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EQUIPMENT AND TECHNOLOGY USED FOR GREEN ENERGY

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Abstract: The effluents of a variety of industrial or commercial activities that include Oil and Grease OG were continuously seen as negative inputs for the receiving bodies that deteriorate their quality or the tentative efficiency. From the other hand and as economy is the major cart for such activities, the energy potential in these OG contents makes it a tempting goal to extract and reuse OG as an energy source whether inside the location or supplied to the market wherever needed. The goal of OG removal and their extraction as a source for biogas production is tested for the aqueous effluent of a vegetable oils and detergents factory via a laboratory-built system that consists of a pressurized flotation basin for the OG extraction from the aqueous industrial effluent via the induced micro-sized air bubbles, that are generated by type RC2, 217 W pressure regulator installed on a 0.75 KW single phase compressor. The skimmed OG is then directed to a 20 l working volume closed cylindrical bio digester to disintegrate the Carbon-Hydrogen bonds anaerobically under controlled thermal environment. Five digesters are built including single phase BG-3D-1 dual impellers rotary mixer and digital thermostat 8820 NTC sensor temperature controller to adjust the temperature of an interior coil heater to examine the impacts of operational time and temperature on the digestion performance for various OG: inoculum ratios and hence determine the performance indicators of the digesters. The chemical oxygen demand COD as the major environmental index in this regard, is determined to yield a reduction of 90.8% of its initial concentration, by the end of operating the bioreactor that worked for a 30 consecutive days at a temperature of 60 ˚C. That is in addition to the production of biogas in about 8.4 l/d (in a daily average of 3.64 l), for a mixture of 5:10 l extracted OG and livestock manure inoculum. These results declare the significant role of installing the suggested anaerobic digester in parallel to the industrial production lines to serve a reduction in overall operational costs via the removal of OG load from the final wastewater treatment plants and the revenue of the produced biogas as an energy source.
***Keywords*:** anaerobic, flotation, biogas**,** OG.

1. INTRODUCTION

A wide range of industrial, commercial, and municipal processes result effluents that contain oil wastes in either solid or liquid forms or both. Industries like Oil and Gas (OG) exploration and production, food industries, detergents industries, etc., may produce large amounts of such wastes that seriously troublesome the traditional treatment units or negatively affect the receiving bodies to which they are disposed. The main characteristics of these wastes are their inclusion of high concentrations of chemical oxygen demand COD, OG, and total suspended solids TSS that make them slowly degradable [1]. On the other side, the inclusion of high-energy potential in these wastes makes them a good asset for the manufacturers to invest in to recap some of the expenses and hence increase their profit margin. This two-fold target is the main goal of this experimental study that uses the liquid effluent of the Al-Rashid factory for detergents, Baghdad as the operating material for a laboratory bioreactor to produce the tentative biogas. Anaerobic digestion is considered as an effective choice for the recycling approach to produce energy, in addition to the main goal of turning out of value wastes to nutrients that are useful for agriculture and helping control the potent greenhouse gas methane emissions. The breakdown of organic bonds of matter is the result of the anaerobic digesters without the need for oxygen. Methan-enriched gas is found as another result of such reactors, in addition to Ammonia, Carbon dioxide, and volatile fatty acids traces in the final product [2]. This approach was followed in numerous industrialized complexes targeting the stabilization of hydrocarbonate waste produced by various industrial and commercial activities. The tentatively produced biogas would be useful fuel in gas pipelines for the production of electricity or as a vehicle fuel after being properly compressed or as cooking gas [3]. Although continuous operation scheme for the digesters provides continuous biogas production, but many studies recommended batch or semi batch operation with the required periodic maintenance, due to its simplicity whether in installation or operation [4].

The bio-digestion process is sensitive to insoluble materials such as OG that would isolate the liquid surfaces of the contents inside the reactor and hence inhibit the continuity of the digestion process [5]. In the oil removal target, distinction is required between the two oil forms that are expected in the industrial effluents. The free oil is that which will naturally distinguish and float up the surface, while the emulsified oil is that detained in suspension by chemical substances as in detergents [6]. While there is no big problem with the free oil that would normally separate and float by gravity to the surface in about 30 minutes, the emulsified oil is kept in a molecular structure termed a micelle. Hence, more efforts should be made to treat the emulsified oil suspensions. Special preparation processes are essential to reduce as much of the aqueous effluent that would boost effective digestion. One of these advised by researchers is the air bubble flotation that would effectively separate the OG on the surface of these effluents before their pouring into the bioreactor [7]. Air Flotation is a treatment process in which the aqueous effluents are clarified by the exclusion of suspended matters whether solids or oil via the injection of under-pressure air bubbles into the containing basin. The adherence of tiny bubbles and the targeted suspended matter, rising towards the surface of the basin makes it easy to mechanically skim and move for the following steps. The use of coagulants such as Alum or ferric chloride was advised to speed up the flocculation of these suspended or dissolved matters and hence increase the flotation rate inside the basin [8, 9].

