Anaerobic treatment of wastewater generated from meat processing industry using up flow anaerobic sludge blanket (UASB) reactor

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Submitted to the college of engineering

In partial fulfillment of the requirements for the

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Chapter One

Proposal

1.1 Introduction

In all communities, wastewater treatment is considered as a crucial environmental issue. Scientists all over the world have been developing new treatment methods for wastewater in order to avoid its adverse effects. Sound and safe handling of wastewater is a sign for civilization and social thriving and can turn out as an important resource of energy for the country if it is properly utilized.

Wastewater is simply that part of water supply to the community or industry which has been used for different purposes and has been mixed with solids either suspended or dissolved. Depends on the source, wastewater may contain harmful biological and chemical pollutants, such as pathogens, microorganisms and toxic compounds. This wastewater can cause a serious pollution problem to eco-systems and threats human's life and public health if not properly managed [1].

Generally, industrial wastewater which produces by manufacturing processes, can be classified into two types:

Inorganic effluent mainly produced from the coal and steel industry, from the nonmetallic minerals industry, and from commercial enterprises and industries of metal surface processing (iron picking works and electroplating plants). This type of wastewater contains heavy metals which are very hazardous and toxic. Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni), cobalt (Co), cadmium (Cd), lead (Pb), arsenic (As), mercury (Hg), and chromium (Cr) are heavy metals [2].

Organic industrial and agro-industrial wastewater effluent from chemical industries, pharmaceutical, oil refining industry, cosmetics, glue and adhesives, soaps, pesticides, herbicides, and food processing industries, is mostly biodegradable, although it may contain toxic materials. This wastewater is characterized by having high concentrations of (COD) and (SS) depending on the source of generation [3].

In Palestine, food industry has been growing fast as a result of rapid population growth which in turn has led to an increasing demand on suppliers, and thus created a challenge for manufacturers. In the meantime, it is noted there is an increase in wastewater and other wastes which usually discharged to the open environment without any treatment, causing massive environmental and public health problems. Among different sources of wastewater, olive mills wastewater, dairy wastewater, potato and meat production are the most recognized.

One of the main sectors of food processing in Palestine is the meat processing industry, which results from the slaughtering of animals in order to manufacture a primary meat output like Beef Mortadella, Turkey Mortadella, Chicken Mortadella, Sausage and Hotdogs… etc. [4].

The production of the above mentioned types of meat products is accompanied by generation of wastewater. The wastewater content of the meat processing commonly includes high concentration of organic material, from body fluids, washing and cooking, and from used supplementary materials like starch and soya. Therefore, this wastewater is expected to contain high concentrations of (BOD_5) and (COD) in addition to (SS). Currently this wastewater is disposed of in an open environment without any kind of treatment causing deterioration of environment [5]. The treatment of this type and other types of wastewater should receive utmost attention.

Wastewater can be treated in three main techniques: physical, chemical and biological methods. The last method is best suited for wastewater with high organic content. For industrial wastewater treatment, both aerobic and anaerobic processes can be used. However, aerobic treatment is not efficient enough to handle the high pollutant concentration and high organic load. Unlike aerobic treatment, Anaerobic treatment generates small amount of biomass (sludge). Anaerobic processes have many advantages, mainly, methane production, which can be utilized as an energy source. Also, they require less operating energy than aerobic treatment [6].

The efficiency of the anaerobic process is highly affected by environmental conditions such as pH, temperature, and nutrients, SS, (C/N) ratio. The rate of biodegradation of organics is enhanced at temperatures (mesophilic conditions 32-39ºC), optimum carbon to nitrogen ratio is in the range (20–30:1), and the optimal pH value to be most favorable for Methanogenesis range, between (6.8 -7.2) [7].

C/N ratio considerably affect the (TAN), and (VFAs) in the anaerobic digestion process. It was noted that when C/N ratio is low (i.e. < 10/1), leads to high accumulation of (TAN) in the digester and as a toxic substance, it inhibits methanogenic activity and further accumulation could result in the failure of the whole anaerobic digestion system. One method to avoid excessive ammonia accumulation is to adjust the C/N ratios by adding high carbon content material or high carbon content wastewater, so improving the digestion performance [8].

One of the major contributors to the success of anaerobic wastewater treatment was the introduction of the so called high-rate reactor systems in which biomass retention and liquid retention are uncoupled. High reactor systems are applied to treat biodegradable compounds and even recalcitrant compounds in wastewaters. High-rate anaerobic digesters have the potential to effectively treat such wastewaters as well as enable capture of methane for use as a relatively clean energy source. Several types of high rate anaerobic reactor systems have been developed since three decades, to treat different types of wastewaters. The most commonly used reactors are the completely mixed anaerobic digester, the up flow and down flow anaerobic filter, anaerobic fluidized and expanded bed, expanded granular sludge bed (EGSB) reactor, anaerobic sequencing batch reactor (ASBR), and up flow anaerobic sludge blanket (UASB) reactor and anaerobic batch reactors [9].

The USAB reactor is the mostly demonstrated high rate reactor system and which is very attractive in tropical countries and hot climate regions like Palestine. Operating UASB is simple, the equipment and operation are not too expensive, and the process works better at almost all ranges of temperature. Moreover, the UASB reactor could be built from local materials. Generally used to treat wastewater with high organic contents, treatment of different types of wastewaters including domestic, industrial, agricultural and agro-industrial wastes. UASB reactor is a septic tank with a sludge bed in which organic pollutants present in wastewater are decomposed anaerobically under a joint action of different types of bacteria, resulting in biogas production, mainly methane and carbon dioxide as by product [10].

For high strength wastewaters, to achieve an appropriate organic matter removal efficiency at (HRT), UASB reactor with no doubt is applied for efficiently treating such types of wastewater including meat processing wastewater. During the process, different major parameters like pH, temperature, nutrients and other parameters are controlled to achieve the best implementation of the reactor [11].

This study aims at assessing the feasibility of using the UASB reactor for treating wastewater produced from Siniora Food Industries company in Al-Azaria in Jerusalem.

The production operations of Siniora began in 1920 in Jerusalem the city which the brand name has been related to for years. The company owned two factories which helped developing and improving the production year after year until today. According to the expansion plans, the factories were extended and production was enhanced by adding more production lines to keep pace with the latest technologies upon the highest quality standards and to cover markets abroad. Siniora today owns the most advanced factory in the field of processed meat compared to many international factories, and the factory discharged 100 m^3 of wastewater daily.

1.2 Literature Review

Treatment methods of various wastewater have been investigated since many years ago. Different methods of treatment were conducted in order to obtain the optimal removal efficiency with reasonable cost. Researchers have been experimenting and performing some of treatment methods. As it turned out, the UASB is the best treatment choice available [12].

In an (OMW) treatment study, a laboratory scale UASB operated for eight months, was used to reduce the COD as a major OMW pollutant. The results showed that under the specified parameters, COD concentration increased gradually from 5,000-30,000 mg/L and the efficiency improved significantly during the operation from 46%-84% COD removal [13]. Other, study also shows that the UASB reactor after operating for 6 months at 35 ± 2 ◦C and pH 7 removed more than 80% of the inlet COD concentration of over 40,000 mg /L, and produces about 300 L biogas/kg COD biodegraded [14].

A research regarding Slaughterhouse wastewater treatment described two identical UASB reactors at two different process temperatures of 30°C and 20°C. Both reactors were operated under semi-continuous conditions. After achieving a steady state conditions, the average treatment efficiency of the filtered COD fraction for both reactors during the period was 85%. With regard to the removal of the total COD, it appears that reactor at 30°C performed slightly better than it did at 20°C [15]. In addition, a study using UASB reactors had a working volume of 2 L was operated at 37°C. The UASB reactor was run at (OLR) of 1–6.5 kg COD/m^3/day, The COD removal reached 90% [16].

