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REVIEW ARTICLE **OPEN ACCESS**

Current status of Effluent treatment Sugar industries by Bioremediation

Pradeep Kumar Choudhary*
*Department of Biotechnology, GLA University, Mathura, UP
Pradeep.choudhary@gla.ac.in

ABSTRACT
In the all world for sugar is the primary driver for Sugarcane Industry and its generate large amount of waste water .Sugarcane Industry wastewater contains highly organic matter, which is harmful to the various life forms of the system like as plants, aquatic flora and human beings. At present time rapid industrialization and urbanization in developing countries like as India are facing many problems in collection, treatment and disposal of Sugarcane Industry wastewater. In sugar mill effluent is found to have high contents of COD, BOD, TSS, TDS, Sulphates, low quantity chlorides, Oil and Grease, toxic compounds and generally DO levels [Dissolve Oxygen] found zero resulting that in large scale contamination of land surface, water and air. This study main aim is a minimizing and removing of COD, BOD, total dissolved solids, TSS, Sulphates, chlorides, Oil & Grease and toxic compounds, before it releases into a land surface or water body by the help of physiochemical and biological treatment. In Sugar industry mainly aerobic and anaerobic biological treatment plant was constructed and operated for waste water treatment. In aerobic treatment system using potential microbes in removing contaminants was determined and it was found that activated sludge is highly effective and cheaper method for treating of sugar mill effluent for the removal of COD, BOD TDS, TSS Sulphates, Chlorides, Oil and Grease. After treatment treated water samples were collected for every 24 hours and checked for its parameter like as pH, TDS, TSS, COD, BOD, Sulphates and Chlorides, Oil and Grease to evaluate the efficiency of the plant. The efficiency of activated sludge process is removal of COD and BOD 65% to 80% respectively. The results of the study show that biological treatment using potential microbes formulation has the potential effect and efficient for improving the quality of sugar mill waste water.
***Keywords**: Sugarcane industry; Wastewater sources, Microorganisms, Activated sludge, USAB reactor, Aerobic & Anaerobic treatment, physicochemical treatment.*

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INTRODUCTION
In India, Sugarcane is grown as a Kharif Crop and it is belongs to Poaceae family of true grasses. It needs hot and humid climate with an average temperature of 21°C to 27°C, 75-150 cm rainfall is favorable for sugar cane cultivation. Sugarcane can grow in any soil which can retain moisture. Ideal soil for sugarcane is deep rich loamy soil. Sugar industry is a big business in India. Sugarcane industry in India is 2nd largest agriculture based industry. Indian sugar mills support ~ 50 million farmers, helpers their families, providing employment to ~0.6 million semi-skilled& skilled persons work in sugarcane mill. In the all world widely and largest sugar-consuming country is India also became the world's largest sugar producer in session 2018/2019.In last crushing session 2018–19 in India sugar mills will produce 35.5 million tons of sugar according to data from the Indian Sugar Mills Association, [1,2] .Sugar beet and sugar cane are main crops for sugar production, and it is very high demand in the marketplace. Also in sugarcane industry biogases is the by-product which is used to provide as a fuel for steam & electricity generation [3]). In India largest sugar producing state is the Uttar Pradesh. In Uttar Pradesh 30 districts produces sugarcane with the western part, similarly upper Ganga-Yamuna, Rohilkhand, Doab, and trans-Saryu areas, together accounting for ~70% production of the total sugarcane. The second-larger of sugarcane producer in India is Maharashtra; it lags behind Uttar Pradesh, accounting for ~32% share sugar production in India. Sugar production country mainly 115 but in 115 Countries, 67 country sugar production by the sugarcane, 39 country by the sugar beets other 9 country used both sugar cane &sugar

beets reported that sugarcane represents 70% of global sugar production, while 30 % generated from sugar beet and cassava. [4,5].

