Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2018, 5(3):384-393

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Examination of Temperature and pH in Anaerobic Digester Process

Ukpaka C.P.[1], Ben–Iwo Juliet[1], Fakrogha J.J.[2]

[1]Department of Chemical/Petrochemical Engineering, Rivers State University, Nkpolu, Port Harcourt, P.M.B 5080,Rivers State, Nigeria
[2]Department of Chemical Engineering, Delta State University, Abraka, Delta State, Nigeria

Abstract The need to monitor and predict the characteristics of temperature and pH in a bio-digester is found necessary since the two parameters are classified to be a contributing factors that influence the rate of production of biogas. The research demonstrates the significance of the functional parameters in terms of product yield and as a way forward to control the techniques and the process that may be contributing factors, which influence the rate of production of biogas. The research is found interesting because of the role these two parameters can play in microbial activities, since it is a new trend of technology that led to alternative source of energy in the recent year. Also the use of fossil fuels as primary source has led to a global climate change, environmental degradation and human health problem. It is observed that improper waste management is one of the major problems confronting every developing nation today. These waste when not properly manage contribute to unhygienic environmental conditions that breed pathogenic microorganisms apart from health implications, waste make an environment unpleasant and unattractive. However, these wastes can be managed properly by conversion into useful and more environmental friendly forms of renewable source of energy called biogas. A batch anaerobic digested with a capacity of 85 liters was designed and fabricated for the conversion of this organic waste (cow dung with Maringa oleifera mixed with water) in the ratio of 1:0.02:1 for the production of biogas. The digester was stirred thrice daily to avoid scum in the digester, the temperature and pH value was also measured thrice daily at an interval of 6hrs (7am, 1pm and 7pm) and the effect of temperature and pH was studied and analyzed in the process. In the course of this work the optimum temperature and pH for the production of biogas in the digester was determined. It was observed that the temperature range of 35.1 ºC to 38.5 ºC was observed and classified as mesophilic condition and pH in the production of biogas was acidic this can be attributed to the raw materials used during this investigation.

Keywords Examination, temperature, pH, anaerobic, digester, process

Introduction

The need to develop an alternative source of energy has become increasingly apparent with incidents of fuel shortages and escalating prices in recent years as well as consider suitable conditions that will favor the optimum production of the desired product by using other technological approach to obtain methane from biodegradable substance [1–3]. Also the use of fossil fuels as primary source has led to global climate change, environmental degradation and human health problems [4–5].

Also improper waste management is one of the major problems confronting every developing nation. These wastes when not properly managed contribute to unhygienic environmental conditions that breed pathogenic microorganisms, apart from health implications, waste make an environment unpleasant and unattractive [6-7].

However these wastes can be managed properly by converting it into a more useful environmental friendly form of renewable energy source called Biogas [8].

Renewable energy source such as Biogas appear to be one of the efficient solution to the problems resulting for the use of fossil fuels. Biogas is produce by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage municipal waste, green wastes, plant materials and crops [3]. But for the case of this research we are going to base our concentration on the design and fabrication of batch type anaerobic digester and also evaluating the effect of temperature and pH on the co-digestion of cow dung and Moringa oleifera in the digester. The reserves for animal waste which a viable source of biogas production as at 2005 was estimated to be 61 million tonnes per year which means there is available raw material for the reaction process [9].

In batch anaerobic digester the principal component of the digester for biogas production is a digester chamber a facility for slurry preparation, storage for the processed slurry, a gas collecting space and an area for the mechanical equipment like the stirrer for agitation and components such as a pressure gauge, thermometer and pH meter are important to monitor the variation of pressure, temperature and pH respectively as they are the major factor that affect the anaerobic digestion process in the digester [6]. The ease of accessibility of the various component of the digester must be emphasis. In the batch system the digester is filled with slurry that is allowed to remain in the digester until the desired treatment is finished, the biodegradable slurry is then removed and replaced with a new batch of material. In designing the anaerobic digester there are many factors which must be considered, the microbial and chemical process of the organic material, the environmental requirements for the process such as the temperature, retention time, loading rate agitations which will be discussed in details later on in the research. An effective production system must control all these factors through provisions within its structural and equipment components [10 - 14].

