleaner Production assessment for this research was made throughout the factory facilities and focused on water consumption and wastewater generation. The main factory facilities that were inspected according to the personnel that collected the data were the Mill house, the Process house and the Boiling house. The activities conducted by the workers and machinery operations in the major sections of the factory were inspected carefully and working procedures by workers were also assessed. A list of possible improvements was developed.

6.3 Phase II: Pre-assessment

The personnel that were contacted to collect the data first provided the description of the processes that takes place in the production of sugar (Section 2.2 & Appendix B). The production process is explained from the unloading of sugar cane to the production of plantation white sugars see section 2.2 of the sugar production process. The sugar production process in BSI utilizes vast amounts of water that are extracted from the New River and underground aquifers (Tables 3 and 4).

During the site inspections of the mill house, process house and the boiler house the following was noted.

- Product leaks and spills consistently occur in the various stages of sugar production Process.
- The grease and lubricants which drip from the plants machinery generally fall to
• The cleaning of product leaks and spill are done with a water hose.
• Some of the workers are not conscious of the need to conserve water.
• Excess condensates are discharge to the ash ponds.
• Laboratory and bathroom wastewaters are connected to wastewater treatment plant
• Constant cleaning areas have rough floors

The site inspection revealed the following problems:
• High consumption of water
• Large amounts of wastewater generated due faulty in-plant practices.
• Large amount of pollutant loads resulting from floor washing.
• Little or no recycling of water occurs in the sugar production process
• Improper monitoring of the production process (e.g. evaporators and vacuum pans overload)

The pre-assessment that was made showed a considerable number of Cleaner Production opportunities in BSI. From the data gathered it was concluded that the implementation of the in-plant CP opportunities that exist in BSI can be achieved with minimal investment. On the other hand, the installation of equipment to recycle and reuse wastewater will require a significant investment.

6.4 Phase III: Assessment

The water inputs streams and wastewater generation streams were measured and this data was sent to be used for this thesis. The data that was collected by the personnel provided an insight of BSI unique production process. It was reported that the data provided for the water streams is an approximation. This is because it is very difficult to provide more detail information because BSI doesn’t have a water consumption monitor system. The data that was collected is as follow.
The loadings in wastewater streams of the Belize Sugar Factory were recorded (Table 16). The percentage of wastewater generated by each stream in comparison to one another was calculated. This are as follow: Cooling Water accounts for 1.4% of the total wastewater generated, Washing of Floors and Equipment accounts for 43.45%, Excess Condensates for 51.9% and Boiler Blow Down for 3.2%.

Based on table 16 the percentage of COD that each of the 4 streams contributes to the total amount of COD of the wastewater was calculated. It was noted that the Cooling Water stream accounts a total of .035% of the total COD. The Washing of Floors and Equipment accounts for 99.7%, Excess Condensate for 0% and Boiler Blow Down for .23%.

The percentage results obtained from table 16 are very important since it can be observed that floor washings contain the most organic pollutant load 99.7%; whilst it also constituting 43.45% of the wastewater volume.

The data about the water inputs of the tower hill sugar factory sugar production process were also collected (Table 17). Four major water input areas was identify. The percentage of the water inputs were calculated based on the total amount of water utilized by the four streams.
Table 17: Breakdown of water inputs of Tower Hill sugar Factory

<table>
<thead>
<tr>
<th>Process Stream</th>
<th>Flow rate (m³/tc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imbibitions water</td>
<td>0.25 m³/tc</td>
</tr>
<tr>
<td>Total Cooling water</td>
<td>0.30 m³/tc</td>
</tr>
<tr>
<td>Boiler makeup</td>
<td>0.43 m³/tc</td>
</tr>
<tr>
<td>Condenser Feed</td>
<td>13.00 m³/tc</td>
</tr>
<tr>
<td>Total</td>
<td>13.98 m³/tc</td>
</tr>
</tbody>
</table>

Source: BSI

- The first water input is water used for Imbibition this accounts 1.79% of the total water used. Cooling Water accounts for 2.15%, Boiler Makeup for 3.08% and Condenser Feed for 92.99%.

- It was concluded that the most water-intensive operations is Condenser Feed. The water use during these operations accounts for 92.98% of the total water inputs of BSI. Any actions taken to minimize the water inputs have to concentrate in water intensive operations, in this case Condenser Feed, to have a significant decrease in water consumption of the factory.

Based on the data collected and activities observed in the industry measures are proposed to BSI to reducing water consumption and minimizing the organic load of the wastewater generated. The measures identified are Cleaner Production opportunities that exist in the in-plant practices and production process of the Belize Sugar Industry.

I. CP opportunities identified in in-plant practices:

- Remind workers that the company is concerned about water conservation and in order to attain this goal, their participation is essential.
- Put signs and posters of water conservation near water faucets and hoses.
- Equip all water hoses in BSI with spray guns.
- Improve floor conditions in BSI especially floor areas that are frequently being cleaned.
- In areas were oil drop to the floor, such as in the power plant and in the boiler house, drip pans are recommended to collect the oil to prevent it from get into the
Whenever possible, the grease and lubricant which collects on the plant floor or equipment should be dry cleaned instead of hosed down.

Instead of cleaning product spills with a water hose, BSI should consider absorbing the spilled product with bagasse.

Prevention or minimization of spills and leaks through regularly inspecting and repairing of the factory processing units.

Install grease traps on all drainage channels which carry a significant amount of grease/lubricants especially in the floor drain which services the mills.

II CP opportunities in production process

- Recycling of cooling and condenser water
- Recycling of excess condensates
- Treatment and recycling of flue gas scrubbing water
- Operate the factory at optimum capacity and try to reduce stoppages
- Use hot water for imbibition and operate equipment at proper levels
- Use of efficient entrainment separators and mist eliminators in evaporators
- Avoid overloading evaporators and vacuum pans and allow suspended particles in filter cloth washings to settle

6.5 Phase IV: Evaluation and feasibility study

The largest array of available options that can bring about a substantial reduction in sugar mill effluents and pollution loads with relatively minor financial investments and the potential for cost-savings consist of in-pant CP measures. The implementation of this CP options are considered to be feasible due to its minor investment and complexity required for its implementation. On the other hand, for BSI to implement the first three CP opportunities mentioned in the production process a significant amount of investment and an in-depth technical and economical analysis need to be done. This research will provide some general information on these three Cleaner Production opportunities. Since, the
Belize Sugar Industry might consider their implementation in the near future, when it feel more comfortable with the concept of CP (these CP opportunities can be financed by the money donated by the EU). Their implementation is important as these will significantly minimize the amount of water used in BSI’s production process. The remaining four CP opportunities in BSI production process are considered to be feasible in the bases that littler investment is required for their application.

