International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:12, No:11, 2018

# Methane Production from Biomedical Waste (Blood)

Fatima M. Kabbashi, Abdalla M. Abdalla, Hussam K. Hamad, Elias S. Hassan

***Abstract*—**This study investigates the production of renewable energy (biogas) from biomedical hazard waste (blood) and eco-friendly disposal. Biogas is produced by the bacterial anaerobic digestion of biomaterial (blood). During digestion process bacterial feeding result in breaking down chemical bonds of the biomaterial and changing its features, by the end of the digestion (biogas production) the remains become manure as known. That has led to the economic and eco-friendly disposal of hazard biomedical waste (blood). The samples (Whole blood, Red blood cells 'RBCs', Blood platelet and Fresh Frozen Plasma 'FFP') are collected and measured in terms of carbon to nitrogen C/N ratio and total solid, then filled in connected flasks (three flasks) using water displacement method. The results of trails showed that the platelet and FFP failed to produce flammable gas, but via a gas analyzer, it showed the presence of the following gases: CO, HC, $CO_2$, and NOX. Otherwise, the blood and RBCs produced flammable gases: Methane-nitrous $CH_3NO$ (99.45%), which has a blue color flame and carbon dioxide $CO_2$ (0.55%), which has red/yellow color flame. Methane-nitrous is sometimes used as fuel for rockets, some aircraft and racing cars.

***Keywords*—**Renewable energy, biogas, biomedical waste, blood, anaerobic digestion, eco-friendly disposal.

## I. Introduction

BIOGAS is naturally produced in nature. Its existence was discovered in the 17th century, and the design and construction of systems and plants to produce biogas began by the mid-19th century [1].

Biogases are renewable fuels that are produced by the decomposition or fermentation of organic substances and the breaking down of its carbon bonds in an oxygen-free environment, this process called anaerobic digestion and the gas produced is called methane. The organic substances (materials) used in the process can be obtained from any type of organic waste (biomass, animal manure, sewage, solid waste, green grass, food waste, agricultural residues, and plant and energy crops). Producing methane in an oxygen-free environment using these waste materials helps to reduce air and water pollution, as well as the amount of waste that must be disposed of using methods that have no environmental benefits likewise, reducing greenhouse gas emissions [1].

Biogas is considered a source of energy that may solve many energy problems that the world faces nowadays. Biogas can be used as fuel in many applications such as heating, cooking, transport and operate any type of thermal engine to generate mechanical or electrical power [1].

Biogas is a mix of flammable gasses composed of methane ($CH_4$) in the range from 40% up to 75% and $CO_2$ with average range from 25% to 60%, as well as water vapor ($H_2O$) and other gasses such as ammonia ($NH_3$), nitrogen ($N_2$) and hydrogen Sophie ($H_2S$). The presence of those gasses depends on the digested organic substance (chemical structure and carbon bonds) and amount of CH4 produced, in carbohydrates and cellulose (CH4) value is 50% of total gas produced and this value goes up to 63.6% in organic substance containing more proteins and highest (CH4) detected in fats with value of 70.2% of total gas [1], [2].

Methane is colorless and odorless gas, blue flame, molecular weight of (16.643 gram/mole), have high density of (0.7175 gram/liter) at conditions of (0 °C and 1013 par), melting point at (-182.47 °C) and boiling point at 161.48 °C [1].

Medical wastes are defined as all wastes that generated from any type of health facilities such as hospitals. Another definition regarding to Biomedical Waste Management Rules (BWMR) in India, biomedical waste is defined as any waste that is produced through fortification, diagnosis or treatment of humans and animals or in scientific activities [3], [4].

Water pollution can be caused by biomedical waste if delivered into lowlands or lakes directly or indirectly. If any liquid waste pour out into any source of clean water, the water becomes perfect media for bacterial growth (water becomes polluted) [5].

Two of the major methods to dispose of biomedical waste are landfill and burning (incinerator) but these methods have many cons, for example, the incinerator smoke causes cancer. The last disposition of all biomedical waste types takes place in landfill, the biomedical liquid wastes are disposed of in landfill after being chemically treated in this case land pollution is unavoidable but it can be reduced by feasible treatment [5].

Toxic air and toxic ash, which are emitted during the incineration of medical waste, are the main source of environmental dioxins. Toxic ash transferred to land for disposal can leak into the groundwater. Polluted lands that contain contaminated ash may become mixed with animal food. If the animals feed on this polluted food, and then humans consume animal products such as meat, milk, and many others, this known as Bio-magnification. Toxic air filled with gases which are emitted from incinerator are harmful gases that cause respiratory disease and cancer [5].

A report published by the World Health Organization (WHO) in 1996, detects that above 50,000 people die daily due to infectious diseases. One of the major reasons for the

A. M. is with the Biomedical Engineering Department, Sudan University of Science and Technology SUST, Sudan (phone: 00249922002462, e-mail: abdallahtr8@gmail.com).

