IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 5 Ver. I (Sep. - Oct. 2017), PP 86-89
www.iosrjournals.org

Refinement of Gas generation estimates from anaerobic lagoons Case Study Dandora Waste water Treatment Plant in Kenya

Stephen Kihanya[1], Kay White [2], David Kimingi [3], Dr Semion Dulo [4], Dr. Zablon Oonge[5]

[1]Department of Civil Engineering, School of Engineering, University of Nairobi, Kenya
[2]SMEC Australia, 71 Queens Road, Melbourne, Victoria 3004 Australia,
[3]SMEC, 3rd Floor, Kipro Centre, Sports Road Westlands, Nairobi Kenya,
[4]Department of Civil Engineering, School of Engineering, University of Nairobi, Kenya
[5]Department of Civil Engineering, School of Engineering, University of Nairobi, Kenya
Corresponding Author: Stephen Kihanya

Abstract *The volume of biogas generated within the anaerobic ponds at the Dandora Estate Sewage Treatment Plant (DESTP) has been estimated based on empirical calculations (refer to graph). The biogas production considers seasonal temperature variations, rainwater dilution of the DESTP influent as well as the composition and calorific value of the sewage.* In order to determine the quantity of biogas produced in the anaerobic ponds, a relationship between BOD_5 removals across anaerobic treatment lagoons as a function of volumetric loading rate, i.e. g $BOD_5/m^3.d$ was developed using published data. On average DESTP has been generating 7,900m^3/day of methane at 52% BOD loading. This would be expected to raise to 15,800 at 100% capacity of 160,000m^3/day which has a potential of generating 8 123MWh per month. Currently all this gas is being released into the atmosphere and has a greenhouse effect.

Date of Submission: 28-07-2017 Date of acceptance: 13-09-2017

I. Introduction

Three quarters of organic carbon in sewage are present as carbohydrates, fats, proteins, amino acids, and volatile acids .If discharged to a waterway, these compounds may lead to increased biological activity which consumes the available dissolved oxygen, thus leading to problems such as fish kills and anaerobiosis. The organic content is typically measured indirectly by either the Biochemical Oxygen Demand (BOD), where the oxygen consumed by a colony of microorganisms fed with the sample is measured over a defined period (most commonly, 5 days), or the more rapid Chemical Oxygen Demand test, which measures chemical oxidation of organic substances. Both are indirect measures of organic content in waste water [1]. To reduce or eradicate these problems associated with discharging sewage into receiving waters, there is a great need of treating sewer to reduce the organic content getting into the natural ecosystem. Waste Stabilization Ponds (WSPs) have proven to be effective alternatives for treating wastewater, and the construction of these low energy-consuming ecosystems.WSPs are relatively large, shallow basins, and have been found to be cost-effective, particularly in climates with warmer temperatures and greater sunlight, such as tropical locations. Operational demands of these ponds are generally low [2].

1.1 Anaerobic Lagoons

One specific sub-set of ponds is anaerobic ponds, which are those ponds where anaerobic conditions exist throughout the water column, as well as in the sludge layer on the floor. Anaerobic treatment is achieved by obligate anaerobic bacteria and it is essentially the conversion, under anaerobic conditions, of organic matter to ‘biogas’ – that is methane and carbon dioxide [2]. Biogas is a valuable fuel which, at large plants (e.g. the modern waste stabilization ponds at Melbourne, can be profitably recovered to generate electricity. Anaerobic digestion proceeds in four stages .These stages are hydrolysis which breaks down complex wastewater organics into simple digestible sugars. This is followed by Acidogenesis which is the anaerobic oxidation of fatty acids and alcohols and the fermentation of amino acids and carbohydrates to volatile fatty acids and hydrogen gas. The next stage is Acetogenesis which is the conversion of butyrate and propionates from Acidogenesis stage to acetates which is finally followed by the Methanogenesis which is the final stage and converts acetates, hydrogen and carbon dioxide, to methane [3]. Many anaerobic and facultative bacterial species are responsible for Stage 1, such as Bacillus, Clostridium, Proteus, Micrococcus, Staphylococcus and Vibrio.

As concerns about environmental impacts have increased in the last few decades, one of the issues which is receiving attention is that of the impact treatment plants are having on the environment, beyond that of discharge of treated effluent and the fate of sludge and other by-products .These impacts include direct Green House Gases (GHG) emissions from the process construction and operation as well as indirect effects such as GHG emissions from power generation. Based on operational experience, however, it is known that emissions from any given process will vary in response to factors such as flow, concentration of organics, pH, temperature and contamination. In addition, design of the process will also influence emissions. Determining a basis for more accurate estimation of gas generation rates will enable more effective assessment of GHG aspects of wastewater treatment.

