DJAS., Vol. (2) (II): (77-85) (2023)

DJAS
Damietta Journal of Agricultural Sciences
مجلة دمياط للعلوم الزراعية

Damietta Journal of Agricultural Sciences

Volume 2 , Issue II , 2023

Damietta Journal of Agricultural Sciences
http://publication.du.edu.eg/journal/ojs302design/index.php/agr/index
ISSN: 2812-5347(Print)- 2812-5355 (Online)

Biogas Cleaning to Remove H_2S and H_2O by Chemical Adsorption

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ARTICLE INFO

Key words: Biogas cleaning; Chemical adsorption; steel wool; silica gel; Hydrogen sulfide (H_2S); Water vapor (H_2O)

ABSTRACT

Reducing H_2S and H_2O content will significantly improve biogas quality. Thus, this study aims to design and manufacture a biogas purification technology system. These experiments were conducted at the Department of Agricultural Engineering, Faculty of Agriculture, Damietta University, Egypt, in 2021. Biogas desulphurisation experiments were conducted by H_2S scrubber 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). Desulphurised biogas was passed through a CO_2 scrubber for purification and then dried the biogas product throughout dehydrator to remove water at different pressures of (1, 2, 3, and 4 bar) and different gas flow rates of (2,3,4 and 6 *L*/min) and different water flow rates of (4,6,8 and 12 *L*/min). The desulfurization experiment results show that when the depth of the steel wool bed is 500 mm and the biogas flow rate is 6 *L*/min, the highest H_2S removal efficiency is 95.40%. The highest weight of the water removed from the purified biogas using silica gel was 0.449 g at a biogas pressure of 1 bar, biogas flow rate of 6 *L*/min, and water flow rate of 12 *L*/min.

1. INTRODUCTION

Using biogas to generate energy is not only a renewable source of energy, but also because it captures and uses the greenhouse gases that are normally released into the atmosphere. Many researchers indicated the importance the biogas production. **Nallamothu *et al*., (2013)** mentioned that dwindling petroleum resources, global warming, and the threat of climate change, exploring other avenues for eco-friendly fuels became essential. Biogas is a clean and environmentally friendly fuel and has become one of the potential alternative fuels. Raw biogas contains methane (CH_4), carbon dioxide (CO_2), traces of hydrogen sulfide (H_2S), and fractions of water vapors. **Elfeki *et al* ., (2017)** reported that data on agricultural wastes in Egypt reveal that there is an approximate amount of 33.4 million tons of waste generated annually. Bioconversion can convert those agricultural wastes into about 12.6×10^9 m^3/year of biogas with about 60% methane, which is equal to 7.6×10^9 m^3 of natural gas. The produced biogas from anaerobic digestion can contribute to about 13% of the Egypt's total natural gas production. The energy content of 1.0 m^3 of purified biogas is equal to 0.97m^3 of NG . Energy consumption in Egypt in 2015 relied mainly on gas (53%), about 70% of Egypt's electricity is fueled by natural gas , ccording to **(EIA, 2015)**. **Shakrum *et al*.,(2022)** mentioned that raw biogas is generally composed of methane (50–75%), and carbon dioxide (25–45%). Other gases (contaminants) present are nitrogen (<2%), oxygen (<2%),water (2–7%), hydrogen sulfide (<1%). **Kaplan *et al*.,(2021)** defined hydrogen sulphide as a colorless, flammable gas with an unpleasant odor, which is highly toxic to organisms and affects the

nervous and respiratory systems. High concentrations of H_2S in biogas can cause corrosion of thermal heat and power units and boilers. H_2S is therefore considered an undesirable component of biogas and should be removed. The removal of hydrogen sulphide (desulphurisation) is one of the most important processes in biogas upgrading. **Konkol *et al*., (2021)** pointed out that H_2S removal methods can be divided into physical using solubility in water and sorbents, chemical based on adsorption and absorption chemical and biological using microorganisms. **Awe *et al*., (2017)** reported that H_2S needs to be removed from biogas to achieve the requirements for the different biogas applications, as natural gas <4 ppm, kitchen stoves <10 ppm and internal combustion engines<50 ppm.

