METHODOLOGY

The methodology for this thesis entails data collection from the Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (Sugar Industry).

Growing the Cane
Sugar cane is a sub-tropical and tropical crop that prefers lots of sun and lots of water - provided that its roots are not waterlogged. It typically takes about 12 months to reach maturity although the time varies widely around the world from as short as six months in Louisiana to 24 months in some places. Where it differs from many crops is that it re-grows from the roots so the plant lasts many cycles [or 'ratoons', a word derived from the Spanish to sprout] before it is worn out.

Harvesting
Sugar cane is harvested by chopping down the stems but leaving the roots so that it re-grows in time for the next crop. Harvest times tend to be during the dry season and the length of the harvest ranges from as little as 2 ½ months up to 11 months. The cane is taken to the factory: often by truck or rail wagon but sometimes on a cart pulled by a bullock or a donkey!

Extraction
The first stage of processing is the extraction of the cane juice. In many factories the cane is crushed in a series of large roller mills: similar to a mangle [wringer] which was used to squeeze the water out of clean washing a century ago. The sweet juice comes gushing out and the cane fibre is carried away for use in the boilers. In other factories a diffuser is used as is described for beet sugar manufacture. Either way the juice is pretty dirty: the soil from the fields, some small fibres and the green extracts from the plant are all mixed in with the sugar.
**Evaporation**

The factory can clean up the juice quite easily with slaked lime (a relative of chalk) which settles out a lot of the dirt so that it can be sent back to the fields. Once this is done, the juice is thickened up into a syrup by boiling off the water using steam in a process called evaporation. Sometimes the syrup is cleaned up again but more often it just goes on to the crystal-making step without any more cleaning. The evaporation is undertaken in order to improve the energy efficiency of the factory.

**Boiling**

The syrup is placed into a very large pan for boiling, the last stage. In the pan even more water is boiled off until conditions are right for sugar crystals to grow. You may have done something like this at school but probably not with sugar because it is difficult to get the crystals to grow well. In the factory the workers usually have to throw in some sugar dust to initiate crystal formation. Once the crystals have grown the resulting mixture of crystals and mother liquor is spun in centrifuges to separate the two, rather like washing is spin dried. The crystals are then given a final dry with hot air before being stored ready for despatch.

**An interactive World Map of Sugar production.** What we call sugar, the chemist knows as 'sucrose', one of the family of sugars otherwise known as saccharides in the grouping called carbohydrates. Carbohydrates, as the name implies, contain carbon and hydrogen plus oxygen in the same ratio as in water. The saccharides are a large family with the general formula $C_nH_{2n}O_n$. The simplest of the sugars is glucose, $C_6H_{12}O_6$, although its physical chemistry is not that simple because it occurs in two distinct forms which affect some of its properties. Sucrose, $C_{12}H_{22}O_{11}$, is a disaccharide, a
condensation molecule made up of two glucose molecules [less a water molecule to make the chemistry work].

The process whereby plants make sugars is photosynthesis. The plant takes in carbon dioxide from the air through pores in its leaves and absorbs water through its roots. These are combined to make sugar using energy from the sun and with the help of a substance called chlorophyll. Chlorophyll is green which allows it to absorb the sun's energy more readily and which, of course, gives the plants' leaves their green colour. The reaction of photosynthesis can be written as the following chemical equation when sucrose is being made:

$$12 \text{CO}_2 + 11 \text{H}_2 \text{O} \quad = \quad \text{C}_{12}\text{H}_{22}\text{O}_{11} + 12 \text{O}_2$$

carbon dioxide + water = sucrose + oxygen

This shows that oxygen is given off during the process of photosynthesis.

Historically, sugar was only produced from sugar cane and then only in relatively small quantities. This resulted in it being considered a great luxury, particularly in Europe where cane could not be grown. The history of man and sugar is a subject in its own right but suffice to say that, even today, it isn't easy to ship food quality sugar across the world so a high proportion of cane sugar is made in two stages. Raw sugar is made where the sugar cane grows and white sugar is made from the raw sugar in the country where it is needed. Beet sugar is easier to purify and most is grown where it is needed so white sugar is made in only one stage.

