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Biogas Production From Anaerobic Waste Stabilization Pond Treating Domestic Wastewater in the Soudano-Sahelian Climate of Burkina Faso

Y. KONATE[1], A.H.MAIGA[1], J. WETHE[1], C. CASELLAS[2], B. PICOT [2]

ABSTRACT

The production of biogas and its content from anaerobic pond treating domestic wastewater have been studied in Soudano-sahelian climate of Burkina Faso. The Biogas production were measured weekly from march to july 2010 using as specific gas collector in Plexiglas and the composition was analyzed using micro-gas chromatograph. The composition of biogas produced was relatively constant in time and homogeneous according to results obtained at different points in the anaerobic pond. The major component of the biogas was CH_4 and accounted for an average on 76%, N_2 for 11%, O_2 for 6%, CO_2 to 2% and others gas accounted for 5%. The mean areal production rates of biogas and methane were respectively 0.15 and 0.11 $m^3/m^2/d$. The average daily volume of biogas and its corresponding methane were evaluated respectively to 6.79 and 5.16 m^3. The conversion of this daily methane production to electricity could reduce the CO_2 equivalent GHG emission from petrol combustion by 4.02kg /day and generate a potential 15.4 kwh/day (considering 3.0 kWh $_{electricity}/m^3$ of pure methane). This study revealed that, the conversion of anaerobic pond to anaerobic lagoon digester with the capture and reuse of biogas would be an interesting option for wastewater treatment in the warm conditions of soudano-sahelian climate of Burkina Faso.

Keywords: Anaerobic pond, biogas, Waste stabilization pond, Burkina Faso.

INTRODUCTION

Growing attention is given now to wastewater treatment in African towns particularly in those of Sub-Saharan Africa such as Burkina Faso characterised by low indices of wastewater treatment plant. Among recent constructions of wastewater treatment plants (3 by 6years) in the two principal towns in Burkina Faso, Wastewater Stabilisation Pond (WSP) systems (including anaerobic in head for primary treatment) were adopted because of their low-cost, simple, easy to operate without high energy need. The use of anaerobic pond as primary treatment pond is explained by the fact it is an efficient way of removing BOB especially in warm climate as the case of Burkina Faso, by converting organic carbon mainly into biogas.

Previous studies were focused on the adaptation and development of anaerobic ponds treatment in soudano sahelian climate by exploring their performance. However, no study was conducted to evaluate gas production in anaerobic pond not only for odour emission of which it is often indexed elsewhere, but also as alternative renewable energy sources.

The goal of this research was to determine the production of biogas and its composition from anaerobic pond treating domestic wastewater in soudano sahelian climate of Burkina Faso, and the implication for potential energy recovery.

MATERIALS AND METHODS

This work was carried out at the pilot scale research anaerobic stabilization pond system (12°22’ 45.5’’N, 1°30’09.3’’W) of the International Institute for Water and Environmental Engineering (2iE) of Ouagadougou, Burkina Faso. The anaerobic pond was continuously in operation more than five years. The raw wastewater originates from the 2IE campus with an average daily flow rate of 42.66 m^3 during the study of biogas production started to march 2010 with ongoing data monitoring in order to evaluate the annual production for one complete year measurements.

[1] Institut International d’Ingénierie de l’Eau et de l’Environnement : 2iE, Rue de la Science, 01 BP 594 Ouagadougou 01 Burkina Faso.
(E-mail : *yacouba.konate@2ie-edu.org, amadou.hama.maiga@2ie-edu.org, joseph.wethe@2ie-edu.org*)
[2]Université Montpellier 1, Département Sciences de l'Environnement et Santé Publique, UMR 5569 Hydrosciences-, Faculté de Pharmacie, BP 14491, 34093 Montpellier cedex 5, France.
(E-mail: *picot@univ–montp1.fr, casellas@univ-montp1.fr)*

The anaerobic pond has a vertical geometry form of a cylinder–cone, and the surface is egg-shaped, with the top surface of 84 m^2 at the water level and the bottom surface of 8m2. Its total depth is 3.1m with 0.5m free board and a wall slope of 2/3. Its effective depth is 2.6 m and the useful volume is 107 m^3. During the biogas production study, the anaerobic pond received an equivalent organic load of 232 Person Equivalent (PE). More details on the climatic conditions of the site are described in a previous study (Konate et al, 2010).

The water quality of the influent and effluent of the anaerobic pond was analyzed at meekly intervals (until 2008-up to 2010) using standard methods (APHA, 2005) for the following parameters: Chemical Oxygen Demand (COD), Suspended Solids (SS), and Volatile Solids (VS). Biological Oxygen Demand (BOD_5) was measured with a special apparatus Oxytop WTW.

The production of biogas was measured with 4 gas collectors in plexiglass adapted from the collectors described by Picot and al (2003) in a similar study on biogas production in Mediterranean climatic conditions. The geometric form of the biogas collector is in half-sphere, with a bottom area of 0.2826 m^2. The 4 collectors were placed on the pond surface water in different locations in order to evaluate the daily biogas productions: two collectors in the middle, one near the entrance and one near the outlet. All the collectors were supported at the surface with floats and anchored with lines to the pond banks to prevent any disturbance. The volume of the gas collected was measured weekly with a graduate scale first established on each collector. This graduate scale permitted to read directly the biogas produce for each collector after 24 hours, and to calculate the daily biogas production rate. Biogas productions were corrected to standard temperature and pressure.