A given amount of organic waste can be converted to a maximum amount of biogas at a given temperature provided optimum conditions are prevalent. This conversion can be accounted by two factors i.e. biodegradability at a specifies temperature and operating condition that depends on kinetics, reactor configuration, retention time of the slurry in the digestion chamber, loading rate within the digester, digestion stage as well as the presence of the inhibitory substances [15 -21].

The evaluation of the reactor design can be made in terms of the rate stability and completion of biochemical reactions as well as emissions of pollutants and recovery of energy of materials. The biomethanization of organic wastes is accomplished by a series of biochemical transformations, which can be mainly separated into two steps. The first step consists of hydrolysis, liquefaction and acidification whereas the second step involves the transformation of acetate, hydrogen and carbon dioxide into methane [22 -26].

One of the major issues regarding with the stability of a batch type anaerobic digestion process is bacterial nutritional requirement because insufficient nutrients may result in an incompletes, unstable bioconversion of the organic wastes and may ultimately cause digester failure [27].

According to previous studies done by various research groups revealed that there was a problem of low biogas yield low methane composition. The problem was due to the design configuration of the reactor. In this study the problems as said above was solved by modifying the design of the batch type anaerobic digester and the optimization of operational parameters such as organic loading rates, retention time, temperature and equipment or parameter used in the design.

The aim of the study is to design and fabricate a batch type anaerobic digester and study the effect of temperature and pH on the co-digestion of the feedstock (cow dung and Moringa oleifera leaf) in the digester

The specific objectives of the study are as follows: fabrication and design model of batch type anaerobic digester, mathematical model development in the area of biomass and substrate kinetics, evaluate the effect of temperature and pH on the digestion process in the digester and one should be able to determine the optimum temperature and pH for the production of biogas.

Materials and Methods

Main component of the system

In the fabrication of a batch anaerobic digester, the main or principal components of the system for the production of biogas (methane) include: digester tank, inlet and outlet for the feeding of the organic waste, horizontal paddle starrier, thermometer, gas collection and purification chambers, 3kg cylinder for storage, table with rollers for the digester tank, pressure gauge and pH meter

Materials required and their functions

Digester Tank: The anaerobic digester tank is a huge vessel where biochemical reactions are carried out in the absence of oxygen. It collects the organic feed and converts the energy store in it into biogas. The digester column or tank in this study is placed horizontal with 2ft and diameter of 1ft4inches.

Horizontal manual stirrer: The horizontal manual stirrer with a connecting rod with four shaft is constructed with the digester chamber to stir the feed in the digester chamber. The aim is to spread the anaerobic bacteria evenly on the feed.

Pressure gauge: The pressure gauge was used to measure the pressure in the digester and that of the gas leaving the digester.

Thermometer: A 76 mm mercury in glass thermometer with a temperature range of 10-100 ºC was used it has a tolerance of $\pm 10^{*}$C. It is used to measure the temperature of the digestion process.

pH Meter: A laboratory pH meter is used for determining the pH of the digester before and after the digestion process. The meter is calibrated using commercial standard (pH 4.0, 7.0, 10.0).

Galvanised steel sheet (2 mm): used in the fabrication of the digester.

Welding Machine: Used for welding and joining the galvanised steel sheet together.

Sheet metal cutter: The sheet metal cutter is used for cutting of the steel metal into size and shape.

Supporting table with Rollers: A supporting table is constructed to support the digester. It is constructed with an angle iron with a length and breadth of 0 .9m and 0.6m respectively.

Thermometer duct cork: This is used for closing the thermometer duct.

Bearing(X2): It is used to make the agitator static and dynamically balance.

Poly filler: This is used for sealing welded joint to avoid leakages.

3kg Cooling Cylinder: This is used for storing yielded gas.

Hand Drilling machine: This is used to create bolt and nut holes to hold the digester to the supporting table.

Rubber Hole: This was used to connect the digester to gas collector.

Clip made of metal plates, bolt and nut: This was used to clip the hose at various points as required during experimental procedure.

Weighing balance: This was used for weighing the material needed or the amount of the feedstock

Cow Dung: This was used as feed stock into the digester.

Moringa oleifera: This was used as co-substrate serving as a stimulator.

Maggots: This was used to exhaust oxygen enclosed in the digester.

Chemical Reagent: The chemical reagent used include

1. Ferric Oxide: The ferric oxide was used to absorb the hydrogen sulphide(H_2S)
2. Siliga Gel: This was used to absorb water vapour.
3. Sodium hydroxide (NaOH): This was used to absorb the Carbon(iv) Oxide (CO_2).

