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[FRTSSDS- June 2018] ISSN 2348 – 8034
DOI: 10.5281/zenodo.1342642 Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

AN APPROACH TOWARDS ZERO DISCHARGE IN SUGAR FACTORY – A CASE STUDY

Anita Gour*[1], Shirin Imam[2], Akruti Gupta[3] & Pooja Thakur[4]
[*1,2,3&4]Department of Chemical Sciences, Christian Eminent College, Indore (M.P.), India

ABSTRACT

The consumption of large volumes of water and the generation of organic compounds as liquid effluents are major environmental problems in sugarcane processing industry. The inadequate and indiscriminate disposal of this effluent in soils and water bodies has received much attention since decades ago, due to environmental problems associated to this practice. Because of the large quantities of effluent produced, alternative treatments have been developed. The low pH, electric conductivity, and chemical elements present in sugarcane effluent may cause changes in the chemical and physical–chemical properties of soils, rivers, and lakes with frequent discharges over a long period of time, and also have adverse effects on agricultural soils and biota in general.

In the present sugar factory bi-products generated are Waste water, Bagasse, Molasses and pressed mud. The waste water is processed in Effluent treatment Plant present within Factory. The processed water is used within industry to fulfil industry's water needs and the remaining water is used for agricultural purpose. Bagasse is supplied to Paper industry for paper generation. Cane molasses is sold to Pharmaceutical industry for medicinal purpose as well as it is used for Liquor production. Pressed mud is sold to bio fertilizer industry. As no harmful bi-products are released outside the industry this sugar industry is Zero Discharge Industry and does not pose any threat to environment.

Key words- *Sugarcane industry, effluent management, treatment, zero discharge*.

I. INTRODUCTION

Increased demand for food and the need to sustain the ever increasing world population have led to massive increase in both agricultural and industrial activities. Agriculture is one of the most significant sectors of the Indian Economy. Sugar Industry is one of the agricultural based industries. Today, India is one of the first ten industrialized countries of the world. India, like any other developing countries, is faced with problems arising from the negative impact of economic development due to water or industrial pollution. Awareness of environmental problems and the potential hazards caused by industrial wastewater has promoted many countries to limit the discharge of polluting effluents [1 & 2].

In many developing countries, especially in Asia sugar cane industry is one of the most important agricultural industries. As a consequence, sugar cane industry has significant wastewater production. Unfortunately, due to the lack of know-how and financial support, most of sugar cane industries in developing countries discharge their wastewater without adequate treatment. Similar with other wastewater generated by food processing plants, wastewater from sugar cane industry generally contains organic materials such as carbohydrates and proteins [3].

Sugar production alone is not profitable. Electricity generation, production of Alcohol and Ethanol are important to ensure sustainability and financial viability and survival in the competitive environment. According to the International Sugar Organization (ISO), Sugarcane is a highly efficient converter of solar energy, and has the highest energy-to-volume ratio among energy crops. Indeed, it gives the highest annual yield of biomass of all species. Roughly, 1 ton of Sugarcane biomass-based on Bagasse, foliage and ethanol output – has an energy content equivalent to one barrel of crude oil.

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II. SUGAR CANE INDUSTRY

In many developing countries, especially in Asia and South America, sugar cane industry is one of the most important agricultural industries. Sugar cane mill industry is one of the oldest industries in India, as in other parts of the world. In India, sugarcane industry is highly responsible for creating significant impact on rural economy after textiles [4]. India is the world's second largest sugarcane producer, with nearly 5 million hectares of cultivated area and provides direct employment to more than 3.6 lakes person.

Most of the distilleries co-exist with sugar mills and utilize the molasses from cane sugar manufacture as the starting material for alcohol production. As per the Ministry of Environment & Forests (MoEF), Government of India, alcohol distilleries are listed at the top of ―Red Category industries having a high polluting potential. The industry generates large volumes (8–15 kL/kL alcohol) of dark brown colour wastewater (spentwash) with high biochemical oxygen demand (BOD) and Chemical oxygen demand (COD).This poses a serious pollution threat; thus it is mandatory for distilleries to take appropriate measures to comply with the discharge standards set by the Central Pollution Control Board (CPCB), which is the national agency responsible for environmental compliance [5 & 6].