[Table 1] Top 5 Sugar producing country in session 2018-2019

S.NO.	Name of the country	Production of sugar in million metric tonnes
1	India	35.5
2	Brazil	29.5
3	Europe	18
4	Thailand	15
5	China	10.6

Sugar industries require water and consequently discharge waste water. From beet, cane factories and factories refineries produce waste effluent with different high organic strengths. Effluent treatment plants are designed for local environment regulations and vary from country to country [6] Generally sugar, the main contaminant industry but effluent is not highly toxic, in this effluent mainly found cane juice, molasses it readily provides a source of soluble food which is an ideal in form of carbon sources for microbial growth. The high growth rate of microbe's in natural stream that causes depletion of oxygen. In aquatic microorganisms that required oxygen will suffer otherwise the lack of oxygen they may die [7]. Waste water treatment systems utilize the very same process, but under controlled conditions. For economic development in India sugarcane mills play main role. However sugar industries generated wastewater that contains maximum organic pollutant this untreated waste water bypasses that causes the ecosystem problems like as terrestrial &aquatic ecosystem [8]. Sugar industry is a seasonal industry and operates for about 6 months in a year, generally from month October to March. Sugarcane mills consume water about 1500 to 2000 liters, if one ton cane crushes that generate about 1,000 liters wastewater [9]. These effluent sources mainly floor washing wastewater, condensate water, leakage in valves and glands of the pipeline add sugarcane juice, syrup and molasses in the effluent. Sugar mills effluents characterization by high, chemical oxygen demand (COD), pH, temperature, colour, odour, Biological Oxygen Demand (BOD), Total Dissolve Solids (TDS), total suspended solids (TSS).In sugarcane effluent mainly found sucrose fructose, Chlorides, Sulphates', Oil & Grease, nutrients, etc [10,11,12,13] Sugarcane industries are mainly seasonal industry that runs generally at least November to May maximum 150 – 210 days. Sugar industry effluents generally contained considerable amount of toxic compounds such as Cu, Zn, Mn Fe, Pb and soluble salts etc. [14].

The sugar mill effluent has a generally chemical oxygen demond (COD) 1800 to 3200 mg/liters& biological oxygen demond (BOD) 750–1,500 mg/liters, but appears relatively clean initially. High load of BOD/COD causes rapid depletion of oxygen content of the waters, result that foul smell, renders the stream unfit for propagating aquatic life, drinking and for other purposes. Biological treatment system of sugar industry effluent generally carried out by aerobic and anaerobic process. Several advantages of anaerobic over aerobic processes, anaerobic processes are easier to control and operate, produce a lower quantity of sludge and their costs are lower. Anaerobic treatment system decompose the organic compounds in an atmosphere free of oxygen and consequently require significantly less energy as compared to aerobic treatment system.(www.cpcbenvis.nic.in/newsletter/agro-dec1994/dec943.htm). In the sugar industry primary treatment of effluent by the help of sedimentation, flocculation, filtration, equalization [15,16]. And the second treatment process are the biological processsuch as activated sludge, lagoons process[17,18,19] fluidized bed reactor (FBR) ,aerated ponds,Up-flow Anaerobic Sludge Blanket expanded granular sludge blanket, [20]. Many sugarcane mills used both aerobic &anaerobic process for the high polluted effluent treatment [21].

Bioremediation/biotreatment methods are almost typical "end-of-pipe processes" applied to remove, degrade, or detoxify pollution in environmental media, including water, air, soil, and solid waste. .by the removal, separation, destruction and immobilization process can be considered as acting on the contaminant [22,23].

In this review, paper was also investigated the sugarcane industry effluent generation sources, effluent characterization, present research &advancements in bioremediation/biological methods(aerobic & anaerobic), physicochemical treatment process, and the areas in which future research is needs and the responsibility that after treatment effluent reuse.

GENERAL CHARACTERISTICS OF WASTE WATER GENERATED FROM SUGAR INDUSTRY

Sugar industries effluents is characterization by the mainly pH, Temperature, COD, BOD, pH,TDS, totals suspended solids oil & grease, sulphates etc. These waste water characteristics parameters and its average ranges shows below in table number (2).The Standard parameters of treated effluent water according to Central Pollutions Control Board (India) norms show in table number (3) (www.cpcb.nic.in/effluent-emission/).