During the technical evaluation it was found that it was desirable and feasible for BSI to adopt all in-plant CP opportunities. These can significantly minimize the pollutant loads and wastewater that is generated. The feasibility was assessed based on complexity and cost for implementing the CP opportunity. The reminder to workers of the need to conserve water in the factory can be done during BSI meetings. The signs put in the factory will further emphasize on the importance of the water conservation initiative. Since, sometimes workers tend to forget to close the faucets after using them. It documented that a running faucet can needlessly waste more than seven hundred liters of water per hour. Equipping the water hoses with spray guns will increase the pressure of the water; thus, resulting in the minimization of water required to wash floors. Also the quality of the floors has a lot to do with how much water is used to clean them. It is well known that rough floors are harder to be washed; thus, require the utilization of more water. In this context, it is recommended that BSI should smooth floors that require constant cleaning to reduce the amount of water used. It is also recommended that the company put grease traps especially in areas such as the power plant and the boiler house were oil was observed to be constantly dropping from the bearings. Grease traps are important because they prevent lubricants to get into floor drains, which eventually will end in the wastewater treatment plant. This will affect the WWTP’s operations. Moreover, grease traps should also be placed in the floor drains incase there are unidentified oil spillages. According, to experienced company they claim that grease traps placed in a floor drain are much more effective than a large grease trap placed at the outlet drains and oil skimmers. The oil that is collected by the oil traps can be recycled or used in the boilers as fuel. It is also recommended that the factory dry cleaning spills/leaks with
bagasse these requires little labor and can significantly reduce the COD load to the lagoons. The bagasse used to clean product leakage or spills can then be collected and burned in the boilers as fuel. It is important for BSI to try to prevent leaks and spills because even though leaks and spills have only a minor effect on the plant’s productivity. This can account for a significant portion of the pollutant load contained in the plant’s wastewater, because they have an extremely high BOD of around 900,000 mg/l (UN ESCAP, 1982). Even a small leak of cane juice (0.5 liter/minute) can increase the load to the lagoons by 90 kg COD/day. This situation is reflected in table 16 as the data reflects that washing are responsible of 99.7% of COD of the wastewater. The importance of minimizing spills and keeping products out of the wastewater stream becomes evident when one considers the COD content of the sugar mill’s intermediate products (Appendix F). To carry the aforementioned CP opportunities, awareness of the concept of Cleaner Production needs to happen at all levels from managers to bottom level workers.

In order to apply the CP opportunities in BSI production process, which include recycling the condenser waters, treatment and recycling of flue gas scrubbing water and recycling of excess condensates, BSI will need to install new equipment in its facility. This will require a significant investment on part of the factory. The other four production process opportunities that exist to reduce the utilization of water in the production process will require little investment; as the company just needs to monitor the operation more keenly. During the technical evaluation it was found that the operation of the factory to its optimum capacity and with minimum stoppages is important because raw water consumption per ton of cane crushed increases when crushing is lower than the optimum capacity. Moreover, for maximum sugar sucrose recovery, condensate hot water should be used for imbibition because, otherwise, the presence of dissolved solids in the water increases the solubility of sucrose in the sugarcane juice. For optimum recovery, imbibition water should be maintained around 25-30% of cane used. However, increasing imbibition water from 15% to this optimum range increases hot water consumption (Hagler Bailly Consulting). BSI needs to fix or replace the entrainment separators because entrainment can be minimized and sugar recovery increased with the use of
efficient entrainment separators and mist eliminators in evaporators. BSI also needs to monitor the evaporators and the vacuum pans to avoid overloading, boiling at excessive rates, or operating at incorrect liquid levels as water conservation and sugar recovery can be improved by taking this measures. The factory can minimize dirt and large particles in effluents by allowing suspended particles in filter cloth washings to settle in a holding tank before being mixed with other effluents and screening wastewater before emitting to remove refuse, dirt, and remnants of the cane.

The exact cost of implementing the in-plant practices was not calculated in this research as more detailed information is needed. Based on the experiences of other industries and the nature of the in-plant CP opportunities identified in BSI, it can be concluded that only a minor investment will be required to adopt these measures. This is because the enforcement of some in-plant CP opportunities only requires a shift from bad habits by employees and development of CP awareness. Moreover, the last four CP opportunities identify in BSI’s production process also require very minimal investment; this is because only minor changes and increase monitoring of the production process is required.

On the other hand, the first three CP opportunities in BSI’s production process will require a lot of investment and retrofitting. These options are considered to be feasible but more research is needed to be done before being implemented. The implementation of these CP opportunities will drastically decrease the amount of water utilized by BSI. For instance, the installation of a spray pond to recycle the condenser feed water can drastically reduce the fresh water consumption by BSI. As shown earlier in table 17, condenser feed waters represent the largest water usage in the sugar factories accounting for a 92.99%. The introduction of a spray pond at 150 Tons of Cane per Hour (TCH) sugar cane factory, accounting for evaporation and wind drift, it is estimated that approx. 8.32 m$^3$ of water per tonne of cane (m$^3$/tc) could be saved, at a capital cost of approx. $0.5M and an annual operating cost of $50 000 (T. Ramjeawon 2000). As mentioned before that the Belize Sugar Industry only uses some of its excess condensates the rest are generally discharged as wastewater due to their high level of sugar entrainment. However,
the Belize sugar industry can recycle these condensates as imbibition water, scrubber water, and makeup water and for other miscellaneous purposes such as floor washing.

By recycling of excess condensates at a 150 TCH factory it is estimated that approx. 0.64 m³/tc could be saved at a capital cost of approx. $75 000 (for hot water storage, pumping etc.), and an annual operating cost of $5000 (T. Ramjeawon 2000).

