



Potentiality of municipal sludge for biological gas production at Soba Station South of Khartoum (Sudan)

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ABSTRACT

Biogas production considered the most encouraging sources of renewable energy in Sudan. Anaerobic process of digestion is considered as efficient techniques of producing biogas. The process also a trustworthy method for treatment of municipal wastes, and the digested discharge could be utilized as soil conditioner to improve the productivity. This research work states at the option of using domestic sludge of the wastewater treatment plant in Soba municipal station (south of Khartoum-Sudan) to produce biological gas (biogas). A laboratory investigation was carried out using five-liter bioreactor to generate biogas for 30 days. The total volume of gas made was 270.25 Nml with a yield of 20 Nml of biogas/mg of COD removed. Chemical oxygen demand, Biological oxygen demand, & total solids drop produced were 89, 91 & 88.23% respectively. Microbial activity was declined from 1.8×10^7 (before starting the process of digestion) to 1.1×10^5 germs/mL (after completion of 30 days of digestion). This study offered a significant energetic opportunity by estimated the power production to 35 KWh.

Key word: Sludge, municipal plant, organic material, anaerobic process, breakdown, biological gas potential

INTRODUCTION: Increasing of urban industries style in the world has given rise to the production of effluents in huge amounts with abundant organic materials, which if handled properly, be able to end in a substantial source of energy. Although of a fact that there is an undesirable environmental effect related with industrialization, the influence can be diminished and energy can be tapped by means of anaerobic digestion of the wastewater (Deshpande *et al.*, 2012). Biological wastewater treatment plant (WWTP) is a station for removal of mainly organic pollution from wastewaters. Organic materials are partly transformed into sludge that, with the use of up-to-date technologies, represents an important energy source. Chemical biological, and physical technology applied throughout handling of wastewater produce sludge as a by-product. Recent day-to-day totals, dry solids range from 60–90 g per population equivalent, i.e. EU produces per year 10 million tons of dry sludge (Bodík *et al.*, 2011). Sludge disposal (fertilizers use, incineration, and landfills) is often explored since of increasingly limiting environmental legislation (Fytli and Zabaniotou, 2008). The energy present in sludge is obviously consumed in anaerobic digestion. Anaerobic Process is considering the most appropriate choice for the handling of organic effluents of strong content. This process upgraded in the last few years significantly with the applications of differently configured high rate treatment processes, particularly for the dealing of industrial releases (Bolzonella *et al.*, 2005). Anaerobic process leads to the creation of biological gas with high content of methane, which can be recovered, and used as an energy source, making it a great energy saver. The produced gas volume during the breakdown process can oscillate over a wide range varying from $0.5 - 0.9 \text{ m}^3 \text{ kg}^{-1} \text{ VS}$ degraded (for waste activated sludge) (Bolzonella *et al.*, 2005). This range rest on the concentration of volatile solids in the

sludge nourish and the biological action in the anaerobic breakdown process. The residue after digestion process is stable, odorless, and free from the main portion of the pathogenic microorganism and finally be able to use as an organic nourishment for different application in agriculture. Sludge significant coming out from breakdown which allows to yield a renewable energy, that was cheap, obtainable, & no polluting. Sustainable development considered the production of biogas as environmentally friendly and an economic key (Poh and Chong, 2009).

OBJECTIVES: Sudan have huge tones of sewage sludge from domestic sewage water is accumulated daily in lagoon of soba sewage treatment plant, so this work, we were carried for energy production and treatment of sludge, which constitutes a plentiful waste which ever know any sort of handling after few years from establishing the station.

MATERIALS AND METHODS: Experimental apparatus: Anaerobic breakdown was done in five liters fermenter. (figure 1).

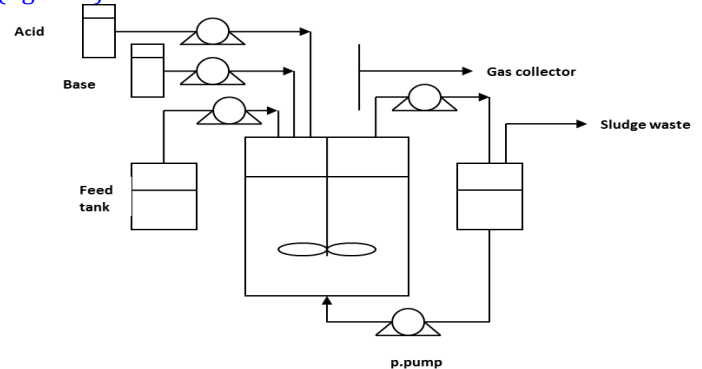


Figure 1: Schematic diagram of the bioreactor used in this study.