[Table 2]Sugar industry waste water characteristics and its average ranges

	Parameters	Average range
1	pH	5.5. to 7.5
2	Chemical oxygen demand (COD)	1800 to 3200 mg /lt.
3	Biological oxygen demand (BOD)	750 to 1500 mg /lt.
4	Total Dissolved Solids(TDS)	500 to 600 mg/lt.
5	Total Suspended solids (TSS)	1000to2500 mg/lt.
6	Oil and grease	10 to 50 mg/lt.
7	Sulphates	500- 1000mg/lt.
8	Temperature	25 to 35 °C

(Note – This parameter of sugar industry waste water average ranges varry from industry to industry)

[Table 3] Standard parameters of treated effluent water

S.NO.	Parameters	Inland surface water	Land for irrigation
1	pH	6.5-8.5	6.5-8.5
2	COD(Chemical oxygen demand)	<250	<250
3	BOD (Biological Oxygen Demand)	< 30	< 100
4	TDS (Total Dissolved Solids	< 2100	< 2100
5	TSS (Total Suspended solid)	< 30	< 100
5	Oil and grease	<10	< 10
6	Final wastewater discharge limit	200 litre per tonne of cane crushed	

SOURCES OF WASTE WATER IN A SUGAR INDUSTRIES

The waste water generated from different sub streams can be classified out of these wastes liquid waste generated as follows-

Waste water from Boiling House;

The sources of effluent from boiling house results that Chemical boiling and tube cleaning of evaporator, pans leakages through pumps, pipelines and the washes of various sections such, juice heaters, clarification, and centrifugation etc.

Waste water from Mill House;

The waste water sources during cleaning of millhouse floor which is liable to be converted by spills and pleased sugar juice (This clearing required for the prevent growth of bacteria on the juice-covered floor). Fresh water used for cooling of mills also forms part of the waste water from this source. Generally this water contains organic matter like sucrose, oil and greases.

Condenser cooling water;

Sugar industry condenser cooling water is re-circulated again unless it gets mixed with juice, and it is possible due to defective entrainment separators. If it gets contaminated, the water should go into the drain invisibly. This volume of condenser cooling water is also increased by additional condensing of vapour which is drained from the boiling juice the pan.

Soda and Acid Wastes;

In sugar industries heat exchangers and evaporator are cleaned by the help of hydrochloric and caustic soda and in order to remove the formation of the deposits of scales on the surface of the tubing. In India, many sugar industries let this valuable chemical go into drains. The caustic soda and acid wash contribute considerable amounts of organic and inorganic pollutions and this washing waste water highly polluted may cause shock loads to wastewater treatment.

Other sources of waste water in sugar industries also from Excess condensate, Boiler Blow-down, Laboratory and domestic water usage.

DIFFERENT STEPS IN WASTEWATER TREATMENT PHILOSOPHY

Sugar industry wastewaters treatment requires process that combines Physico-chemical, and biological treatment. In Sugar industry bar screening, Equalization, sedimentation, grit removal, etc, is uses for the removal of Total suspended Solids (TSS) in the effluent. Aerobic and anaerobic method is used to reduction of disinfectants &soluble organic pollutants [24]**.**The process design involves Biological and Physico-chemical processes will be chosen as per our final requirement of treated water parameters.

Physico-chemical treatment

Physico-chemical parameters pH, conductivity, COD, sulphate, chloride, TDS, calcium, and magnesium, present in sugarcane mill waster they affect the germination of seeds [25].In Physico-chemical treatment process flocculation/coagulation mostly useful removal of dissolve solid, suspended solids as well as colloidal solid, in effluents. For the primary purification of wastewater, coagulation/flocculation is generally used in effluent treatment [26].

The aim of flocculation/coagulation process treatment is to destabilize charged particles of suspended solids and it is removes by filtration/sedimentation. Researchers found in one literature coagulant adding to limewater and subsequent adsorption by the activated charcoal [27].The main problems in chemical treatment increase amount of sludge production by using flocculants.

