Investigation on Wastewater Treatment of Maize Processing Effluent

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Abstract— In this study a treatment unit for wastewater resulted from maize processing for sucrose, fructose and starch production is proposed. Wastewater obtained with a capacity of 3960 m^3/day is analysed. Main pollutants in wastewater are settable matter, sulphide, SO_2, ammonia; COD and BOD while no problems concerning pH, temperature, oil and grease. The recommended treatment process is a high rate aerobic activated sludge (sludge load 0.5 kg BOD/ kg sludge day). Total dissolved solids will be critical even after aerobic. Most of the organic will be removed, but inorganic salts may be too high. This will require some type of reverse osmosis (RO) treatment which is suitable also for Cl--removal; while total phosphorus removal will be done by chemical precipitation.

Keywords: Glucose syrup, Fructose maize syrup, Strach, Maize wastewater; Aerobic & Anaerobic treatment.

1 Introduction

Maize starch is the major industrial raw material for glucose and fructose syrup production in the US and in major other parts of the world [1].

The industrial processing of starch to sugars can be carried out either by acid or enzymatic hydrolysis [2]. However the use of enzymes is preferred to acid, once it produces high yields of desired products and less formation of undesired products such as toxic compounds [3].Chemically, sugar is the substance sucrose which can be hydrolysed in acidic solution (i.e. below pH 7) to from the mono-saccharides glucose and fructose [4]. For starch production, maize grains are digested, which is capital intensive and time consuming (24 to 52h) and acidic pH (4 to 5) created with lactic bacteria [5,6] which inhibits the survival and multiplication of bacterial pathogens [7].

A large quantity of wastewater is resulting in all process steps as well as from washing of industrial surfaces [8]. The waste effluents for processing products from fresh maize containing substantial amount of protein [9].

Different techniquies are used to treate the wastewater before discharging as anaerobic and/or aerobic degradation [10], electrocoagulation [11] etc.

The main objective of this investigation is to treate the waste effluent and maximize water consumption by recycling portion of treated water to reuse in washing steps or elsewhere. Proposed treatment unit presents an effluent and low cost indusrial wastewater treatment plant to meet the required effluent standards.

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2 Experimental Techniques

2.1 Wastewater Characteristics

Samples collected from the 165 m^3/hr, resulting wastewater from National Company for Maize Products (NCMP) in Egypt; are analyzed and results of analyses are shown in table (1).

Table (1): NCMP Waste Effluent Composition

PARAMETER	AVERAGE	Permissable Limits *
Wastewater Flow (m^3/d)	3,960	
(m^3/ hr)	165	
Chemical Oxygen Demand COD (mg/l)	8000	< 700
COD (kg/day)	31,680	-
COD / BOD_5 ratio	1.73	1.75
BOD5 (kg/day)	18,312	-
Temperature (°C)	30 - 35	< 40
Suspended Solids (SS mg/l)	< 600	< 500
N-Kjeldahi (mg N/l)	125	40
Phosphate (mg PO_4 /l)	12	30
pH	5 - 8	6-10
Sulphate (mg SO_4 /l)	150	< 10

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* Minister of Housing & Utilities Decree 463/1962 implementing Law 93/1962: section 6 sets the specification and standards that must be fulfilled for wastewater discharge into public sewers (Egypt).

Furthermore we have assumed that there are no toxic or inhibiting substances in the wastewater which could negatively influence the tratment process.

2.2 Technological Considerations

This principal set-up of the plant is similar as in the earlier designs mentioned in prevoius studies [12, 13 & 14].Main difference is two Biobed reactors in parallel are used (because of the high load of BOD) instead of one. 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 meat the required discharge limits.For the moment it is assumed that the biogas will be flared. Biogas purification for H_2S (H_2S in the Biogas will be approximately 0.5 vol. %), can be offered as an option.

Biological treatment processes have the primary purpose of removing organic materials from the effluent. Biological treatment process is expected to remove only biodegradable fraction of the organic materials present. Aeration devices in biological treatment reactors should be designed as that they can transfer oxygen at a sufficient rate to satisfy the demaned of the biomass and maintain the dissolved oxygen concentration above 2 kg/m^3 [15]. Over the years experinace has indicated that 43 – 123 m^3 of air/kg BOD treated are required [16].

2.2.1 Experimental Procedure

The factory produces two streams of wastewater which are mixed in a sump tank. The effluent from the sump tank passes through a rotary screen 0.5 mm mesh to remove coarse solids, then flows to a buffer tank then to a conditioning tank in which NaOH is injected to control the process pH while $FeCl_3$ and micronutrients (Co, Cu, Mo and Ni) are dosed. From there, the wastewater is transfered to two biobed reactors to treat it anaerobically. Evolved biogases are collected for various purposes and sludge produced is dewatered to disposal. Effluent from biobed reactors flows to aeration tank then to a settler tank.