F. M. K. is with the Biomedical Engineering Department, Sudan University of Science and Technology SUST, Sudan (phone: 00249991922254, e-mail: fmkabbashi@gmail.com).

H. K. H. is with the Biomedical Engineering Department, Sudan University of Science and Technology SUST, Sudan (phone: 00249904884668, e-mail: hussam.kamal93@gmail.com).

E. H. is with the Biomedical Engineering Department, Future university, Sudan (phone: 00249912378733, e-mail: Elias_siddig@hotmail.com).

increase in infectious diseases is the improper handling and management of biomedical waste [5].

According to general information about blood bank waste in Sudan and with the approval from the Ministry of Health (MOH) in Khartoum, the data has been collected during rounds in Khartoum public and private hospitals at a rate of 70.4% and 29.6%, respectively The largest amount of expired blood in hospitals comes from Laboratories waste at a rate of 21.1% and Blood banks at 54.9%. The largest amount of waste in Laboratories and Blood banks is blood with percentages of 77.5% and 77.5%, respectively. The expired blood bags and blood platelet bags produced by Blood banks weekly, is less than 100 bags. Disposal of these bags is being managed by sending it to incinerator or landfill at a rate of 70.4% and 26.8%, respectively.

## II. Methodology

All authorizations were given by the Ministry of Health (MOH) to visit and collect blood samples from blood banks for this experiment.

### *A. C\N Carbon to Nitrogen Ratio Test*

The experiment took place at the National Center for Energy Research (NCER) in Khartoum-Soba. All samples have been collected and tested in Ministry of Petroleum and Gas (MOP) Petroleum Laboratories, Research and Studies (PLRS), in Khartoum Elamarat Street 61, by a device called a CHNS Elemental Analyzer, to determine the carbon to nitrogen ratio and is shown in Table I.

TABLE I
Carbon \ Nitrogen Ratio in Blood Component

| Samples | Carbon | Nitrogen |
|---|---|---|
| Blood | 13.91 | 4.079 |
| RBCs | 13.38 | 4.007 |
| Blood2 | 9.119 | 1.431 |
| Blood platelet | 5.1059 | 1.323 |

### *B. Total Solids Test*

Total Solid is an expression used in material leftover in the crucible after the evaporation of water. The sample is evaporated in a weighed Crucible on a steam bath and is starting to dry to a steady mass in the oven at temperature 103-105°C or 179-181°C, then Total solids/leftovers are calculated. Calculation of the samples is shown in Table II. Measurement of total Solids can be made in a verity of liquid biomedical waste like blood samples (whole blood, RBCs, and blood platelet).

$$\text{Total solid \%} = \frac{WR}{WW} \times 100 \quad (1)$$

### *C. Experiment*

The method used in this experiment is the Water Displacement (WD) method used in laboratories, as shown in Fig. 1.

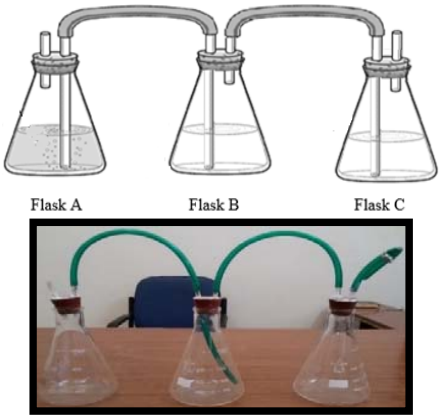



Fig. 1 Experimental set up A

TABLE II
Total Solid

| SAMPLE No | $W_W$ g | $W_R$ g | TOLAL SOLID% |
|---|---|---|---|
| Whole blood | 1.002 | 0.20 | 19.9% |
| Whole blood2 | 0.620 | 0.21 | 33.8% |
| Whole blood3 | 1.000 | 0.12 | 12% |
| Whole blood4 | 1.010 | 0.13 | 12.9% |
| Whole blood5 | 1.017 | 0.37 | 36.5% |
| Whole blood6 | 1.017 | 0.37 | 36.5% |
| Whole blood7 | 1.040 | 0.31 | 29.8% |
| RBCs | 0.980 | 0.22 | 22.4% |
| RBCs 1 | 1.010 | 0.29 | 28.7% |
| RBCs 2 | 1.010 | 0.29 | 28.7% |
| Blood platelet | 1.000 | 0.12 | 12.0% |
| Blood platelet1 | 1.020 | 0.09 | 8.8% |
| FFP | 1.020 | 0.09 | 8.8% |

WW=Weight of sample. WR=Weight of dray sample.

