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Treatment of wastewater resulted from sucrose, fructose and starch production by aerobic activated sludge process

Abstract

Main pollutants in wastewater, resulted from sucrose, fructose and starch industry are settlable matter, SO_2, ammonia, COD and BOD_5. Concerning pH, temperature, oil and grease no problems encountered. In this investigation most of the organic pollutants will be removed by high rate aerobic activated sludge process, but some type of reverse osmosis (RO) is recommended for total dissolved solids or inorganic salts and chlorine removal. Chemical precipitation process is suitable for phosphorus removal. Anaerobic treatment reduces the organic pollutants above 90% and they are converted to biogas with very low to negative operating cost. The proposed treatment unit presents an effluent and low cost industrial wastewater treatment plant to meet the required effluent standards. Also detailed engineering design of the various components of proposed industrial wastewater treatment plant (IWWTP) is achieved. Characterizations of wastewater after treatment fulfill the requirements of governmental regulations so it can be reused industry as cooling water or in irrigation; also the resulted sludge can be used as fertilizer or animal fodder after minor treatment.

Keywords: aerobic & anaerobic treatment, fructose syrup, glucose syrup, starch, wastewater treatment

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Introduction

Starch which is naturally occurring polymer has numerous industrial applications, as well as food, cosmetic, pharmaceutical, medicine, chemical, papermaking, textile, detergents and other industrial sectors as one of the main raw material.[1–3] Sucrose or table sugar is made out of sugar cane and sugar beet, neglecting the small part produced from sweet sorghum and sugar palm.[4] However, there are many other sweeteners that are used for our food production. Two examples are High Fructose Maize Syrups and artificial or high intense sweeteners.[1] Starch, glucose and fructose syrup in the US and in major other parts of the world are mainly produced from maize as raw material.[5] Wastewater generated from starch processing has to be treated because it represents an environmental challenge due to the large chemical oxygen demand (COD) of the wastewater, generally ranging between 6 and 10 g/L.[6–9] Removing more than 80% of COD after 3 days using Filamentous Fungi for treating starch plant wastewater was investigated.[10]

Usually settlable solids recovered by settling or clarification are reused as animals feed additives but without using any flocculants or coagulant aids in the decantation process.[8] Removal of suspended solids from industrial, domestic, building material and livestock wastewater was achieved using bio-flocculent as a new water treatment agent.[8,11–13] Bio-flock technology does not need any increasing in basic natural resources of water and land, also it minimize damage to the environment and support social sustainability & economic.[14–18] Removal rates of chemical oxygen demand (COD), total ammonia nitrogen (TAN), and suspended solids (SS) in aquaculture wastewater reached 64, 63.61, and 83.8%, respectively using a bio-flocculent-Producing Bacterium Bacillus mega-terium.[19] Reduction the environmental footprint from water and waste streams, by maximizing reuse of water, by turning waste to value, and by minimizing energy consumption and waste is the main objective of this investigation. Wastewater and sludge treatment help production of clean effluent for discharge or water reuse, recover heat and reduce the amount of sludge for disposal.

Experimental

Treated wastewater is produced from two streams which are mixed in a sump tank then passed through rotary drum screen 0.5 mm mesh to remove big suspended particles. After screening the effluent flows to a conditioning tank in which FeCl3 and micronutrients (Co, Cu, Mo and Ni) are dosed. From there, the wastewater is transferred to anaerobic treatment step in two bio-bed reactors. Then wastewater was subjected to aeration then to settling processes. Finally evolved biogases are collected for various purposes and sludge produced is dewatered to disposal.

Technological Considerations

The main components of the treatment plant are similar to earlier designs in previous investigations[20–22] but the essential difference lies in using two bio-bed reactors due to the high load of BOD. So design is based mainly on solids removal and buffering, using a conditioning tank, an-aerobic high rate treatment with a bio-bed reactor and final polishing in an aerobic type of activated sludge plant to meet the required discharge limits and evolved biogas purification from H_2S.