Present sugar industries are facing lots of challenges and problems in total water management in the industries which is leading them face legal actions from statutory board. Increase in production capacity, variation of cost of sugar tax and duty on production and availability of source of water and cane and its transportation has lead to have a serious look to address the issues pertaining to water management in many of the sugar industries [7 - 10].

Sugarcane produces mainly two types of biomass, Cane Trash and Bagasse. Cane Trash is the field residue remaining after harvesting the Cane stalk and Bagasse is the milling by-product which remains after extracting juice from the stalk.

Surface water pollution potential is mainly due to the high contents of organic matters in stillage. Organic matters cause oxygen depletion by heterotrophic biodegradation when enter in surface water. Stillage also contains high concentration of potassium which can accumulate at toxic levels in the soil [11 - 14].

Bagasse is the fibrous residue left over after milling of the Cane, with 45-50% moisture content and consisting of a mixture of hard fibre, with soft and smooth parenchymatous (pith) tissue with high hygroscopic property. Bagasse contains mainly cellulose, hemi cellulose, pentosans, lignin, sugars, wax, and minerals. The quantity obtained varies from 22 to 36% on Cane and is mainly due to the fibre portion in Cane and the cleanliness of Cane supplied, which, in turn, depends on harvesting practices.

- Bagasse is usually combusted in furnaces to produce steam for power generation.
- Bagasse is also emerging as an attractive feedstock for bio-ethanol production.
- It is also utilized as the raw material for production of paper and as feedstock for cattle.

Bagasse is often used as a primary fuel source for Sugar mills; when burned in quantity, it produces sufficient heat and electrical energy to supply all the needs of a typical Sugar mill, with energy to spare. The resulting CO2 emissions are equal to the amount of CO2 that the Sugarcane plant absorbed from the atmosphere during its growing phase, which makes the process of cogeneration greenhouse gas-neutral.

Bagasse is used for our biodegradable takeaway boxes and containers, our range of disposable plates and bowls and our ice cream cups. They are: Reasonably priced: Comparative to paper and foil products Heat resistant up to 100˚C Water resistant Oil proof Microwave safe Freezer friendly Breathable –Your food won't sweat.

The power produced substitutes the conventional thermal alternative and reduces greenhouse gas emissions. In India, interest in high-efficiency bagasse based cogeneration started in the 1980s when electricity supply started falling short of demand. High-efficiency bagasse cogeneration was perceived as an attractive technology both in terms of its potential to produce carbon neutral electricity as well as its economic benefits to the sugar sector.

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Raw sugars consist of varying shades of yellow to brown sugars and is processed by boiling till it solidifies. From sugar beet juice, the raw beet sugars are extracted and are then used to fabricate white sugar. These are available in crystalline and loaf Ponta, where the moulds are then allowed to dry up and the resulting product is called jaggery or gur. Raw sugar is not so popular in South America. Mill white sugar is produced by exposing the sugar to sulfur dioxide but it retains the coloured impurities.

Blanco direct is a white sugar used much more in India and Asia and is less purer than the white sugar. It undergoes the process: of phosphation and is more devoid of impurities. White refined sugar, popular in the West, is processed by dissolving the raw sugar and purifying it with phosphoric acid or by filtration strategies. White sugar is available in granulated form. Granulated sugar includes coarse grained sugars such as sanding sugars, caster sugar and superfine powdered sugar and they are divided on the basis of fineness of granules.