The fermenter was maintained at 35°C in a thermostatic bath and stirred regularly. U shaped glass tube was connected to the fermenter, allowing the measurement of produced biogas volume and pressure. Water displacement technique was used for determination of the volume of produced biological gas (biogas) at the beginning of each sampling. Testing of the biogas combustibility was determined by connecting one of ends of the tube to a gas collection and storage device (balloon), the other end to a Bunsen burner. In the process of reduction of carbon dioxide (CO₂) to maximum dissolution in the tube the liquid must be a salty saturated acid solution (5% citric acid, 20% NaCl, pH ¼ 2) (Connaughton *et al.*, 2006).

Substrate: About 5L sludge containing culture medium were taken from the lowest part of the first settling tank in Soba station. The moisture content of initial substrate was 35%. The collected sample was preserved at 4°C prior to loading the biological reactor (Tomei *et al.*, 2008). Table 1 showed the sludge features in the reactor with a loading rate of 16 g TS/L, (Connaughton *et al.*, 2006; Tomei *et al.*, 2008).

| Parameter | Concentration, mg/L |
|--------------------------------------|----------------------|
| pH | 7.3 |
| Total Solids (%) | 8.5 |
| Volatile Solid (%) | 58 |
| Biological Oxygen Demand, BOD (mg/L) | 790 |
| Chemical Oxygen Demand, COD (mg/L) | 1300 |
| Total germs (germs/100 mL) | 1.8x10 ⁷ |
| Faecal streptococci (germs/100 mL) | 130 |
| Fecal Coliforms (Coliforms/100mL) | 1.5 x10 ⁶ |
| Escherichia coli (germs/100 mL) | 80 |

Table 1: Characteristics of the raw sludge and microbiological substances.

Analytical Methods: The pH was controlled by using HANNA HI 8314 model as pH meter device. Assay was used for determination of Alkalinity & Volatile fatty acids (Kalloum *et al.*, 2011). The standard method of analysis was used for recognized the Chemical Oxygen Demand (COD) (Raposo *et al.*, 2009). Titrimetric method was used for analyzing Volatile fatty acids (VFA). Alkalinity assay was used for determination of Total Alkalinity (TA). Oxitop assay was used for measuring the biological oxygen demand. Ignition method was used for measuring Volatile Solids (VS) by losing weight in dry sample at 550°C in the furnace, & Total solids were done to constant weight at 104°C (Monou *et al.*, 2009). A method of water displacement was used for determination of the total volume of Biological gas produced (Moletta, 2005).

Microbial species & analyses were determined by microbial standard assay. Sample analysis was done by explore of three replicates and the outcomes were the middling of these replicates. Startup of experiments continues until a bubble of gas was detected.

RESULTS AND DISCUSSION: Measurement of pH: Figure 2 exhibited pH trends during 30 days with a drop pattern from 7.0 to 6.0 during the first five days; this was mainly because of the breakdown of organic materials and the development of (VFA). Then later, an increasing pattern in pH was noticed to 6.98, for the next week, then Steadying around this pH level was continued till the completion of the breakdown period which taken 30 days. Those out comes were also reported by other researchers (Raposo *et al.*, 2008).

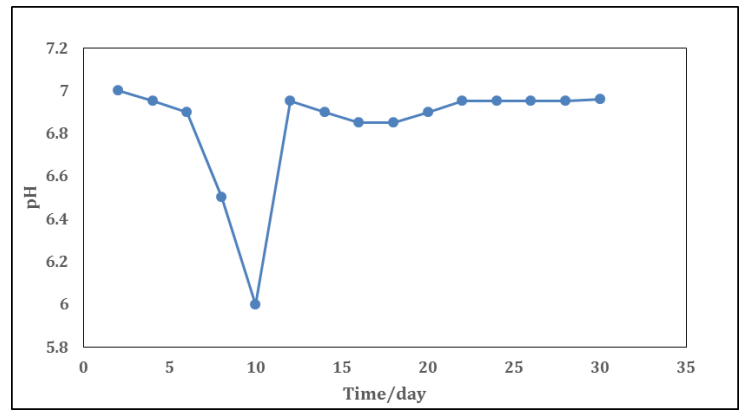


Figure 2: Effect of anaerobic digestion on the trend of pH during decomposition.