A UASB reactor was used to treat (DWW). UASB reactor was operated at a constant HRT of 24 h throughout the study, while OLR varied from 1.9 to 4.4 kg COD total/m^3. d due to changes in influent composition. The average total (COD total) and total BOD5 concentrations of the UASB reactor effluent were 1385 and 576 mg/L respectively. The results showed the UASB reactor was efficient in treating DWW at an average temperature of 20ºC and a HRT of 24 h. The reactor achieved removal values of 69% for COD total,79% for BOD_5 and 72% for (TSS) [17].

UASB was applied in potato wastewater treatment, temperatures were maintained at 37ºC, with an active volume of 0.84 L and a constant flow rate of 5 mL/h. After 100 days of experiments, the results showed that OLR increased from 1.5 to 7.0 g COD/L/day, and the COD removal efficiencies of reactor were greater than 90%. The methane yield increased by increasing OLR up to 0.23 L CH_4/g COD degraded in the UASB reactor [18].

In a sugar cane mill, huge amounts of wastewater with large quantities of SS and organic matter are generated. The UASB reactor was applied to provide some sort of pre-treatment for the mill's effluent. The temperature of the rector was maintained at (33–36.8 ºC). The results showed that more than 90% COD removal can be obtained with organic loads lower than 16 kg COD m^{-3} d^{-1}, and the treatment removed 71% TSS, 43% COD total [19].

Another successful application of UASB reactor was in treating wastewater of cheese industry. The system showed stable operation up to a 75% cheese whey fraction in the feedstock, at an applied organic loading rate of 19.4 kg COD m-3 d -1, and under a constant HRT of 2.2 days. COD removal of 94.7% and a volumetric methane production rate of 6.4 m^3 CH4/ m^3d were obtained [20].

Wastewater produced from fish processing contains high levels of SS, which are mainly proteins and lipids. UASB was found to be efficient in treating wastewater with a high lipid content (47% of the total COD). The total COD removed andconverted to methane was 92% and 47%, respectively. However, in treating wastewater that contains 3–4 g\L total COD of which 5–9% was lipids, the COD removal efficiency and the fraction converted to methane were 78% and 61%, respectively [21].

As for the untreated biomedical wastewater, UASB reactor is efficient enough for treating such kind of wastewater. In this study, the maximum COD removal of 81% was obtained at an OLR range of (50 – 60) mg COD/L day and the maximum turbidity removal of 73% was obtained at an OLR range of (70 – 80) mg COD/L day [22].

1.3 Problem Statement

This research project will investigate the following main and sub main questions.

- **Main Question**

Is the high rate continuous flow UASB reactor technically feasible in treating wastewater generated form meat processing industry?

- **Sub problems**

1. What are the physical and chemical characteristics of wastewater?

2. How does the operating conditions including (C/N ratio, pH, temperature) affect the treatment efficiency?

3. What is the effect of Organic Loading Rate on the reactor performance?

4. What is the highest organic loading rate, the reactor can accommodate without a decline in its performance at steady state conditions?

1.4 Goals and Objectives

The main objective of this work is to investigate the applicability of UASB reactor for the treatment of wastewater produced from meat processing industry.

- **Sub goals:**

1. To characterize the wastewater that is generated from the factory.
2. To investigate the effectiveness of UASB reactor in treating this type of wastewater based on COD removal.
3. To monitor the amount of biogas generated and the percentage of methane.

1.5 Significance of Study

The importance of this study is to use cheap and efficient treatment using UASB reactor in order to reduce the organic load and other pollutants to acceptable levels for municipal wastewater discharge to sewer system and to evaluate the methane production rate as by product (energy source) to offset the needs of fossil fuels.

1.6 Research Methodology

- Collection of wastewater from the Siniora Food Industries.
- Collection of sludge from AL-Beera wastewater treatment plant based in AL-Beera city, Ramallah.
- The reactor will be seeded with anaerobic sewage sludge
- The Wastewater will be introduced to the reactor using master-flexi pump.
- pH, COD of both influent and effluent will be monitored and the biogas production rate will be measured on daily basis).

1.7 Action Plan

This research project was implemented in two stages. The action plans for the two stages are illustrated in table 1.1 and in table 1.2.

Table 1.1 Action plan for the first semester.

TASKS	February				March				April				May
	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1	Wk_2	Wk_3	Wk_4	Wk_1
Identification of Project Idea													
Literature Review													
Field visits													
Lab test													
Due date													

Table 1.2 Action plan for the second semester.

TASKS	September	October	November	December

	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4	W_1	W_2	W_3	W_4
Filed visit																
Wastewater samples collection																
Sludge sample collection																
Lab tests for both samples																
UASB start up																
Monitoring factors																
Due date																

1.8 Budget

This project is expected to have a total cost of $ 900, as shown in table 1.3.

Table 1.3 The total estimated cost for project implementation.

NO.	Item	Cost
1	Transportation	$ 100
2	Sample collection	$ 100
3	Equipment (glassware, wet gas meter)	$ 300
4	Samples analysis	$ 200
5	Chemicals	$ 200
Total cost		$ 900

Chapter Two

Wastewater treatment

2.1 Introduction

Wastewater generates from domestic sewage, urban run-off, agriculture wastewater and industrial effluents. Typically, these effluents contain various types of pollutants, such as: inorganic chemicals, organic compounds, toxic materials and pathogens. Accordingly, the effects of discharging untreated produced water into the environment represent a significant public and environmental concern [23].

2.2 Water Pollution

Water pollution is defined as any change in the chemical, physical and biological characteristics of the water bodies due to the entry of contaminates. Different types of pollutants may be present in wastewater [24]:

1. Organic compounds: are chemicals that contain carbon atoms, this includes pesticides, solvent, chloroform, gasoline, herbicides pharmaceutical, plastic and industrial chemicals from a variety of industrial and agricultural operations. Some organic compounds leach from landfills into the surface and groundwater. Other, such as pesticides, seep downward through soil into the groundwater. Some industries discharge their waste water directly into the valleys.

2. Inorganic chemicals: are contaminants which contain element other than carbon, such as salts, acids and heavy metals. Most of inorganic compounds find their way into both surface and groundwater from different sources such as mines, irrigation, industries and urban runoff. Some of inorganic pollutants are toxic to the aquatic life which makes the water unsuitable for survival, drinking and other purposes.

3. Pathogens: these are microorganisms such as bacteria, viruses and protozoa that cause diseases such as typhoid fever, cholera and dysentery.

2.3 Main Sources of Wastewater Pollution[25]

2.3.1 Domestic Wastewater

Domestic sewage, also called sanitary sewage, is discharge from commercial and residential establishments, it contains organic matter, detergents, laundry, bathing and others. The main constituents, contained in wastewater are (TDS), (TSS), Nitrogen, Phosphorus, Pathogenic viruses, bacteria, protozoa and helminthes may be present in domestic wastewater.

2.3.2 Agricultural Wastewater

Agricultural wastewater generates from Cultivated land and pasture, fertilizer, pesticides and the water from washing the fruit and vegetables. It contains dissolved organic solid, nitrogen, phosphorus, and sulfate.

2.3.3 Industrial Wastewater

Wastewater generated from manufacturing and cooling processes. It contains organics substance and also high BOD, COD values which comes from soap, leather, tanneries, food processing and inorganics which is composed of high load of heavy metals and toxic compounds. The main constituents of wastewater are shown in table [2.1].

Table 2.1 Types of industry that produce inorganic and organic wastewater [26].

Organic industry	**Main pollutants**	**Inorganic industry**	**Main pollutants**
Meat processing	Proteins, SS	Mining	Metals, salts
Slaughter house	COD,BOD, SS	Fertilizers	As, Cd, Hg, Pb
Dairy and milk processing	Fat, BOD, Proteins	Tanning	Chromium

2.4 Wastewater Treatment Methods

Wastewater treatment technologies can be divided into three general methods: Physical, Chemical, and biological methods.