2.2.2 Proposed Treatment Unit

From the output of the above experimental steps the main components of the treatment plant were suggested as follows:

a. Static or rotary down screen,
b. Buffering tank,
c. Conditioning tank,
d. Two biobed reactors,
e. Aeration tank,
f. Settling tank,
g. Sludge holding tank,
h. Sludge thichener, and
i. Centrifuge

The above components are provided with different types of pumps, air blowers, storage tanks, piping, control and instrumentation system.

3 Results and Discussion

The design of the wastewater treatment plant is based on information resulted from analyses of wastewater and experimental data from laboratory and bench scale for the mixed two effluent streams. Figure (1) shows the block flow diagram for the proposed industrial wastewater treatment plant (IWWTP).

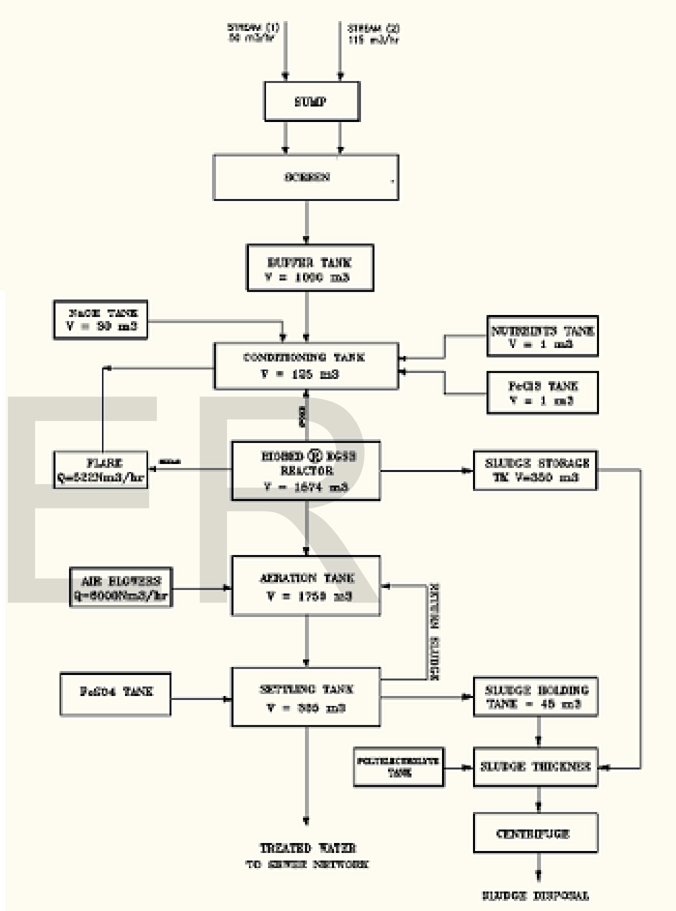

Figure (1) BLOCK FLOW DIAGRAM FOR NCMP IWWT PLANT

3.1 Principal Steps of IWWTP

Details for the dimensioning of the various components are explained below in the coming section considering 3960 m3/day (165m^3/hr) of wastewater loaded with 31680 kg COD/day and 18312 kg/day of BOD.

3.2 Process Descriptions

3.2.1 Pumping Station, Screens, Buffer Tank

The buffer tank is designed to receive the Industrial wastewater coming from the lift pump station. It is designed with the suitable capacity, complete with the transfer pumps and the accessories. It is assumed that the factory effluent is

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supplied at sufficient pressure in the vicinity of the conditioning tank.

Some valves / piping will be required to connect a by-pass possibility to the aerobic plant (manual operated) and (manual) sampling facilities.

3.2.2 Conditioning Tank

The conditioning tank will need to have a wet volume of 125 m^3.We have assumed that a separate acidification tank is not required, so a hydraulic retention time of approx. 0.5 hours (based on the design feed flow to the reactor) is sufficient.

3.2.3 Caustic Dosing Facilities

Dosing average caustic dosing is 0.075 kg NaOH (100%) / kg COD removed. This results into a caustic consumption of 1,800 kg NaOH (100%) per day or ± 3.75 m^3 (33% NaOH) per day.

3.2.4 $FeCl_3$ and Micronutrients Dosing Facilities

$FeCl_3$ 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 feedline to the reactor). Design average Fe requirement is 5 ppm. Design average concentrations for Co, Cu, Mo and Ni are respectively 0.01, 0.025, 0.001 and 0.035 ppm.

This results into a consumption of 20 kg Fe / day or 100 l / day (41 %) $FeCl_3$ solution to be mixed with 20 l / day of micronutrients solution.

3.2.5 Biobed Reactor Feed Pumps

Two (one duty, one standby) centrifugal pumps with a capacity of 252 m^3/ hr each will be required to feed the conditioned wastewater from the conditioning tank to the biobed reactor.