III. MANUFACTURING PROCESS

1. Cane Milling

The cane is crushed at mill tandem after preparation in five mill tandem. The maceration is done by applying hot water in mill house. Cane residue is called Bagasse which is sent to boilers as a fuel through a conveyor called Bagasse Carrier. In extracted juice phosphate is added to maintain the phosphate content. A weighed quantity of raw juice is heated in juice heaters up to 70 to 72 °C. There after juice is limed and sulphited. Lime is added for clarification and neutralization. Sulphited juice is again heated up to 100 to 102 °C and is sent for settling to clarifier. From here the clarified juice is sent to pan for evaporation in quintuple for making syrup. Syrup after sulphitation is sent to pan section where pan boiling system is adopted. Massecuite's are dropped in crystallizer and purged by centrifugal machine. Mother liquor is re-circulated for low massecuites.

A Massecuite is purged and commercial white sugar is bagged from grader and is weighed. After weighing the bags are stitched and sent to go-down for storage by bags conveying system.

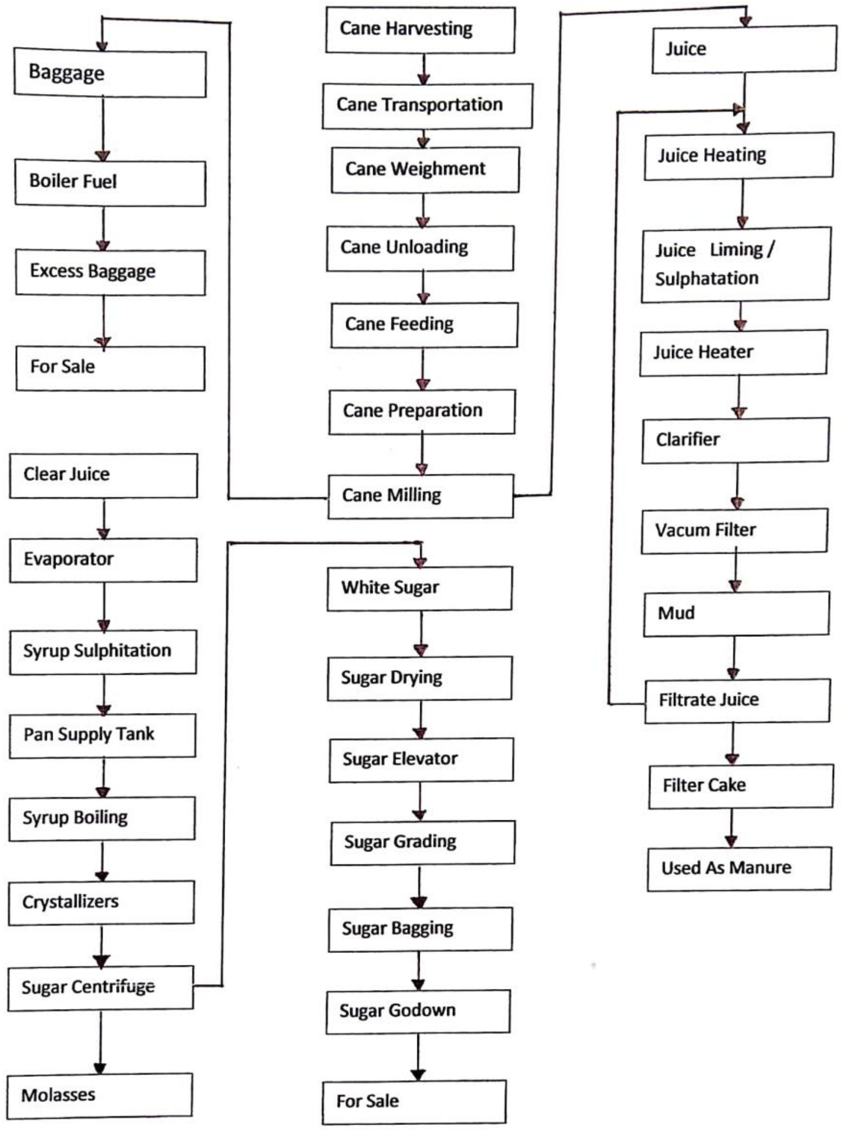

Figure 1. Flowchart showing sugar manufacturing process

2. Creation of vacuum in pan

At starting of season, each pan is washed with steam & air which is then condensed by the condenser connected to the pan & vacuum is created. The pan boiling process starting from syrup to final molasses, stating disposal of intermediate molasses and sugar products. Number of crystallizer and their massecuite wise distribution. There are 9 crystallizer are used in this factory. Out of it, 3 crystallizer are used for 'A' m/c, 2 crystallizer are used for 'B' m/c, 1 crystallizer is used for 'C' m/c. The massecuite is taken to the crystallizer from pan and is dropped in the crystallizer by force of gravity Centrifugal floor.

3. Centrifugal sugar to bagging stage

There are three hoppers 1500 mm wide x 10 m long (Hot & cold air blower). Hot air blower is connected between hopper no. 1 & 2 to remove moisture percentage from sugar i.e. to dry the sugar. The hopper consist of an inlet connection for steam & rotary fan which expellees income steam from blower to sugar on the hopper. Cold air

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blower is connected between hopper no. 2 and 3 to cool the sugar i.e. to lower down the temperature of sugar. It consists of inlet connection for cold air and a rotary fan to expel the air on the sugar. The sugar from hopper falls at bottom of the elevator which is filled partially in the bucket and lifted at the top and thrown on the grader. At