### *Flask A (The Digesters)*

First, add Blood or RBCs or Blood platelet (BPL), then Bacteria, and then water using the equations:

$$\text{Sample weight g} = \frac{10\%}{\text{total solid \%}} \quad (2)$$

$$\text{Water value} = 1000 \text{ g} - \text{sample weight} + (100\text{g}) \quad (3)$$

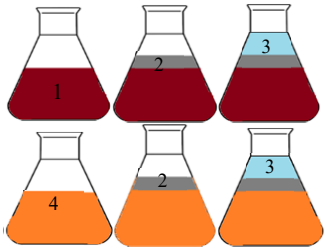



Fig. 2 Flask A (The Digesters). 1. Blood or RBCs. 2. Bacteria. 3. Water. 4. Blood platelet (BPL). Note: 1000 g = flask capacity, 100 g = bacteria weight

### *Flask B (Water + Methyl red)*

First, fill the flask with water then drops of Methyl red (red color); the watercolor becomes pink, as shown in Fig. 3:

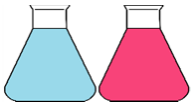


Fig. 3 Flask B (Water + Methyl red)

*Flask C (Empty)*

Fig. 4 Flask C (Empty)

At the beginning of the experiment flask C will be empty, then the bacteria starts to digest the biomaterial (Blood, RBCs, Blood platelet) this means the process of producing biogas began in flask A. the water in flask B is displaced via the gas produced in flask A in to flask C . By the end of the experiment flask B is full of gases (Methane, $CO_2$, $NH_3$), flask C is full of water, as shown in Fig. 5.


Fig. 5 Experimental set up B

## III. Results

*RBCs*

The experiment started to produce gas from the digester at day 25, as shown in Fig. 6, and it continued to produce gas for 150 days. The full quantity of produced gas was 1470 ml from 446.4 g of RBCs with a temperature average value of 31.57°C.

*RBCs 1*

The experiment started to produce gas from the digester at day 15, as shown in Fig. 7, and it continued to produce gas for 110 days. The full quantity of produced gas was 2625 ml from 348.4 g of RBCs with a temperature average value of 29.44°C.

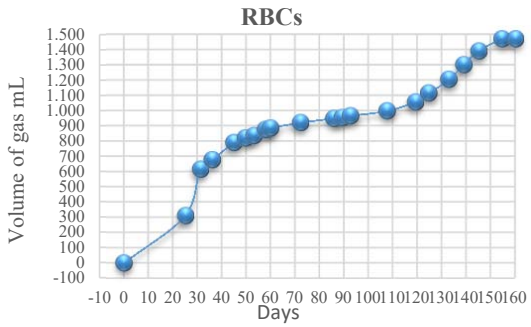



Fig. 6 RBCs

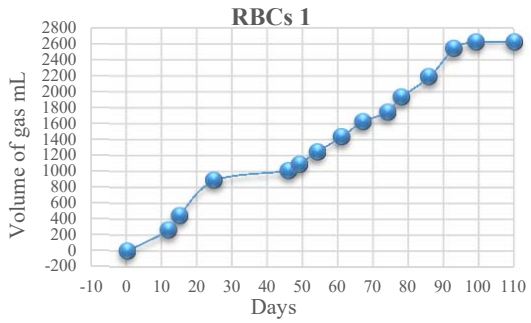



Fig. 7 RBCs 1

*RBCs 2*

The experiment started to produce gas from the digester at day 12, as shown in Fig. 8, and it continued to produce gas for 90 days. The full quantity of produced gas was 304 ml from 348.4 g of RBCs with a temperature average value of 29.25°C.

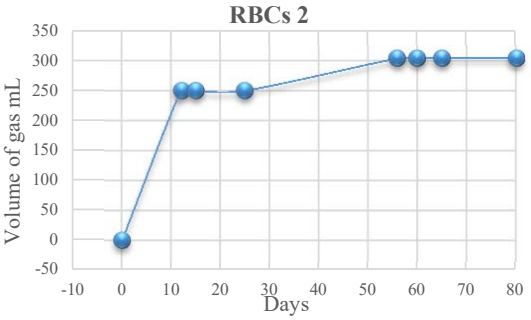



Fig. 8 RBCs2

Quantity average (QAV) = 381g
Produce average (PAV) = 1466.3 ml

$$1\ g\ \rightarrow 3.84855643\ ml$$

$$1\ g\ \rightarrow\approx 3.848\ ml$$

1 ton = $10^6$ gram = $3.848\times10^3$ L

So this means 1 ton of RBCs products 3848 L of biogas

1 L = 0.001 $m^3$ → 3848 L = 3.848 $m^3$ of flue

*Whole Blood 5*

The experiment started to produce gas from the digester at day 5, as shown in Fig. 9, and it continued to produce gas for 20 days. The full quantity of produced gas was 3075 ml from

274 g of whole blood with a temperature average value of 29.25°C.