Electro-Chemical method is used for sugar industry waste water treatment. In this treatment process the organic pollutant is oxidized in CO_2 & H_2O another oxides, electrochemically generates nascent oxygen and/or oxidizing agent. In electro coagulation method generation of anode material hydroxides and/or poly hydroxide that is removes organic matter from effluent by coagulation. Whereas in electro-flotation method removal of organic matters from waste water by using buoyant gases bubbles which is generates electrolysis time, and taken with pollutant on upper side of water body [28].

Researchers find that electro coagulation & electro oxidation for the treat spent ion-exchange method of effluent to sugarcane refinery that is different current loads like as electro-oxidation (EO) process showed removal of COD 63.1%, de-colorization 99.9%, and TSS 90.5%, at 5A in seven hours electrolysis. The Electro-coagulation process reduction of COD18.5%, de-colorization 71.2%, and TSS 97.4% found at 5A in 8 h electrolysis time [29].

Biological methods of sugar industry waste water;

In the biological treatment/bioremediation removals of pollutants from waste water by help potential micro-organisms. The components of wastewater could be of chemical, physical or biological nature and they can induce an environmental impact, changes in species structure, aquatic habitats, biodiversity and also water quality. Therefore it is an important and difficult task to find out the potential consortia of microorganism and treatment system for a different type of effluents, and remove the non-settleable colloidal solids to degrade waste water pollutant mainly sulphates, N, PO_4, Cl, organic, heavy metal etc, which are present in wastewater [30,31] **.**Generally these compounds are toxic to microorganisms; pretreatment may be required [32] In biological treatment system requires that the waste water may be rich in unstable organic matter, so that microorganisms break up these unstable organic pollutants into stable products like CO_2, CO, NH_3, CH_4, H_2S, etc.[33]. Since in the sugar mills effluents mainly found highly organic pollutants, VFA (volatile fatty acids), found in sugar mill effluent that result they not easily biodegrade; that result need both aerobic &anaerobic methods is best option for the sugar industry effluent treatment .

Aerobic Treatment

In aerobic treatment system organic pollutants from industrial waste water easily biodegrade. [34] The basic reaction in aerobic treatment system is represented by the following reactions):

1.Organic material $+ O_2 \xrightarrow{cells} CO_2 + H_2O +$ new cells

Microbial cells undergo progressive auto-oxidation of the cell mass:

2. Cells $+ O_2 \rightarrow CO_2 + H_2O + NH_3$

In Aerobic treatment process use of O_2 by micro-organisms degrades the organic pollutants from waste water. In this process mainly involvement of activated sludge system, aerated lagoons, trickling filters, [35] Lagoons and low rate biological filters have mainly limi-ted industrial applications. The processes can be exploited as activated sludge system or attached growth (fixed film) systems [36,37]. Effluents of sugar mill mainly biodegradable but due to long chain fatty acid which is produces from oil & greases is not easily degrades in anaerobic treatment process because oil & greases kill the methanogenic bacteria that result affect the production of CH_4 gas [38,39] Researchers find out that long-chain fatty acids kill the methanogenic bacteria [40]**.** In aerobic treatment system aeration tanks used for the activated sludge process that's allow suspended growth of bacterial biomass which is occur during biological (secondary) wastewater treatment, while trickling filter is support that attached growth of bacterial biomass [41].

In some sugar industry for effluent treatment allows advanced types of activated sludge systems by usingO_2 and it is operates in huge concentration of biomass. Sugar industries activated sludge process is one of the biological methods for effluent treatment. The activated sludge process consists of converting the suspended and particulate organic pollutants in the waste water into harmless end products and new cells growth with the help of aerobic microbes (www.sugarprocesstech._com/activated sludge process/#Activated_Sludge_process_Description**)**. The generation of activated Sludge when these micro-organisms are allowed to coagulate with the organic pollutant in the waste water result that "Flocs' formation. Under this process biodegradable organic matter which is present in effluent engulf by the biomass of microbes in the presence of oxygen, resulting in-

1. Aerobic micro-organisms consuming O_2 that satisfy for the energy sources.
2. Formation of excess sludge generated from a surplus of living and inert matter in the wastewater.
3. In the activated sludge process maximum reduction of effluent BOD and COD is 80 % and 65% respectably.