Mohanakrishnan *et al*., (2016) established a Pilot level biogas-cleaning unit by Chemical scrubbing method to desulphurise. Biogas was passed through iron sponge (iron oxide) bed depth of 100 mm, 300 mm and 500 mm. The removal of H_2S was 55.56 %, 63.22 % and 70.37 % respectively. **Kulkarni and Ghanegaonkar.,(2019)** used a column to remove hydrogen sulfide from biogas. Gas flow rates are varied as 2, 5 and 10 *L*/min, at a constant pressure. When the biogas flow rate is maintained at 5 *L*/min, the steel wool reduced the H_2S content from 790 to 60 ppm with hydrogen sulfide removal efficiency is higher (92.41%) using single column. Therefore, they recommended dry desulfurization using steel wool which provides the most suitable option for hydrogen sulfide removal from biogas, in the context of cost considerations.

Al Mamun and Torii (2015) stated that water vapor can be particularly dangerous because it is highly corrosive when H_2S and water vapor react to form sulfuric acid (H_2SO_4), which can be very corrosive to pipelines and other equipment exposed to biogas. Even if H_2S is removed, water vapor can react with CO_2 to form carbonic acid (H_2CO_3), which is likewise corrosive. **Mezmur and Bogale., (2019** decided to use silica gel because it has an excellent moisture absorbing capacity. The biogas enters the dehumidification column after passing the biogas upgrading system to make certain that the biogas become dry as silica gel. They used a silica gel column with a height of 150 mm and a diameter of 50 mm to dehydrate the biogas. According to **Rohani,2009**, how the water is removed from the biogas depends on the quality of the desiccant and since it only focuses on the operating pressure, the temperature is constant. At a constant temperature, the water content of a gas decreases with increasing pressure, so there is less water to remove when drying a gas at high pressure. The content of saturated biogas vapor decreases with increasing pressure or decreasing temperature.

The purpose of this research is to produce an enriched biogas conforming to the natural gas standard and achieve a significant contribution to Egypt's future energy requirements. So , the hydrogen sulfide separation technology has been designed based on dry adsorption of H_2S using steel wool (iron oxide).Finally, the dehydration process was done using adsorption drying where H_2O is adsorbed on the silica gel.

2. MATERIALS AND METHODS:

A biogas cleaning system was manufactured 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 cleaning.

2.1. Materials:

2.1.1. Biogas production

The operating conditions of the reactor are as follows:

A plastic reactor for the decomposition of cow dung, with a capacity of 200 liters, is used for the production of biogas. The feed gas produced daily in the reactor is collected in tire tube for 45 days, and the pH value in the reactor is maintained in the range of (6.5 to 7.5) by manual stirring during the anaerobic treatment. The operating temperature is (30-35°C) under moderate temperature conditions, the C/N ratio is 25:1 and the total solids is 8%. The following physicochemical properties of cow dung were observed: moisture 43%, dry matter 20.83%, organic matter 57%, density 625 kg/m3, carbon content 31%, nitrogen content 1.46%. The raw material gas produced by the plant is collected through tire tubes for 30 days, as shown in **Fig.1** and the biogas composition are presented in **Table .1.**

Figure .1. Raw Biogas collection by tyre tube

Table .1. Composition of biogas.

Gas	Concentration
Methane (CH_4),%	53.6
Carbon dioxide (CO_2),%	25.8
Hydrogen sulphide (H_2S),ppm	420
Heating value, MJ/m^3	22.5

2.1.2. Biogas cleaning system:

As shown in **Fig.2**, the H_2S scrubber had made of a PVC with an outer diameter of 0.2 m (8 inches) by a length of 1 m. It is designed and customized to remove H_2S from biogas using a steel wool bed and a chemical adsorption process. An experimental study has been conducted to determine the efficacy of steel wool for use in the adsorption of H_2S. A bed of steel wool with two different depths of 300 and 500 mm was provided for the desulphurisation of the raw biogas.