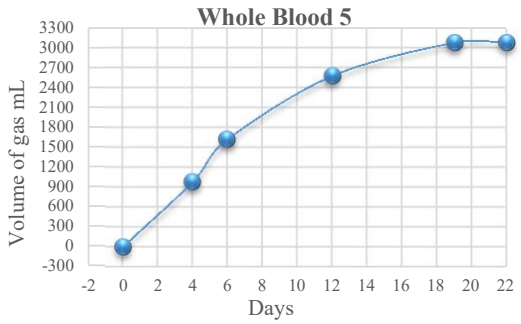



Fig. 9 Whole Blood 5

*Whole Blood 6*

The experiment started to produce gas from the digester at day 6, as shown in Fig. 10, and it continued to produce gas for 20 days. The full quantity of produced gas was 2570 ml from 274 g of whole blood with an average temperature value of 29.89°C.

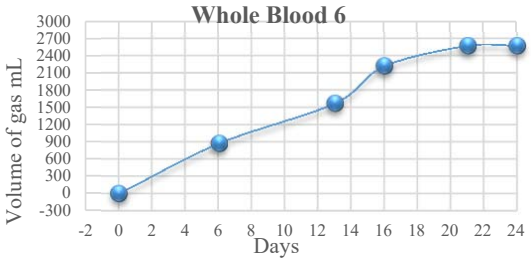



Fig. 10 Whole Blood 6

Quantity average (QAV) = 274 g
Produce average (PAV) =2822.5 ml

$$1\ g\ \rightarrow 10.30109489\ ml$$
$$1\ g\ \rightarrow \approx 10.301\ ml$$
$$1\ \text{ton} = 10^6\ \text{gram} = 10.301 \times 10^3\ \text{L}$$

So this means 1 ton of whole blood produces 10301 L

$$1\ \text{L} = 0.001\ \text{m}^3 \rightarrow 10301\text{L} = 10.301\text{m}^3\ \text{of flue}$$

***NOTE:*** Velocity of production and length of time period is determined by the concentration of bacteria.

$$\text{Concentrated bacteria} \xrightarrow{\text{digestion ratio}} \text{Fast} \xrightarrow{\text{time period}} \text{less time}$$
$$\text{Un Concentrated bacteria} \xrightarrow{\text{digestion ratio}} \text{low} \xrightarrow{\text{time period}} \text{more time}$$

TABLE III
SUMMARY OF SECOND TRAILS OUTCOME

| Experiment | Quantity | Production |
|---|---|---|
| RBCs | 446.4 g | 1470 ml |
| RBCs 1 | 348.4 g | 2625 ml |
| RBCs 2 | 348.4 g | 304 ml |
| Whole Blood 5 | 274 g | 3075 ml |
| Whole Blood 6 | 274 g | 2570 ml |

The gas test was carried out a Using Gas Chromatograph Mass Spectrometer (GCMS) (UMST) via a mass spectrometer.

TABLE IV
FINAL RESULTS

| Name | Ret-Time | Area% | Formula | Structure |
|---|---|---|---|---|
| Carbon dioxide | 1.195 | 0.55 | $CO_2$ | |
| Methane, nitroso- | 1.375 | 99.45 | $CH_3NO$ | |

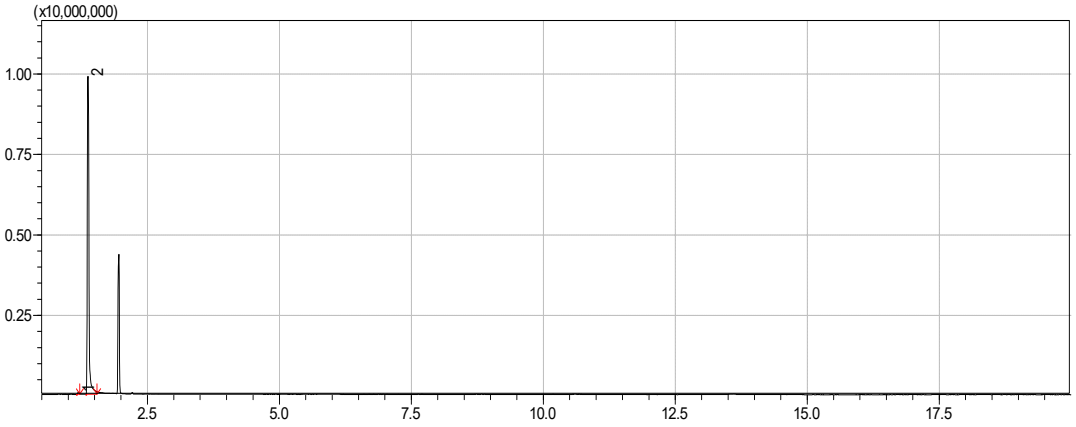



Fig. 11 Final Results

The results of the experiment show that the platelet and FFP failed to produce flammable gases; however, via the gas analyzer, it showed the presence of the following gases presented in Tables V and VI.

