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Methane Enrichment in Biogas Mixture Using Physical and Chemical Absorption

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Steel wool
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ABSTRACT

Proper exploitation of biogas is key to recovering energy from bio waste in the framework of a circular economy and environmental sustainability of the energy sector. This study aimed to design and manufacture an engineering unit for biogas purification. Experiments were carried out through the year of 2021 at Agricultural Engineering Department, Faculty of Agriculture, Damietta University, Egypt. The main parts of the biogas purification system were as follows: Two scrubbers, water pump, compressor and pressure cylinder. The experimental results of desulphurization showed that the highest value of H2S removal efficiency was 95.40% at 500 mm depth of steel wool bed and 6 l/min biogas flow rate. Whereas, the experimental results of purification showed that the lowest CO2 content of 3.54% and the highest CH4 content of 93.86% were found in run (13) at the following conditions: (using desulphurised biogas at 4 bar of pressure, 2 l/min of biogas flow rate and 12 l/min of water flow rate).

INTRODUCTION

In recent years, the issue related to global warming encouraged several countries to take part in international agreements oriented to reduce greenhouse gas emissions. Since the energy sector is currently the main source of GHG, achieving this goal requires a shift in each nation's energy mix leading to a lower presence of fossil fuels and strategically exploitation of the locally available non-fossil energy sources, **Paolini *et al*., (2018).** Among the several non-fossil energy sources, biomass wastes can be exploited to produce biogas via anaerobic digestion. This strategy allows energy recovery whilst taking part in the waste disposal process. Therefore, it merges the concepts of renewable energy and circular economy. The high methane content of biogas makes it suitable for several energy-related uses, such as CHP production and the synthesis of chemical energy vectors as biomethane via upgrading and platform molecules production, **Tian *et al*., (2021).** Purified biogas can be used as an energy source for electricity generation or as a raw material in industry, **Soehartanto *et al*., (2021).** Methane is burned faster hence yields a higher thermal efficiency compared to raw biogas when used as fuel, **Shah and Nagarsheth (2015).** One of the key factors determining biogas application is its composition. Raw biogas contains methane CH4, carbon dioxide CO2, hydrogen sulfide (H2S) and traces of water vapour H2O. Biogas purification is the process in which CO2 and H2S are removed in order to raise the calorific value of the treated biogas, **Abd Elfattah *et al*., (2016).** It is advisable to separate the H2S prior to CO2 removal as H2S causes corrosion in pipelines and engines, **Soehartanto *et al*., (2021). Mohanakrishnan and Rintala (2016)** recommended that the purified biogas dispensed to any vehicle shall comply BIS standards: CH4 ≥ 90%, CO2 ≤ 4% and H2S ≤ 20 ppm. They carried out an experiment in H2S scrubber using sponge iron (steel wool) for H2S removal, when biogas with H2S concentration of 27 ppm was passed through steel wool bed depth of 100 mm, 300 mm and 500 mm, H2S removal reached 70% of primary concentration at a steel wool bed depth of 500 mm. **Kulkarni and Ghanegaonkar (2019)** planned to desulphurise biogas using steel wool at biogas flow rates of 2, 5 and 10 l/min, which gives a hydrogen sulfide content 40, 30 and 35 ppm, respectively. **Walozi *et al*., (2016) and Kapoor *et al*., (2021)** recommended water scrubbing as the simplest, cost effective, eco-friendly and practical method for simultaneous removal of CO2 and H2S from biogas**. Gantina *et al*., (2020)** fabricated a water scrubber column with 97.5 cm column height and 5.5 cm diameter. The variables used are the biogas pressures of 2, 3 and 4 bar and water flow rates of 0.1 and 0.15 l/s. The greatest effectiveness in CH4 increase of 38.2% were obtained at biogas pressure of 4 bar, water flow rate of 0.15 l/s.

To achieve the objectives of this study, the following criteria were taken into consideration: design and manufacture of an engineering unit for biogas purification; determination the most appropriate operating parameters affecting the biogas purification unit; evaluation the performance of the biogas purification unit to obtain the highest biogas purification efficiency and production of

enriched methane conforming to the natural gas standard and achieving a significant contribution to Egypt's future energy requirements.

MATERIAL AND METHODS

A local biogas purification system was manufactured and constructed at a private workshop in New Damietta City, Damietta Governorate, Egypt. Experiments were carried out through the year of 2021 at Agricultural Engineering Department, Faculty of Agriculture, Damietta University, to evaluate the performance of the manufactured system for biogas purification.