Rollers: The rollers are attached to the table to enable easy movement of the digester.

Polyvinylchloride (PVC): This PVC was used as the purification chamber to trap CO_2, H_2S and water (H_2O)

The experimental set – up is made of the following equipment and materials such as, anaerobic digester, reactor stand, thermometer, pressure gauge, pH meter, gas cylinder, stirrer, purification chamber 5 filled with Ferric Oxide to remove H_2S (hydrogen sulphide), purification chamber 6 filled with Silica Gel to remove water vapour, purification chamber 7 filled with NaoH (sodium hydroxide) to remove CO_2 (carbon iv oxide), hose and 3kg Gas cylinder to receive the wet methane produced from the process.

The anaerobic digester was connected to three water dispenser connected in series for the purpose of purification and removal of impurity present in wet methane produced in the bio-digester and recovering of the main product to the gas cylinder for storage.

Figure 1: Experimental Set – Up

Experimental Procedures

The Cow Dung and Moringa oleifera used in this research was obtained from the Rivers State University School Farm in Port Harcourt of Rivers State, Nigeria. The fresh Cow dung was obtained from animal pen unit.

The Cow dung and Moringa oleifera was properly weigh and mixed properly with tap water. The ratio of the Cow dung, Water and Moringa oleifera is in the ratio of 1:1:0.023. Cow dung was analyse based on its total solid content (TS), volatile solid content (VS), pH and moisture content.

The co-digesting feedstock was then fed into the digester through the inlet hole, the digester volume of 85m^3 was used and the total volume of the feedstock was half the total volume of the digester.

The digester was then stirred thrice daily with the manual horizontal paddle stirrer to avoid scum formation in the digester.

The temperature was taken thrice daily after every 5 hours with the aid of the mercury-in-glass thermometer via thermometer duct provided. The measurement was taken at 7am, 1pm and 7pm. This was done to determine the temperature changes during the day.

A. Cow Dung B. Mixed Substrate

C: Moringa Oleifera leaf

Figure 2: Samples illustrating cow dung, mixed substrate and Moringa oleifera leaf

Analysis of the properties of the feedstock

- **Total solid content (TS):** The total solid content in the sample (substrate) can be defined as the ratio of the weight of the oven dried sample (W_d) to the weight of the weight sample (W_w) in kilogram.

  Mathematically; TS = $\frac{W_d}{W_w} \times 100$

Where; TS= total solid in percentage (%)

W_d= weight of oven dried sample (kg)

W_w = weight of wet sample (kg)

- **Volatile Solid Content (V_s):** The volatile solids content and the non-volatile solid content of the sample can be analysed by the relationship after the dried sample have being ignited in the furnace.

$V_s = W_d - \frac{W_a}{W_d} \times 100$

$NV_s = \frac{W_a}{W_d} \times 100$

Where; V_s= the volatile solid in dry sample (%)

NV_s= non- volatile solid content (%)

W_a= weight of dry ash left over after igniting the sample (kg)

To find the amount of TS and VS in the slurry we used the following relation.

TS =%TS [total weight of slurry]

VS = %VS [total TS]

Biogas Purification

The biogas has to be purified before used. The main requirement would be the removal of acid gases (CO_2 and H_2S) and also water vapour which can be removed with the help of the free chambers provided with the digester.

H_2S Removal: The hydrogen Sulphide (H_2S) removal was done in the first chamber, whereas the gas collected from the digester was passed through terrace oxide (Fe_2O_3) to remove hydrogen sulphide.

Water Vapour Removal: The biogas from the H_2S chamber was then passed through silica get to absorbed water vapour.

CO_2 Removal: The CO_2 gas was removal by passing the biogas through 0.5 mole of sodium hydroxide (NaOH) where the pure gas was then trapped in a cylinder.

Results and Discussion

The table below shows the measured weight of substrate (Cow Dung and Moringa Oleifera) indicating the mixing ratio in a digester of 85 liters. It also shows the composition of the substrate indicating all parameters determine from the analysis of the substrate.