Many researchers such as Halalsheh et al., 2005, and Bouallaggui et al., 2009, suggested these separated OG be thoroughly and continuously or periodically in process mixed with fairly energy potential inoculums like agricultural wastes, or livestock manure to enhance their microbial sustenance and offer pH buffering ability. The mixing process is traditionally made via either vertical or side shaft/propeller mixers to ensure stable and homogeneous environment for the process along the operation time [11]. The inoculum is a highly essential biomass for the start-up of the process and to ensure lifetime continuity [10].

2. MATERIALS AND METHODS

The material of this study is the effluent of vegetable oil and detergents factory. The main characteristics of that aqueous effluent are summarized in Table 1. The high value of COD and OG parameters as shown above made it highly encouraging to step forward in the tentative production of the biogas via the biological reactor in addition to the main goal of the removal of their inhabitance to the environmental remediation processes.

Table 1. The characteristics of the effluent under study

Characteristic	Value
pH	3- 5
COD	435 g/l
TSS	131 g/l
OG	860 mg/l

Two stages model is made in the laboratory; Air bubble flotation and bio digestion reactor. A basin of the dimensions (60x120x40 cm) is prepared for the air flotation process, with a tapered bottom to collect the gravity-separated sediments. A single-phase compressor (0.75 KW) is detached to supply the required air (20 l/min under 8 bar) through air distribution holes located at the bottom of the basin. Type RC2, 217 W, pressure regulator is utilized to maintain a constant airflow through the process.

The anaerobic bio digestion is tested via the use of five 20 l working volume closed cylindrical tank models denoted as B1, B2, B3, B4, and B5 respectively, as shown in Figure 1. Each of these models is equipped with an internal coil heater around the model`s internal perimeter to maintain the required operating temperature via a digital thermostat 8820 NTC sensor temperature controller. A single phase BG-3D-1 dual impellers rotary mixer is also utilized to guarantee the homogenization of the reactor contents; skimmed OG and inoculum, and hence ensures the good distribution of bacteria, although single propeller would be satisfactorily used according to the depth/diameter rule but the dual one is utilized to overcome the presence of dense inoculum. The mixer is equipped with an analog speed controller to maintain the minimum rotating speed of 10 rpm for 15 minutes' duration each 3 hours for the first few days until the start of significant biogas production and then it would be 10 minutes each hour for the rest of the experiment duration, to maintain the process stability.

The product of the air-bubble flotation basin should be dewatered before pouring into the digestion reactors to avoid the expected negative effect of moisture. In addition, the pH of the skimmed sludge needs to be adjusted to the neutral range 6- 8 via 2N Sodium Hydroxide solution which was advised by many researchers to ensure the good performance of the bio-digestion reactor [12].

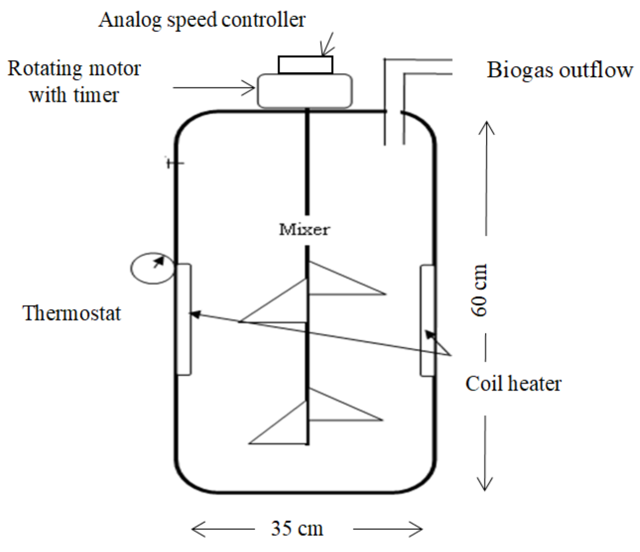

Fig. 1. A schematic for the bio-digestion model

The skimmed, dewatered, and pH-adjusted OG from the flotation basin is utilized as the input of each of the bioreactors in each of which, an amount of 10 l of water-diluted livestock manure would initially poured in. Each of these bio digestion reactors is set to operate for 30 days under each of the combination of different temperatures; 40°C, 60°C, and OG: inoculum ratio; 1, 2, 3. 4, and 5:10 l that are to be well blended before the operation. The production of biogas is measured in a graduated column via the displaced water, while the APHA 2010 standard methods are followed through the analysis of the COD and TSS [13].