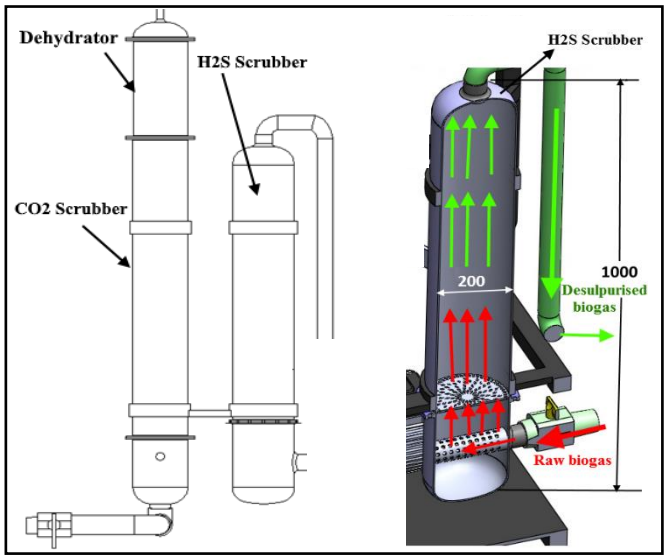

Figure .2. Schematic drawing of the biogas cleaning system, all dimensions in mm

Raw biogas is passed through the H_2S scrubber filled with the steel wool bed. At first, the color of steel wool is gray and then the color changes to black, which indicates that it needs to be replaced and it can be safely disposed, as shown in **Fig.3**.

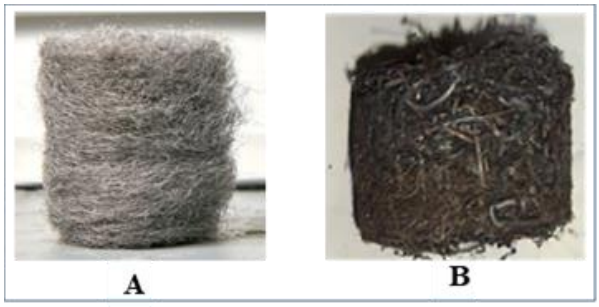

Figure.3. Photos of steel wool, (A): Before absorbing H_2S, (B): After absorbing H_2S.

A silica gel dehydration system with a diameter of 150 mm (6 inches) and a height of 300 mm was placed direct above CO_2 scrubbing system in the same column, as shown in **Fig.4**. A dehydrator was filled with a diameter 150 g of silica gel (Mesh 5–6 mm). Purified biogas enters the dehydrator after passing through the CO_2 scrubber to ensure removing moisture from it.

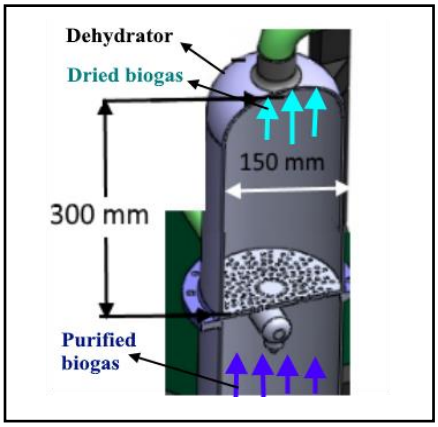

Figure .4. Schematic 3D drawing of the biogas dehydrator, all dimensions in mm

As seen in **Fig. 5**, the silica gel's colour changed from blue to pink as a result of absorbing the water vapour from the purified biogas.