TABLE V
GAS ANALYZER READING FOR PLATELET

| GAS | VOLUME (vol/%) |
|---|---|
| CO | 0.01 |
| HC | 2226 |
| $CO_2$ | 64.9 |
| NOX | 5894 |

Note: x unknown gas

TABLE VI
GAS ANALYZER READING FOR FFP

| GAS | VOLUME (vol/%) |
|---|---|
| CO | 0.01 |
| HC | 1954 |
| $CO_2$ | 35.4 |
| NOX | 108.39 |

## IV. CONCLUSION

In the present investigation, it has been found that biomedical waste is a lethal, highly polluting substance and cannot be disposed of through landfill or incineration unless proper measures are taken. However, this waste can be anaerobically digested to generate biogas (methane-nitrous) with high-quality manure. In this way, the disposal of biomedical waste will be eco-friendly. These findings can also help all local corporations and academic research related to the biomedical waste management system, and to energy and the environment in disposing of such wastes through conversion to worthy resources.

***The results of the study include:***

- Producing biogas renewable energy,
- Reducing the environmental hazard of medical waste,
- Managing the disposal of blood bank waste in a safe and more environmentally friendly way.

## V. RECOMMENDATION

Regarding the achieved results recommended that:

- Increasing carbon ratio via adding other organic substance.
- Mixing all blood bank wastes (whole blood, RBCs, platelet, plasma) together in one experiment.
- Redo this experiment for infected blood with (HIV, AIDS and hepatitis) and test the remaining of the experiment to detect if there is a presence of the virus.
- Test the remaining of the digester by the end of the experiment.
- Redo this experiment on animals' blood obtained from slaughterhouses.

## APPENDIX

### *A. C/N Raito Test*


MINISTRY OF PETROLEUM & GAS (Mop)
SUDANESE PETROLEUM CORPORATION (SPC)
PETROLEUM LABORATORIES, RESEARCH & STUDIES PLRS
Khartoum Elamarat Street 61
وزارة النفط والغاز
المؤسسة السودانية للنفط
المعامل والبحوث والدراسات النفطية
الخرطوم العمارات شارع 61

TEST REPORT

Sample Type: Blood
Sample Code: EA/0417/0004004 Report Number:0020234
Sample ID: 0020234 Date /Time Reported:13/04/2017
Customes Name: Student
Customes Ref: _____
Date / Time Receiver:11/04/2017

| Elements | Test Method | Unit | Result |
|---|---|---|---|
| Nitrogen | ASTM D 5291 | Wt% | 1.431 |
| Carbon | | | 9.119 |

MINISTRY OF PETROLEUM
SUDANESE PETROLEUM CORPORATION
13.4.2017

* TEST (S) Has thave been subcontrcted ,please refer to PLRS for deails
* No part of this report can be reproduced except full in any form or by any electric or mechanical including photocopying and recording without awritten permission of the issuing laboratry

Reported by:
Sig:

Fig. 12 C/N Ratio Test 1


MINISTRY OF PETROLEUM & GAS (Mop)
SUDANESE PETROLEUM CORPORATION (SPC)
PETROLEUM LABORATORIES, RESEARCH & STUDIES PLRS
Khartoum Elamarat Street 61
وزارة النفط والغاز
المؤسسة السودانية للنفط
المعامل والبحوث والدراسات النفطية
الخرطوم العمارات شارع 61

TEST REPORT

Sample Type: Blood
Sample Code: EA/0417/000405 Report Number: 0020270
Sample ID: 0020270 Date /Time Reported: 04/05/2017
Customes Name: Student
Customes Ref: _____
Date / Time Received: 24/04/2017

| Elements | Test Method | Unit | Result |
|---|---|---|---|
| Nitrogen | ASTM D 5291 | Wt% | 4.079 |
| Carbon | | | 13.91 |

MINISTRY OF PETROLEUM
4.5.2017

* TEST (S) Has thave been subcontrcted ,please refer to PLRS for deails
* No part of this report can be reproduced except full in any form or by any electric or mechanical including photocopying and recording without awritten permission of the issuing laboratry

Reported by:
Sig:

(F-04-22)

Fig. 13 C/N Raito Test 2

MINISTRY OF PETROLEUM & GAS (Mop)
SUDANESE PETROLEUM CORPORATION (SPC)
PETROLEUM LABORATORIES, RESEARCH & STUDIES PLRS
Khartoum Elamarat Street 61
Tel: +(249)-1-83571064 - +(249)-1-83429641
Fax:+(249)-1-83 429641
P.O.BOX:2986
E-mail:info.cpl@spc.sd

وزارة النفط والغاز
المؤسسة السودانية للنفط
المعامل والبحوث والدراسات النفطية
الخرطوم العمارات شارع 61
+(249)-1-83571064 - +(249)-1-83429641 تلفون
2986 ص.ب :+(249)-1-83 429641 فاكس