2.1. Materials:

2.1.1. Raw biogas:

Biogas purification system uses an aerobic digestion to decompose cow manure in a digester as the raw material for biogas production. The digester made of plastic tank of 200 liters capacity was used. The digester was fed within the ratio of 1:1 of dung to water. The operating temperatures of the digester were maintained within mesophilic conditions. The digester was batch operated, the daily raw gas produced was collected through a tire tube for 30 days, as shown in **Fig. 1** and the biogas composition are presented in **Table 1.**

2.1.2. Biogas purification system:

Two commercially available Polyvinyl chloride (PVC) columns were used as packed bed scrubber. In the first (PVC) scrubber column wich have a 0.2 m (8 inch) outer diameter by 1 m length, it is designed and fabricated to remove H2S from raw biogas by chemical adsorption method using steel wool bed. The second scrubbing column is designed and fabricated to remove CO2 from desulphurised biogas by physical absorption method using water scrubbing. Scrubbing column used a polyvinyl chloride (PVC) pipe with a 0.15 m (6 inch) outer diameter by 1.5 m length. Column was constructed with 9.6 mm wall thickness withstand an operating pressure 10 bar. **Fig. 2** shows the component and design of the biogas purification unit. The height of the middle section of the scrubber is 1000 mm, it is fitted with random (PVC) raschig rings as packing material with diameter of 25 mm (Mendes 2011), to promote large contact surface at the interface for the liquid and gas phase which allow sufficient gas residence time for contact. The bottom end is equipped with biogas inlet and waste water outlet. The (PVC) raschig rings shown in **Fig. 3.**

Steel wool bed was provided for two different depths to desulphurise raw biogas. An experiment about the effectiveness of commercially available steel wool with for adsorption of H2S has been made. Raw biogas is passed through H2S scrubber which filled with packing material of steel wool, as shown in **Fig. 4.**

2.1.3. Biogas storage and compression system:

A compressor having 0.55 kW (¾ hp) power rating is utilized for compression of desulphurised biogas up to 6 bar pressure then a pressure cylinder was used to storage the compressed biogas before sending it to the CO2 scrubber. The compressor pressure switch was used to measure the pressure inside pressure cylinder and shuts off the compressor when it reaches to the wanted pressure of biogas and it helps to maintain the proper pressure level during the experiment. Pressure gauges were installed on the pressure cylinder to measure the pressure of biogas entering and leaving the pressure cylinder. Pressure gauge range is 0 ~ 180 PSI or 0 ~ 12 bar, as shown in **Fig. 5.**

2.2. Methods:

Biogas desulphurisation experiments were carried out using two different depths of steel wool bed of 300 and 500 mm, with different biogas flow rates of 2, 3, 4, 5, 6, 9, 10 and 12 l/min. The raw biogas is passed through the H2S scrubber which filled with the steel wool bed. H2S is removed through chemical mechanism as it reacted with iron oxide (Fe2O3) to form iron sulphide (Fe2S3), the steel wool can be safely disposed. Desulphurised biogas was passed through a CO2 scrubber for purification experiments using water scrubbing at different pressures of 1, 2, 3 and 4 bar and different biogas flow rates of 2, 3, 4 and 6 l/min and different water flow rates of 4, 6, 8 and 12 l/min. The water passed from water inlet at the top of the scrubber is sprayed inside the entire volume of scrubber unit. This sprayed water particles collide with pressurised biogas molecules. CO2 and H2S in the biogas are dissolved in water and the non-water soluble methane gas is separated and flows through the gas outlet at the top. The raw and purified biogas is directly tested for its content of CH4, CO2 and H2S. The result of each sample was tested in Taguchi experimental design in 16 runs.

2.2.1. Measurements and determinations:

1. Biogas analyzer:

Biogas analyzer **Bosean Model (K-600)** was used to measure the chemical composition (v/v) of the gases in biogas. It can analyze and measure biogas using a gas sampling method by pump and a high-sensitivity sensor, as shown in **Fig. 6-A.** Its measurements ranged from (0-100%) for CH4, (0-50%) for CO2 and (0-3000) ppm for H2S. It features with an accuracy reach to ≤±5% of reading with a response time ≤30.

2. Biogas flow meter:

The tyre tube was connected to a biogas flow meter to measure the amount of raw biogas, as shown in **Fig. 6-B.** A biogas flow meter **(Chint ZT-G2.5S)** was used to measure the amount of biogas. It features a high accuracy to ±2% of reading, with maximum working pressure of 0.5 bar**.**

3. Calculation method:

(A) Purification efficiency:

The H2S removal efficiency (η^{H_2S}), the CO_2 removal efficiency (η^{CO_2}) and the CH4 enrichment efficiency (η^{CH_4}) were calculated, according to **Huang et al. (2015)** as follows:

$$\eta_{H_2S} = \frac{H_2S_{in} - H_2S_{out}}{H_2S_{in}} \times 100 \quad (1)$$

$$\eta_{CO_2} = \frac{CO_{2_{in}} - CO_{2_{out}}}{CO_{2_{in}}} \times 100 \quad (2)$$

$$\eta_{CH_4} = \frac{CH_{4_{out}} - CH_{4_{in}}}{CH_{4_{in}}} \times 100 \quad (3)$$

Where:

H_2S_{in} and H_2S_{out} = The volume of H_2S in raw biogas and purified biogas, respectively;

$CO_{2_{in}}$ and $CO_{2_{out}}$ = The volume of CO_2 in raw biogas and purified biogas, respectively.