The Belize Sugar Industry also has the opportunity to treatment and recycling the flue gas scrubbing water, effluent from the fly-ash scrubbers can be filtered and re-used as feedwater to the scrubbers. By recycling the scrubber water at a 150 TCH factory, accounting for evaporation and the water content of the leftover fly-ash, it is estimated that approximately 0.79 m³/tc could be saved at a capital cost of approx. $200 000, and an annual operating cost of $15 000 (T. Ramjeawon 2000).

The implementation of the CP opportunities identified in BSI, based on different achievements in different case studies and demonstration projects around the globe, there is ample evidence that Cleaner Production will have a significant improvement potential in BSI manufacturing process. In particular, in the reduction of environmental degradation it is estimated that waste and emissions are usually reduced between 20 % and 40 % when implementing CP opportunities (Berkel, R.V 1999). It is also claimed that the hydraulic load could be reduced to 50% and pollution load could be reduced by 30% by adopting the CP path. International experience has revealed that this approach is more practical and cost effective (Ahmed, M).

This research presents several CP opportunities that were identified in the BSI facility. It is recommended that the company train the employees at all levels and implement these CP opportunities.
6.6 Phase V: Implementation and Continuation

The Cleaner Production opportunities identify in this research will be recommended to the manager of BSI. Before the implementation of the CP opportunities identified by this research the establishment of a comprehensive action plan to guide the preparation and implementation of process modifications will be needed (Table 18). The plan shall also take into account the time required for training of the employees without disrupting the normal production. Moreover, as part of the implementation process, a monitoring program needs to be established to document improvements. The opportunities implemented by the company if successful will serve as the base for BSI to peruse new CP opportunities in the company. This will initiate ongoing Cleaner Production activities.

Table 18: Checklist of the main steps that are generally included in an action plan

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Establish a core group of plant staff to evaluate the options provided in this report. Review the data and calculations, determine if any information was misconstrued by the audit team and if necessary make the appropriate adjustments to the report’s calculations and results.</td>
</tr>
<tr>
<td>2)</td>
<td>Prioritize the recommendations in accordance with their potential value to your facility and ease of implementation.</td>
</tr>
<tr>
<td>3)</td>
<td>Conduct a detailed technical and an economic evaluation of the selected options. Obtain price quotations for the required equipment or plant modifications. Ask appropriate questions such as: Is training necessary first? Will production need to be stopped? Will the vendor provide acceptable service? Will the change create other environmental problems?</td>
</tr>
<tr>
<td>4)</td>
<td>Solicit employees input and ideas on the selected recommendations.</td>
</tr>
<tr>
<td>5)</td>
<td>Develop an implementation schedule.</td>
</tr>
<tr>
<td>6)</td>
<td>Implement the recommendations and provide the required training to the personnel.</td>
</tr>
<tr>
<td>7)</td>
<td>Establish a mechanism to measure the effects of the implemented recommendation and pollution prevention progress within the plant. Track relevant accounting information such as waste treatment and disposal costs, water and sewer costs, energy</td>
</tr>
</tbody>
</table>
and raw materials consumption and costs.

| 8) | Establish routine auditing procedures to ensure that the standard operating practices are respected. Rotate the auditing duties among all process operators. |
| 9) | Regularly evaluate the facility’s operations to identify ways to increase productivity and reduce materials, water and energy use. |

Source: Hagler Bailly Consulting, Inc.

Nevertheless, implementing the Cleaner Production opportunities identified will not be an easy task as BSI will encounter several barriers such as economic, technical, institutional and attitudinal barriers, both internal and external to BSI. Internal barriers that might be encountered are insufficient involvement of employees, limited access to information and technology, hesitancy to take risks, policy aimed at financial support for end-of-pipe measures, and a lack of environmental policy and/or enforcement (Frijns, J. 1999). External constrains that BSI might face when implementing the CP opportunities include governmental barriers (such as pricing, policy of water, regulatory emphasis on end-of-pipe treatment approach, lack of financial incentives or funding) and other barriers (such as lack of information and lack of market demand) (Khoa, L. Van 2006).

Therefore, there is a need for the Belize Sugar Industries to diffuse the concept of CP to all its workers; by exposing the workers to this innovative approach BSI will be able to overcome some of the internal problems that the factory might encounter when integrating the CP opportunities. The CP opportunities identified by this research in BSI facilities can serve as the foundation for initiating the integration of the concept of CP but BSI will need to make a more detailed study about the CP opportunities than exist within its facility. Also the Belizean authorities should give incentives to BSI in order to foster the implementation of CP. Demonstration projects that were mentioned in chapter 4 serve as prove that the integration of CP in industries result in the reduction of operating costs, improve profitability, worker safety and reduce the environmental impact. The two major
incentives that will drive BSI to integrate the Cleaner Production opportunities identified in this research are future market changes and public pressure to improve environmental conditions of the New River.

The integration of the CP opportunities in BSI will take time but the conditions of the New River requires immediate measures to be taken; thus, this research give some recommendations to BSI on how to improve the removal efficiency of COD of its wastewater treatment plant, in order to reduce environmental impact. The study that was conducted on the WWTP and the recommendations for improvement found are discussed in chapter 7.
7. BSI WASTEWATER TREATMENT PLANT

7.1 Current situation of BSI wastewater treatment ponds

The Belize Sugar Industry wastewater treatment ponds operate in series. This wastewater treatment plant consist of seven ponds of which ponds #1 to #4 are used to treat the heavily polluted waters of the mill house, evaporators, process house, flour wash wastewater, storm water, laboratory and toilet wastewater. Major factors affecting the performance of wastewater lagoons include temperature, organic loading rate, retention time, pH, and the presence of inhibitory or toxic chemicals.