TEST REPORT

Sample Type: Blood let
Sample Code: EA/0417/000407 Report Number: 0020273
Sample ID: 0020273 Date /Time Reported: 04/05/2017
Customes Name: Student
Customes Ref: _____
Date / Time Received: 25/04/2017

| Elements | Test Method | Unit | Result |
|---|---|---|---|
| Nitrogen | ASTM D 5291 | Wt% | 1.323 |
| Carbon | | | 5.1059 |

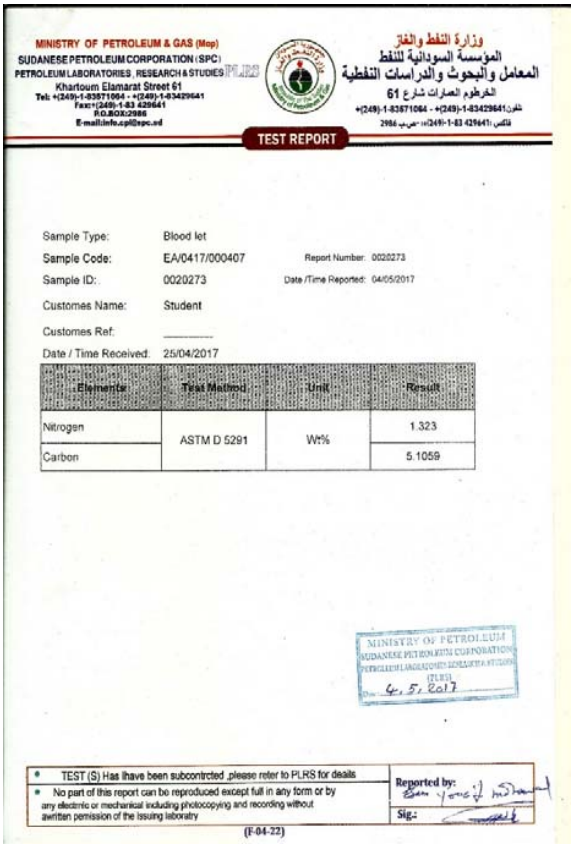
MINISTRY OF PETROLEUM
SUDANESE PETROLEUM CORPORATION
PETROLEUM LABORATORIES RESEARCH & STUDIES
(PLRS)
Date: 4, 5, 2017

- TEST (S) Has Ihave been subcontrcted ,please refer to PLRS for deails
- No part of this report can be reproduced except full in any form or by any electric or mechanical including photocopying and recording without awritten permission of the issuing laboratry

Reported by: Ebtsam Yousif Mohamed
Sig.:

(F-04-22)

Fig. 14 C/N Raito Test 3



MINISTRY OF PETROLEUM & GAS (Mop)
SUDANESE PETROLEUM CORPORATION (SPC)
PETROLEUM LABORATORIES, RESEARCH & STUDIES PLRS
Khartoum Elamarat Street 61
Tel: +(249)-1-83571064 - +(249)-1-83429641
Fax:+(249)-1-83 429641
P.O.BOX:2986
E-mail:info.cpl@spc.sd

وزارة النفط والغاز
المؤسسة السودانية للنفط
المعامل والبحوث والدراسات النفطية
الخرطوم العمارات شارع 61
+(249)-1-83571064 - +(249)-1-83429641 تلفون
2986 ص.ب :+(249)-1-83 429641 فاكس

TEST REPORT

Sample Type: Blood let
Sample Code: EA/0417/000407 Report Number: 0020273
Sample ID: 0020273 Date /Time Reported: 04/05/2017
Customes Name: Student
Customes Ref: _____
Date / Time Received: 25/04/2017

| Elements | Test Method | Unit | Result |
|---|---|---|---|
| Nitrogen | ASTM D 5291 | Wt% | 1.323 |
| Carbon | | | 5.1059 |

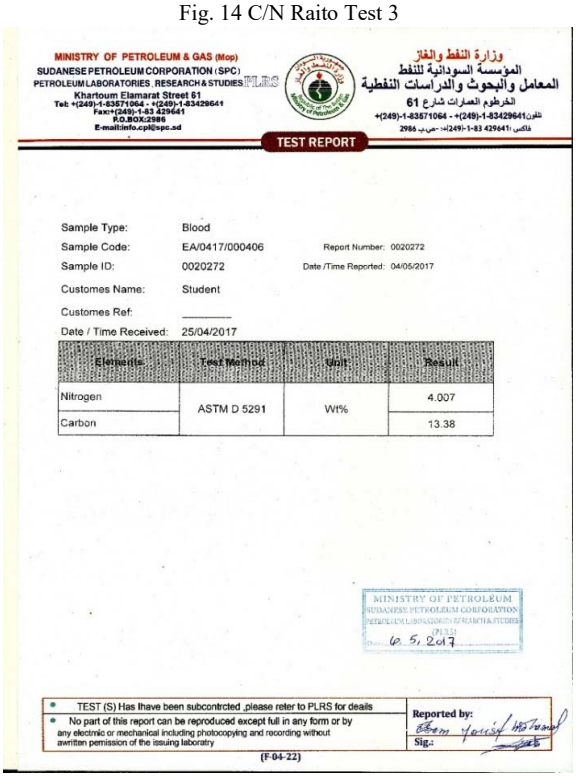
MINISTRY OF PETROLEUM
SUDANESE PETROLEUM CORPORATION
PETROLEUM LABORATORIES RESEARCH & STUDIES
(PLRS)
Date: 4, 5, 2017