$CH_{4_{in}}$ and $CH_{4_{out}}$ = The volume of CH_4 in raw biogas and purified biogas, respectively.

(B)Heating value:

Heating value is a magnitude of a fuel's energy density and is expressed in energy unit per specified amount. Heating value, HV can be calculated using the following equation. The equations have been used in this study according to **Badr (2019).**

$$\mathbf{HV = \%CH4 \times \rho \times LHV} \quad (4)$$

Where:

%CH4: The percentage of methane obtained after purification process LHV: The lower heating value of the methane = 50 MJ/kg at standard conditions.

(C) Energy Generation (EC):

Energy Generation can be calculated using the following equation **(Badr ,2019)**.

$$E_G = \frac{HV}{C_F} \quad (5)$$

(D) Energy consumption (EC)

The specific energy consumption can be calculated using the following equation **(Surroop and Mohee, 2012 and Badr ,2019).**

$$E_C = [P_C + P_p] \times S_F \quad (6)$$

$$E_C = [(P_m \times \eta_m) + P_p] \times S_F \quad (7)$$

Where:

Pc is power required for operating gas compressor.

Pp is power of water pump = 0.735 kW (1 hp) .

SF is service factor assumed to be1.25 to operate continuously.

Pm is power of motor compressor = 0.55 kW (¾ hp) .

ηm is mechanical efficiency = 85%.

RESULTS AND DISCUSSION

3.1. Effect of biogas flow rate and depth of steel wool on biogas desulphurisation:

For H2S removal, run (1) with composed of steel wool depth 300 mm and biogas flow rate 2 l/min. The actual values of H2S content, the signal to noise (S/N) ratios of the control factors in H2S response and H2S removal efficiency are presented in **Table 2.** The 3D response surface plot for H2S are shown in **Fig.(7).** The interaction between the inputs (biogas flow rate and steel wool depth) and output (H2S removal efficiency %).

Interaction of individual plot shows a trapezoidal relation. The increase in biogas flow rate from 2 to 6 l/min increases the H2S removal efficiency noticeabley, while increase in biogas flow rate from 6 to 9 l/min shows a slight decrease in H2S removal efficiency. In contrast, increase in biogas flow rate from 9 to 12 l/min shows a significant decrease in H2S removal efficiency of 95.40%.

The mean values of S/N ratios for the main effects of biogas flow rate on H2S is plotted as shown in **Fig.(8).** Figure illustrate the results of biogas desulphurisation in H2S scrubber, the optimum levels were biogas flow rate of 6 l/min (level five) and steel wool depth of 500 mm (level two). The percentage contribution and main effects of operating parameters were analysed for biogas desulphurisation. Biogas flow rate is found to be the dominant factor followed by steel wool depth. The results showed the percentage of the importance of each factor and the most important factor for desulphurisation, biogas flow rate 77.28%, while steel wool depth was represented 22.72%. This result agree with **Magomnang and Villanueva (2015); Magomnang and Rintala (2016) and Kulkarni and Ghanegaonkar (2019).**

The H2S content before water scrubbing process is 65 ppm. After scrubbing, it was observed that the water scrubbing process affected on the content of H2S in purified biogas, as a decrease in its content occurred, because the acidic components of the biogas such as CO2 and H2S are more easily dissolved in water. Results show that H2S content was reduced to 6 ppm with H2S removal of 90.77% which was observed during purification experiments in run 13. It can be seen that the H2S absorption effectiveness of biogas increases along with higher biogas pressure and water flow rate. The result of H2S removal of 95.40% using steel wool in H2S scrubber is superior to that of removing H2S of 90.77% using water purification in a CO2 scrubber. This result agree with **Horikawa *et al*., (2004).**

3.2. Effect of biogas pressure, biogas flow rate and water flow rate on increasing CH4 content during biogas purification:

In purification experiments, run (1) with composed of biogas pressure 1 bar, biogas flow rate 2 l/min and water flow rate 4 l/min. The actual values and the S/N ratios of the control factors in response to CH4 and CO2 from the following-mentioned trials are presented in **Table (3).** The 3D response surface plot for CH4 where the interaction between the inputs (biogas pressure, biogas flow rate and water flow rate) and output (CH4) is shown in the following Figures.