2.4.1 Physical Wastewater Treatment

It is considered as a primary treatment, it is a removal of substances by use of naturally occurring forces, such as gravity, electrical attraction, and van der Waal forces. It is representing a body of technologies that we refer largely to as solid-liquid separations techniques. It is including: screening, settling, Filtration, sedimentation, flotation, and adsorption [25].

2.4.2 Chemical Wastewater Treatment

It is considered as a primary treatment. The mostly implemented chemical treatment processes are: coagulation, neutralization, disinfection (chlorine, ozone, ultraviolet light), and ion exchange [24].

2.4.3 Biological Wastewater Treatment

The secondary treatment, used to remove any material remaining after primary treatment. The settled wastewater is introduced into a specially designed bioreactor under aerobic or anaerobic conditions or in sequence. The organic matter is utilized by microorganisms such as bacteria, algae, and fungi [26].

2.4.3.1 Aerobic Wastewater Treatment

Aerobic system is a biological wastewater treatment, used to break down organic matter by microorganisms (aerobes) in the presence of molecular oxygen, and then convert organic compounds into energy, new cells and residual matter. Aerobic treatment systems are suitable for the treatment of low strength wastewaters from of industries, including industrial processors (i.e. paper, pulp mills, and food processing). Aerobic processes application includes activated sludge, oxidation ditches, trickling filter, lagoon-based treatments, and aerobic digestion and other [27].

2.4.3.2 Anaerobic Wastewater Treatment [28]

Anaerobic digestion is a power generation process, in contrast to an aerobic system that generally requires a high energy input for aeration process. It's a technically simple and comparatively cheap technology which exhaust less energy, space and produces less excess sludge in comparison to the traditional aerobic digestion technology an attractive option over another treatment process .

The generation of liquid industrial waste in large quantities with high organic content due to increased manufacturing trend worldwide which, if treated properly, it can lead to a significant energy source. Anaerobic digestion seems to be best suited for processing of liquid that contains high-strength organic wastes.

There are four groups of microorganisms can be recognized in the anaerobic treatment of wastewater:

1) Hydrolysis: during anaerobic digestion, by exo-enzymes deteriorated polymer particles into smaller molecules that can cross the cell barrier. Where proteins are hydrolyzed to amino acids, a polysaccharide converted into simple sugars, and lipids to (LCFA), and this operation is also extremely sensitive to temperature and the change in temperature variability.

2) Acidogenesis: step is to transform the fastest in the anaerobic food chain, where the product in hydrolysis step (amino acids, simple sugars, LCFA) Spread inside the bacterial cell through the cell membrane and thus oxidized anaerobically. Products include at this stage of (VFAs), and alcohol, lactic acid, CO_2, H_2, NH_3, and H_2S, as well as a new cell material.

3) Acetogenesis: where products, after acidogenesis, are converted into acetate, hydrogen (H_2), and CO_2, in addition to new cell material.

4) Methanogenesis: organic matter is converted to methane and carbon dioxide by the bacteria. At the same time methanogenic archea group uses hydrogen and acetate for CH_4 formation resulting in CO_2 reduction. Influent COD is converted to gaseous form and leaves the system in this final stage. Figure 2.1shows the microbial aspect in anaerobic digestion.

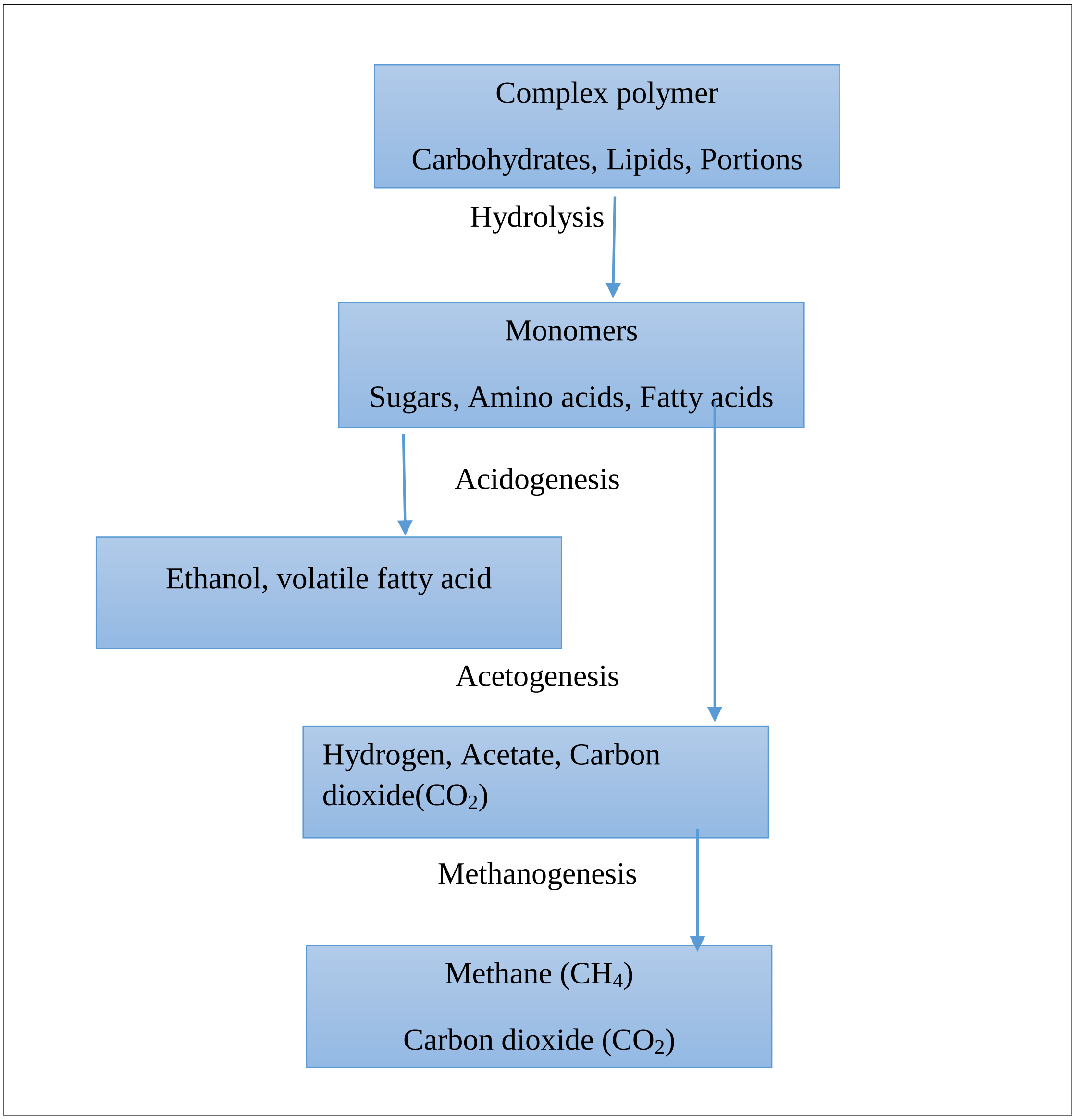

Fig 2.1 The microbial aspect in anaerobic digestion [29].

Table 2.2 Comparison of aerobic and anaerobic treatment [30].

Feature	**Aerobic**	**Anaerobic**
Sludge production	30-60 kg/100 kg COD influent	5 kg /100 kg COD influent
Energy production	Heat loss	Biogas produced (70% CH_4)
Startup time	2-4 weeks	2-4 months
Temperature sensitivity	Low	High
Organic loading rate	Moderate	High
Bioenergy and nutrient recovery	No	Yes

Anaerobic treatment is considered as a core (heart) of wastewater treatment and recovery technology. This characteristic was enhanced by the introduction of high rate reactor systems.

2.5 Types of the Reactors

To choose the most appropriate reactor type for a particular application, it is essential to conduct a systematic evaluation of different reactors configurations with the wastewater stream.