- TEST (S) Has Ihave been subcontrcted ,please refer to PLRS for deails
- No part of this report can be reproduced except full in any form or by any electric or mechanical including photocopying and recording without awritten permission of the issuing laboratry

Reported by: Ebtsam Yousif Mohamed
Sig.:

(F-04-22)

Fig. 16 C/N Raito Test 5



MINISTRY OF PETROLEUM & GAS (Mop)
SUDANESE PETROLEUM CORPORATION (SPC)
PETROLEUM LABORATORIES, RESEARCH & STUDIES PLRS
Khartoum Elamarat Street 61
Tel: +(249)-1-83571064 - +(249)-1-83429641
Fax:+(249)-1-83 429641
P.O.BOX:2986
E-mail:info.cpl@spc.sd

وزارة النفط والغاز
المؤسسة السودانية للنفط
المعامل والبحوث والدراسات النفطية
الخرطوم العمارات شارع 61
+(249)-1-83571064 - +(249)-1-83429641 تلفون
2986 ص.ب :+(249)-1-83 429641 فاكس

TEST REPORT

Sample Type: Blood
Sample Code: EA/0417/000406 Report Number: 0020272
Sample ID: 0020272 Date /Time Reported: 04/05/2017
Customes Name: Student
Customes Ref: _____
Date / Time Received: 25/04/2017

| Elements | Test Method | Unit | Result |
|---|---|---|---|
| Nitrogen | ASTM D 5291 | Wt% | 4.007 |
| Carbon | | | 13.38 |

MINISTRY OF PETROLEUM
SUDANESE PETROLEUM CORPORATION
PETROLEUM LABORATORIES RESEARCH & STUDIES
(PLRS)
Date: 6, 5, 2017

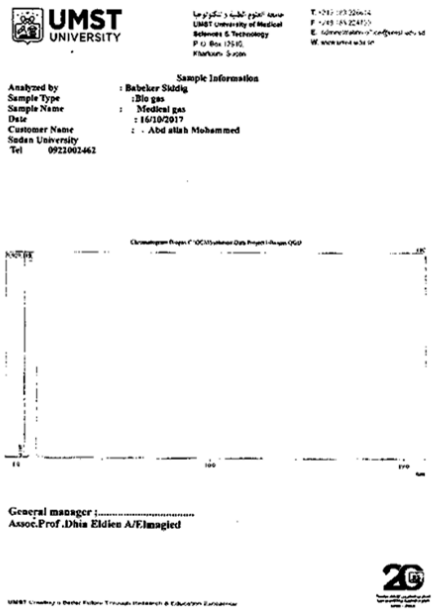
- TEST (S) Has Ihave been subcontrcted ,please refer to PLRS for deails
- No part of this report can be reproduced except full in any form or by any electric or mechanical including photocopying and recording without awritten permission of the issuing laboratry

Reported by: Ebtsam Yousif Mohamed
Sig.:

(F-04-22)

Fig. 15 C/N Raito Test 4

*B. Gas Test Results*



UMST UNIVERSITY

Sample Information

Analyzed by : Babeker Siddig
Sample Type : Bio gas
Sample Name : Medical gas
Date : 16/10/2017
Customer Name : - Abd allah Mohammed
Sudan University
Tel 0921002462

General manager :.....
Assoc.Prof .Dhia Eldien A/Elmagied

Fig. 17 Gas Test Results 1

10/18/2017 14:05:04

Peak Report TIC

| Peak# | R.Time | Area | Area% | Name |
|---|---|---|---|---|
| 1 | 1.197 | 121805 | 0.55 | Carbon dioxide |
| 2 | 1.375 | 22096496 | 99.45 | Methane, nitroso- |
| | | 22218301 | 100.00 | |