Table 1: Analyzed Properties of the feedstock

Parameter determined	Cow dung	Moringa Leaf	Water
Mass	21kg	0.5kg	21kg
pH	5.0	5.6	7
% Total solid @ 105 ^{o}C	27.995	46.25	-
Moisture content	71.52	23.0	
Volatile solid 550 ^{o}C	70.00		
Mixing ratio	1	0.02	1
No. of days of digestion	30	30	30

From the analysis of the feedstock which is a co–digestion of Cow dung and Moringa Oleifera and water mixing in the ratio of 1:0.02:1 which is $\frac{1}{2}$ of the volume of the digester.

Effect of Temperature variation on Anaerobic Digestion

The table 1 below shows the variation of temperature and pH value of slurry in the digester for 30days retention time where the measurement where taking thrice daily morning at 7am, afternoon at 1pm and evening at 7pm.

Table 2: Temperature variation at different time interval

Retention Time(day)	TEMP AT 7am	TEMP AT 1pm	TEMP AT 7pm
1	35.7	35.8	36
2	35.6	35.9	36
3	35.2	35.7	35.9
4	35.7	35.8	36
5	35.2	35.7	35.9
6	35.7	35.8	35.8
7	35.2	35.6	35.7
8	35.3	35.5	35.6
9	35.2	35.4	35.5
10	35.1	35.3	35.9
11	35.5	35.7	36.3
12	35.9	35.9	36.7
13	36.4	36.4	36.3
14	36.3	36.5	36.4
15	36.4	36.5	36.4
16	36.4	36.5	36.5
17	36.8	36.6	36.4
18	37.4	37.2	37
19	37.2	37.4	37.2
20	37.4	37.6	37.6
21	37.9	38.1	38.4
22	38.1	38.1	38.3
23	38.5	38.2	38.3
24	38.2	38.1	38.1
25	37.5	37.8	37.9
26	37.1	37.4	37.5
27	36.4	36.7	36.8
28	36.2	36.3	36.4
29	35.1	35.6	35.8
30	35.8	35.9	35.7

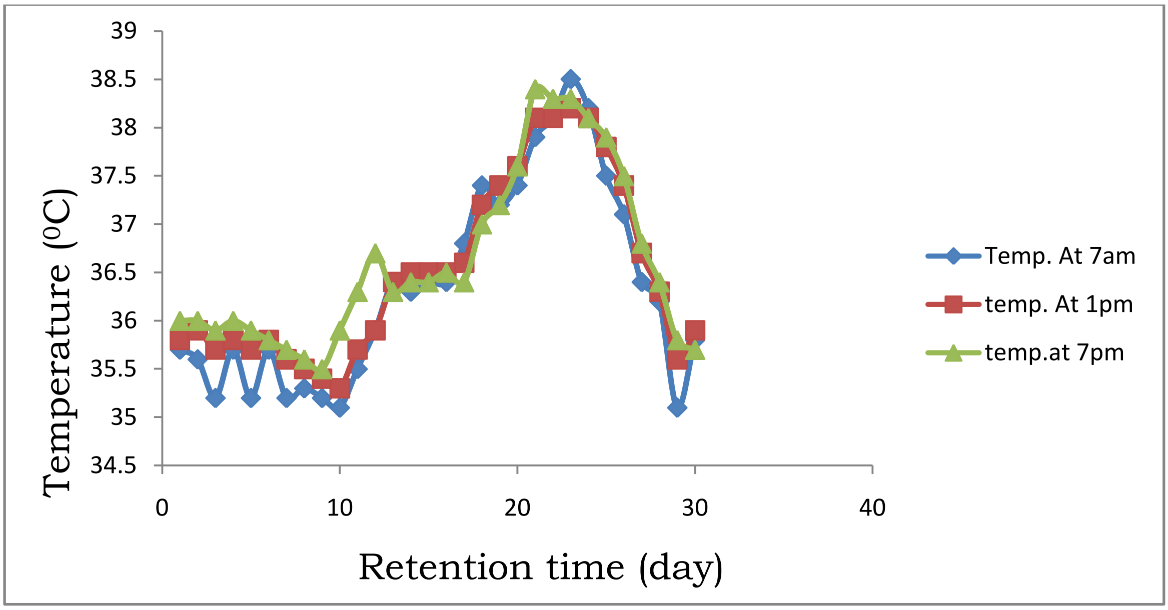

Figure 3: A graph of temperature against retention time

Temperature was recorded thrice daily throughout the digestion period, fig 3shows the temperature variation profile over a retention time of 30days. It is one of the critical factors that is needed to be monitored for better performance of the digester. Methanogens are very sensitive to sudden thermal changes. Therefore, any drastic change in temperature should be avoided.