The daily production biogas was sampled in a tedlar bag and transported to the laboratory for analysis. The composition of the biogas in terms of CH_4, CO_2, O_2, and H_2 was determined using a micro-gas chromatograph (Micro-GC) type Varian 490-GC. The concentration of others gas were calculated by subtraction.

RESULTS AND DISCUSSION

The characteristics of the raw wastewater (COD/BOD_5 =1.4 <2) showed that it is a domestic wastewater easily biodegradable (Metcalf and Eddy, 2003). The influent and effluent water quality of the anaerobic pond and the organic loading rates are summarized in the table 1. The average organic loading rates in terms of Kg $BOD_5/m^3/d$ and Kg VS added/m^3/d were respectively 0.13 and 0.066. The removal efficiencies were 39.2% 58.7% respectively for BOD_5 and VS. These removal efficiencies are lower than that expected for anaerobic pond in warm climate. This low performance is explained by the duration of operating of pond (more than five years and the reduction of hydraulic retention time due to the reduction of the useful volume of the pond due to the sludge accumulation (evaluated to 42 m3) after five and half years of continuously operation.

The composition of biogas produced was relatively constant in time and homogeneous according to results obtained at different location of biogas collection in the pond. The major component of the biogas was CH_4 and accounted for an average on 76%, N_2 accounted for 11%, O_2 for 6%, CO_2 to 2% and others gas (such H_2, H_2S, and others) accounted for 5%. The biogas methane content in this study in soudano-sahelian is relatively low than those found by picot et al (2003) in biogas produced in anaerobic ponds under Mediterranean conditions (83% of methane content). However, the value of 76% methane content in our study is higher than the concentration of the biogas produced from anaerobic digester where the values of 65%-70% were reported (Metcalf and Eddy, 2003). The CO_2 content (2%) in the biogas on anaerobic pond is however lower comparatively to the gas produced on anaerobic digester where the values of 25-30 are reported (Metcalf and Eddy, 2003).

Gas production is usually estimated from percentage of volatile solids reduction. In this study, biogas and methane production rates were calculated based on organic loading: per VS added (VSa), per VS removed (VSr), per BOD_5 added and per BOD_5 removed. The different production rates are given in table 1. The areal biogas production rate was averaged at 0.15 $m^3/m^2/d$. This biogas production rate is 3 times higher than the production rate of 49 l/ m^2/d reported by picot et al. (2003) on biogas production in anaerobic pond in Mediterranean climatic conditions. Even though the methane content found by picot et al 2003 is higher than that is in our study, the mean areal methane production rate was 0.11 $m^3/m^2/d$, nearly 3 times higher than the methane production rate found by Picot et al. (2003). The average biogas and methane production rates respectively (1.24 m3/Kg BOD5 removed and 1.21m3/Kg VS removed) were higher than the results reported by Park and Craggs (2007) studying the biogas production from anaerobic pond treating piggery wastewater in New Zealand. These efficiencies showed that the anaerobic pond operate well in the warm conditions of soudano-sahelian climate of Burkina faso.

The average daily volume of biogas and its corresponding methane were evaluated respectively to 6.79 and 5.16 m^3. The conversion of this daily methane production to electricity could reduce the CO_2 equivalent GHG emission from petrol combustion by 4.02kg /day and generate a potential 15.4 kwh/d (considering 3.0 $kWh_{electricity}/m^3$).

Table 1 Averages and standards deviation (s.d) of Biogas and Methane production rates from pilot scale anaerobic pond at 2IE (March to july 2010)

Parameter	Mean	s.d	n
Areal Biogaz Production Rate (m^3/m2/d)	0.15	0.04	16
Biogaz Production Rate (m^3/Kg VSa)	0.99	0.3	16
Biogaz Production Rate (m^3/Kg VS removed)	1.59	0.48	16
Biogaz Production Rate (m^3/Kg BOD_5a)	0.48	0.14	16
Biogaz Production Rate (m^3/Kg BOD_5removed)	1.24	0.38	16
Areal Methane Production Rate (m^3 CH_4/m^2/d)	0.11	0.034	16
Methane Production Rate (m^3CH_4/Kg VSa)	0.75	0.23	16
Methane Production Rate (m^3 CH_4/Kg VS removed)	1.21	0.37	16
Methane Production Rate (m^3 CH_4/Kg BOD_5a)	0.37	0.11	16
Methane Production Rate (m^3 CH_4/Kg BOD_5removed)	0.95	0.23	16

CONCLUSION

The objective of this study was to evaluate the production of biogas form an anaerobic pond in soudano sahelian climate of Burkina Faso characterised by warm condition favourable to it functioning. The study has revealed that the biogas production is effective with a high content of methane (averaged at 76%). The results showed good organic digestions with averages biogas and methane production rates respectively evaluated to 1.24 m^3 /Kg BOD5 removed and 1.21m^3/Kg VS removed. These reveal that the conversion of anaerobic pond to anaerobic lagoon digester with the capture and reuse of biogas would be an interesting option for wastewater treatment in the warm conditions of soudano sahelian climate of Burkina Faso.

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