To read more about the history of the industry and see how the various processes work with the final results, the sugar we buy, click on the appropriate link.
A letter to these parties was sent requesting the following information:

- The detailed manufacturing processes and the main manufacturing stages of the Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (Sugar Industry). The data collected on the manufacturing process was crucial in order to understand the factory’s unique process. Knowing (TSSSK Ltd) manufacturing process allowed for the identification of CP opportunities that exist within (TSSSK Ltd). 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 (TSSSK Ltd) 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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (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 Bori 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 (TSSSK Ltd) (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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (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 (TSSSK Ltd). 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 (TSSSK Ltd) 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 (TSSSK Ltd)’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 Shri Tuljabhavani Shetkari Sahakari Sakhar Karkhana (Sugar Industry). Since the concept of Cleaner Production is new for (TSSSK Ltd) 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 (TSSSK Ltd) will initiate and assure the ongoing application of Cleaner Production.

**Sulphate and Nitrate Removal**

The anaerobic reactor had a diameter of 500 mm and a height of 4200 mm. It was filled with 2001 of palletized ash as support medium for bacterial growth. The void ratio of the pebble medium was 50%. A biologically active film was established on the pebble medium by inoculating the reactor with anaerobic sludge from a sulphate reducing laboratory plant.

The temperature was kept constant at 35°C by means of a thermostat. Hydrogen gas was introduced into the anaerobic reactor by recirculation of a side stream downwards, over packing material, through a pressure vessel, filled with hydrogen gas at a pressure between 200 and 500 kPa. The water leaving the pressure vessel was saturated with hydrogen. The flow rate of the water recycled through the pressure vessel was
controlled by a valve. The amount of hydrogen fed was a function of the flow rate through the pressure vessel and the pressure. Carbon monoxide was introduced in a similar way. Water was fed from the anaerobic reactor to the pressure vessel with a positive displacement pump (mono pump). The pump was activated and stopped by lower and higher level controls in the pressure vessel respectively. Feedstock was pumped from a 1500 l holding tank to the anaerobic reactor at a rate between 40 and 120 l d⁻¹. The chemical composition of the feedstock was as follows: NaF, 3 mg l⁻¹; SrCl₂6H₂O, 20 mg l⁻¹; H₃bo₃, 30 mg l⁻¹; KBr, 100 mg l⁻¹; KC₁, 700 mg l⁻¹; CaCl₂6H₂O, 200 mg l⁻¹; Na₂SO₄, 2000; MgCl₂6H₂O, 500 mg l⁻¹; NaSiO₂9H₂O, 20 mg l⁻¹; Na₄EDTA, 1mg l⁻¹; NH₄Cl, 1000 mg l⁻¹; K₂HPO₄, 500 mg l⁻¹; gypsum, 2500 mg l⁻¹.

The pilot plant was run for a period of 50 days at a hydrogen:carbon monoxide ratio of 90:10 days at a ratio of 50:50, and for the remaining period at a ratio of 90:10 once more.

In parallel with the pilot plant, a laboratory plant was also operated in a similar way, but with only carbon monoxide as energy source. The reactor had a diameter of 150 mm and a height of 1500 mm.

Samples were taken daily and analyzed for sulphate, sulphide, alkalinity, calcium and pH. Complete analyses were carried out every fortnight.

The reactor was manufactured from stainless steel and had a volume of 500 ml. It was filled with 10 mm diameter reaching rings as support medium for bacterial growth. The rings had an active biofilm as they were taken from a laboratory sulphate reducing plant. The temperature was kept constant at
35° C by means of a thermostat. Carbon monoxide was fed from a gas cylinder. The pressure was kept constant for the course of an experiment at a specific pressure, except for short periods at specific intervals, when the gas was replaced with fresh carbon monoxide, in order to replace the produced H₂S. The produced gas was bubbled through an iron (III) solution for H₂S-trapping. After each experiment, the biomass was allowed to settle, for use in the next experiment. The following solutions were used as feedstock during the batch studies.

Biological techniques which is used to treat waste water from the sugar industry after the use of algae from the family Chlorophyceae, Protococcineae, Chlamydomonous, Diatomeae and Cyanophyceae