In **Fig. 9-a, b** Interaction of individual plot shows a Parallelogram relation, while in **Fig. 9-c** Interaction of individual plot shows a trigonometric relation. The increase in biogas pressure from 1 to 4 bar and an increase in water

flow rate from 4 to 12 l/min increases the percentage of CH4 content, in contrast to increase in biogas flow rate 2 to 6 l/min decrease the percentage of CH4 content. It can be seen that the amount of CH4 after passing through the water scrubber has increased along with the increasing biogas pressure and water flow rate and decreasing biogas flow rate. This is because the solubility of CO2 increases in water as pressure increases. When the rate of water flow increases, the contact point between gases and the water will be wider such that the reaction between CO2 and water absorption will become more effective. In contrast to the higher flow rate of biogas, it also leads to a decrease in biogas absorption due to the lower amount of water to biogas. This implies that purification at higher water to gas flow rate ratios is more effective. This result agree with **Walozi *et al*., (2016) and Kapoor *et al*., (2021).**

The mean values of signal to noise (S/N) ratios for the main effects of pressure, water flow rate and biogas flow rate on CH4 is plotted as shown in **Fig.(10).** The response graph indicates higher CH4 at higher S/N ratios. It is evident that a combination of pressure 4 bar and water flow rate 12 l/m and lower biogas flow rate 2 l/m could yield a maximum enrichment efficiency of CH4 93.86%. The greatest effectiveness in CH4 increase of 75.11% was obtained in purified biogas.

This can be compared with the results of **Gantina *et al*., (2020),** the greatest effectiveness in CH4 increase of 38.2% was obtained. The percentage contribution and main effects of input parameters were analysed for CH4. Biogas pressure is found to be the dominant factor (80.58 %) followed by biogas flow rate 9.95% and water flow rate 9.47%.

3.3. Effect of biogas pressure, biogas flow rate and water flow rate on CO2 absorption:

Based on the result data, the effectiveness of the CO2 removal is related to CO2 content before and after purification. Following figures illustrate the 3D response surface plot for CO2 where the interaction between the inputs (biogas pressure, water flow rate and biogas flow rate) and output CO2.

In **Fig. 11-a, b** interaction of individual plot shows a Parallelogram relation, while in **Fig. 11-c,** interaction of individual plot shows a trigonometric relation. The increase in biogas pressure from 1 to 4 bar andwater flow rate from 4 to 12 l/min increases the CO2 removal efficiency, in contrast to increase in biogas flow rate 2 to 6 l /min decrease the CO2 removal efficiency. It can be seen that with the water flow rate raised, the water will fill the water scrubber column which in turn makes the contact area even greater. The reason for the decrease in the solubility capacity of CO2 in water is due to the increase in the concentration of biogas molecules interacting with the water molecules, which became saturated of CO2.

The mean values of signal to noise (S/N) ratios for the main effects of biogas pressure, biogas flow rate and water flow rate on CO2 is plotted as shown in **Fig. 12.** The response graph indicates lower CO2 at higher S/N ratios.It is evident that a combination of biogas pressure 4 bar and biogas flow rate 2 l/min and water flow rate 12 l/min could yield the lowest content of CO2 (3.54%).

This helped to identify the influence of parameters and their intensity. The percentage contribution and main effects of input parameters were analysed for CO2. Biogas pressure is found to be the dominant factor 68.74% followed by water flow rate 15.84% and biogas flow rate 14.43%. This result agrees with **Shah and Nagarsheth. (2015),** but it is superior to experiments results of **Olugasa and Oyesile. (2015),** they indicated that CO2 has been reduced by 55%.

The product gas must meet the heating values, which are required to ensure optimum operation of gas turbines and combustion equipment to minimize emissions. The maximum of heating value and energy generation of purified biogas were 35.65 MJ/m3 and 9.35 MJ/m3 respectively at pressure 4 bar, biogas flow rate of 2 l/min and water flow rateof 12 l/min, which makes purified biogas more convenient for use in natural gas applications. The specific energy consumption of purification process was 1.5 kW.

CONCLUSION

Experimental work was carried out to produce enriched methane gas conforming to the natural gas standard and to achieve a substantial contribution to the future energy demand in Egypt, by exploring a more suitable process for biogas purification using cheap media such as water and steel wool. Taguchi method suggested the optimum conditions for biogas purification. So, the important obtained results could be concluded in the following points:

- The results of desulphurisation showed that the highest value of H2S removal efficiency was 95.40% at 500 mm depth of steel wool bed and 6 l/min of biogas flow rate, therefore H2S content was reduced to 65 ppm.
- Results recommended that using (run 13), at pressure of 4 bar, 2 l/min of biogas flow rate and 12 l/min of water flow rate, to obtain a minimum content of both H2S and CO2 of 6 ppm and 3.54%, respectively.
- The highest removal efficiency of both H2S and CO2 were 90 % and 86.28%, respectively. The optimum operating parameters for CH4 enrichment in purified biogas were also found to be 93.86% in run (13), so the greatest effectiveness was obtained in increasing CH4 by 75.11%.
- After purification with optimum parameters, it was noticed that the biogas obtained is satisfying the BIS 16087: 2013 standard for CH4, CO2 and H2S content.
- The maximum of heating value of purified biogas was 35.65 MJ/m3 and the energy generated from purified biogas was 35.9 MJ/m3 (at pressure 4 bar, biogas flow rate of 2 l/min and water flow rate of 12 l/min), when the energy consumption of biogas purification process up to 1.5 kW.