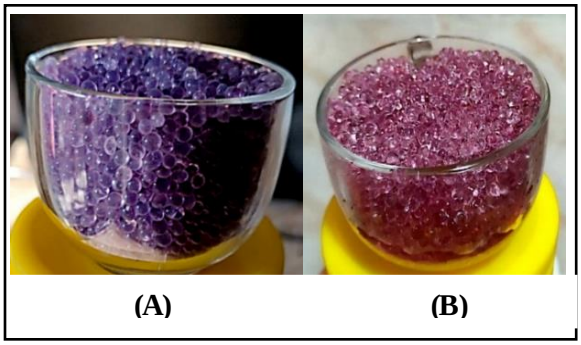

Figure.5. Photographic view of silica gel , (A) Granular form silica gel before water absorbed , (B) after water absorbed.

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 H_2S scrubber which filled with the steel wool bed. H_2S is removed through chemical mechanism as it reacted with iron oxide (Fe_2O_3) to form iron sulphide (Fe_2S_3), the steel wool can be safely disposed. The silica gel filter executed the chemical drying method in its basic way which is the adsorption for moisture removal from purified biogas. It was filled with 1.5 kilos of silica gel which reaches to around three-fourth of its total volume. The biogas enters the dehydrator after passing the CO_2 removal system to ensure that the biogas was dry by using silica gel. The silica gel was weighted before and after biogas passes to estimate water content in purified biogas. The difference

of weight gave the quantity of water removed (Quantitative Analyzing).

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 CH_4, (0-50%) for CO_2 and (0-3000) ppm for H_2S. 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 .

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

3.Digital balance:

Balance made in China, model SF-400 with measuring range of 0-3kg ± 0.001kg was used to determine the mass of the silica gel before and after dehydration process (samples 150g).

3. Calculation method:

(A) Cleaning efficiency:

The H_2S removal efficiency (ηH_2S), the CO_2 removal efficiency (ηCO_2) and the CH_4 enrichment efficiency (ηCH_4) were calculated, according to **Huang *et al.* (2015)** as follows:

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

H_2S_{in} and H_2S_{out} = The volume of H_2S 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).**

$HV = \%CH_4 \times \rho \times LHV$, **MJ/m^3** (2)

Where:

$\%CH_4$:The percentage of methane obtained after purification process ,

ρ : methane density = 0.717 kg/ m^3

LHV : The lower heating value of the methane = 50 MJ/kg **(Badr ,2019)** ,

LHV : The lower heating value of the methane = 35.85 MJ/m^3 **(Badr ,2019)** ,

The average lower heating value of a raw biogas varies between 30 and 35 MJ/kg **(Mezmur and Bogale., 2019).**

3.RESULTS AND DISCUSSION:

3.1. Effect of steel wool depth and biogas flow rate on H_2S content:

The results of each sample passing through H_2S scrubber were tested in 16 runs. The experimental results were assigned for testing and analysis using Taguchi method to study the effects of input parameters on H_2S content. Results in **Table .2.** showed the actual values of H_2S content, also the signal to noise (S/N) ratios of the control factors in H_2S response and identify the influence of parameters in each run.

Fig.7 showed the main effects plots for the signal to noise (S/N) ratios of the control factors in H_2S response and identify the optimal levels of these factors. The lowest H_2S content of 19 ppm was obtained in run 10 at the optimum levels of factors with a biogas flow rate of 6 *L*/min (level five) and a steel wool depth of 500 mm (level two).

Table .2. Response data of Taguchi design of treated biogas.