3.2.6 Biobed Reactors

High biomass concentrations can be maintained resulting in high COD loading rates (15-30 kg COD removed / m^3 active volume. day). Due to the high upflow velocities for water and gas (can be both as high as 6 m / h) the necessity arises to perform an excellent phase separation for water - Biogas and sludge in the top of the reactor. This is facilitated by a specially designed, developed and patented settler.

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.When the waste water contains a large amount of readily settleable suspended solids, these will be washed out from the Biobed reactor, and will not have a negative influence on the sludge quality (dilute, the active sludge).When the wastewater contains specific toxic, but biodegradable, compounds (e.g. phenol - formaldehyde - benzaldehyde etc.) the Biobed system can be applied due to the fact that a high internal dilution flow (recirculation) decreases the chemical concentrations be low the critical level. In most cases the choice for a Biobed system will be determined by other aspects like price, space requirement etc. (all non - technological considerations).

3.2.7 Biogas Handling

The Biogas production of the reactor will be measured and used to prevent overloading of the plant (interlock with the conditioning tank feed pumps).

3.2.8 Anaerobic Sludge Holding Tank

To enable a quick re - start of both reactions, a 350 m^3 wet volume Anaerobic sludge holding tank has been taken in the design (alternatively a lagoon). The tank has sufficient capacity to store approx. 17,500 kg of organic biomass which is sufficient to replace the content of sludge in the reactor in emergency cases.

3.2.9 Anaerobic Surplus Sludge Pump

To enable to pump sludge from the reactor to the Anaerobic sludge holding tank and viseversa or a truck for disposal off site, a sludge pump, with a capacity of 10 m^3 /h will be required.

3.3 Aerobic Activated Sludge Process

3.3.1 Design Basis

- Flow 165m^3/hr.
- COD load (after anaerobic) < 6,000 kg COD/day.
- BOD load (after anaerobic) < 2,600 kg BOD/day.

3.3.2 Aeration Process Description

Direct gravity flow from the spitterpipe at the conditioning tank to the aeration basin (inlet under water) no intermediate buffer tank is required.

3.3.2.a Aeration Tank

This unit is designed to achieve the Aerobic biological treatment contact between the effluent from anaerobic plant and the bacterial growth to achieve the removal of the organic materials from the anaerobic effluent. The mixing and aeration are achieved by air diffusing with air blowers. The returned sludge from the final settling tanks will be transfer by a submersible and/or air lift pump to the front inlet area of the aeration tank.

3.3.2.b Settling Tank

This tank is cylindrical in shape with conical bottom and radial flow from the control stilling chamber to the perimeter. The inlet is a pipe enters the stilling chamber and the outlet is a perimeter overflow weir. The tank bottom is inclined by 45 degrees to the hopper bottom area that is equipped with outlet pipes for sludge removal using centrifugal pumps.

3.3.2.c FeSO$_4$ Storage Tank

Number of	One (1)
Volume (net indicative)	1.0 m^3
Material	*HDPE
Medium	FeSO$_4$ Solution

* HDPE (High-density polyethylene)

3.3.2.d Sludge Holding Tank

This tank is designed to achieve additional sludge stabilization to decrease its volume. The unit consists of a rectangular tank equipped with air diffusers and receives sludge from the final settling tank for sludge storage period.

The effluent sludge is thickened and its volume is reduced to 50% of the influent.

3.3.2.e Sludge Dewatering System

This system consists of:

- A picket fence sludge thickener with rakes and gear box.
- Centrifuge with polymer conditioning and control for sludge dewatering to 15 %with a capacity of 15 m^3/hr.

3.4 Evaluation of Overall Treatment Processes

The good functioning of the overall treatment process appears in the result of the final effluent quantity as illustrated in Table (2)

Table (2) Characteristics of Final Effluent

Parameters	Units	Values
pH		6 – 9
COD	mg/l	700
BOD	mg/l	400
Settleable 10	cm^3/l	5
Settleable 30	cm^3/l	10
Color		Colorless
Sulfides	mg/l	1
Chlorides	mg/l	100
Ammonia	mg/l	50
TSS	mg/l	500
Oil & grease	mg/l	100
Max. Temp.	^oC	< 40

It is clear that the treated effluent fulfill with a great extent the permissible limits regulations in EGYPT.

4 Conclusions

- The recommended treatment of NCMP wastwater effluent is suitable due to its high performance.
- The sepecifications of treated wastewater fulfill the requirments of governmental regulations to discharge in sewer network system.
- 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 the plant's steam boiler.
- The anaerobic system which reduces the organic water pollution above 90% allows moderate investment and very low to negative operating cost.
- Whether anaerobic system is economical depends on the amount of biogas the system produces.

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