the top of the grader screen of 6 mesh is attached followed by screen of 8, 10, 12, 18 mesh. The sugar from elevator falls on the upper most screen on which oversize material is separated through conical bottom by gravity. In this way, sugar is graded on the remaining screens & undersize material i.e. dry seed is separated. The sugar from 8 mesh screen is taken as L & M and sugar. The sugar from 12 mesh screen i.e. fine sugar is melted & taken as dry seed to the pan no.1.The net weight of sugar bagged is 50kg. Bags are stored in go-down. Sugar recovery % cane is 11.11%.

4. Boiler

Boiler is the important part of sugar industry and also called as the heart of sugar industry. All the heat transfer processes conducted on juice is done by using steam. The sugar factory also requires large steam amount of electricity for its working. Therefore production is necessary in sugar industry for above two purposes. Cost of steam production plays a prominent role in the success of any industry. The cane sugar industry is fortunate in being able to materially reduce cost of its steam production by utilizing one of its bye-product (Bagasse) as a fuel.

5. Preparation of sulphur dioxide gas

The SO_2 is generated by burning commercial sulphur in excess of air in sulphur burner made by cast iron. The dry air is supplied to the compressor. Air is compressed to about 0.6 to 0.7 kg/cm pressure and supplied to 'sulphur furnace'. The hot gas of 300°C has to be cooled. The pipes between burner & scrubbers are therefore water jacketed.

6. Scrubber

It is water jacketed cylindrical C.I. &tank with a false bottom &packed with refractory bricks. The gas is introduced through a pipe up to bottom. The gas rises through the layer of bricks to trap the sublimed sulphur & thus the filtered gas is introduced to the sulphited through a Spurger or gas coil. The gas temperature while entering to the sulphitor should be 600°c to700°c as the temperature inside the sulphitor is of 70% approximately.

7. Clarifier Section

Juice received from milling section i.e. mixed juice is turbid, Contain undesirable impurities and have dark colour as grey, greenish or blackish. It is opaque and acidic in nature having ph 5 to 5.4. This mixed juice is composed of water, organic non sugars, inorganic non sugars and sugars. Out of these it is an interest to recover sugar to the maximum possible extends in the form of crystals and eliminates maximum possible non sugars. The water can be evaporated. But for the removal of other content it is necessary to subject the juice for clarification according to the nature of non-sugars present in mixed juice.