2.5.1 High Flow Rate Reactor System [31]

It is able to retain large amounts active biomass with relatively low HRT, (SRT), according to the type of biomass growth in the system, which permits the slow-growing microorganisms to remain within the reactor. The most common high rate reactor systems used in wastewater treatment are:

2.5.1.1 Completely Mixed Anaerobic Digester

The feed will enter the reactor and completely mixed anaerobic digestion will occur, with an equal (SRT) and (HRT) in the range of 15-40 days, that's provide sufficient retention time for both process and operation stability, with high solids concentrations. Completely mixed anaerobic digesters without recycle are more suitable for wastes with high solids concentrations. Although many waste streams are usually diluted, However, this system requires high volumetric loading rate is achieved with quite concentrated waste streams with a biodegradable (COD) content. Typical (OLR) for completely mixed anaerobic digester is between 1-5 kg COD/m3day.

2.5.1.2 Anaerobic Filter (AF)

Both up -flow and down- flow packed bed processes can be applied, most of the biomass is present as suspended in the interstitial pore volume of the support media. The direction of liquid flow through the packing is the major difference between another these reactors, in down-flow systems the prevention of methanogens found at the lower levels of the reactor can easily be achieved in comparison to up-flow systems. According to high efficiency the system is operated for treating various type of industrial wastewater. OLR is often in the range of 8-16 kg COD/m^3.day which higher than the design loading rates for aerobic processes.

2.5.1.3 Fluidized and Expanded Bed Reactors

In the anaerobic fluidized bed (AFB) reactor the bacteria attach with small media, such as granular activated carbon or sand, according the high flow rate around the particles good mass transfer will result, due to the large pore spaces formed through bed expansion and high specific surface area of the carriers due to their small size make fluidized bed reactors highly efficient. However, difficulty in developing strongly attached biofilm containing the correct blend of methanogens, detachment risks of microorganisms, negative effects of the dilution near the inlet as a result of high recycle rate and high energy costs due to the high recycle rate are the main drawbacks of this system. The expanded granular sludge bed (EGSB) reactor is a modification of the AFB reactor with a difference in the fluid's upward flow velocity. The up flow velocity is not as high as in the fluidized bed.

2.5.1.4 Up Flow Anaerobic Sludge Blanket Reactor

It is invented by Lettinga and his co-workers (Lettinga et al., 1980) it is used high rate of anaerobic treatment. At the bottom of the reactor wastewater enters, during some particles of biomass are suspended at the upper part of the reactor, above the sludge bed, organic matter breaks down by the bacteria living in the sludge during anaerobic digestion, a blanket zone is formed. This zone acts as a separation zone between the water flowing up and the suspended biomass.

Organic matter breaks down by bacteria living in the sludge, during anaerobic digestion and transforming it into biogas. When the bubbles rise it will mix the sludge without the assistance of any mechanical parts. The material that reaches the top of the tank pushes down by sloped walls. The normal start-up procedure generally involves feeding of the reactor continuously at low organic and volumetric loading rates, and increasing these parameters stepwise once the substrates have been reduced considerably [32]. Table 2.3 shows the advantages and disadvantages of UASB reactor. Figure 2.2 shows the component of the UASB reactor.

Table 2.3 Advantages and disadvantages of UASB reactor [33].

Advantages	**Disadvantages**
High treatment efficiency	Long startup phase.
Low sludge production	Not suitable in cold climate regions
Reduction of CH_4 and CO_2 emission	Require skilled staff for construction, operation and maintenance
No aeration system required	Treatment may be unstable with variable hydraulic and organic loads.
Low odor emissions	
Effluent is rich in nutrients and can be used for agricultural irrigation.	
No mixing in the reactor	
Production biogas can be used as energy	
Low land demand	

2.6 Factors Affecting UASB Reactor Performance [33].

1. pH

There are two responsible bacteria for hydrolysis: methane producing bacteria and acid-producing bacteria. The last one often tolerating a low pH, but the optimum pH range is 5-6. At a pH range [6.8 -7.2], the methane producing bacteria work better. But if that range is not maintained, this will cause negative effect on the performance of the reactor because the activity of the methane producing bacteria will be reduced.

2. Temperature

Temperature is the important parameter affects the anaerobic process, because it is affect the ability of microorganisms to produce biogas. The suitable temperature conditions of the reactor mesophilic or thermophilic which provides the microorganisms with low viscosity and high degradation.

3. Hydraulic Retention Time

HRT is an important for operating parameter which controls the UASB reactor performance, long HRT will have adverse effect on the sludge granulation process.

4. Organic Loading Rate

Also important parameter to control the UASB reactor performance, any increase of OLR will cause problem in the operation process, OLR is important factor for COD removal.

Chapter Three

Experiment work

3.1 Materials

Wastewater samples were collected from Siniora Food Industries Company in Al-Azaria, Jerusalem from different locations at different time intervals.Anaerobic digested sewage sludge for seeding the UASB reactor was obtained from Al-Bireh wastewater treatment plant based in AL-Beera city, Ramallah, Palestine. Table salt (NaCl), sulfuric acid (H_2SO_4) and pigment were used to preparegas collection solution. For COD test, standard potassium dichromate digestion solution, H_2SO_4, ferroin indicator solution, standard ferrous ammonium sulfate titrant (FAS)were used as reagents.

3.2 Methods

3.2.1 Characterization of Wastewater

The physical and chemical properties of wastewater were measured. The pH of the sample was measured with (Mil150 pH, accuracy .01 pH, made by MILWAUKEE COMPANY, USA), The TS and TSS were measured by drying the homogenized samples at 103 ºC for 24 h, and the VSS fraction were determined by incineration in a muffle furnace at 550 ºC for 1 h [34] .The COD wasdetermined by using closed reflux method according to standard methods [35] .The sludge inoculums was characterized for its TSS and VSS.

Fig 3.1 COD test

3.2.2 Experimental Setup

UASB was designed and fabricated for the treatment of meat processing wastewater as shown in figure (3.2). The reactor consists of:

1. Cylindrical shaped reactor made of Plexiglass [6.45L capacity].
2. Three phases [gas-liquid-solid], separator made of plastic equipped in the upper zone of the reactor.
3. Feed pump [shielding glass car pump].
4. Gas-liquid separator (1-liter capacity Erlenmeyer flask filled with 750 ml of tap water.
5. Water displacement system.
6. Wastewater distributor.
7. A silicon rubber heating tape with adjustable thermostat control was installed in a spiral around the length of the reactor.

Based on the results obtained from batch reactor experiments, a UASB reactor with a total volume of 6.45 L and working volume of 5.78 L was designed for the treatment of wastewater. The reactor was operated as batch for two days, and continued with semi continuous until it is acclimatized. The anaerobic sewage sludge was seeded in the reactor with amount 2.15 L (6 g VSS/L), which occupied about one third of the total working volume. The wastewater was fed to the reactor from tank 1 through the pipe by a pump with a flow rate of 1.5 L/d. The biogas formed from the anaerobic digestion was collected from the three separator phases through the pipe and the gas was measured by water displacement method. A gas collection solution was made of 21 g NaCl, 250 ml of distilled water and 2 g of pigment in order to observe the change. The pH of gas collection solution was brought down to (1-1.5) with (H_2SO_4) for the dissolution of carbon dioxide. The UASB reactor was operated at a constant HRT of 3.8 days, temperature of (35 ± 2 ºC) and OLR of 0.6-0.8 g COD /L. d.