The fluctuation in the digester within a range of 6hrs is below 1ºC. This is because the digester is painted with a silver cooler which does not absorbed much heat from sunlight. Temperature ranged from 35.1ºC to 38.5ºC throughout the retention time. Therefore, the condition is mesophilic because it ranges between (25-50ºC). The temperature reached its maximum value of 38.5ºC after 11days of digestion in the morning, afternoon and evening. This is expected because at this stage a drop in pH was recorded due to quick production of volatile fatty acid. Between the (11-18) days of digestion a relatively constant temperature was observed. This is also in line with a relatively constant p^H indicating the cessation of the anaerobic digestion process. As the temperature increases the population of the enzymes also increases. The specific growth rate of microorganisms is greatly affected by medium pH and temperature. Optimum pH and temperature differ from one microorganism to another.

Effect of variation of pH on Anaerobic Digestion process

The table below shows the variation of P^H on an anaerobic digestion process which range from 5.0 to 6.98 over a 30days retention time.

Table 3: pH variation at different time interval

Retention time (day)	pH at 7am	pH at 1pm	pH at 7pm
1	6.85	6.98	6.95
2	6.85	6.97	6.94
3	6.84	6.96	6.93
4	6.83	6.95	6.92
5	6.82	6.94	6.92
6	6.81	6.93	6.91
7	6.8	6.92	6.9
8	6.79	6.91	6.87
9	5.48	6.0	5.87
10	5.5	5.8	5.84
11	5.5	5.5	5.7
12	5.5	5.48	5.49

13	5.48	5.48	5.48
14	5.5	5.49	5.5
15	5.5	5.48	5.48
16	5.8	5.5	5.49
17	5.4	5.55	5.5
18	5.2	5.8	5.4
19	5.3	5.5	5.5
20	5.2	5.3	5.2
21	5.4	5.2	5.1
22	5.1	5.4	5.2
23	5.3	5.2	5.2
24	5.8	5.9	6.1
25	5.5	5.9	5.9
26	5.1	5.2	5
27	5.2	5.0	5.1
28	5.3	5.2	5
29	5.1	5.0	5.3
30	5.1	5.0	5