3. RESULTS AND DISCUSSIONS

As expected, the contents of each of the bioreactors would take some time to adapt to the operational environment of each because of the release of the long aliphatic chain carboxylic acid from the hydrolysis of triglycerides OG content. The more the OG content, the longer the adaptation time for the contents of each reactor for both tested temperatures, as shown in Figures 2 and 3, which demonstrate the anaerobic performance of each bioreactor in the COD removal. The performance in this regard showed higher efficiencies in the models of low OG contents as compared to those of higher ones for both tested temperatures, as it reached the value of 85.3% in model B1 that worked under the temperature of 40°C. In comparison, it was as low as 60% in the model B5. The same trend is determined for the models worked under the temperature of 60°C where the COD removal efficiencies are 90.8% and 53.3% for models B1 and B5 respectively.

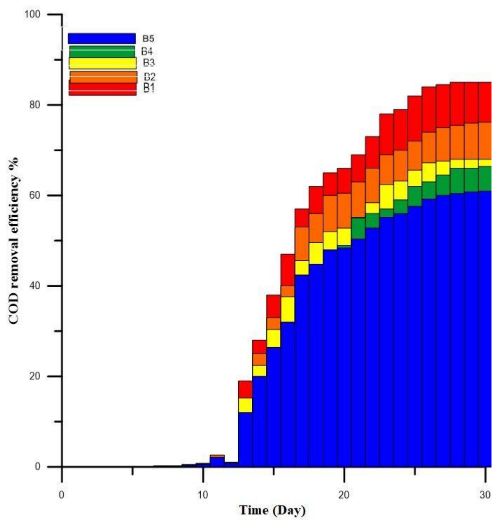

Fig. 2. COD removal efficiency at 40°C

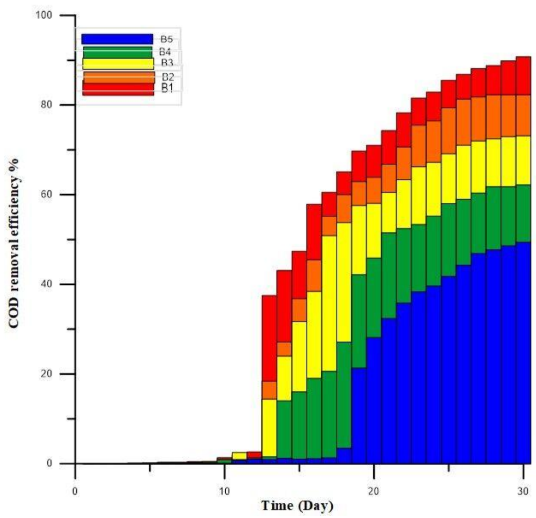

Fig. 3. COD removal efficiency at 60°C

The other important remark from these results is that the COD removal efficiency showed significant enhancement with the higher operational temperature. This can be justified by the fact that OG is a thermophilic substance, and hence it is more soluble at higher temperatures and this in turn makes it highly biodegradable. The maximum COD removal efficiencies for each bioreactor under each of the two operational temperatures are demonstrated in Table 2. During the whole operation time, the pH is required to be monitored as it plays a critical role as indicated before. This is demonstrated in Figure 4, which clearly shows a pseudo-neutral mixture along the whole reactor lifetime.

Table 2. COD removal efficiency by the tested models

Model	OG: inoculum L:L	COD removal efficiency %	
		40 ˚C	60 ˚C
B1	0.5:10	85.3	90.8
B2	1.5:10	75	83.2
B3	2.5:10	68	74
B4	4.0:10	66	63
B5	5.0:10	60	53.3