Measurement of VFA: Development of VFA throughout 30 days was depicted in figure 3, an increase in volatile fatty acids up to 1400 mill equivalents per liter (meq/L) in the first ten days.

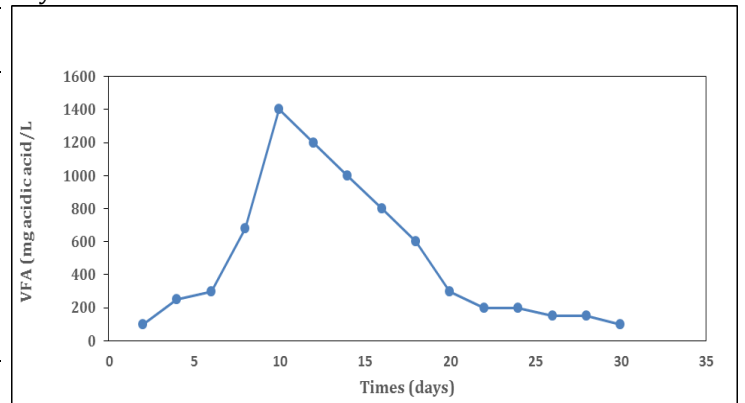


Figure 3: Effect of anaerobic digestion on the development of volatile fatty acids (VFA).

This criterion of making of volatile fatty acid is typical to the researcher's report of identification of hydrolysis in acidogenesis stage (Parawira *et al.*, 2006). The decline in volatile fatty acids after the tenth day was owing to intake by bacteria which would relate to the stage of acetogenesis.

Total alkalinity (TA): During the ten days, we observed rise in volatile fatty acids content followed by a drop in a pH in the same time (figures 4 and 5). Encountered to these alterations, an increase in the total alkalinity in the medium for reestablishing situations of alkalinity to the outbreak of methanogens stage (figure 4).

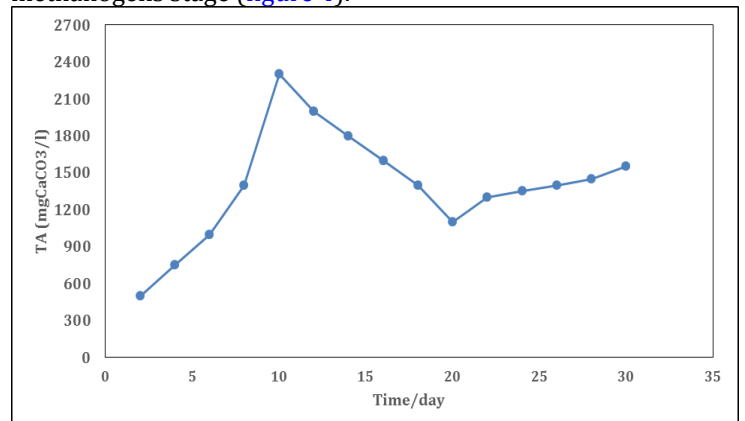


Figure 4: Effect of anaerobic digestion on the development of total alkalinity (TA).

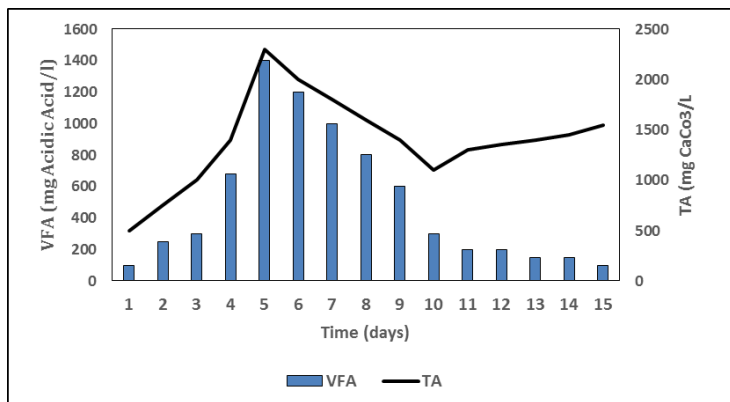


Figure 5: Effect of anaerobic digestion on the relationship of VFA and total alkalinity (TA).

Through all the digestion period the ratio of VFA/TA which was equal and lower than 0.6 ± 0.1 were described in figure 6.