The wastewater from the evaporators and the boiling house is discharged into separate drains which lead into an effluent tank where the wastewater of these two sources mix. The wastewater from the effluent tank can then be discharged to either pond #1 or to a buffer pond. If the wastewater is not heavily polluted it is discharged to the drain that leads to pond #1 where it will receive anaerobic treatment but before reaching pond #1 this wastewater has to pass through an oil separation tank. If the wastewater is heavily polluted it is then released to a buffer pond and then into pond #1 (Appendix C). The purpose of the Buffer pond is to prevent loading shocks, which can affect the treatment process. On the other hand, the wastewater generated by the Toilets, Generator Houses, Mill House and the Carrier Sump are directly discharged into one drainage leading to treatment pond #1. Before the wastewater from these sources reach pond #1 it needs to pass through a sump followed by a sieve and a oil separation tank. When the wastewater has passed throughout all the aforementioned its treatment starts in pond #1 where the wastewater will receive an anaerobic treatment, followed by pond #2 and #3 that provides facultative treatment and pond #4 that offer an aerobic treatment (Fig 14). Finally, the wastewater from pond #4 is discharged to a swamp where it will receive further treatment in order to meet the wastewater discharge standards.
BSI has three boilers and an incineration which is used to burn the bagasse; water is used to wash the ashes that result from the burning of the bagasse. This wastewater that is generated by the washing of the ashes is treated in ponds #6 and #7 (see ash pond and ash pond #2) respectively in Appendix C. These two ponds operate in series; the reason for this is to maximize the settling of the suspended solid. The water is then discharged from ash pond #2 into a swamp for further treatment and then it’s discharged into the New River.

7.2 The removal efficiency of COD of ponds 1 to 4 of BSI wastewater treatment plant.

The Belize Sugar Industry laboratory department sends a monthly report of the BSI’s wastewater treatment plant to the department of environment. In this report BSI states all the components that comprise the treatment plant and the type of treatment this component provides. This report states the levels of pH, COD, DO and temperature of the wastewater as it passes through the components of the wastewater treatment plant. The COD of the wastewater is measured by a Closed Reflux Titrimetric Method. The pH and DO is measured by a Probe Method and Temperature by a Thermometer Method.

In order to calculate the COD removal efficiency of ponds #1 to #4 of BSI’s wastewater treatment facility, the monthly reports of 2007 were collected. The average pH, Temperature and COD of the wastewater treatment ponds of the crop season of 2007 was calculated (Table 19 and Fig 14).

Table 19: COD removal efficiency of available WWTP in BSI

<table>
<thead>
<tr>
<th>Pond No.</th>
<th>Influent</th>
<th>Effluent</th>
<th>Removal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25,935</td>
<td>26,252</td>
<td>-1.22</td>
</tr>
<tr>
<td>2</td>
<td>26,252</td>
<td>14,008</td>
<td>46.64</td>
</tr>
<tr>
<td>3</td>
<td>14,008</td>
<td>15,386</td>
<td>-9.84</td>
</tr>
<tr>
<td>4</td>
<td>15,386</td>
<td>7,393</td>
<td>51.94</td>
</tr>
<tr>
<td>swamp</td>
<td>15,386</td>
<td>34</td>
<td>99.54</td>
</tr>
</tbody>
</table>
The above diagram illustrates the four wastewater treatment ponds that are used by BSI to deal with the wastewater generated by the production process. Based on the data that this diagram illustrated the efficiency of COD removal of each of the ponds was calculated. The anaerobic treatment of Pond #1 caused an increase of 1.22% of COD of the wastewater. This wastewater then flows to facultative treatment pond #2 where there was a 46.64% decrease of COD of the wastewater. The wastewater then flows to pond #3, where it undergoes a facultative treatment; here there was an increase of 9.84 % of COD of the wastewater. After the facultative treatment in pond #3 the wastewater is treated in Pond #4 by aerobic treatment. The reduction of COD of the wastewater is 51.94%. Finally, the wastewater is discharged to a swamp where the COD of the wastewater is reduced by 99.54%. This wastewater then flows to the New River.

### 7.3 Problems identified and proposed solutions

The purpose of the wastewater treatment ponds in the BSI’s treatment plant is to decrease the levels of COD of the wastewater in order to attain dischargeable standards imposed to
them by the government of Belize. When the removal percentage efficiencies of ponds #1 and #3 were calculated it is noted that there was an increase of COD of the wastewater, instead of a decrease. Since, the ponds were design decades ago it was assumed that this problem was due to the piping arrangement of the wastewater treatment plant. It was thought that the pipes at the wastewater treatment ponds #1 and #3 were located at the bottom of the pond, as a result, causing the resuspension of the already settled sludge, thus, increasing the COD of the wastewater. Upon inspection of the wastewater treatment plant it was noted that all the pipes were situated at the top of the ponds. This reason was discarded, for the increase of COD that occurs in pond #1 and #3. While inspecting the position of the pipes it was noted that the sludge that was removed from the Ponds over the years has been placed around the wastewater treatment ponds. Pieces of sludge erode into the wastewater treatment ponds causing the increase of organic compounds of the wastewater. This results in the increase in COD of the wastewater. In order to avoid this problem and to improve the COD removal efficiency of the wastewater treatment plant, it is recommended that the sludge is removed from around the ponds and deposited on a site far from any other water or wastewater source. The site where this sludge is then deposit needs to be located in an accessible area. So that cane farmers can reclaim and use the sludge to improve the soil texture of their sugar cane plantations. The other justification associated with the increase in COD of the wastewater in ponds #1 and #3 is that during the rainy season, which is from June to November, storm water enters the wastewater treatment pond. This brings allot of organic compounds into the treatment system, resulting in the increase in the COD of the wastewater. This justification is furtherer supported by a compliance monitoring site visit made by the department of the environment to BSI in 2004. In the report made it was recommended that BSI looked into the separation of the storm drains on the compound from the drains that take effluent into the treatment ponds.