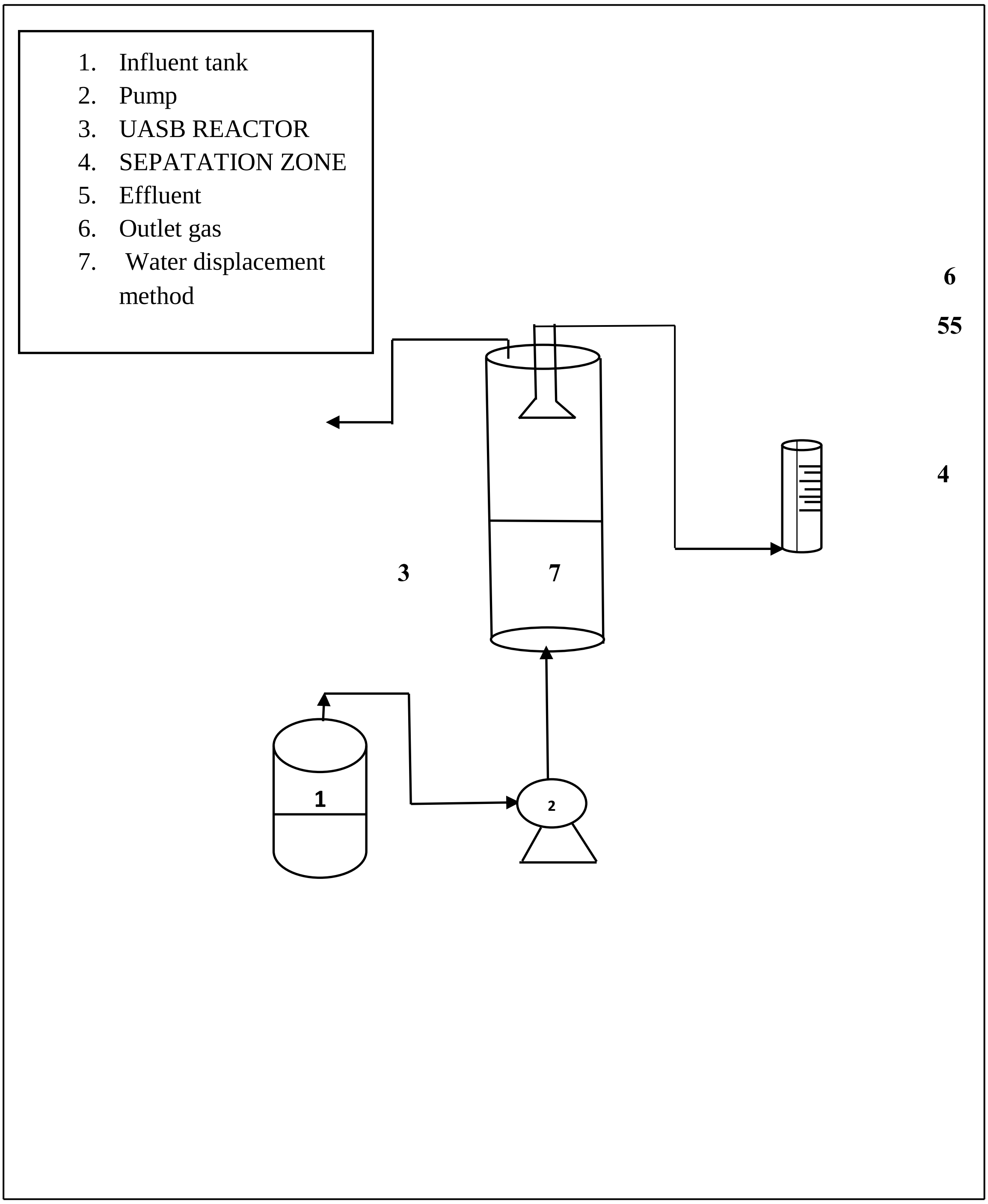

Fig 3.2 The Schematic diagram of UASB reactor

The COD mass balance applied to UASB is given as:

$\sum$ COD in = $\sum$COD out equation (3.1)

COD in = COD out +COD biogas + COD sludge equation(3.2)

COD removal efficiency % = $\frac{COD\ in - COD\ out}{COD\ in} * 100$ equation (3.3)

The OLR and HRT were calculated using equation 3.4 and 3.5 respectively:

OLR = $\frac{Q * COD\ in}{V}$ (g/L.d.) equation (3.4)

HRT = $\frac{V}{Q}$ equation (3.5)

Where:

HRT: hydraulic retention time (days),

V: volume of reactor (L), and

Q: influent flow rate (L/d)

Fig 3.3 UASB reactor in operation.

Chapter Four

Results and Discussion

4.1 sludge characteristics

The characteristics of the inoculum sludge used for UASB reactor treating MPWWinclude TS, VS, VSS, TSS. These characteristics are measured in the lab. Their values are illustrated in table 4.1.

Table 4.1 Characteristics of sludge used for UASB reactor

Parameter (g/L)	Value
TS	26.967
VS	23.696
TSS	21.972
VSS	18.73
VS/TS ratio	0.888

The measured values of these parameters were found to be similar to those in literature for anaerobic digested sewage sludge[36].

4.2 Wastewater characteristics

The physio-chemical properties of MPWW were selected for the present study. Its characteristics at the time of the experiments, which include BOD, COD, Ammonia, TSS, Total Nitrogen and pH, are shown in table (4.2).

Table 4.2 Meat processing Wastewater characteristics.

Parameters	Values
BOD (mg /L)	1340
COD (mg /L)	2243
Ammonia (mg /L)	2.6
TSS (mg /L)	760
Total nitrogen (mg /L)	149.1
Ph	6.8-7.2

From the results shown in table 4.2, this type of wastewater can be classified as low strength wastewater and the concentrations of different parameters exceeds the permitted values for the disposal of wastewater to sewer system and thus needs a treatment or at least pretreatment.

4.3 Anaerobic digestion result

The parameters were measured continuously include pH, COD and Biogas.

4.3.1 pH effect

The pH of inlet and outlet wastewater was monitored with time. Prior to feeding the influent reactor, pH value was adjusted to neutral range (6.8-7) by the addition of acid solution (H_2SO_4). Although the effluent pH was in the range (7.4–7.7), the maximum pH recorded was7.8 as shown in Fig (5.1). This indicates an active metabolism occurring by the methanogenic bacteria (mainly the decomposition of fatty acids). Temperature was maintained at 35±2 C°.