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This research did not receive any funding

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

All authors developed the concept of the manuscript. Khafagy wrote the manuscript and achieved the experimental work and measurements. All authors checked and confirmed the final revised manuscript.

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Fig. 1. Raw Biogas collection by tire tube.

No.	Part name	No.	Part name
1	Carbon dioxide scrubber column	6	Purified biogas cylinder
2	Hydrogen sulfide scrubber column	7	Unit stand
3	Compressor	8	Hose
4	Biogas valve	9	Water pump
5	Pressure gauge	10,11	Water valve

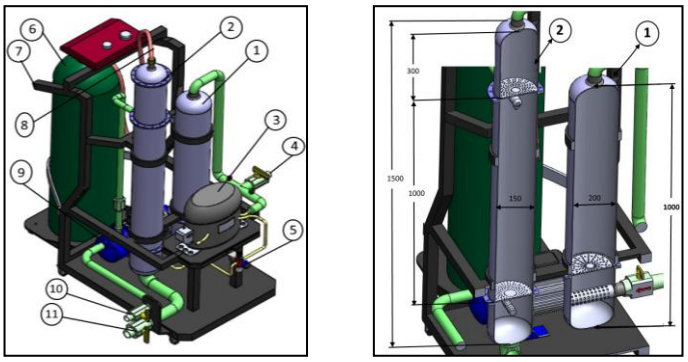
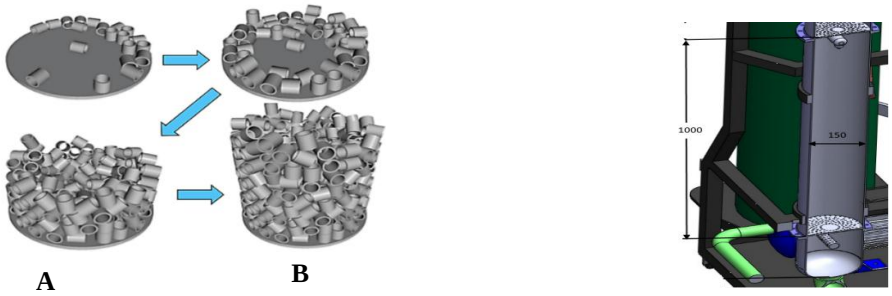
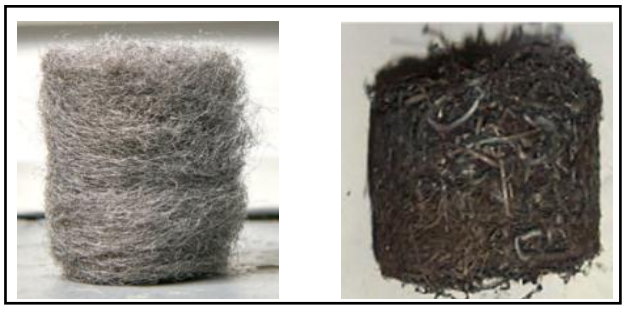


Fig. 2. Schematic 3D drawing of the biogas purification unit.



A **B**

Fig. 3. (A): Raschig rings made of (PVC), (B): Middle section of the H_2S scrubber.



A **B**

Fig. 4. Photos of steel wool, (A): Before absorbing H2S, (B): After absorbing H2S.

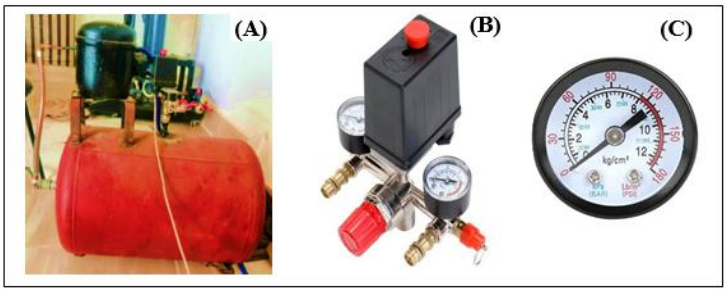


Fig. 5. (A): Biogas storage and compression system, (B): Compressor pressure switch and (C): Pressure gauges.

Fig. 6. Photos of measuring instruments, (A): Biogas analyzer, (B): Biogas flow meter.

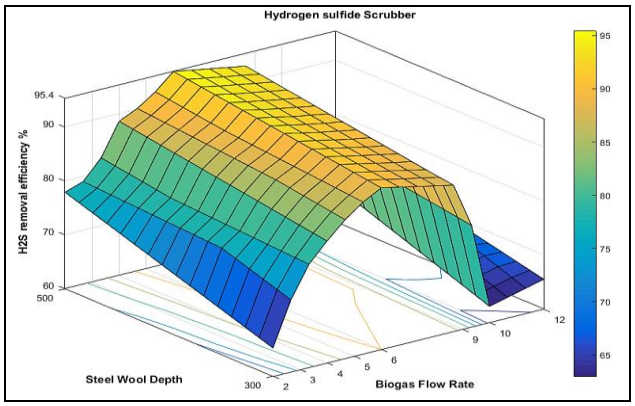


Fig. 7. The 3D response for H_2S removal efficiency.