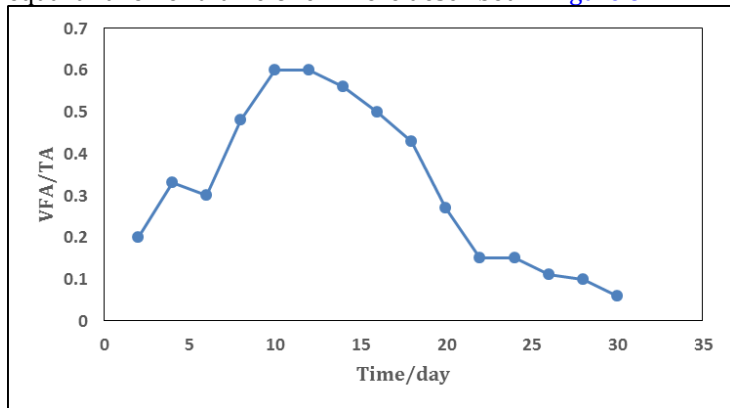


Figure 6: Effect of anaerobic digestion on the exhausted VFA/TA ratio.

These ratios designated the achievability of the procedure despite the essential production of volatile fatty acid (Chen and Huang, 2006; Nordberg *et al.*, 2007). The anaerobic digestion process may be hinder by the production of volatile fatty acid.

Biogas production: Pressure measurement and biogas volume were used for controlling biogas production. Figure 7 explained the changing in biogas pressure throughout the digestion period.

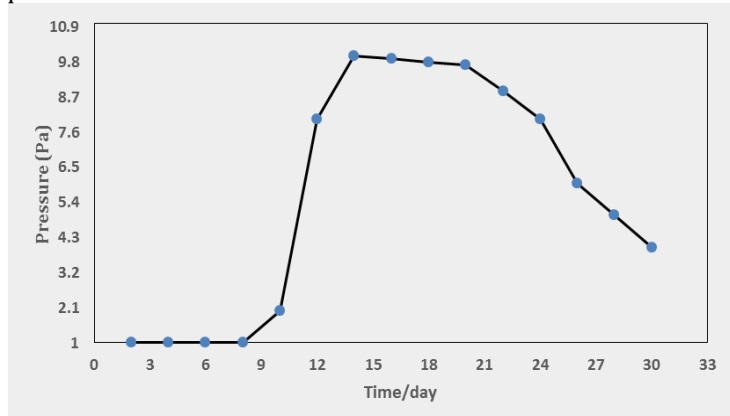


Figure 7: Effect of anaerobic digestion on the biogas pressure.

Biogas pressures starting evolve from the tenth day. Methanogens stage was approached at this instant. The biogas production continued until the 21th day then starting decreasing till the last day (30 day) this due to instability of the culture medium of fermentation which became completely exhaust. Combustion characteristics indicated that adequate

quality of Biogas was obtained with minimum methane of 40% (Bougrier *et al.*, 2005; Lefebvre *et al.*, 2006). Total volume of biological gas production was 270.25 Nml. The yield of biological gas was 20.25 Nml/mg COD removed, which is in range of the others researcher report (Tomei *et al.*, 2008). Biogas production can be calculated from the following formula (Álvarez *et al.*, 2006):

$$\text{Biogas production} = \frac{\text{Total quantity of biogas produced}}{\text{Total solid}}$$

The COD and BOD removal: Chemical oxygen Demand (COD) and Biological Oxygen Demand (BOD) showed a significant reduction of 89% and 91% respectively (figures 8 and 9).

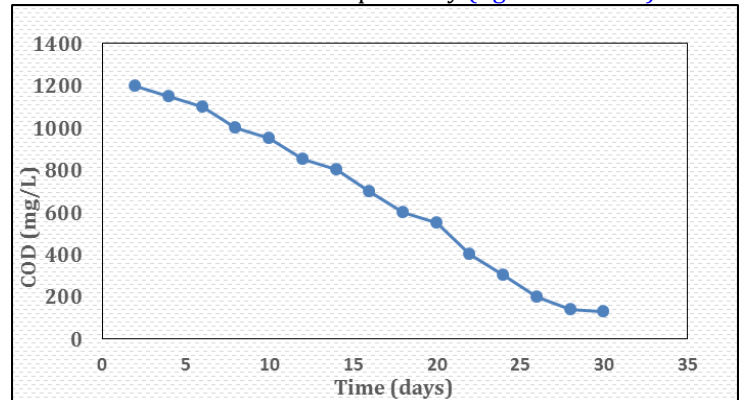


Figure 8: Effect of anaerobic digestion on the removal of chemical oxygen demand (COD).