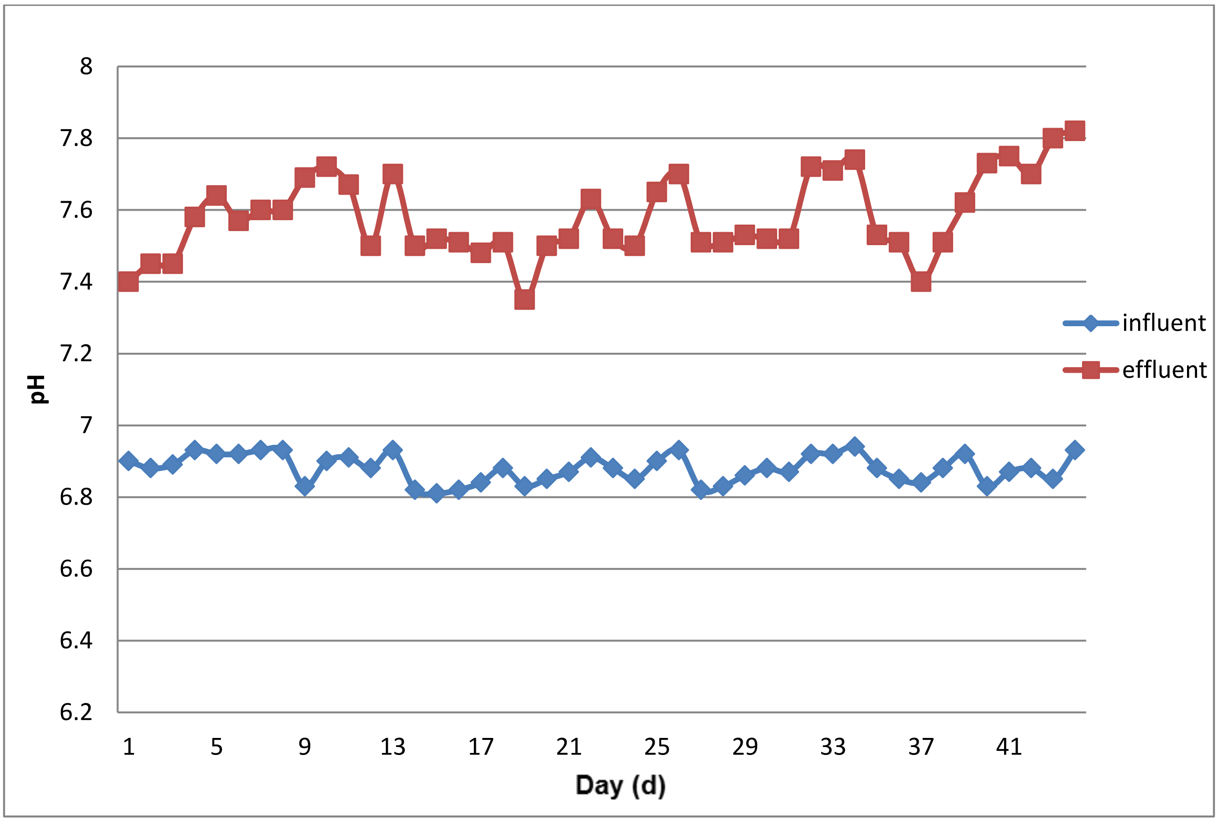

Fig 4.1 Daily pH of influent and effluent of wastewater stream.

From figure 4.1 pH values of the effluent are in the optimum range for Methanogens activity and this improved the active digestion and the treatment efficiency of the wastewater.

5.3.2 COD concentration and COD removal efficiency

COD in the reactor was measured periodically every seven days. Table (4.3) shows the COD concentrations of the reactors' influents and effluents for two samples thatwere collected on October,1st,2017 and November ,12th,2017respectively.

Table 4.3 COD influent and effluent concentration for samples one and two.

Sample one				Sample two		
Day	COD influent (mg/L)	COD effluent (mg/L)	Date	COD influent (mg/L)	COD effluent (mg/L)	Date
1	3264	3264	29 October 2017	2560	2560	12 November 2017
71	3275	2018	5 November 2017	2575	1760	19 November 2017
14	3289	1920	12 November 2017	2583	1280	26 November 2017
21	-	-	-	2592	832	3 December 2017
28	-	-	-	2600	630	10 December 2017

As seen in table 4.3, there is a significant reduction in COD concentrations for both samples with time. This indicates a good anaerobic digestion activity for wastewater and the successful biodegradation of organic and inorganic material.

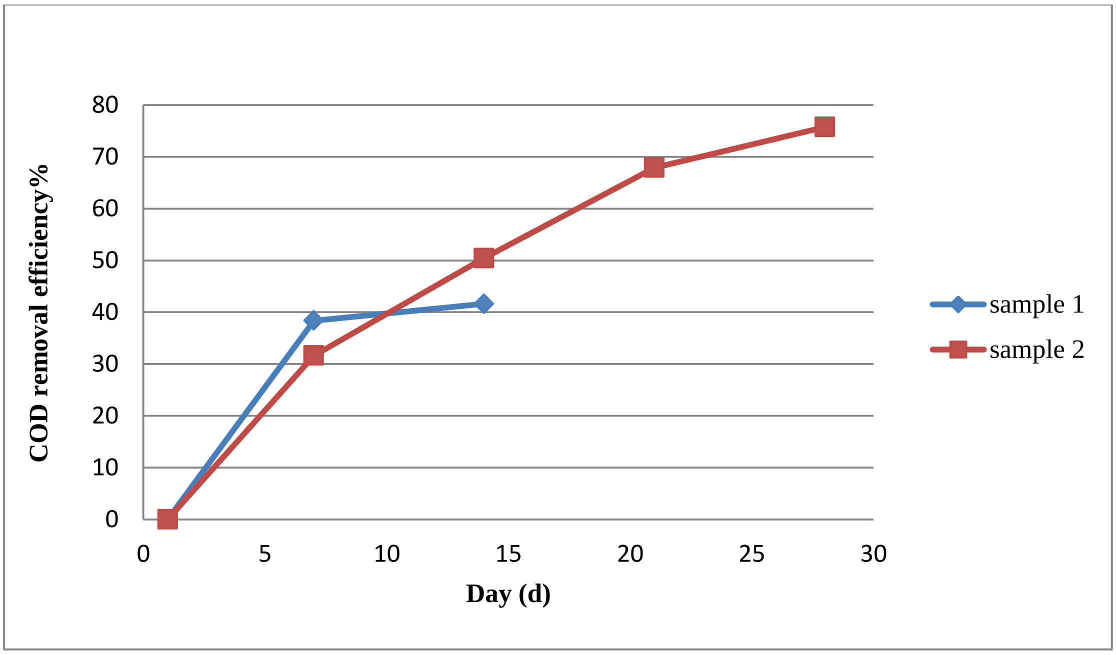

Fig 4.2 COD removal efficiency for sample 1 and sample 2.

As noted from figure 4.2.The percentage of COD removal efficiency increased with time as the concentration decreased. The performance of the reactor was based on the removal of COD as well as the production of biogas. At the beginning of the experiment, COD concentration was 3264 mg/L for sample 1, and 2560 mg/L for sample 2. A slow removal rate of 38.1% was obtained at the beginning of the experiment, probably because microorganisms have not adapted to the type of wastewater yet. However, as the experiment progressed, there was a gradual increase in efficiency, which reached its maximum percentage of 76% after one and half month. This result shows the successful treatment of wastewater by biological process.

4.3.3 Biogas production

The amount of biogas in the reactor was measured daily by using water displacement system, biogas production rates mainly refers to CH_4 and CO_2 gases. At the initial stage of start-up experiment the generation of biogas was Poor, and small increase in the gas production was observed from the 3rd day, where the amounts of maximum gas produced about 19 mL/ day as show in Fig (5.3).

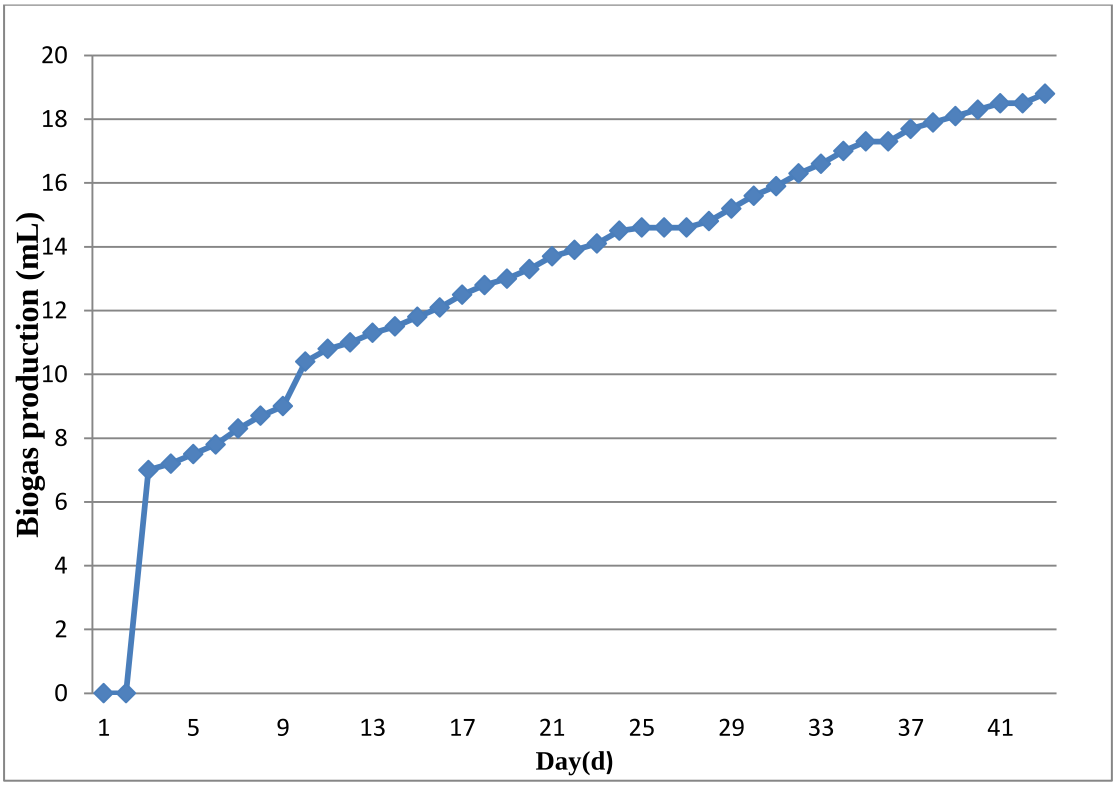

Fig 4.3 Daily biogas production rate (mL/d)

From the figure 4.3 the amount of biogas production is small compared to information in literature, and that's probably because of gas leakage, and the low C/N ratio(too low) to prevent the accumulation of ammonia, which affects the gas produced because it imparts the activity of anaerobic bacteria especially methanogenic. C/N ratio of this wastewater is the only obstacle for adequate generation of biogas and appropriate biodegradation of pollutants. Biogas production can be improved by adding carbon source and that's achieved by co-digestion process.