II. Objective Of The Study

This study aims to establish and empirical correlation between BOD_5 removal and BOD loading in the anaerobic ponds at Dandora Estate Waste Water Treatment Plant (DEWWTP) in Nairobi Kenya. This correlation could be used to facilitate estimation of BOD removal across the ponds which can be used to model biogas production from these ponds.

III. Dandora Estate Wwtp

This plant is Located 30 km from East of Nairobi in Kenya, (DEWWTP) features the largest wastewater stabilisation pond in Africa, treating 80,000 m³/day of waste water generated in Nairobi currently. The plant consists of intake works of 160,000 m³/day consisting of Screens and Grit chambers for primary treatment before eight series of ponds comprising of Anaerobic, Facultative and Maturation ponds. The plant has a total of 23 anaerobic ponds with series one carrying two and the rest three ponds each as described in

Table III-1below [4].

Table III-1: Details of Anaerobic ponds at DEWWTP

Series	Number of Ponds	Size of Ponds	Arrangement
Series 1	2	70m by 35m	Parallel
Series 2	3	70m by 35m	Parallel
Series 3	3	65m by 65m	Parallel
Series 4 to 8	3	120m by 90m	Parallel

Each series has 1 fulcaultaive pond measuring 700m by 300m with 3 maturation ponds measuring 300m by 150m in parallel in series 3 to 8.Series 1 and 2 have each 3 maturation ponds in series measuring 300m by 300m as shown in Figure III-1 below. After treatment, this the effluent is discharged into Nairobi River.

Figure III-1: Pictorial Representation of DEWWTP

IV. Data Analysis

This study analysed the influent and effluent BOD_5 loading across the anaerobic ponds at DESWWTP from year 2007 to year 2013.This data was collected from the plant operator and analysed using Microsoft excel to run a multiple regression to determine the correlation between the percentage of BOD_5 removal and the BOD_5 in the influent. The plant received a minimum of 145mg/l of BOD, an average of 381mg/l and a maximum of 762 mg/l for the period 2007-2013.This was 74% of the designed BOD loading of 512mg/l. Table IV-1 below:

Table IV-1: Monthly Average Influent BOD into DESTP

Year/Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2007/2008	280	480	218	261	282	247	240	270	301	279	232	304
2008/2009	383	416	417	417	403	427	524	586	652	590	518	531
2009/2010	655	784	907	781	650	609	369	540	499	315	331	257
2010/2011	428	523	522	516	272	379	581	517	359	498	477	391
2011/2012	373	387	364	338	287	221	299	442	384	276	163	231
2012/2013	294	306	379	318	247	198						
AVERAGE	402	483	468	438	357	347	403	471	439	392	344	343

The observed BOD removal averaged at 67%.this compared well with the designed BOD removals of 52% at a temperature of 16°C [5].At the mean temperature of 22°c, which was the mean of the observed temperature at the plant, the designed BOD^5 removal would be 64%.

However, the plant has been operating with three anaerobic ponds against the designed two anaerobic ponds and at an average temperature of 22°C which is above the designed operating temperature of 16°C. This has resulted into reduced volumetric loading to each anaerobic pond under loading the ponds and higher operating temperatures which attributes to the slightly increased efficiency by three percent.