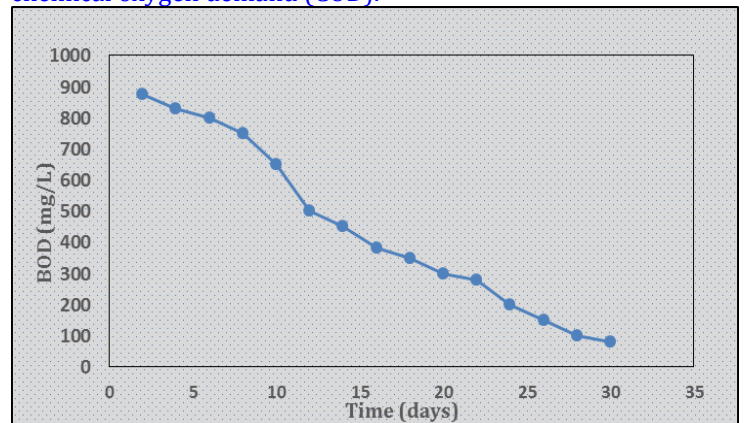


Figure 9: Effect of anaerobic digestion on the removal of biochemical oxygen demand (BOD).

Consequently these reduction in contaminants proved that anaerobic process of digestion was an operational technique for removal of organic pollution. Some researchers reported the same results (Bolzonella *et al.*, 2005; Álvarez *et al.*, 2006; Wang *et al.*, 2006).

Another criterion for proving the removal of organic pollutants was reduction of total solids (TS), where the drop approached 88.23% (figure 10). Some researcher's reports approached the same drop (Hutnan *et al.*, 2006; Linke, 2006; Raposo *et al.*, 2009). Therefore it was possible to conclude that anaerobic digestion necessary showed decrease or reduction of organic pollutants rates because of the transformation of organic substances into biogas and accordingly led to the drop of chemical oxygen demand (COD). This could be explained in figure 11 by the comparison of the two techniques during the anaerobic digestion process. That means the chemical oxygen demand (COD) drop should be tailed essentially by Total solids drop (TS).

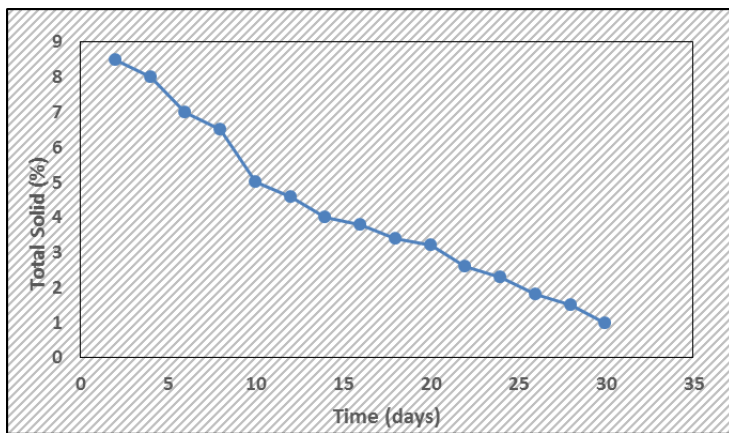


Figure 10: Effect of anaerobic digestion on the total Solids (TS) removal.

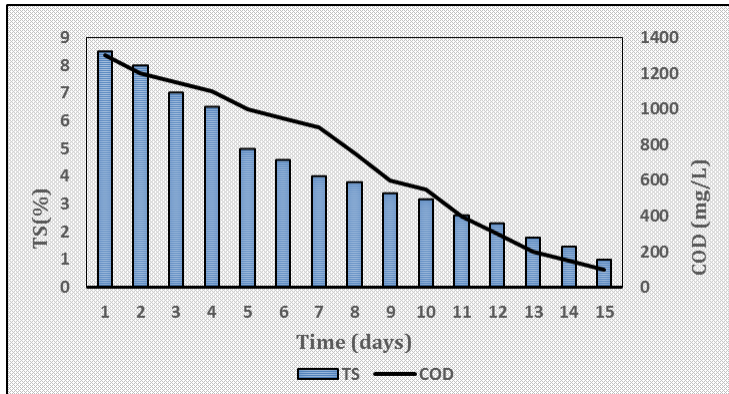


Figure 11: Effect of anaerobic digestion on the total solids (TS) and chemical oxygen demand (COD).