To further determine the reason of the increase in COD of the wastewater in ponds #1 and #3 the pH and Temperature constitutes of the wastewater were measured in each of the ponds (Fig 14). The levels of pH and Temperature where analyzed in each of the
ponds, since it is well known that microorganisms are affected by this. According to a study conducted by Zhang he stated that there are two types of microorganisms that thrive in anaerobic ponds. The success of these microorganisms depends on the level of pH of the wastewater. If the wastewaters have a pH of 6.8 to 7.5, with the lowest pH being 6.2 methanogens will thrive. On the other hand, if the wastewater has a pH of 5 to 8, with the optimum level being 5 to 6 acidogens will thrive. Following Zhang study it can be noted that in pond #1 the pH level is very low for methanogens and acidogens to decrease the levels of COD of the wastewater; thus, this pond is not functioning appropriately. The reason for low pH in anaerobic pond is because the influent organics are subjected to the acidogenic transformation. Volatile fatty acids and carbon dioxide are formed in the acidogenic phase. If the alkalinity is not sufficient for neutralization, pH in the anaerobic pond decreases. To deal with this problem BSI needs to add White lime to pond #1 in order to increase the intrinsic alkalinity of the pond. This will increase the pH levels to meet the pH requirements by methanogens and acidogens. By increasing the pH to acceptable ranges methanogens and acidogens can thrive in this wastewater, which will decrease the COD of the wastewater. On the other hand, the pH level on pond #3 is on the working range of these microorganisms. However this pond is a facultative pond not an anaerobic pond. Data gather from BSI states that Water Lilies are place in pond #3 and that wastewater is allowed to overflow from pond #3 to the Main drain, which flows into the New River Stream. Based on the data gathered from the wastewater treatment facility report of crop 2007 it is not recommended for the wastewater to overflow from treatment pond #3 because the levels of COD are too high to be released to the New River. If this is done the factory is not complying with the discharged standards (appendix A). Moreover, the overflowing of this pond may also interrupt the treatment of the wastewater treatment plant. Also the placement of water lilies in pond #3 is not recommended since it interrupts the natural as well as the mechanical aeration of the ponds. The water lilies can be placed in the swamp at the end of the process where the can serve as natural filtration media and to use up some of the nutrients in the wastewater.
In order for the BSI’s wastewater treatment plant to operate to its full capacity the recommendations aforementioned need to be taken in consideration by the managers of the Belize Sugar Industry. The need to clearly review Ponds #1 and #3 operations is very clear as these ponds are utilizing resources and are not functioning properly. The recommendations given to BSI by this research will help to improve the current situation of the wastewater treatment plant (Fig 14) but a more detailed study is needed in order to determine the overall efficiency of the wastewater treatment plant and problems associated with it.

**Note:** Million US Gallons, Refer to the capacity of the pond (Table 8)

Figure 15: BSI wastewater treatment facility report-crop 2007 average figures, with amendments made.

**Table 20:** COD removal efficiency of available WWTP with amendments made.

<table>
<thead>
<tr>
<th>Pond No.</th>
<th>Influent</th>
<th>Effluent</th>
<th>Removal efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25,935</td>
<td>18,157</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>18,157</td>
<td>6,354</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>6,354</td>
<td>2,097</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>2,097</td>
<td>1,007</td>
<td>52</td>
</tr>
<tr>
<td>swamp</td>
<td>1,007</td>
<td>10</td>
<td>99</td>
</tr>
</tbody>
</table>
If the pH of pond #1 is increased to 7 microorganisms needed to decrease the COD of the wastewater will be able to thrive. According to literature the removal efficiency of anaerobic ponds in adequate conditions ranges from 30% to 90%. In this thesis the minimal percentage of COD removal efficiency that anaerobic ponds can achieve was calculated for pond #1. In figure 14 the wastewater that flowed from pond #1 to pond #2 has a pH of 4.64 then it increased to 7; thus, this had an influence in the removal efficiency of this pond. When the recommendations given are taken into consideration the microorganisms in pond #2 will start to work at a pH of 6.80; as a result, the removal efficiency will increase to 65%. The wastewater then flow to pond #3 to receive a similar treatment where the removal efficiency was calculated to be 67%. The wastewater then flow to pond #4 where the removal efficiency attained is 52% and then into the swamp which achieves a removal efficiency of 99%. The COD removal percentages in figure 15 and table 20 that the BSI’s wastewater treatment ponds can achieve were assumed based on the visit to the Taiwanese sugar factory and existing literature. Even with the increased COD removal efficiency discharged standards in pond #3 is not attained. As a result, it is recommended that wastewater should not be allowed to overflow from this pond at all.

There are many reasons why swamp can achieve high levels of pollutant removal. This is because as wastewater filters through wetland vegetation and soils, nutrients, sediments, and pollutants are removed. This improves the wastewater quality. For example, low oxygen levels in swamp water and soils promote the removal of nitrate-nitrogen through denitrification. Additionally, low oxygen levels and organic soils can promote other biochemical reactions that can detoxify other pollutants. Swamps in Florida in the USA are known to remove 98% of nitrogen and 97% of phosphorous of wastewaters. By following the recommendations made in this thesis BSI will be able to meet the COD discharge standards imposed to them by the government of Belize (Appendix A).

As a result, of the different uses that some individuals give to the New River (Fig 11) and some sicknesses that have been experienced by these individuals (Fig 10). It is
recommended that BSI disinfect its wastewater; since toilet wastewaters are also treated in the wastewater treatment plant. It is well known that human faeces contain high levels of fecal coliforms. These bacteria can cause diseases in humans. By disinfecting the wastewater generated BSI will kill these disease-causing organisms. It is recommended that chlorination can be utilize since chlorine, at present, is less expensive and offers more flexibility than other means of disinfection. Chlorination is the most practical method of disinfection. Before chlorination of pond effluents BSI requires to consider the wastewater characteristics which are unique to pond effluents (appendix I). Adequate disinfection can be obtained with combined chlorine residuals of between 0.5 and 1.0 milligrams per liter after a contact period of approximately 50 minutes, i.e., disinfection can be achieved without discharging excessive concentrations of toxic chlorine residuals into receiving waters.
8. CONCLUSIONS

As an industry in a developing country BSI is going to face many problems in upcoming years. If the industry doesn’t change old practices its certain that BSI will not be able to be a cost competitive supplier in the new market environment and deal with national environmental problems. Unless the factory reduces its cost of production and becomes more efficient, its future is uncertain. In such a context, BSI has no option but to undertake a major reform that would increase its level of competitiveness and reduce its environmental impact. It is herewith proposed that BSI should shift from a Conventional Production approach to a Cleaner Production approach in order to face all its future challenges. This innovative approach will open new possibilities for the industry to reduce its cost of production, become more efficient and competitive and reduce environmental impact.