Run	Biogas Flow Rate, *l*/min	Depth of steel wool media, mm	H_2S Content ,ppm	S/N (H_2S)
1	2	300	146	-43.2871
2	2	500	93	-39.3385
3	3	300	95	-39.5545
4	3	500	85	-38.6224
5	4	300	73	-37.2665
6	4	500	48	-33.5643
7	5	300	53	-34.5400
8	5	500	38	-31.5957
9	6	300	42	-32.4650
10	6	500	19	-25.7261
11	9	300	55	-34.8597
12	9	500	30	-29.6384
13	10	300	155	-43.8253
14	10	500	97	-39.7055
15	12	300	145	-43.2074
16	12	500	107	-40.6147

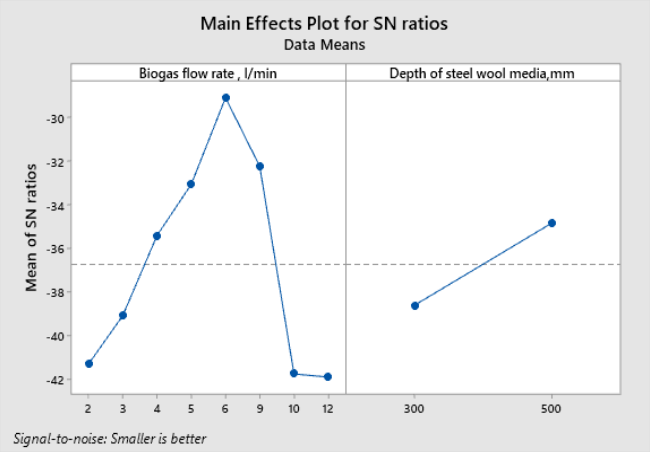

Figure .7. Main effect for S/N ratios of the control factors in H_2S removal.

The interaction plot gives better insight on optimum levels and combinations desired. It is clear that there exists prominent interdependencies among the biogas flow rate and the depth of steel wool.

It is understood from **Fig.8** that when the biogas flow rate was increased from 2 to 6 *L*/min at steel wool depth of 300 and 500 mm, the H_2S content first was decreased but when the biogas flow rate was increased from 6 to 12 *L*/min, it was found that the H_2S content was increased. The minimum H_2S content was observed at 6 *L*/min biogas flow rate and 500 mm of steel wool depth. After experiments in H_2S scrubber, the desulphurised biogas has a heating value 23.7 MJ/m^3 and its wobbe index was 24 MJ/m^3.

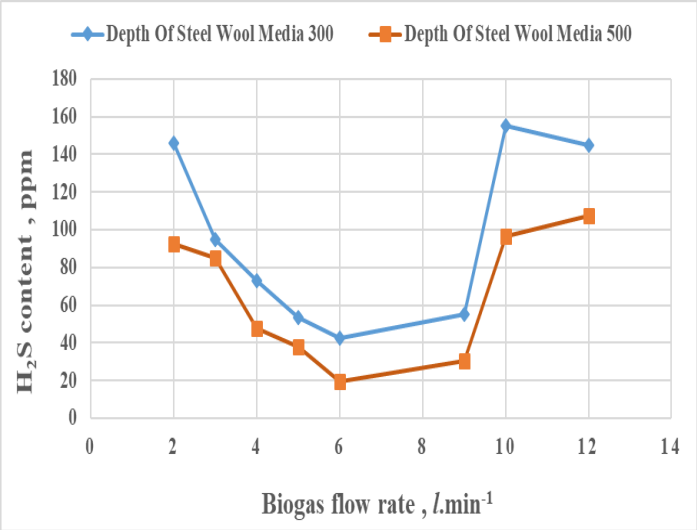

Figure .8. Interaction plot for H_2S content in desulphurised biogas.

The optimum results of the effect of steel wool bed depth at biogas flow rate 6 *L*/min on desulphurisation is presented in **Table.3.** The H_2S content in the raw biogas was 420 ppm. Steel wool bed depth of 300 mm reduced the H_2S concentration to 42 ppm. Finally, when the biogas was fed through 500 mm steel wool bed depth, the H_2S content of the desulphurised biogas was found to be 19 ppm. The removal of H_2S was 90 % and 95.40 % for steel wool bed depth of 300 mm and 500 mm, respectively, when biogas flow rate is 6 *L*/min. From the above-mentioned results, a maximum of hydrogen sulfide removal efficiency of 95.3% was achieved at a steel wool depth of 500 mm with a flow rate of 6 *L*/min.