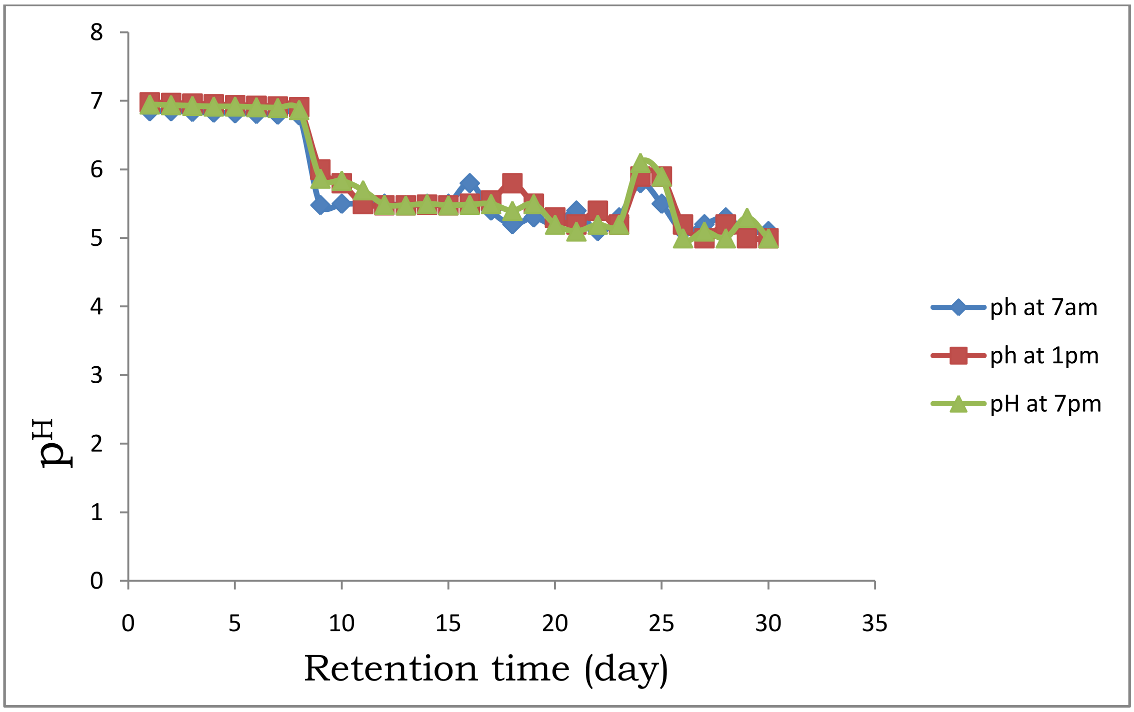

Figure 4: A graph of pH against retention time

Variation of pH in Anaerobic Digestion Process

The variation of P^H over the period of digestion is shown in figure 4 and range from 5.00 to 6.98 there is no significance change in P^H during the first week of digestion. The initial decrease in P^H started to drop fast and reached minimum values at after 12days. After 12days I observed a relatively constant P^H which results in the observation of a relatively constant temperature. Thus P^H is one of the important parameters affecting an anaerobic digestion.

Conclusion

From the study, the following conclusions can be made:

1. Biogas can be produced by the microbial digestion of organic matter in the absence of air. Various wastes, such as municipal wastes, kitchen waste, animal waste and crop residue can also be used in the production of biogas.
2. Biogas production technology has established itself as a technology with great potential which could exercise major influence in the energy scene in the world.
3. Biogas production took place within the retention period of four weeks from microbial digestion of cow dung and moringa oleifera in an anaerobic condition.
4. The percentage yield of products of biogas produced depends on the type of substrate used and its chemical constituents.
5. A biogas digester that is air-proof without leakage was constructed for this to ensure the breaking down of cow dung and moringa oleifera by anaerobic bacteria.

Factors affecting anaerobic digestion was studied, such factors include; temperature and pH. As the temperature increases from the experiment the population of the enzymes also increases thereby increasing the rate of biogas production. The temperature reached its maximum range of 38.5ºC between the (11-18) days of digestion. This is due to a drop in pH value recorded at that range and recorded a relatively constant temperature which is in line with a relatively constant pH indicating the cessation of the anaerobic digestion process thus as the temperature of the system is relatively constant we have a relatively constant p^H which have a great influence on the activities of the microorganism in the digester.

References

[1]. Akinbami, J.F.K., Ilori, M.O., Oyebisi, T.O., Akinwuni, I.O., Adeoti, .O., (2001). “Biogas Energy use in Nigeria: current status, future prospects and policy implications”. Renew. Sustain. Energy. Rev., 5, 97-112.

[2]. Bejan, M., and Rusu, T., (2007). A Source of Renewable Energy – Biogas from Organic Residues” AGIR Bulletin, 1, 13 – 19.

[3]. Budiyono, W. I. N., & Johari, S. (2011). Study on Slaughterhouse Wastes Potency and Characteristic for Biogas Production, 5, 4–7.

[4]. Daxiong, Q., (1990). Diffusion and Innovation in the Chinese Biogas Program”. Tsinghua University Beijing. World Development, 18, 555-563.

[5]. Enweremadu, C.C., Ojediran, J.O., Oladeji, J., and Afolabi, I.O., (2004). Evaluation of Energy Potential of Husks from Soy-beans and Cowpea” Science Focus, 8, 18-23.

[6]. Speece, R. E. (1983).Anaerobic biotechnology for industrial wastewater treatment. Environmental Science, and Technology, 17(9), 416

[7]. Wu B. (2012). Integration of mixing, heat transfer, and biochemical reaction kinetics in anaerobic methane fermentation. Biotechnology, 109

[8]. Kayhanian, R. (1995). Pilot-scale high solids thermophilic anaerobic digestion of municipal solid waste with an emphasis on nutrient requirements- Biomass and bioenergy, 14

[9]. Okoromah, C. O and Ukpaka, C. P. (2013). Modeling the biosorption of crude oil in water using plantain pseudo stem as the adsorbent. *Journal Engineering and Technology Research*, 5(4), 122-138,

[10]. Ukpaka C.P and Otabiri, B. (2013) Responses Application to monitor and predict of crude Distillation rate using Pneumatic control System on a Furnace. *Journal of Engineering and Technology Research*, vol. 5(7), 217 – 229.