The proposed CP opportunities identified in BSI are cost effective; the first CP opportunities that the industry needs to focus on are the in-plant pollution prevention measures. This is because the implementation of these CP opportunities requires minimal investment and the outcome of its application are often experienced in a short period of time. Moreover, such measures often generate substantial financial savings in addition to the environmental benefits as seen in the section 3.2 benefits of Cleaner Production. The second CP opportunities in BSI production process which include water recycling and process modifications to decrease wastewater generation are more complex and will need much more investment but are still considered feasible. Undertaking these CP opportunities will lead BSI to potentially increase its efficiency, decrease cost of operations and reduce wastewater volume and pollutant load. The implementation of the CP opportunities in BSI clearly illustrates that the company will achieve major economical and environmental benefits.

Since this paper does not calculate the actual costs required to implement the CP opportunities identified it is difficult to evaluate which CP opportunities would have the shortest pay back periods and the most savings for the factory. Nonetheless, the
procedure outlined here demonstrates that BSI can do things differently in an ecologically friendly and sustainable manner, resulting in industrial and environmental benefit. Above all, the CP opportunities identified in this paper if implemented appropriately will definitely have a positive impact.

It should be mentioned that CP approach should not be taken as a replacement of end-of-pipe treatment systems. Rather the CP approach if implemented properly will help BSI to reduce fresh water consumption, reduce the volume of wastewater discharged to the wastewater treatment plant, increase the retention time of the wastewater in its ponds, and improve their performance. The aforementioned will be economically beneficial to BSI and also to the environment as less wastewater will be generated and treated. This paper also investigated the present situation of BSI’s wastewater treatment plant and some problems where identified. It is recommended the BSI takes into consideration the recommendations given in this paper in order for its wastewater treatment plant to function properly. In order to ensure continuous improvement, legal compliance, and a better relationship with authorities and neighboring communities’ proper operations of the wastewater treatment system is necessary.

Unfortunately, however there are many barriers and problems that will need to be addressed before the application of the CP opportunities identified in this research. First more accurate data need to be collected in regards to the CP opportunities in the BSI’s production process. If BSI really wants to consider these options a more in-depth analysis needs to be carrying out. Specific information of the complexity of retrofitting technology in the factories manufacturing process need to be collected and analyze in order to consider its feasibility. The factory as well needs to consider if there are technical experts within the factory to manage and monitor this new technologies. This specific analysis of the CP opportunities identified in this research was not possible due to the lack of data and information.

This paper introduces the concept of Cleaner Production to the factory since it has been
embraced by many competitive factories around the globe. The exposure to this innovative approach is important as BSI gets prepared to face environmental and economic challenges in the future. CP will help BSI to be a more competitive industry in the global markets as well as to deal with its environmental problems. It is thus expected that this research will foster BSI to do more in-depth studies about Cleaner Production in its facility. This conclusive research will further contribute to the betterment of the factory practices leading to economical and environmental gain.

8.1 Recommendations

Based on the result of chapter 6 “Cleaner Production opportunities for wastewater reduction in BSI” it is recommended that BSI should first focus on the in-Plant CP opportunities identified. The reason for this suggestion is that little investment is required for implementing them and comparatively immediate results. The implementations of the in-plant CP will increase efficiency, decrease cost of operations and reduce wastewater volume and pollutant load. These will result in substantial financial savings in addition to the environmental benefits, as demonstrated by the example in section 4.3 “Benefits of Cleaner Production” in Ho Chi Minh City. Moreover, the successful implementation of the in-plant CP opportunities will provide a stage for BSI to become more aware and comfortable with the concept of CP. This will initiate a gradual shift from unsustainable Conventional Industrial Production to sustainable Cleaner Industrial Production.

On the other hand, the production process CP opportunities identified will require a large capital investment and substantial maintenance costs as shown in section 6.5 “Phase IV: Evaluation and feasibility study”. In order for BSI to implement the first three CP opportunities identified in the production process more data need to be collected in order to understand the effects and complexities of there implementation. Also, BSI needs to fully understand the concept of CP. The implementations of these CP opportunities will result in a significant reduction of the water that is used for the production process; thus, decreasing the wastewater generated by the factory.
The study that was conducted on the wastewater treatment plant of BSI revealed that the problems that exist in the treatment ponds are due to improper monitoring. BSI should assign personnel to monitor the ponds temperature, organic loading rate, retention time, pH, and the presence of inhibitory or toxic chemicals because these are some of the major factors that affect performance. In section 7.3 “Problems identified and proposed solutions” discusses the current problems that need to be addressed in order to increase COD removal efficiency of BSI’s WWTP. Currently, BSI WWTP consists of lagoon or pond solutions to treat the wastewater that is generated from the production process. It is recommended that BSI should compare its current wastewater treatment plant solutions to other solutions that exist to treat wastewater. This will aid in finding out which solutions are more beneficial or feasible for the factory. Other solutions are shown in Appendix G: “Comparison of Wastewater Treatment Technologies”.

The implementation of the CP opportunities identified will lead to the reduction of wastewater resulting in less wastewater requiring treatment. As a result, restructuring of the current wastewater treatment plant will have to be done. To treat the new wastewater volumes that will be generated by the production process.

8.2 Further studies

During the research areas that required further study where identified these are as follow:

- Ecological Studies to examine water quality in the New River, downstream and upstream of BSI in order to determine the level of degradation of the river waters, when they come in contact with the factory effluents.
- The claims of health problems due to the polluted river found during the questionnaire survey, urges for a health assessment study on the affected communities.
- Cost-benefit analyses to study the impacts of integrating the CP opportunities identified.
Appendix A: Environmental Protection (Effluent Limitations) Regulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>33³C</td>
</tr>
<tr>
<td>pH</td>
<td>6 to 9 (units)</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>5</td>
</tr>
<tr>
<td>BOD₅ at 20°C</td>
<td>50</td>
</tr>
<tr>
<td>COD</td>
<td>100</td>
</tr>
<tr>
<td>Chloride (as Cl)</td>
<td>600</td>
</tr>
<tr>
<td>Sulphate (as SO₄)</td>
<td>500</td>
</tr>
<tr>
<td>Iron</td>
<td>20</td>
</tr>
<tr>
<td>Zinc</td>
<td>1.0</td>
</tr>
<tr>
<td>Total Metal*</td>
<td>2.0</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1.0</td>
</tr>
<tr>
<td>Phosphate (as PO₄)</td>
<td>5.0</td>
</tr>
<tr>
<td>Nitrate (as NO₃)</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Units mg/l unless stated
* The concentrations of toxic metals should not exceed these limits individually or in total