The main principle of activated sludge process is following-

a) The actual process of bio-degradation/bioremediation is the activated sludge process. In this process coagulated organic matter is degrade using potential microbes and these microbes are converts to new bacterial cells and harmless product.

b) The microbe's uses O_2 that is provided as a form of energy source for the cell growth and released CO_2 & H_2O as final by product. Microbes are live using oxygen and work by adsorbing organic food matter.

c) In the activated sludge two types of microorganisms found first is the flock forming (easily settledin the clarifiers) and second is the Filament forming microbes (not easily settled, float on surface of water)

d) Maintained sludge balances if huge amount of sludge generates from the system.

e) The efficiency of activated sludge process depends on some factors like as temperature, pH, air quantity, culture growth, suspended solids, and concentration of mixed liquor suspended solids (MLSS).

f) Continuous recycling of activated sludge. For microbial growth in aeration tank required time to time nutrients.

Researchers found that the microorganism such as many species of bacteria, algae and fungi, is useful for removal of pollutants from sugar industry effluents. Some bacteria like as Klebsiella pneumonia, *Enterobacter aeruginosa, Staphylococcus aureus, Escherichia coli* and *Bacillus cereus*, reported that play important role in the biological treatment/bioremediation of sugar mill effluents [42] Another study found that consortia of immobilized bacteria like as (*Serratia marcescens + Enterobacter asburiae + Bacillus subtilis*) are used for the bioremediation of sugar mill effluent [43].

Earlier, lagoon system is used for sugar industry wastewater treatment because of being an economic system [44]. The main disadvantages of lagoon system need largearea, during running time annoying odour and emission unpleasant smell [45]. The performance of ASFF(aerated submerged fixed-film) in this system diffused aeration condition attachment of bio-film on the submerged ceramic tiles. The capability of this process is handle various types of organic pollutants range 5 to120 g BOD/m^2 d with minute decrease removal efficiency of BOD 97.9 to 88.5% and removal efficiency of COD is 73.6 to 67.8% [46]. In aerobic treatment rate of nitrification rate are high compare to anaerobic treatment.

Sugar industry activated sludge process flow diagram

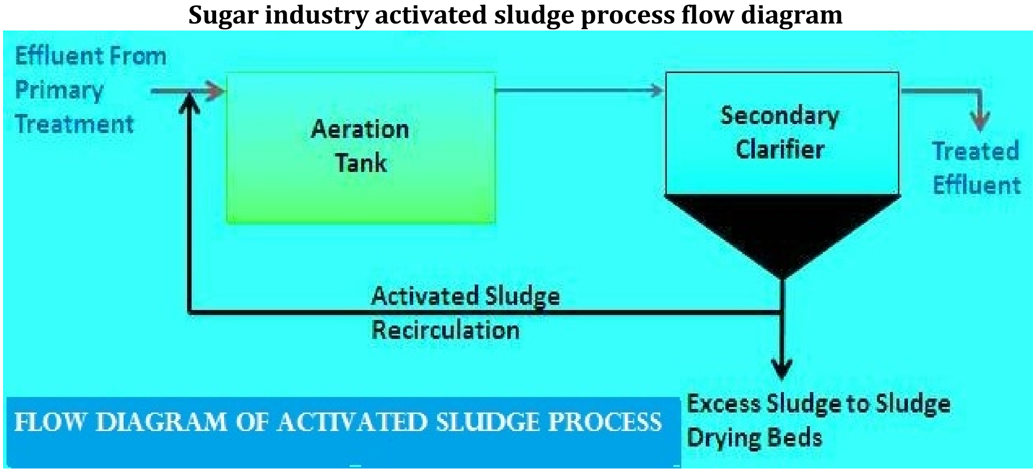


Fig 1: activated sludge process
(www.sugarprocesstech.com/activatedsludgeprocess/#Activated_Sludge_process_Description)