Conclusions

Meat processing wastewater containing 2560 to 3264 mg/L of COD was treated in 5.78 L UASB. The fabricated anaerobic digester was proven effective for lab-scale UASB treatment. From this research, it is possible to conclude that the anaerobic digestion by using UASB is an efficient also treating meat processing wastewaters as low strength wastewater, although UASB reactor was designed to treat high strength ones. The UASB was effective specifically in reducing COD and color in meat processing wastewater. Anaerobic digestion showed the highest COD removal after one and a half month. This UASB react time allowed high organic matter removal of 76% COD and producing of 19 mL/d of biogas. The retained sludge inside the digester can be used as a composting material as it contains nutrients that can be utilized by plants. Data from this lab-scale experiment will be useful in the succeeding scaled up as a centralized wastewater treatment plant.

Recommendations

It is recommended that this type of wastewater should be blended with high carbon source wastewater likes olive mills wastewater to improve the production rate of biogas and thus improving the methane gas production rate. Moreover the variation in concentration of COD in wastewater might affect the performance of the reactor, therefore equalization of this wastewater should be used in case of large wastewater treatment plant is constructed.

It is also recommended to use anaerobic digestion technology using UASB reactor to treat different types of wastewaters in Palestine because it's a cheap technology and energy producer (CH_4).

Continuous flow UASB should be used instead of batch and semi-continuous as its expected to show better performance in terms of biogas production and COD removal and lower HRT.

The digested sewage sludge should be tested in fertilizing soil and plants and assess its use in agriculture instead of chemical fertilizers.

References

1. Goel, P. K. *Water pollution: causes, effects and control*. New Age International, 2006:2-3.

2. Ahluwalia, Sarabjeet Singh, and Dinesh Goyal. "Microbial and plant derived biomass for removal of heavy metals from wastewater." *Bioresource technology* 98.12 (2007): 2243-2257.

3. Hanchang, S. H. I. "Industrial wastewater-types, amounts and effects." *Point Sources of Pollution: Local Effects and their Control-Volume II* (2009): 191.

4. Siniora Food Industries company.

5. Cristian, Oneţ. "Characteristics of the untreated wastewater produced by food industry." *University of Oradea-Faculty of Environmental Protection* (2010):709-708.

6. Ersahin, Mustafa Evren, et al. "Anaerobic treatment of industrial effluents: an overview of applications." *Waste Water, Treatment and Reutilization* (2011): 1-27.

7. Rajeshwari, K. V., et al. "State-of-the-art of anaerobic digestion technology for industrial wastewater treatment." *Renewable and Sustainable Energy Reviews* 4.2 (2000): 135-156.

8. Wang, Xiaojiao, et al. "Optimizing feeding composition and carbon–nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw." *Bioresource Technology* 120 (2012): 78-83.

9. Tauseef, S. M., TasneemAbbasi, and S. A. Abbasi. "Energy recovery from wastewaters with high-rate anaerobic digesters." *Renewable and Sustainable Energy Reviews* 19 (2013): 704-741.

10. Rodriguez R., L. Moreno (2009), Modeling of Substrate Degradation and Microorganism Growth in an UASB Reactor, In Proceedings of the International Conference on Chemical, Biological & Environmental Engineering (CBEE 2009), Singapore, October 9-11, 2009, Singapore; Kai Ed., pp 76-80.

11. Technologien, Naturgerechte, and Bau-und Wirtschaftsberatung. "Anaerobic treatment of municipal wastewater in UASB-reactors." *TBW GmbH, Frankfurt* (2001).

12.Yasar, Abdullah, and Amtul Bari Tabinda. "Anaerobic treatment of industrial wastewater by UASB reactor integrated with chemical oxidation processes; an overview." Pol. J. Environ. Stud 19.5 (2010): 1051-1061.

13. Khatib, Awni, FathiAqra, Nader Yaghi, Yousef Subuh, Bassam Hayeek, Mohammed Musa, Subhi Basheer, and IsamSabbah. "Reducing the environmental impact of olive mill wastewater." *American Journal of Environmental Sciences* 5, no. 1 (2009): 1.

14. Sabbah, Isam, Taisir Marsook, and Sobhi Basheer. "The effect of pretreatment on anaerobic activity of olive mill wastewater using batch and continuous systems." *Process Biochemistry* 39.12 (2004): 1947-1951.

15. Sayed, Sameh, Lies van Campen, and GatzeLettinga. "Anaerobic treatment of slaughterhouse waste using a granular sludge UASB reactor." *Biological Wastes* 21.1 (1987): 11-28.

16. Ruiz, I., et al. "Treatment of slaughterhouse wastewater in a UASB reactor and an anaerobic filter." *Bioresource Technology* 60.3 (1997): 251-258.

17. Tawfik, A., M. Sobhey, and M. Badawy. "Treatment of a combined dairy and domestic wastewater in an up-flow anaerobic sludge blanket (UASB) reactor followed by activated sludge (AS system)." *Desalination* 227.1-3 (2008): 167-177.

18. Parawira, Wilson, et al. "Comparative performance of a UASB reactor and an anaerobic packed-bed reactor when treating potato waste leachate." *Renewable Energy* 31.6 (2006): 893-903.

19. Nacheva, P. Mijaylova, et al. "Treatment of cane sugar mill wastewater in an upflow anaerobic sludge bed reactor." *Water science and technology* 60.5 (2009): 1347-1352.

20.Rico, Carlos, et al. "High-load anaerobic co-digestion of cheese whey and liquid fraction of dairy manure in a one-stage UASB process: Limits in co-substrates ratio and organic loading rate." *Chemical Engineering Journal* 262 (2015): 794-802.

21. Palenzuela-Rollon, A., et al. "Treatment of fish processing wastewater in a one-or two-step upflow anaerobic sludge blanket (UASB) reactor." *Water science and technology* 45.10 (2002): 207-212.

22. Murugesan, M. P., et al. "Treatment of Hospital and Biomedical Waste Effluent Using HUASB Reactor." *International Journal of Innovation and Scientific Research* 11.2 (2014): 379-386.

23. Dhir, Amit, and Chhotu Ram. "Design of an anaerobic digester for wastewater treatment." *Int J Adv Res Eng Appl Sci.* 1.5 (2012): 56-66.

24.Cheremisinoff, Nicholas P. *Handbook of water and wastewater treatment technologies*. Butterworth-Heinemann, 2001.

25. Cheremisinoff, N.P., *Handbook of water and wastewater treatment technologies*. 2001: Butterworth-Heinemann.

26. Hanchang, S. H. I. "Industrial wastewater-types, amounts and effects." *Point Sources of Pollution: Local Effects and their Control-Volume II* (2009): 191.