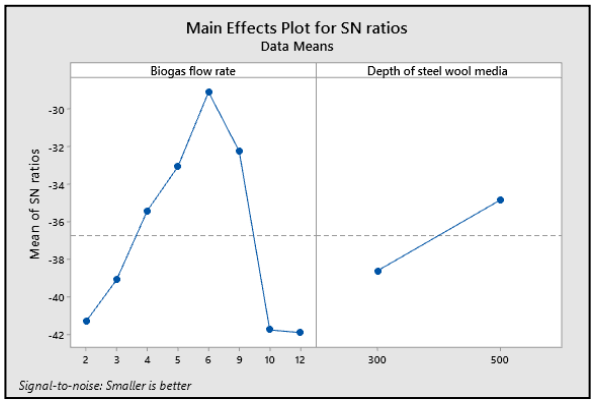


Fig. 8. Main effect for S/N ratios of H2S removal from raw biogas.

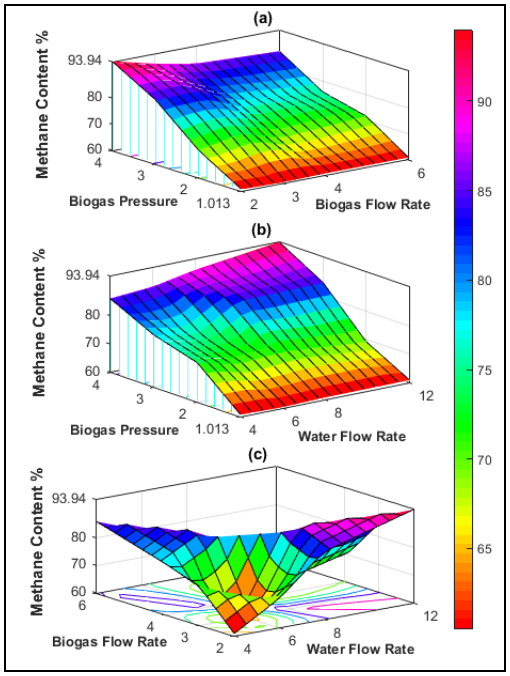


Fig. 9. 3D effect of biogas pressure, biogas flow rate and water flow rate on CH_4 content.

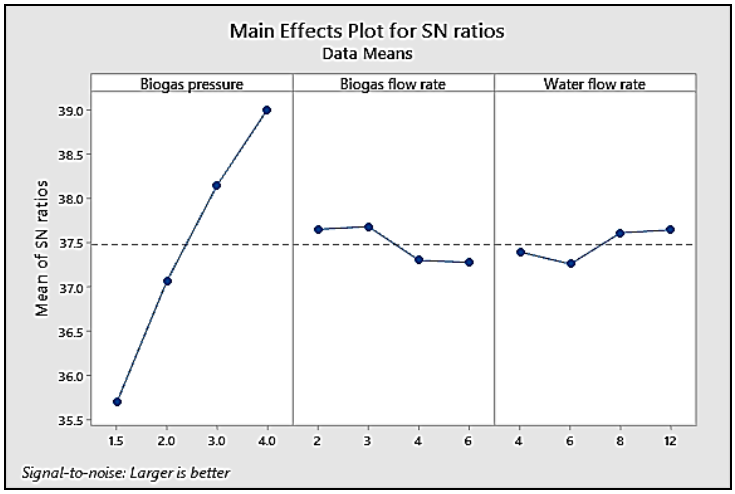


Fig. 10. Optimum conditions for CH_4 enrichment in the purified biogas.

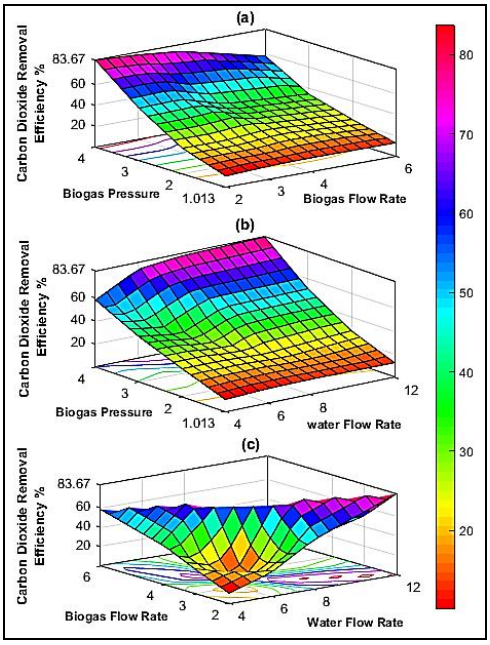


Fig. 11. 3D effect of biogas pressure, biogas flow rate and water flow rate on CO_2 content.