[11]. Ukpaka, C.P. (2014). Studying fermentation characteristics of some palmwine obtained in Niger delta area of Nigeria, *International Journal of Novel Research in Engineering & Pharmaceutical Sciences*, 1(2),1 – 5.

[12]. Ukpaka, C. P. The concept of chemical and biochemical oxygen demand in inhibiting crude oil degradation in fresh water pond system. *Merit Research Journal of Environmental Science and Toxicology*, vol.1, no. 7, pp. 136 - 146, (2013).*Availableonlinhttp://www.meritresearchjournals.org*

[13]. Ukpaka, C. P.(2013). Evaluating the pH characteristics on the kinetics of crude oil degradation in salty water pond. *Comprehensive Research journal of Biological Science. (CRJBS)*, 1(1), 6-20.

[14]. Ukpaka, C. P. (2014). The inhibiting effect of conductivity on crude oil degradation in fresh water pond, *International Journal of Novel Research in Engineering and Pharmaceutical Sciences*, vol. 1(3), 31 – 40.

[15]. Ukpaka, C. P. (2013). Prediction of crude oil degradation upon the influence of bacteria by using the approach of least square method. *Scientific Research and Impact*, 2(4), 73-101.

[16]. Ukpaka, C. P.(2013). Project cost management: solid waste disposal using Port Harcourt city as a case study. *International Journal of Novel Research in Engineering & Pharmaceutical Sciences*, 1(01), 19 – 29.

[17]. Ukpaka, C. P. (2013). Application of Polynomial method to Monitor and Predict the Aromatic Hydrocarbon Degradation using *Pseudonomas sp. Comprehensive Research Journal of Biological Science (CRJBS)*, 1(1), 6-20.

[18]. Ukpaka, C. P.(2013). Evaluating the effect of conductivity on crude oil degradation in salt water pond, *International Journal of Applied Chemical Sciences Research*, 1(9), 144-158,

[19]. Ukpaka, C. P.(2013). Application of competition model to predict and monitor the bacteria and fungi characteristics in solid waste degradation, *International Journal of Novel Research in Engineering & Pharmaceutical Sciences*, 1(01), 30 - 42

[20]. Ukpaka, C. P;Ogoni, H. A; Amadi, S. A and Akor, A. J. (2013). Dry Season Predictive Technique for Estimating the Hydrocarbon Degradation in a Continuous Discharge of Wastewater in Pond System. *International Journal of Physical Science*, 8(33), 1676 -1693.

[21]. Ukpaka, C. P. (2014). Modeling the Effect of pH Characteristics in Biodegradation of Crude Oil in Fresh Water Pond., *International Journal of Novel Research in Engineering & Pharmaceutical Sciences*, 1(2), 6 -14.

[22]. Ukpaka, C.P, and Amadi, S.A. (2013). Comparative analysis of thermal and microbial enhanced oil recovery, *Basic Research Journal of Engineering Innovation*, vol. 1, no. 4, pp. 7 – 13.

[23]. Amadi, S.A. and Ukpaka, C.P. (2014). Evaluation of microbiological corrosion of carbon steel in fresh water environment, *International Invention Journal of Biochemistry and Bioinformatics*, 2(1), 16 - 26.

[24]. Ukpaka, C.P, Wami, E.N and Amadi, S.A. (2015). Effect of Pollution on Metal Corrosion: A Case Study of Carbon Steel Metal in Acidic Media, *International Scientific Organization: Current Science Perspective*, 1(4), 107 – 111.

[25]. Amadi, S.A. and Ukpaka, C.P. (2014). Petrochemical effluent on pollution monitoring, *International Journal of Environmental Science and Toxicology*, 2(1), 16–21.

[26]. Ukpaka, C. P. (2013). Application of discrete compartment models to predict and monitor degradation of crude oil in an ecosystem using matrix. *Journal of Modelling, Simulation and Control (AMSE)*, 74(2), 50-60.

[27]. Ukpaka, C. P and Ogoni, H. A. (2015). Investigation into the effect of velocity distribution on dry season hydrocarbon degradation in pond system. *International Journal of Novel Research in Engineering and Pharmaceutical*, 1(4), 36 – 50.