Appendix B: Location of Belize

Appendix C: BSI wastewater treatment plant

Source: Belize Sugar Industry Ltd
Appendix D: BSI production process

Source: Belize Sugar Industry Ltd
Appendix E: Questionnaire

The Belize New River

I am conducting a survey on the current situation of the Belize New River and the Belize sugar industry that are located near your community. I am requesting your help to make this effort a success. Only a small random sample of people that live along or near the river has been selected to receive this survey. Therefore, your response is very important. Your response will help to illustrate if you are satisfied or not with the current situation of the Belize New River. I am conducting this survey because your views regarding the current situation of the Belize New River and the Belize Sugar Industry are extremely important.

You are not being asked to provide personal information on the questionnaire, so all responses are anonymous. This questionnaire will only take approximately 5 minutes of your valuable time to be completed.

Thanks for taking the time to complete the questionnaire. I need and value your opinions.

Sincerely,
Questionnaire

1) What is the name of your community? ________________________________

2) What is your attitude toward the Belize Sugar Cane industry located near your community?
   □ Pleased 30
   □ Indifferent 33
   □ Unpleased 32

3) Has the sugar cane industry brought about any benefits to your community?
   □ Yes 67
   □ No 28
   If yes state one benefit, ________________________________
   If no state one disadvantage ________________________________

4) Do you directly benefit from the sugar cane industry?
   □ Yes 21
   □ No 74
   If yes state how ________________________________

5) Are you satisfied with the New River’s current state?
   □ Satisfied 14
   □ Neutral 32
   □ Unsatisfied 49

6) The area of the New River in your community is polluted?
   □ Strongly Agree 33
   □ Agree 43
   □ Neutral 15
   □ Disagree 2
   □ Strongly Disagree 2

7) The Belize Sugar Industry is the main source of pollution?
   □ Strongly Agree 21
☐ Agree 46
☐ Neutral 17
☐ Disagree 9
☐ Strongly Disagree 2

8) Does the New River have bad odor?
☐ Yes 69
☐ No 26

9) Does the New River have unusual dark coloration?
☐ Yes 81
☐ No 14

10) Have you ever felt unpleasant as a result of living too close to the river?
☐ Yes 56
☐ No 39
If yes state why

11) Have you ever suffered any illness and thought it was because of the river?
☐ Yes 16 (please state what illness it was)_____________________
☐ No 79

12) Have you witnessed plant life and animal life dying in the New River?
☐ Yes 62
☐ No 33
What kind of animal________________________

13) Do you know of anyone who has become ill while swimming in the New River?
☐ Yes 31
☐ No 64

14) Is the New river and important recreational area in your community?
☐ Yes 66
15) The Belize Sugar Industry informs near by communities of improvements made to protect the environment?

☐ Strongly Agree 7
☐ Agree 21
☐ Neutral 23
☐ Disagree 34
☐ Strongly Disagree 10

16) During what months of the year is the river condition worse?

☐ November to January 38
☐ February to April 35
☐ May to June 22

17) Do you utilize the river water for?

☐ Swim 5
☐ Irrigation of plants 12
☐ Fish 20
☐ Wash clothes 2
☐ Other 20
☐ None 36

18) Do you think actions need to be made immediately to improve the New river current situation?

☐ Yes 92
☐ No 3

If no why __________________________
Appendix F: Chart flow of wastewater treatment plant in Taiwan Sugar Factory

High concentration wastewater

In flow well

Adjusting pond I

Facultative tank I

Adjusting pond II

Facultative tank II

Aerobic Pond I

Aerobic Pond II

Aerobic Pond III

Final sedimentation pond

Sludge reservoir

Sludge dryer

Recycle

(Recycle for fertilizer)

Low concentration wastewater
Appendix G: The wastewater treatment components of the Taiwan Sugar Factor

Figure a: Adjusting pond

Figure b: Facultative tanks

Figure c: Aerobic ponds

Figure d: Sedimentation pond

Figure e: Sludge dryer
Appendix H: Composition of sugarcane juice and its reflection in wastewater produced

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Percentage (%)</th>
<th>Reflection in Wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>70 – 72</td>
<td>Water</td>
</tr>
<tr>
<td>Fibrous Material</td>
<td>13 – 15</td>
<td>SS</td>
</tr>
<tr>
<td>Sucrose (organic matter)</td>
<td>8 – 15</td>
<td>BOD, COD</td>
</tr>
<tr>
<td>Reducing Sugar (organic matter)</td>
<td>0.5 – 2</td>
<td>BOD, COD</td>
</tr>
<tr>
<td>Organic matter other than sucrose</td>
<td>0.5 – 1</td>
<td>BOD, COD</td>
</tr>
<tr>
<td>Inorganic matter (phosphates, chlorides, sulfates, nitrates, silicates, Na, K, Ca, Al, Fe, etc.)</td>
<td>0.2 – 0.6</td>
<td>TDS</td>
</tr>
<tr>
<td>Nitrogenous matter (Albuminoids, amides, amino acids, ammonia, xanthene bodies)</td>
<td>0.5 – 1</td>
<td>TKjN</td>
</tr>
<tr>
<td>Ash</td>
<td>0.3 – 0.8</td>
<td>SS</td>
</tr>
</tbody>
</table>

SS – Suspended Solids  
BOD – Biochemical Oxygen Demand  
COD – Chemical Oxygen Demand  
TDS – Total Dissolved Solids  
TKjN – Total Kjeldhal nitrogen (organic nitrogen plus ammonia nitrogen)