Sulphured juice of about 6.9-7.1 ph is heated to its boiling point i.e. 100-103°c when this heated sulphured juice is observed in the test tube, precipitate formed settles down at the bottom while turbid free, transparent, golden yellow coloured clear juice is obtained at the top of the test tube. The same happens in a juice clarifier. In old days, settling tanks were in use. Then come the improved design known as `multi feed door'. Presently a further improved design known as `rapidon' is in use. The process of settling takes place very well at 100-103°C and 6.9-7.1 pH. Also, at this high temperature bacterium dies, which prevents the inversion of sugar. Therefore sulphured juice is again heated to 100 - 103°C and sends to clarifier.

8. Chemicals Used in Clarification

Lime

Lime is used in the clarification process as calcium oxide (CaO) lime is obtained by burning high grade calcium carbonate ($CaCO_3$) i.e. limestone in kiln evolving carbon dioxide (CO_2). Consumption of lime is about 0.12 to 0. 15% cane. Lime helps to increase pH of juice in sulphitation tank. During clarification, process, lime reacts with phosphoric acid and SO_2 gas to form calcium phosphate [$Ca_3(PO_4)_2$] and calcium sulphide [$CaSO_3$] respectively which settles down quickly and imparts good setting. Thus, removal of soluble non-sugar is done by lime by way of precipitation.

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Sulphur
Sulphur is used in the process in the form of sulphur dioxide gas SO_2. The consumption of sulphur is about 0.04 to 0.06 cane. Sulphur is used in the sulphitation tank to increase pH 11 of juice. During clarification process, SO_2 reacts with lime to form calcium sulphide [$CaSO_3$] which settles down quickly and helps for settling process. SO_3 also has bleaching action on mixed juice.

Phosphoric Acid
It is available in solid powder or granular form. The consumption of Phosphoric Acid is about 0.015 to 0.02% of cane. During clarification process, Phosphoric Acid reacts with lime to form calcium phosphate which settles down quickly and helps for settling process. The phosphate content in juice is in terms of P_2O_5 is ranging from 80-150ppm. This level should be between 300 to 350 ppm to remove non-sugars in the form of precipitate. Therefore, phosphate is to be added externally to bring the P_2O_5 level to 300 to 350ppm.

9. Surface active agents
They are mainly used to remove colloids from Raw Juice. They are high molecular weight poly-acrylamids. The sole of about 0.005 to 0.1% is made in water and added at the rate of 2-5ppm of juice. The addition of Flocculants helps to reduce the volume of mud in the clarifier and improve the clarity of the juice.

10. Rotary Vacuum filter
The settled mud from the clarifier is of 6.8 to 7.0 pH and of 1.08 to 1.1 specific gravity i.e. 22 to 24 Brix. The purity is approximately 78 to 82. In order to recover juice from the settled mud, mud is subjected to a Vacuum filter. Vacuum filter consist of following parts:-

Mud Mixer
Mud mixer is 'u' shaped vessel in which mud and bagacillo is mixed by rotating stirrer. Mud is taken from the clarifier by the gravity and bagacillo is continuous fed by blower. The rotating stirrer is provided in the vessel to mix the mud and bagacillo. Mud and bagacillo is mixed together and forms a mixture.

Mud Trough
Mud mixed with bagacillo is fed continuously to the mud trough. Anagitator is provided in the mud trough which oscillates in to and fromotion to prevent settling of mud.

Rotary filter
The filter drum rotating around horizontal axis is always partly submerged in the mud trough. It is horizontal cylinder with corrugated surface which is covered by 24 no. of fine copper or stainless steel screen. The screens have 96 holes/cm, each with an opening of 0.5 mm diameter. The drum is with a drive unit by a constant speed motor through reduction gear and 'N' belt with a variable speed system. The drum is generally revolved with 18 to 20 rph. The diameter of drum is generally 2.44 to 3.50 meter and length is 4.88 to 7 meter.