Fig. 18 Gas Test Results 2

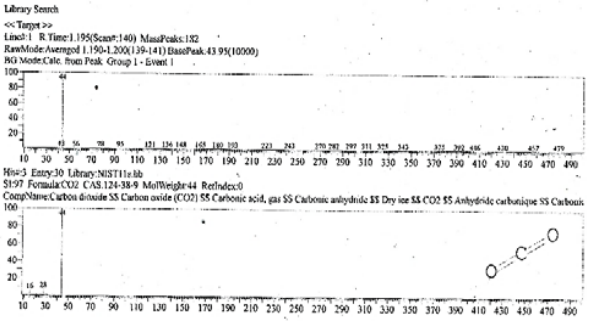



Fig. 19 Gas Test Results 3

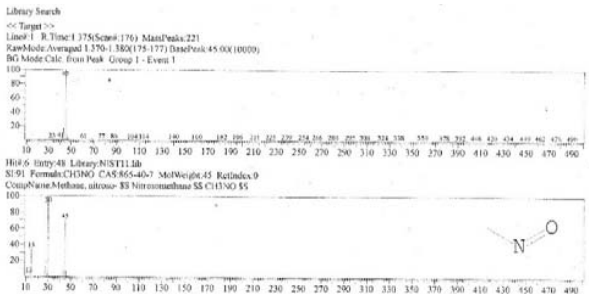



Fig. 20 Gas Test Results 4

### *C. GCMS Specifications*

**Method**

[Comment]

===== Analytical Line 1 =====

[AOC-20i]

| | |
|---|---|
| # of Rinses with Presolvent | :2 |
| # of Rinses with Solvent(post) | :2 |
| # of Rinses with Sample | :2 |
| Plunger Speed(Suction) | :High |
| Viscosity Comp. Time | :0.2 sec |
| Plunger Speed(Injection) | :High |
| Syringe Insertion Speed | :High |
| Injection Mode | :Normal |
| Pumping Times | :5 |
| Inj. Port Dwell Time | :0.3 sec |
| Terminal Air Gap | :No |
| Plunger Washing Speed | :High |
| Washing Volume | :8uL |
| Syringe Suction Position | :0.0 mm |
| Syringe Injection Position | :0.0 mm |
| Use 3 Solvent Vial | :1 vial |

[GC-2010]

| | |
|---|---|
| Column Oven Temp. | :30.0 °C |
| Injection Temp. | :200.00 °C |
| Injection Mode | :Splitless |
| Sampling Time | :0.00 min |
| Flow Control Mode | :Linear Velocity |
| Pressure | :85.1 kPa |
| Total Flow | :50.0 mL/min |
| Column Flow | :1.61 mL/min |
| Linear Velocity | :45.5 cm/sec |
| Purge Flow | :3.0 mL/min |
| Split Ratio | :-1.0 |
| High Pressure Injection | :OFF |
| Carrier Gas Saver | :OFF |

Oven Temp. Program

| Rate | Temperature(°C) | Hold Time(min) |
|---|---|---|
| - | 30.0 | 0.00 |
| 3.00 | 90.0 | 0.00 |

| | |
|---|---|
| < Ready Check Heat Unit > | |
| Column Oven | : Yes |
| SPL1 | : Yes |
| MS | : Yes |
| < Ready Check Detector(FTD) > | |
| < Ready Check Baseline Drift > | |
| < Ready Check Injection Flow > | |
| SPL1 Carrier | : Yes |
| SPL1 Purge | : Yes |
| < Ready Check APC Flow > | |
| < Ready Check Detector APC Flow > | |
| External Wait | :No |
| Equilibrium Time | :3.0 min |

[GC Program]

[GCMS-QP2010 Ultra]

| | |
|---|---|
| IonSourceTemp | :200.00 °C |
| Interface Temp. | :220.00 °C |
| Solvent Cut Time | :0.00 min |
| Detector Gain Mode | :Relative |
| Detector Gain | :0.89 kV +0.00 kV |
| Threshold | :0 |

[MS Table]

Fig. 21 GCMS Specifications 1

--Group 1 - Event 1--

| | |
|---|---|
| Start Time | :0.50min |
| End Time | :20.00min |
| ACQ Mode | :Scan |
| Event Time | :0.30sec |
| Scan Speed | :1666 |
| Start m/z | :33.00 |
| End m/z | :500.00 |
| Sample Inlet Unit | :GC |

[MS Program]

| | |
|---|---|
| Use MS Program | :OFF |

Fig. 22 GCMS Specifications 2

## REFERENCES

[1] Bendixen, A. B. N. F., Biogas – green energy. 2009: p. 36.
[2] Jarvis, A. S. a. Å., Microbiological Handbook for Biogas Plants. 2009: p. 138.
[3] Kamlesh Tewary, V. K., Pamit Tiwary, Biomedical Waste Management A Step Towards a Healthy Future. p. 6.

[4] Singhadia, V., An Analysis of Energy Yield From BioMedical Waste: An Anaerobic Approach. 2015: p. 3.
[5] Abhay Kumar Sharma, R. K. R., Surendra Singh, Best Energy from Lethal Bio-Medical Waste. 2012: p. 6.