Anaerobic Treatment

Anaerobic treatment system is the best suited technology for sugar industry waste water treatment. For industrial effluent treatment anaerobic process are mostly used .Compression to aerobic process has several advantages, such as methane can be used as form of fuel, (the production of CH_4 gas during degradation of organic pollutants), low energy requirement, sludge generation rate less so the benefit for sludge dispose [47,48,49].Mainly Up-flow Anaerobic Sludge Blanket reactor (UASB), anaerobic fixed-bed reactors (AFR), Up-flow anaerobic fixed bed (UAFB) are useful for sugar mill waste water treatment. Sugar industry effluent treatment at different (HRT) hydraulic retention times such as (0.5, 1.0, 2.0, & 4.0 d), found that the increase in HRT increased organic pollutants removal and more than 90% removal of COD by the AFR treatment process in 4 day hydraulic retention time [50]**.** Discharged Effluent from sugar industries required treatment that prevents adverse environmental effects in water bodies. Generally many sugar industries can be also used treated water in irrigation purpose, RO system, but if a solid not completely removes that create clogging problems [51].

Therefore needs to complete bio-remediate organic matter from effluent is necessary. The mesophilic UASB reactor was studied and evaluated that for the treatment of sugar mill effluent and found that COD removes 90%. Cyanobacteria are effectiveness for the bioremediation of sugar industry effluent [52]. It is removes color 39.2%, BOD 25.69%, COD 37.9%, and TDS 48.51%, in four weeks of treatment.

UASB Reactor

For Industrial waste water treatment Up-flow Anaerobic Sludge Blanket (UASB) reactor are applicable (A.S. Tanksali 2013)**.** UASB has advantages over aerobic treatment. The complex organic pollutants are converted into CH_4 gas through the stages such as hydrolysis, acidogenesis and methanogenesis inanaerobic treatment process [53]. Mainly the following are the 4 steps carried out in UASB reactor.

Hydrolysis

Generally in waste water organic concentration is complex in nature. In anaerobic digesters bacteria utilize these complex organic constituents should breaks into small constituent parts. These constituent parts, or monomers, such as sugars, are readily available to other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called ‘hydrolysis. During this stage complex organic matter are breaks into amino acids, simple sugars, &fatty acids. Methanogens directly used acetate and hydrogen which is produced from first stage.

$$\text{Organic waste} \xrightarrow{Hydrolysis\,Step} \text{Organic acids}$$

Acidogenesis

The Second biological process is acidogenesis, where simple monomers are converted into volatile fatty acids by using acidogenic bacteria.

Acetogenesis

In the acetogenesis process formation of acetate is produced either by the reduction of carbon dioxide or by the reduction of acids. In this stage mostly volatile fatty acid formed**.** During acidogenesis phase simple molecules are digested by the acetogens that produce acetic acid, hydrogen, CO_2 and new bacterial cells.

$$\text{Organic acids} \xrightarrow{Acetogenesis\,Step} \text{Acetic acid, } H_2\text{, } O_2\text{, at 35°C, pH 5-6}$$