Proposed treatment unit

The proposed treatment plant consists mainly of:

a) Rotary drum screen 0.5mm mesh.

b) Buffering tank, with 6hours hydraulic retention time, to level out the main fluctuations inflow and composition.

c) Conditioning tank to condition the feed for the bio-bed reactor.

d) Two bio-bed reactors equipped with all required internals (influent distribution system and three phase separators (settlers).

e) Anaerobic sludge holding tank (for granular anaerobic sludge).

f) Aerobic polishing tank (high loaded activated sludge type) to meet the discharge limits.

g) Sludge dewatering facilities.

The above components are provided with mixers, pumps of different types, blowers, centrifuge, air distributer, pH& temperature measurement instruments, dosing devices and control system.

Design basis

Taking in consideration industrial effluent characteristics design starting points are:

- Water flow–3960m^3/day
- COD load–8000mg/l
- BOD load–4624mg/l
- Sludge load–0.5kg BOD/m^3
- Sludge concentration–3kg sludge/m^3
- Sludge productionv0.6kg sludge/kg BOD removed
- Sludge return flow–100%
- Sludge return capacity–165m^3/hr
- Surplus sludge production–1,560kg sludge/day
- Final Surface load of clarifier–1m/hr
- Aeration capacity required–300 kg O_2/hr
- Total air requirement of–5.500 Nm^3/hr

Results & discussion

Experimental data from laboratory bench scale and results of analyses of wastewater for the mixed two effluent streams were the basis of the design of the industrial wastewater treatment plant (IWWTP).

Treatment process description

The design is based on solids removal and buffering, use of a conditioning tank, anaerobic high rate treatment with a BIOBED reactor and final polishing in an aerobic type of activated sludge plant to meet the requirements of governmental Egyptian regulations for discharging limits.

Principal units of IWWTP

Detailed engineering design of the various components of proposed IWWTP is given in the following paragraphs.

Effluent pumping station, solids removal (screens), buffer tank and feed pumps to the conditioning tank

The Buffer tank is designed to receive the industrial wastewater coming from the lift pump station. It is designed with the suitable capacity, completed with the transfer pumps and the accessories. It is assumed that the factory effluent is supplied at sufficient pressure in the vicinity of the conditioning tank. Some valves/piping will be required to connect a by-pass to the aerobic plant and sampling facilities. Conditioning tank must be provided with a mixer, a splatter box to split anaerobic effluent and anaerobic recycling, facilities for dosing chemicals and micronutrients (Co, Cu, Mo and Ni) fed to the bio-bed reactor. The Conditioning tank operate under normal operating pressure in the gas/head space 0.05 bar/design pressure 0.075 bars)-Biogas from the reactor will be extracted via (the gas-space) of the conditioning tank.

Chemicals and micronutrients dosing facilities

Caustic soda, $FeCl_3$ and micronutrients dosing facilities are to be designed for adding Fe, and micronutrients (if required, Co, Cu, Mo and Ni) as a nutrient (in the feed line to the reactor. Storage tank volumes for used chemicals depend on available (minimum) bulk supply volume and were supplied dosing pumps regulated by timer. Two (one duty, one standby) centrifugal pumps with a capacity of 252m^3/hr each will be required to feed the conditioned wastewater from the conditioning tank to the BIOBED reactor.

BIOBED reactor feed pump

Two centrifugal pumps (one duty, one standby) required to feed the conditioned wastewater from the conditioning tank to the BIOBED reactor.

BIOBED reactors

The BIOBED process is a cross-breeding between the UASB process and the FB (Fluid Bed) process. The Biomass in the reactor is present in a granular form. These granules resemble the granules that occur in the reactor. It is in fact possible to inoculate a BIOBED reactor with granular sludge that originates from the reactor. Due to the conditions imposed on the sludge with respect to liquid and gas up flow velocities a granular sludge develops which has excellent settling properties (35-80m/h) and in some cases a higher specific activity than in the UASB concept. In order to create optimal conditions for the growth of the granular sludge a mild hydraulic regime near the outlet nozzles in the distribution system is of special importance. This is more or less in contradiction with the need for good flow distribution and the minimizing of dead space. However, due to a high hydraulic throughput a good compromise was found. Due to the high up flow velocities for water and gas (can be both as high as 6m/h) the necessity arises to perform an excellent phase separation for water-biogas and sludge in the top of the reactor and Figure 1 illustrates a schematic drawing of the used BIOBED reactor.