26. Grady Jr, CP Leslie, et al. *Biological wastewater treatment*. CRC press, 2011.

27. Mittal, Arun. "Biological wastewater treatment." *Water Today* 1 (2011): 32-44.

28. van Lier, Jules B., Nidal Mahmoud, and Grietje Zeeman. "Anaerobic wastewater treatment." *biological wastewater treatment, principles, modelling and design* (2008): 415-456.

29. Appels, Lise, et al. "Principles and potential of the anaerobic digestion of waste-activated sludge." Progress in energy and combustion science 34.6 (2008): 755-781.

30. Chan, Yi Jing, et al. "A review on anaerobic–aerobic treatment of industrial and municipal wastewater." *Chemical Engineering Journal* 155.1 (2009): 1-18.

31. Ersahin, Mustafa Evren, et al. "Anaerobic treatment of industrial effluents: an overview of applications." *Waste Water, Treatment and Reutilization* (2011): 1-27.

32. Seghezzo L., Zeeman G., Lier J., Hamelers H., Lettinga G. (1998). A review: The Anaerobic Treatment of Sewage in UASB and EGSB Reactors. Bioresource Technology 65: 175-190.

33. Kaviyarasan, K. "Application of UASB Reactor in Industrial Wastewater Treatment–A Review." *International Journal of Scientific & Engineering Research* 5.1 (2014): 584.

34. McIntosh, Dennis, and Kevin Fitzsimmons. "Characterization of effluent from an inland, low-salinity shrimp farm: what contribution could this water make if used for irrigation." *Aquacultural Engineering* 27.2 (2003): 147-156.

35. Raposo, F., et al. "Assessment of a modified and optimised method for determining chemical oxygen demand of solid substrates and solutions with high suspended solid content." *Talanta* 76.2 (2008): 448-453.

36. Tawfik, A., M. Sobhey, and M. Badawy. "Treatment of a combined dairy and domestic wastewater in an up-flow anaerobic sludge blanket (UASB) reactor followed by activated sludge (AS system)." *Desalination* 227.1-3 (2008): 167-177.

ABBREVIATIONS

COD: chemical oxygen demand.

TSS: total suspended solid.

TDS: total suspend solid.

SS: suspend solid.

VSS: volatile suspend solid.

VS: volatile solid.

UASB: up flow anaerobic sludge blanket reactor.

AF: anaerobic filter.

AFB : anaerobic fluidized bed.

HRT: hydraulic retention time.

SRT: sludge retention time.

OLRs: organic loading rates.

BOD_5: biochemical oxygen demand.

TAN: total ammonia nitrogen.

C/N: carbon to nitrogen ratio.

OMW: olive mill wastewater.

FAS: ferrous ammonium sulfate.

Abstract

Meat processing industry generates wastewater with relatively low levels of organic pollutants expressed as chemical oxygen demand (COD) and the total suspended solids (TSS) in addition to other pollutants like ammonia nitrogen and organic nitrogen. According to the initial chemical analysis conducted by Seniora company on Mar ,25 /2017, the COD, TSS, ammonia nitrogen and total nitrogen concentration was found to be 2243, 760, 2.6 and 149.1, mg/L respectively.

In Palestine, the wastewater from meat processing industry is usually discharged either to the sewer system or to the open environment without any treatment causing serious environmental problems. This study aimed at investigating the feasibility of Up flow anaerobic sludge blanket (UASB) reactor as a possible method and mostly demonstrated reactor worldwide in treating the wastewater generated from Siniora meat industrial company located in Al-Azaria, Jerusalem. Anaerobic treatment is not only reduce the pollutants concentration, but also produce an alternative energy in form of methane. Using UASB reactor directly is not advisable unless conducting experiments using batch reactor systems which will be carried out together by our colleagues (Sana'a and Fatima), because UASB is a continuous flow reactor, so it is not an easy task to determine the optimum conditions for appropriate anaerobic treatment, Therefore, we depended on the results obtained from batch reactor experiments in operating the UASB reactor.

An UASB reactor of 6.4 L total volume was seeded with 2.15 L anaerobic digested sewage sludge of 18.7 g/L VSS so that the reactor received 6.3 g VSS/ L reactor volume. The meat processing wastewater was introduced to the bottom of reactor and flows up through a sludge blanket and was operated as batch reactor for couple days. Afterwards it was fed semi-continuously. The UASB reactor was operated at a hydraulic retention time (HRT) of 3.8 days and organic loading rates (OLRs) ranging from 0.6-0.8 g COD /L. d. The COD concentration decreased from 3264 mg/L to 1920 for sample 1 with a removal efficiency of about 42%. The reactor then was fed with the same wastewater but with 2560 mg/L COD concentration. The effluent COD was measured after 49 days to be 630 mg/L with a removal efficiency of about 76%.

الإهداء

بسم الله الرحمن الرحيم

(وقل اعملوا فسيرى الله عملكم ورسوله والمؤمنون)

صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولايطيب النهار إلى بطاعتك.. ولاتطيب اللحظات إلا بذكرك.. ولا تطيب الآخرة إلا بعفوك.. ولا تطيب الجنة إلا برؤيتك

.. إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة.. إلى نبي الرحمة ونور العالمين

سيدنا محمد صلى الله عليه وسلم

إلى من كلله الله بالهيبة والوقار .. إلى من علمني العطاء بدون انتظار .. إلى من أحمل أسمه بكل افتخار .. أرجو من الله أن يمد في عمرك لترى ثماراً قد حان قطافها بعد طول انتظار وستبقى كلماتك نجوم أهتدي بها .. اليوم وفي الغد وإلى الأبد

والدي العزيز

إلى ملاكي في الحياة.. إلى معنى الحب وإلى معنى الحنان والتفاني.. إلى بسمة الحياة وسر الوجود

إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب

أمي الحبيبة

الى الشموع التي تحترق لتضيء للأخرين الدروب الى قدتنا ومن اضاء العلم في طريقنا

اساتذتنا الفاضلين

الى جنتي وملاذي الاول والاخير، الى من ارتوى ترابها بالدماء الى تلك الارض المقدسة الى وطني

فلسطين

ولنذكر هنا كلمة الاصفهاني حين قال إنّي رأيتُ أنّه ما كَتَبَ أحَدُهم في يومه كتاباً إلا قالَ في غدِهِ لو غُيِّرَ هذا لَكانَ أحسن ولو زِيْدَ ذاكَ لَكانَ يُستَحسن، ولَو قُدِّمَ هذا لكانَ أفضل، ولو تُرِكَ ذاكَ لَكانَ أجمل، وهذا من أعظَمِ العِبَر، وهو دَليلٌ على استيلاءِ النَّقصِ على جُملةِ البَشر.

الشكر

الحمد الله الذي بفضله تتم النعم والصالحات...الحمد الله الذي وفقنا في دربنا

الشكر دائما لله على حسن توفيقه وكريم عونه

الشكر لكل من علمنا حرفا.....لكل من انار دربنا ولم يبخل علينا بشيئ

الشكر لوالدينا الاعزاء

فضلكم يا والدي عمني حتى اللحم...كل هم قد اصابنا زاركم بالطبع هم...ان كل ما جنينا من جهودك نجم

الشكر وكل الشكر والعرفان للدكتور يوسف صبيح والدكتور الفاضل حسن صوالحة

كما ونشكر كل من ساعدنا ودعمنا وقدم لنا يد العون وكان لنا سندا من زملاء واصدقاء

نشكر زملائنا رزان الشرباتي، خلود الجنيدي ،جنى قطينة،سوسن الصرصور،سناء جبيل،فاطمة حميدات

لكل منكم بصمة في حياتنا للابد

كما اخص بالشكر انا سنابل رفيق روحي وسندي زوجي (مهند) وفلذات كبدي بناتي(مايا وميرا) ووالديّ

واخواني واخواتي ولمن اعتبرتهم والديّ الاخرين (حماي وحماتي)

واخص بالشكر انا اسماء والدي واخواني واختي لمساندتهم لي ودعمهم المستمر

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