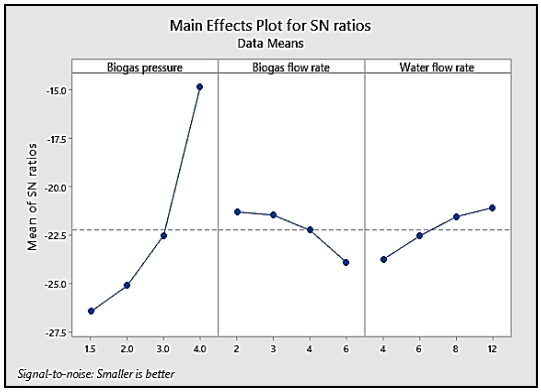


Fig. 12. Illustrate the optimum conditions for CO2 absorption.

Table 1. Composition of biogas.

Gas	Concentration
Methane (CH_4),%	53.6%
Carbon dioxide (CO_2),%	25.8 %
Hydrogen sulphide (H_2S),ppm	420 (ppm)

Table 2. Response data of Taguchi design.

Run	Biogas flow rate, (*l*/min)	Depth of steel wool	H_2S content, (ppm)	S/N (H_2S)	H_2S removal efficiency, (%)
1	2	300	146	-43.2871	65.24
2	2	500	93	-39.3385	77.94
3	3	300	95	-39.5545	77.38
4	3	500	85	-38.6224	79.68
5	4	300	73	-37.2665	82.62
6	4	500	48	-33.5643	88.65
7	5	300	53	-34.5400	87.30
8	5	500	38	-31.5957	90.95
9	6	300	42	-32.4650	89.92
10	6	500	19	-25.7261	95.40
11	9	300	55	-34.8597	86.83
12	9	500	30	-29.6384	92.78
13	10	300	155	-43.8253	63.02
14	10	500	97	-39.7055	76.98
15	12	300	145	-43.2074	65.56
16	12	500	107	-40.6147	74.44

Table. 3. Response data of Taguchi design to purify desulphurized biogas

Run	Biogas pressure, (bar)	Biogas flow rate, (*l*/min)	Water flow rate, (*l*/min)	CO_2 content	S/N (CO_2)	CH_4 content	S/N (CH_4)
1	1	2	4	19.47	-26.6444	60.46	35.606
2	1	3	6	19.03	-26.4468	60.76	35.387
3	1	4	8	18.87	-26.3752	60.89	35.404
4	1	6	12	18.90	-26.3892	61.04	35.426
5	2	2	6	16.45	-25.1825	70.43	36.669
6	2	3	4	16.46	-25.1860	73.78	37.072
7	2	4	12	15.70	-24.7760	69.19	36.515
8	2	6	8	16.79	-25.3582	71.67	36.821
9	3	2	8	10.84	-21.5617	84.46	38.247
10	3	3	12	10.57	-21.3401	84.93	38.295
11	3	4	4	13.15	-23.2355	78.34	37.594
12	3	6	6	14.25	-23.9315	75.62	37.286
13	4	2	12	3.54	-11.8386	93.86	39.163
14	4	3	8	4.00	-12.9035	89.94	38.793
15	4	4	6	4.88	-14.6264	87.04	38.508
16	4	6	4	9.04	-19.9857	85.85	38.389

تعزيز الميثان في خليط الغاز الحيوي باستخدام الامتصاص الفيزيائي والكيميائي

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الغاز الحيوي هو غاز عديم اللون وأخف من الهواء وقابل للاشتعال، يستخدام في الطهي والإنارة والتدفئة وتشغيل المحركات و ماكينات الري وتوليد الكهرباء، وتختلف قيمته الحرارية باختلاف نسبة الميثان في المخلوط والذي يمثل الجزء القابل للاشتعال فيه. يهدف هذا البحث إلى تنقية الغاز الحيوى من ثاني أكسيد الكربون وكبريتيد الهيدروجين ورفع القيمة الحرارية للغاز الناتج و زيادة نسبة الميثان، حيث أن وجود كبريتيد الهيدروجين مع الغاز يعمل على تآكل الآلات وقصر عمرها الافتراضي ، وتواجد ثانى أكسيد الكربون في الغاز يقلل من القيمة الحرارية للغاز الحيوى.
تم تصنيع وحدة تنقية الغاز الحيوي في ورشة خاصة بمدينة دمياط وتم إجراء التجارب العملية في قسم الهندسة الزراعية، كلية الزراعة، جامعة دمياط في عام ٢٠٢١ م، وذلك لتقييم أداء هذه الوحدة في عملية تنقية الغاز الحيوي . الأجزاء الرئيسية لوحدة تنقية الغاز الحيوي هى: عمود تنقية كبريتيد الهيدروجين، عمود تنقية ثاني أكسيد الكربون، مضخة مياه ، ضاغط وإسطوانة ضغط تستخدم لتخزين الغاز المضغوط.
أجريت التجارب الرئيسية لوحدة تنقية الغاز الحيوى على مرحلتين:

- المرحلة الاولى (تنظيف الغاز الحيوى): حيث يتم إزالة كبريتيد الهيدروجين بإستخدام تقنية الامتصاص الكيميائي الجاف لإزالة الكبريت ويترسب الكبريت على أكسيد الحديد (الصوف المعدنى).
- المرحلة الثانية (ترقية الغاز الحيوي): حيث يتم إزالة ثاني أكسيد الكربون بإستخدام تقنية الامتصاص الفيزيائي التى تعتمد على إذابة ثاني أكسيد الكربون فى الماء، وتمتاز المواد الخام المستخدمة بأنها رخيصة ومتوفرة محلياً.

وتحددت أهداف الدراسة الرئيسية فيما يلي:

- تصميم وتصنيع وحدة محلية الصنع لتنقية الغاز الحيوى.
- اختبار أنسب عوامل التشغيل التي تؤثر على أداء وحدة تنقية الغاز الحيوى.
- تقييم أداء وحدة تنقية الغاز الحيوى للحصول على أعلى كفاءة تنقية للغاز الحيوى.
- إنتاج غاز الميثان المخصب المطابق لمعيار الغاز الطبيعي وتحقيق مساهمة كبيرة في متطلبات الطاقة المستقبلية في مصر.

تم تقييم أداء وحدة تنقية الغاز الحيوي بأخذ عوامل التشغيل التالية:

- فى المرحلة الأولى (إزالة كبريتيد الهيدروجين في عمود تنقية كبريتيد الهيدروجين): معدل تدفق الغاز الحيوى (٢، ٣، ٤، ٥، ٦، ٩، ١٠ و١٢ لتر/ دقيقة) وعمق طبقة الصوف الفولاذى فى عمود التنقية (٣٠٠ ،٥٠٠ ملم).
- فى المرحلة الثانية (إزالة ثاني أكسيد الكربون في عمود تنقية ثاني أكسيد الكربون): ضغط الغاز الحيوى (١،٢ ،٣ و ٤ بار) ومعدل تدفق الغاز الحيوى (٢، ٣، ٤، ٦ لتر/ دقيقة) ومعدل تدفق ماء الغسيل (٤، ٦، ٨ و١٢ لتر/ دقيقة).

تم تقييم أداء وحدة تنقية الغاز الحيوى من خلال القياسات التالية:

١. نسب مكونات الغاز الحيوى قبل وبعد عملية تنقية كبريتيد الهيدروجين.
٢. نسب مكونات الغاز الحيوى قبل وبعد عملية تنقية ثاني أكسيد الكربون.
٣. كفاءة تنقية الغاز الحيوي.

أظهرت النتائج التجريبية أن تقنية إزالة كبريتيد الهيدروجين التي تتضمن استخدام طبقة من الصوف الفولاذي عمقها ٥٠٠ ملم في عمود التنقية ومعدل تدفق للغاز الحيوي يبلغ ٦ لتر/ دقيقة حققت كفاءة إزالة لكبريتيد الهيدروجين تبلغ ٩٥,٤٠ ٪. كما أظهرت النتائج التجريبية فى مرحلة تنقية ثاني أكسيد الكربون أنه فى المعاملة التجريبية رقم ١٣(عند ضغط ٤ بار، ٢ لتر/ دقيقة من معدل تدفق الغاز الحيوي و١٢ لتر/ دقيقة من معدل تدفق الماء) تم الحصول على أعلى محتوى من الميثان فى الغاز الحيوي المنقى٩٣,٨٦٪ وفى المقابل تم خفض نسبة ثاني أكسيد الكربون إلى ٣,٥٤٪. بعد تنقية الغاز الحيوى الخام باستخدام عوامل التشغيل المثلى للتجربة، لوحظ أن الغاز الحيوي الذي تم الحصول عليه يلبي معيار BIS 16087: 2013 لمحتوى CH4 و CO2 و H2S .
قد أظهرت النتائج المتحصل عليها بعد التنقية أن أقصى قيمة حرارية للغاز الحيوى بلغت ٣٥،٦٥ميجا جول/متر مكعب و الطاقة المتولدة من الغاز الحيوي ٣٥، ٩ ميجا جول/متر مكعب (عند ضغط ٤ بار، ومعدل تدفق الغاز الحيوي ٢ لتر/ دقيقة ومعدل تدفق المياه ١٢ لتر/ دقيقة) ، وذلك عند استهلاك طاقة لتنقية الغاز الحيوى بلغت ١،٥ كيلو واط.

الكلمات المفتاحية : تنقية الغاز الحيوي ، الصوف المعدنى ، حلقات PVC ، تنقية المياه.

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