11. Filtrate receiving and pumps
Each screen over the drum forms a segment connected to a vacuum system through tubes. The segments are equally spaced and each one occupies an area corresponding to 15 of the circumference along the entire length of the drum. Small method tubes connected the revolving segments individually to the stationary distribution valve through which filtrates withdrawal pipes are drawn and lead to the filtrate receiving vessels under Vacuum. The collected filtrate from each vessel is further pumped by filtrate pump and both the filtrates through common arrangement are mixed to the raw juice receiving tank.

12. Vacuum system
In this factory, Vacuum system consists of barometric condenser coupled with air pump Evaporators. The clear juice coming out from clarifier is of 15 to 16 Brix. In order to crystallize this juice it is necessary to condensate it. In order to conduct the boiling process at low temp it is necessary to reduce the pressure on liquid i.e. to

create Vacuum in the body. The no. of evaporator are connected to each other in this way, that a steam of 0.4 - 0.7 kg/cm^2 pressure is given to first body & it is reduce in next evaporators followed by increase in Vacuum. Due to this temperature of juice, in body less than that of last body. Therefore vapours come out from 1st body are used to concentrate juice in next body. Similarly, vapours coming out from 2nd body. This procedure is followed up to last body.

13. Pan section
The basic material used in pan boiling is syrup of 60° Brix and 80 - 82 purity. The pH is 5.0 to 5.4. The Brix of sugar is assumed as 100. As a result, the concentration of syrup to massecuite is forming 60 - 100 Brix.

14. Condenser
A close vessel in which condensation of vapour takes place is called condenser. Vapour are received from the multiple effect evaporator & from vacuum pans. It is to be installed at a height of 11 m above the ground level of the sugar factory. Water column at sea level can be of 10.33m. The heat from the hot vapour is absorbed by the cold water introduced to the condenser. Thus the vapour after exchanging heat are converted into water. Water then flows out under gravity along with condensed vapour. The temperature of outgoing water is ranging from 40°- 45°C. Warm water leaving the condenser is pumped in a cooling pound. The same after proper cooling returns at a lower temperature & is used as cold water required & introduced to the condenser, this is a close system.

15. Crystallizer
The process of crystallization starts in vacuum pan and completes in crystallizer. In pan boiling, crystals of sugar start to appear in syrup and massecuite is prepared in various pans. When these crystals grow to sufficient size the massecuite is dropped in crystallizer. The massecuite is the mixture of sugar crystals and mother liquor around them. This mother liquor still contains sucrose and to recover maximum sugar time should be given to it to have contact between crystals mother liquor. Therefore, the massecuite from pan is dropped in crystallizer.

The aim of keeping the massecuite in motion is as under :
- To have contact between the crystals and mother liquor to achieve better deposition of sugar from the mother liquor on the existing crystal surface to achieve high degree of crystallization.
- To avoid solidification of massecuite especially in case of high grade massecuite.

Air cooled crystallizer
It consists of a "u" shaped horizontal vessel opened from the top. A horizontal rotating shaft carrying helical arms is provided incrystallizer. In some cases, double helical arms are provided. These arms rotate in opposite direction to each other. The massecuite at the one end of the crystallizer is moved forward by stirrer and is discharge through a gate at another end and send to centrifugal machine. The stirrer is rotating at about 1 rpm. A double arms arrangement helps for better circulation of massecuite and faster cooling. The massecuite is allowed to have contact with air for long time.

Water cooled crystallizer
The construction of air cooled and water cooled crystallizer is same. In addition, in water cooled crystallizer provision of cold water and hot water is provided. The cold water is used for cooling & hot water is use for to reduce the viscosity of cooled massecuite. This hot and cooled water is either circulation through circulating coils, hollow shaft or through helical shaft.

Vertical Crystallizer
It consists of vertical cylindrical tank having dia. 3.5 to 5m and height 7 to 16m. a hollow vertical shaft carrying rotating arms is provided at the central of the tank. This stirrer helps for circulation of massecuite. The circulating pipe carrying hot and cold water is placed between two arms horizontal parallel to the ground level. The no. of pipe is generally range from 6 to 19. The water inlet in tubes is providedfrom outside. The

[FRTSSDS- June 2018] ISSN 2348 – 8034
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massecuite enters in tank from top through main door provision. The support is given to stirrer through thrust bearing at bottom. The cooling and heating of massecuite is done through pipes.