Microbial activity: Figure 11 showed the microbial variation during anaerobic digestion. The total micro flora (total germs) declined from 1.8×10^7 (before starting the process of digestion) to 1.1×10^5 germs/mL (after completion of 30 days of digestion). Moreover figure 12 obviously explained what was running during the process of digestion in the reactor, microbial species vanishing after the 30 days such as streptococci and *Escherichia coli*.

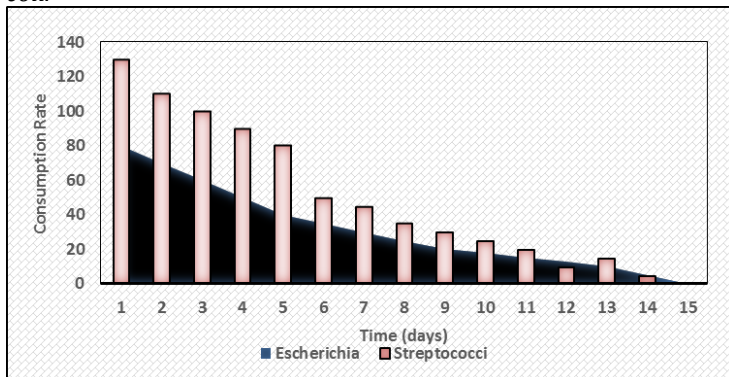


Figure 12: Effect of anaerobic digestion on the variation of micro flora.

Some researchers reports explained that there was some sort of relationship between physicochemical and the biological parameters of micro flora with total solid (TS). Figure 13 described obviously this relationship of the drop of micro flora which go along with total solids reduction. This intended that consumption and a declining in the mass residue of organic materials created at the termination of digestion was the outcome of the transformation of organic materials into biological gas and also

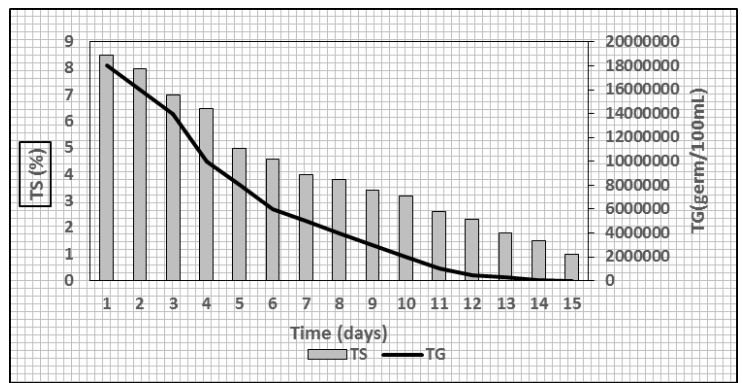


Figure 13: Effect of anaerobic digestion on the relationship between micro flora and total solids.

the sum of microorganism reduction. This attained result proved that the process of anaerobic digestion was a good process for decontamination (Deng *et al.*, 2006; Perez *et al.*, 2006; Davidsson *et al.*, 2007).

CONCLUSION: Soba sludge's municipal station carried in this research paper demonstrated operative for biological gas production (biogas). During the first five days, breakdown of organic materials and the formation of volatile acids were started. Volatile fatty acids increased up to 1400 mill equivalents per liter (meq/L) in the first ten days, then started to decline in after the tenth day this owing to intake by bacteria which would resemble to acetogenesis stage. The biogas production lasted until the 21th day then starting decreasing till the last day (30 day) this due to instability of the culture medium of fermentation which became completely poor. COD and BOD showed a significant reduction of 89% and 91% respectively. Another criteria for proving of removal rate of organic pollutants was reduction of total solids (TS), where the reduction rate approached 88.23%. Total volume of biological gas production was 270.25 Nml. The yield of biological gas was 20.25 Nml/mg COD removed, which is in range of the others researcher report. The total micro flora (total germs) declined from 1.8×10^7 (before starting the process of digestion) to 1.1×10^5 germs/mL (after completion of 30 days of digestion). Study proved that process of anaerobic digestion was a good process for decontamination.

Industries and will be usefulness for bioremediation in marine environment and petroleum industry.

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CONFLICT OF INTEREST: The authors wish to express their appreciation to Soba treatment plant, for their financial support of this research.

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