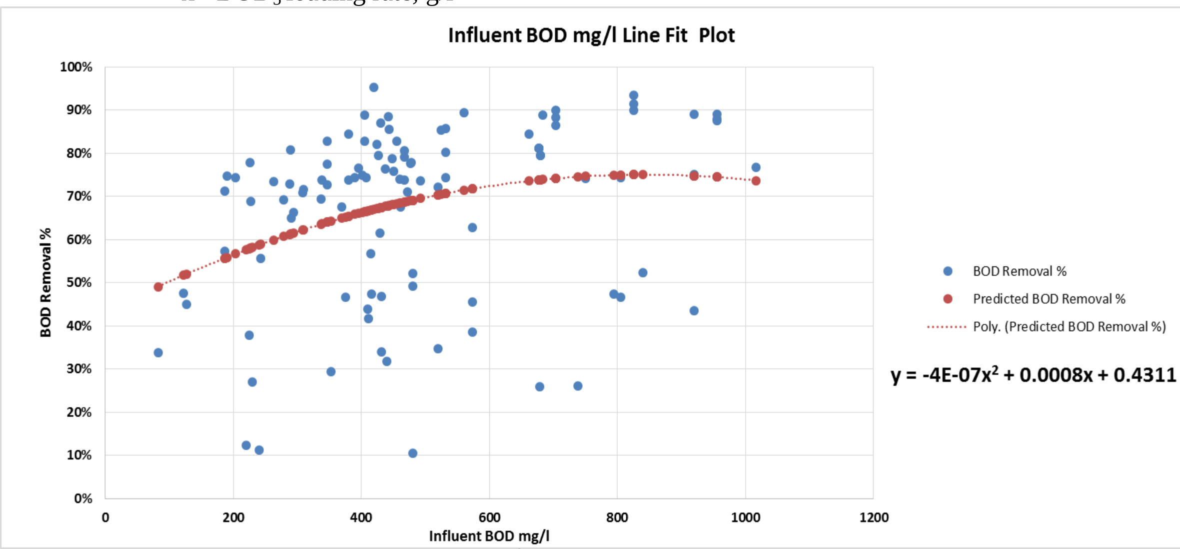
V. Results and Discussion

A correlation equation of BOD_5 removal and influent BOD_5 can be useful in estimating the removal of BOD_5 across the anaerobic ponds and thus provide data for estimation of biogas production from the ponds. For In order to determine the quantity of biogas produced in the anaerobic ponds, a relationship between BOD_5 removals across anaerobic treatment lagoons as a function of volumetric loading rate, i.e. g $BOD_5/m^3.d$ was developed using obtained data from DEWWTP and analysis of this data . This relationship for the percentage BOD_5 removal is given as (1) below:

$$\mathbf{y = -4E\text{-}07x^2 + 0.0008x + 0.4311} \quad (1)$$

Where:

y = % BOD_5 removal, and
x= BOD_5 loading rate, g/l



Noting that at a BOD_5 loading rate of 220.0 $g/m^3.d$, a BOD removal of 60% is obtained from (1) above, which compares with a result of 60% obtained by using Mara's equation (2) below at 20°C

$$\mathbf{BOD\%R=2T+20} \quad (2)$$

Where:
T = Mean air temperature of 20°C for the DEWWTP and Temperature used in the design of DEWWTP

With an understanding of the seasonal effect of temperature variations as well as BOD_5 loading rate, the seasonal variation in BOD_5 removal across the Anaerobic Pre-treatment Ponds can thus be computed based on the equation (1) above. Knowing the BOD_5 removal across the ponds, the amount of biogas produced on a seasonal basis can thus be determined. One way of testing the accuracy of regression is a plot of residuals not showing a partern.From the analysis, the residuals showed no pattern and thus the regression was considered to be reliable and coupled with a low value of significance of 1.20597012042784E-30.

VI. Conclusions

Regression analysis was performed for removal percentage of BOD_5 at the anaerobic ponds of DEWWTP which indicated a correlation between loaded BOD_5 and the removals percentage. The treatment process at this plant has been operating with the removal of BOD_5 being depended on the loading of BOD_5 and the study concluded that the removal of BOD5 across the anaerobic ponds at the DEWWTP can be estimated using equation. (1)

On average DESTP has been generating 7,900m^3/day of methane at 52% BOD loading. This would be expected to raise to 15,800 at 100% capacity of 160,000m^3/day which has a potential of generating 8 123MWh per month. Currently all this gas is being released into the atmosphere and has a greenhouse effect.

References

[1] Glynn Henery, J., 1989. Water pollution. In: Heinke, G.W., GlynnHenery, J. (Eds.), Environmental Science and Engineering.Prentice-Hall Inc., Englewood Cliffs, New Jersey, pp. 297–329.

[2] Mara, D.D., Pearson, H.W., Oragui, J.I, Arridge, H. and Silva, S.A.(2001). Development of a new approach to waste stabilization pond design.School of Civil Engineering, University of Leeds, Leeds, England.

[3] Metcalf & Eddy., et al., Wastewater engineering: treatment and reuse. 4th ed. McGraw-Hill series in civil and environmental engineering. 2003, Boston: McGraw-Hill.

[4] Otieno Odongo et.al (1998), Nairobi Master Plan for Sewer,Sanitation and Drainage,Third Nairobi Water supply Project.

[5] Sir Alexander GIBB and Partners,(1998).Dandora Sewage Treatment Plant ,Phase 2,Final Design Report.

Stephen Kihanya. "Refinement of Gas generation estimates from anaerobic lagoons Case Study Dandora Waste water Treatment Plant in Kenya." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 14, no. 5, 2017, pp. 86–89.