Biogas Handling

Biogas produced contained approximately 75-80% of CH_4, H_2S of 0.5 % and average caloric value of 32MJ/m^3. The biogas production from the reactor will be measured and released to prevent overloading of the plant (interlock with the conditioning tank feed pumps).

Anaerobic sludge holding tank

This tank has adequate capacity to store organic biomass sufficient to replace the content of sludge in the reactor in emergency cases. This tank is supplied with a sludge pump to transfer the sludge from the reactor to the anaerobic sludge holding tank and vice versa.

Aeration tank

Aerobic biological treatment contact between the effluent from anaerobic plant and the bacterial growth was achieved for removal of organic materials from the anaerobic effluent. Mixing and aeration are achieved by diffusing air from air blowers. The tank is a channel shape with horizontal helical flow, due to the diffused air effect. Sludge from the final settling tanks will be recycled by a submersible and/or air lift pump to the front inlet area of the aeration tank. The following Figure 2 shows the pipelines and the PFD of the treatment plant.

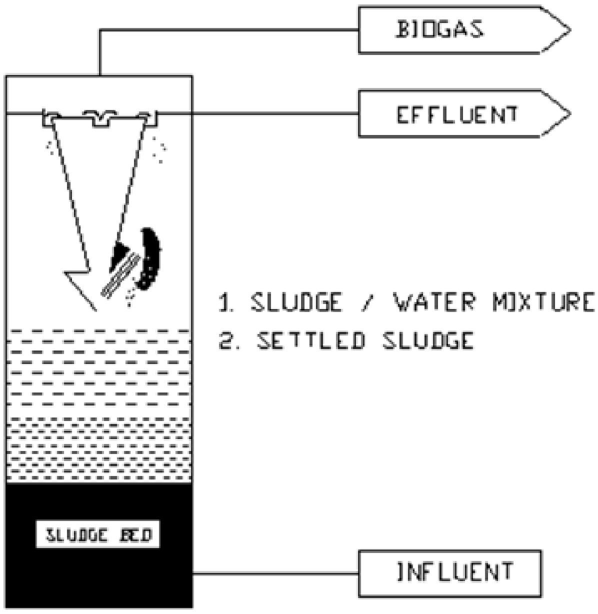

Figure 1 Drawing of a BIOBED reactor.

Settling tank

This tank is designed to remove the stabilized organic matters from aeration tank using the mechanical properties of the suspended solids. The tank is circular in shape with radial flow from the control stilling chamber to the perimeter. The inlet pipe enters the stilling chamber and the outlet is a perimeter overflow weir. The tank bottom is of conical base inclined by 45 degree and is equipped with outlet pipes for sludge removal using centrifugal pumps.

$FeSO_4$ holding tank

It is a cylindrical tank made of high density polyethylene (HDPE) for ferrous sulphate storage.

Sludge tank

This tank is rectangular in shape and it is equipped with air diffusers and receives sludge from the final settling tank for sludge storage period. In this unit additional more sludge stabilization was achieved to reduce its volume to 50% of the influent.

Sludge thickening

In this step sludge was dewatered thickening then centrifuged with polymer conditioning to 15%.