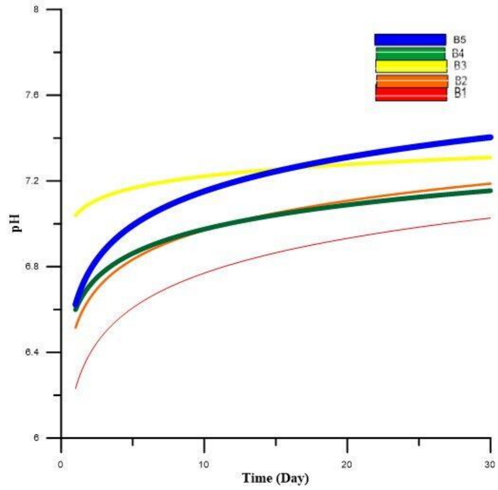

Fig. 4. The pH values during the lifetime of model bioreactors

The influence of the OG: inoculum ratio from one side and the operation temperature from the other side Figures 5 and 6 demonstrate the gas production rate of the anaerobic bio-digester. The first indication from these two figures is that it takes less time to start producing the gas in reactors B4 and B5; about 5 days, as compared to the rest of this study`s reactors; about 10 days. In addition, a significant upsurge occurs via pouring the various reactors with the OG: inoculum mixture as compared to utilizing the anaerobic digestion of the diluted livestock manure only. As regards the mixture`s contents, the records show that higher OG content which in turn means higher COD, has the tendency to result in higher biogas rates for both operation temperatures (40 ˚C and 60 ˚C). This agrees with Thomas et al. [14], and interprets the carbohydrate's greater biodegradability and energy potential. At the temperature of 40˚C, it is remarked that the biogas production rates for reactor B4 lead or equal those of reactor B5, although the latter involves a higher OG: inoculum ratio as shown in Figure 6. B5 and B4 have achieved a maximum gas production rate of 5.9 l/d (on a daily average of 2.64 l). The higher OG content and salt concentration in the B5 plays an effective role in inhibiting the biological conversion, and hence, adversely affects the biological activity to produce the gas. To overcome that seize of biogas production rate at higher OG content, the reactors were tested at 60C. The first gain of that is the boost of the gas production rates versus high OG: inoculum ratios to reach about 8.4 l/d (in a daily average of 3.64 l) for reactor B5 as compared to that for reactor B4; 7.1 l/d and 2.75 l respectively, as shown in Fig. 6. In addition, the biogas production rates for all reactors is raised to about 150% of these gained for the same substrate ratios when operated at the temperature of 40˚C.

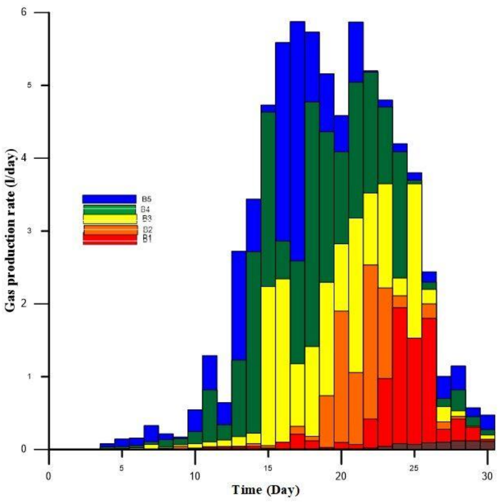

Fig. 5. The biogas production rate for at 40 ˚C.

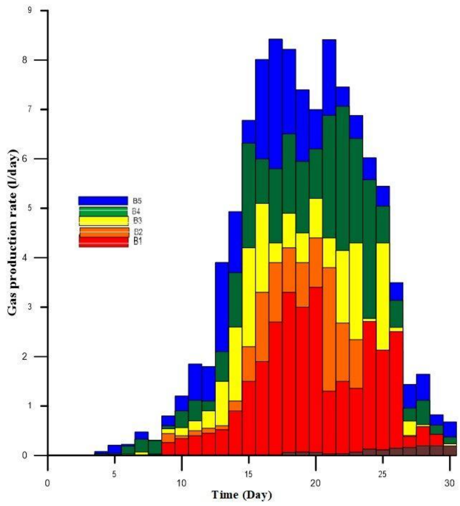

Fig. 6. The biogas production rate at 60˚C.

3. CONCLUSIONS

The energy potential in wasted OG content of many various sizes of industrial processes was targeted during the anaerobic digestion process that essentially aims for the reduction of the COD content of the effluents of these industries. The most effective parameters of the anaerobic digestion process; namely the OG concentration and the working temperature were tested via five laboratory-built reactors to test a variety of combinations of these two parameters for 30 days. The two stages batch laboratory system consists of a pressurised flotation basin that is equipped with an air compressor for the supply of micron-sized bubbles that serve as the separation medium of the dissolved OG from the aqueous industrial effluent, and the second stage is a closed vertical digesting reactor that is equipped with an internal rotating mixer and coil heater to result the anaerobic breakdown of organic bonds of the separated OG. The contents of each reactor were prepared by the mixing of livestock manure with the dried product of the bubble flotation basin. Both tested working temperatures; 40 ˚C and 60 ˚C, showed close good COD removal efficiencies; 85.3% and 90.8% respectively with the lower tested OG: inoculum ratio of l: 10 l. These efficiencies were found to decrease with the increase of the OG constituent. This thermophilic characteristic of the substrate made it beneficial for the significant enhancement of the biogas production rate of the reactors of higher OG constituent that were operated at the temperature of 60 ˚C. Rates of 8.4 l/d from a reactor that contained OG: inoculum of 5: 10 l under a temperature of 60 ˚C could be achieved. Based on the results of this study, the installation of this simply operated and maintained system; flotation basin and anaerobic digester in parallel to the various manufacturing systems/industries would effectively serve twofold important mission; the removal of most of the dissolved OG and hence reduce the loads on the wastewater treatment facilities from one side, and serve as a good and continuous supply of an environment friendly, low-cost energy source either for the internal uses or to be delivered to the market.

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