Appendix I: List of considerations before chlorinating pond effluents

<table>
<thead>
<tr>
<th>Chemical oxygen demand (COD)</th>
<th>Total chemical oxygen demand concentration in a pond effluent is virtually unaffected by chlorination. Soluble oxygen demand, however, increases with increasing concentrations of free chlorine. This increase is attributed to the oxidation of suspended solids by free chlorine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids</td>
<td>Some reduction in suspended solids, due to the breakdown and oxidation of suspended particulates and resulting increases in turbidity, are attributed to chlorination. However, this reduction is less than that resulting from settling. Suspended solids can be reduced by 10 to 50 percent from settling in chlorine contact tanks.</td>
</tr>
<tr>
<td>Algae.</td>
<td>Filtered pond effluent exerts a lower chlorine demand than unfiltered pond effluent due to the removal of algae. Chlorine demand is directly related to chlorine dose and total chemical oxygen demand.</td>
</tr>
<tr>
<td>Temperature.</td>
<td>Disinfection efficiency is temperature dependent. At colder temperatures, the reduction in the rate of disinfection was partially offset by reductions in the exertion of chlorine demand; however, the net effect was a reduction in the chlorine residual necessary to achieve adequate disinfection with increasing temperature for a specific contact period.</td>
</tr>
</tbody>
</table>

Source: TM 5-814-3/AFM 88-11, Volume III
### Appendix G: Comparison of Wastewater Treatment Technologies

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Technical Characteristics</th>
<th>Operational Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lagoons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Anerobic lagoons are deep earthen basins used for high strength organic wastewater with high solid concentration.</td>
<td>• BOD5 loading kg/m3/d? least efficient</td>
</tr>
<tr>
<td></td>
<td>• Facultative lagoons are earthen basins filled with screened or primary effluent in which stabilization of waste is brought about by a combination of aerobic, anaerobic and facultative bacteria.</td>
<td>• BOD5 removal efficiency? 85 - 90 %</td>
</tr>
<tr>
<td></td>
<td>• Aerobic lagoons are large, shallow earthen basins used for treatment of wastewater by natural processes involving both algae and bacteria.</td>
<td>• Energy requirement for aeration kwh/kg BOD treated? moderately efficient</td>
</tr>
<tr>
<td></td>
<td>• Maturation ponds are low rate stabilization ponds usually designed to provide for secondary effluent polishing and seasonal nitrification</td>
<td>• Hydraulic detention time? very high</td>
</tr>
<tr>
<td><strong>Trickling Filters</strong></td>
<td>• Wastewater flows from top to bottom, dispersed over filter material (stones, lava or plastic) during which soluble compounds are removed and, to a lesser extent, solids are taken up into the biofilm adhered to the carrier material.</td>
<td>• Mechanical complexity? low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reactor resilience for power failure and shock loads? moderate to high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• By-product? nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• On-site environmental impacts - soil infiltration and aerosoles dispersion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Land requirement? large</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Man power requirement? skilled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Frequency of repair &amp; maintenance -medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BOD5 loading kg/m3/d? least efficient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• BOD5 removal efficiency? 85 - 90 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Energy requirement for aeration kwh/kg BOD treated? most efficient (natural ventilation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hydraulic detention time? most efficient (recirculation is required)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mechanical complexity? low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reactor resilience for power failure and shock loads? moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• By-product? nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• On-site environmental impacts - insects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Land requirement --- small</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Man power requirement? skilled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Frequency of repair &amp; maintenance -low</td>
</tr>
</tbody>
</table>
**Upflow Anaerobic Sludge Blanket (UASB) Reactor**

- The basic idea of this system is that the flocs of anaerobic bacteria will tend to settle under gravity, when applying a moderate up-flow velocity of water. In this way no separate sedimentation tank is necessary.
- The wastewater passes the reactor from the bottom to top. To guarantee sufficient contact between the incoming wastewater and the bacteria in the sludge layer the wastewater is fed evenly over the bottom of the reactor. Further mixing is brought about by the production of the gas.
- The organic compounds are consumed by anaerobic bacteria during passage of wastewater through the sludge layer and produces bio-gas.

<table>
<thead>
<tr>
<th>BOD5 loading kg/m3/d?</th>
<th>very efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD5 removal efficiency?</td>
<td>80 - 90 %</td>
</tr>
<tr>
<td>Energy requirement for aeration kwh/kg BOD treated?</td>
<td>most efficient (only for pumping)</td>
</tr>
<tr>
<td>Hydraulic detention time?</td>
<td>most efficient</td>
</tr>
<tr>
<td>Mechanical complexity?</td>
<td>low</td>
</tr>
<tr>
<td>Reactor resilience for power failure and shock loads?</td>
<td>moderate</td>
</tr>
<tr>
<td>By-product?</td>
<td>bio -gas</td>
</tr>
<tr>
<td>On-site environmental impacts</td>
<td>nil</td>
</tr>
<tr>
<td>Land requirement</td>
<td>-- small</td>
</tr>
<tr>
<td>Man power requirement?</td>
<td>highly skilled</td>
</tr>
<tr>
<td>Frequency of repair &amp; maintenance</td>
<td>low</td>
</tr>
</tbody>
</table>

**Activated Sludge Treatment (Sequential Batch Reactor)**

- Many variations of activated sludge treatment exist, depending on load characteristics. Sequential Batch Reactor most appropriate for high organic pollution loads. Most successfully applied if hourly flow is low.
- System consists only of aeration tank (operated as fill and draw system) and mechanical surface aerators. Aeration and sedimentation takes place in the same reactor on the following cyclical principle: feeding and aeration of the reactor during a certain period, switch off of the aeration, followed by settling of the sludge and discharge of the effluent.

<table>
<thead>
<tr>
<th>BOD5 loading kg/m3/d?</th>
<th>very efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD5 removal efficiency?</td>
<td>85 - 95 %</td>
</tr>
<tr>
<td>Energy requirement for aeration kwh/kg BOD treated?</td>
<td>least efficient</td>
</tr>
<tr>
<td>Hydraulic detention time?</td>
<td>moderately efficient</td>
</tr>
<tr>
<td>Mechanical complexity?</td>
<td>high</td>
</tr>
<tr>
<td>Reactor resilience for power failure?</td>
<td>low and for shock loads? moderate</td>
</tr>
<tr>
<td>By-product?</td>
<td>nil</td>
</tr>
<tr>
<td>On-site environmental impacts</td>
<td>aerosol dispersion and noise</td>
</tr>
</tbody>
</table>

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