Process performance and evaluation

The results of the final analyzes show the quality of the treated water and the good performance of the treatment process as shown in the following results which enable us to reuse treated water according to the Egyptian environmental regulations and laws:

a) pH 6-9
b) COD 60mg/l
c) BOD 20mg/l
d) TSS 20mg/l
e) O&G5 mg/l

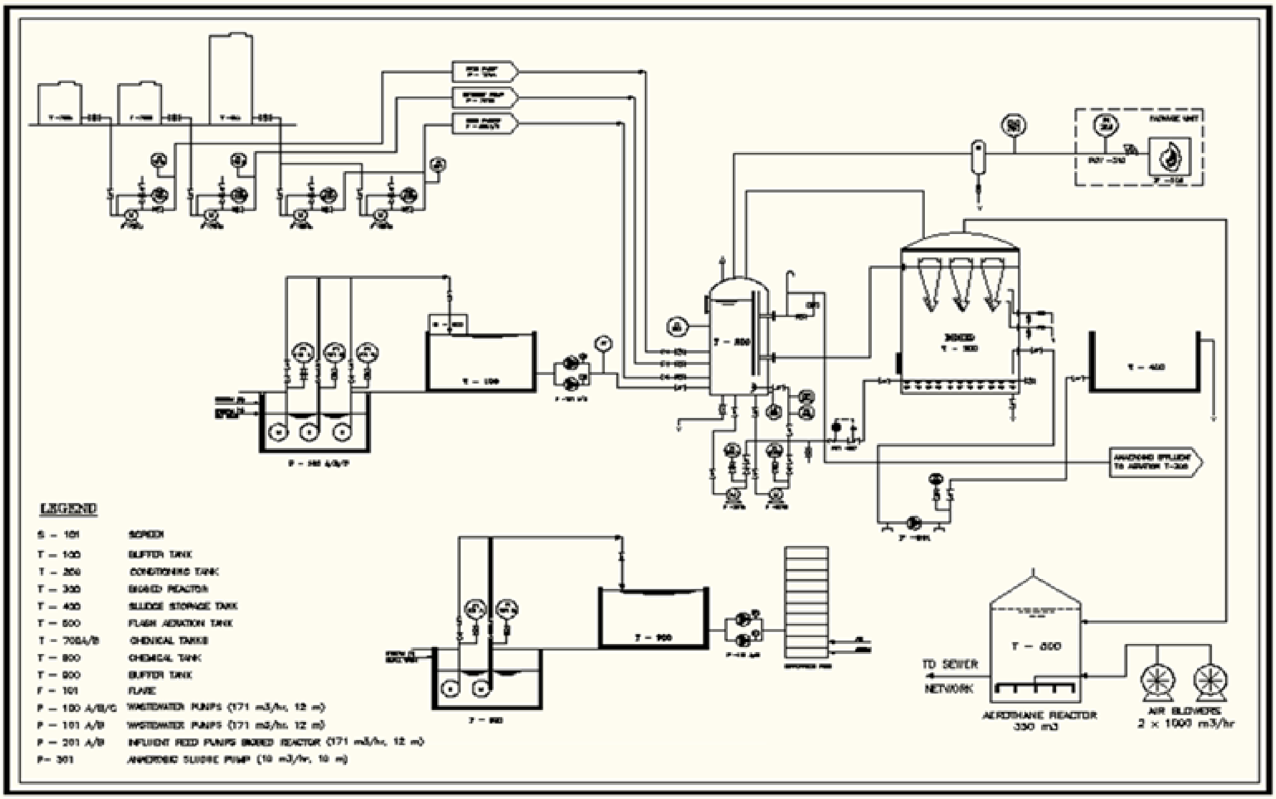

Figure 2 shows the pipelines and the PFD of the treatment plant.

Conclusion

The recommended treatment process of wastewater effluent is suitable with high performance because:

a) The organic compounds present in the wastewater are largely degraded by anaerobic sludge treatment and converted to biogas which can be used as fuel for other purposes in the plant.

b) The anaerobic system reduces the organic pollutants in wastewater by above 90% with moderate investment and very low to negative operating cost.

c) The specifications of treated wastewater fulfill the requirements of governmental regulations so it can be reused as coolant or in irrigation of non edible crops like wood trees.

d) Whether anaerobic system is economical depends on the amount of biogas produced from the system.

Acknowledgments

None.

Conflicts of interest

The author declares that there is no conflicts of interest.

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