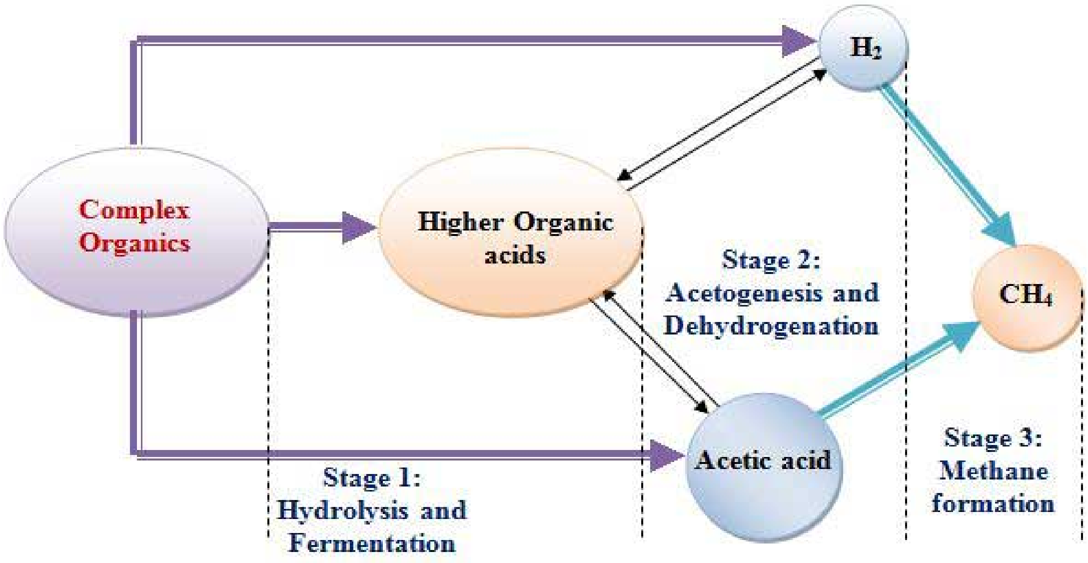
Methanogenesis

Methanogenesis is the formation of CH_4 & CO_2 from the decomposition of acetic acid and the methane can be produced by decomposition of other volatile. The methane forming bacteria are more sensitive to the pH, temperature and toxicity etc. Compression to acid forming bacteria the growth rate of methanogenic bacteria is low. So during shock condition it takes more time to recover compare acid forming bacteria.

The production of methane gas depends on pH & alkalinity. For the methanogenisis optimum pH range between 7 to 8 pH, but the methanogenic bacteria generally not harmful if pH drops about 7. It is advisable for anaerobic reactor to maintain the above pH level 6.5-8 (www.sugarprocesstech. com/anaerobic-treatment).

$$\text{Acetic acid} \xrightarrow{Methanogenesis\,Step} \text{Methane (}CH_4\text{), }CO_2\text{ at 45° C, pH 6.5-8}$$

Fig 2: Energy flow diagram of Anaerobic Digestion Process



(www.sugarprocesstech.com/anaerobic-treatment/)

Compression of Aerobic and anaerobic process waste water treatment of sugar industry;

Aerobic treatment	Anaerobic treatment
➢ Aerobic treatment process carried out in presence of oxygen. ➢ Large aeria required ➢ Energy consumption is high ➢ Efficiency of nutrient removal is good ➢ Excess amount of biomass produced (6 to 8 times more compression to anaerobic process ➢ Oil & greases is degrade ➢ No need further treatment of treated effluent. ➢ Medium range of COD load required	➢ Anaerobic treatment process carried out in absence of oxygen. ➢ Required small size of reactor. ➢ Low energy required. ➢ Poor nutrient removal. ➢ Low biomass produced. ➢ Not easily degrade oil & greases ➢ Required further treatment of treated effluent ➢ Required medium to very high range of COD load

CONCLUSION

Since the sugar industry operates on a seasonal basis, wastewater production is also obviously seasonal. A large variation is observed in the quality and quantity of effluent discharged from various sugarcane mills. The untreated effluent has a high COD, BOD, Suspended Solids, TDS and also most acidic pH**.** Sugar industry wastewater treatment generally done by the anaerobic and aerobic process. In anaerobic process oil & greases are not biodegradable due to long-chain fatty acids, one drawback of this treatment process nutrients are not completely removes. So this process needs one more treatment of treated effluent. Compression to anaerobic treatment process the aerobic activated sludge process is better treatment of nutrient &organic matters. UASB reactor is best for wide variety sugarcane mill effluent treatment. Performance of Up-flow Anaerobic Sludge Blanket reactor is gets affected by the pH, HRT,OLR, temperature and VFA to alkalinity ratio.

Compare to huge amount of waste water discharging industry, sugar industry play crucial and main role for the wetland and aquatic water bodies' pollution. If with ought treated effluent uses for the irrigation that is more toxic for plants plant, and aquatic phenomena. In the view of sugar industry waste water treatment needs physico-chemical, aerobic and anaerobic treatment methods for better quality treated wastewater that is reuse irrigation and other purpose.

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