Vacuum Crystalliser

This is a cylindrical crystallizer totally enclosed from top. A vacuum connection is provided to this equip.& so is called as vacuum crystallizer. In general after graining in batch pan is transferred to this crystallizer which can be intact in the crystallizer. As & when required the material can be transferred from pan to vacuum crystallizer.

IV. EFFLUENT TREATMENT PLANT

Sources of wastewater

- **Mill House**: Gland cooling & occasional floor washings that bring along high concentration of oil & grease.
- **Boiler House**: Boiler blow-downs, it is, more or less, clean water but has high TDS & phosphates.
- **Condensates**: Vapour from last effect evaporators and pan boiling are cooled in condensers & condensate goes to tank for reuse. Overloading or poor operating conditions leads to overflow or loss of sugar in condensates through entrainments.
- **Occasional Spills & Leakages**: This is usually because of process disturbances.
- **Process Cleaning**: Evaporators, juice heaters, pans etc, are cleaned once in a month for scale removal. Caustic soda washings are stored for reuse, but one-time use may lead to discharge of chemicals in drain.

The ETP plant consists of Primary clarifier, Secondary clarifier, Equalisation tank, Bio-Tower, Sludge treated tank, Aeration tank and Filter

1. Bar Screen chamber

The 1st unit operation encountered in waste water treatment plant is screening. A screen is device with opening, generally of uniform size i.e used to retain the coarse solids found in waste water.

2. Oil chamber

It is a process in which oil & grease is separated from waste water &then it is used for boiler. This is based on specific gravity between oil & waste water and between the suspended solids & waste water.

3. Equalisation tank

In this tank oxygen absorbed from atmosphere with the help of air compressor & this oxygen is mixed in water for down the COD &BOD. And then it is help to dissolved solid in water to settling tank.

4. Primary settling tank

In this tank chemical sludge is separate & this water is taken for water tank.

5. Water storage tank

In this tank water is stored & left by pump for bio-tower unit.

6. Bio-tower

In this tower plastic media is used. Waste water is sprayed upon plastic media above 6m height. Because of this the atmospheric oxygen is mix with waste water, thus the temperature of waste water become low. The BOD & COD is lower because of bio-logical process.

7. Settling tank

In this tank, sludge is settle & this sludge is collected on sludge bed. The waste water is proceed to next.

8. Aeration tank

The convention activated sludge system contains a tank for wastewater aeration followed by a settler & a solids recycle line. The wastewater flows through under constant aeration in the presence of activated sludge. & exist at end of tank after 4-8 hrs. of residence time.

9. Secondary clarifier

Bio-logical sludge is settle. And this sludge is taken in collection tank & this sludge is used for aeration tank with the help of pump &then sent to treated water tank. & this water is used in farm.

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V. CONCLUSION

Bi-products generated in sugar industry are Waste water, Bagasse, Molasses and pressed mud. The waste water has high COD, BOD, suspended solids and also it's acidic in nature. The waste water has very low nutritional contents such as nitrogen, phosphorus, etc. This waste water is processed in Effluent treatment Plant present within Factory. The processed water is used within industry to fulfil industry's water needs also the remaining water is used for agricultural purpose.

Other bi-product Bagasse is supplied to Paper industry for paper generation. Cane molasses is sold to Pharmaceutical industry for medicinal purpose as well as it is used for Liquor production. Pressed mud which useful nutrients such as calcium, phosphorus and organic contents are useful for farming. This useful pressed mud is sold to bio fertilizer industry. As no harmful bi-products are released outside the industry, they don't pose any harm to environment. As discussed above all the bi-products are reused in some or other manner, hence we can say that, this sugar industry is Zero Discharge Industry and does not pose any threat to environment

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