Table .3.Effect of depth of Steel wool on biogas desulphurisation

Steel wool bed depth , mm	H_2S in raw biogas , ppm	Biogas flow rate , *L*/min	H_2S in desulphurised biogas , ppm	H_2S removal ,%
300 mm	420	6	42	90
500 mm	420	6	19	95.40

This result agree with **Kulkarni and Ghanegaonkar.,(2019)**, they attained the removal efficiency of hydrogen sulfide of 92.41% using fixed bed of steel wool when biogas flow rate is maintained at 5 *L*/min. **Mohanakrishnan *et al.*, 2016** achieved a minimum hydrogen sulfide content at a steel wool bed

depth of 500 mm. This can be compared with **Machunda and Pogrebnaya.,(2020)** , they reported that biogas flow rate was one of parameters that influenced the H_2S removal efficiency. Therefore, high H_2S adsorption was observed at low flow rates as the adsorbent had more time to contact the biogas. According to literature, the adsorption capacity of the adsorbent decreases with increasing biogas consumption. At high flow rates, the contact time of the adsorbent with the biogas decreases; therefore, H_2S passes through the adsorbent without being adsorbed; therefore removal efficiency is low compared to low flow rates.

3.2. Effect of water flow rate, biogas pressure, and biogas flow rate on H_2O removal:

By passing biogas through the column, water was eliminated by the anhydrous silica gel, which completely absorbs the water. Water vapor may be adsorbed to the surface of a solid by actual chemical bonds from a reaction, through formation of loose hydrated compounds or by weaker physical or Vander Walls forces. Near the bottom of the column, the silica gel's colour changed to a light blue colour. The colour change of all silica gel from blue to pink was a sign of the silica gel's initial point of saturation in the column and an indication that the packing material was depleted. 1500 g of Silica gel are needed to remove the moisture. Before and after each run, the silica gel was weighed where the silica gel gradually turned pink. The amount of moisture present was determined using a qualitative method. Data in **Table .4** showed the ratio between water flow rate and biogas flow rate (L/G) and weight of removed water (g) for 16 runs.

Table .4. Data for silica gel test.

Run	Biogas Pressure , bar	Biogas flow rate ,l/min	Water flow rate ,l/min	L/G	Weight of removed water , g
1	1	2	4	2.0	0.190
2	1	3	6	2.0	0.230
3	1	4	8	2.0	0.322
4	1	6	12	2.0	0.449
5	2	2	6	3.0	0.276
6	2	3	4	1.3	0.138
7	2	4	12	3.0	0.414
8	2	6	8	1.3	0.172
9	3	2	8	4.0	0.273
10	3	3	12	4.0	0.380
11	3	4	4	1.0	0.134
12	3	6	6	1.0	0.130
13	4	2	12	6.0	0.207
14	4	3	8	2.7	0.238
15	4	4	6	1.5	0.184
16	4	6	4	0.7	0.127

Fig.9 showed the 3D response surface plot for weight of removed water where the interaction between the inputs (water flow rate, biogas flow rate and biogas pressure) and output (weight of silica gel after drying) was shown in the following Figures. In **Fig.9-a,** interaction of individual plot shows a trigonometric relation. The increase in biogas pressure from 1 to 4 bar decreases the weight of silica gel at biogas flow rate of 6 *L*/min. It can be seen that the weight of silica gel has decreased along with with the increasing biogas flow rate. In **Fig.9-b,** interaction of individual plot shows a Parallelogram relation. The increase in water flow rate from 4 to 12 *L*/min increases the weight of silica gel, also increases in biogas pressure from 1 to 4 bar decreases the weight of silica gel.

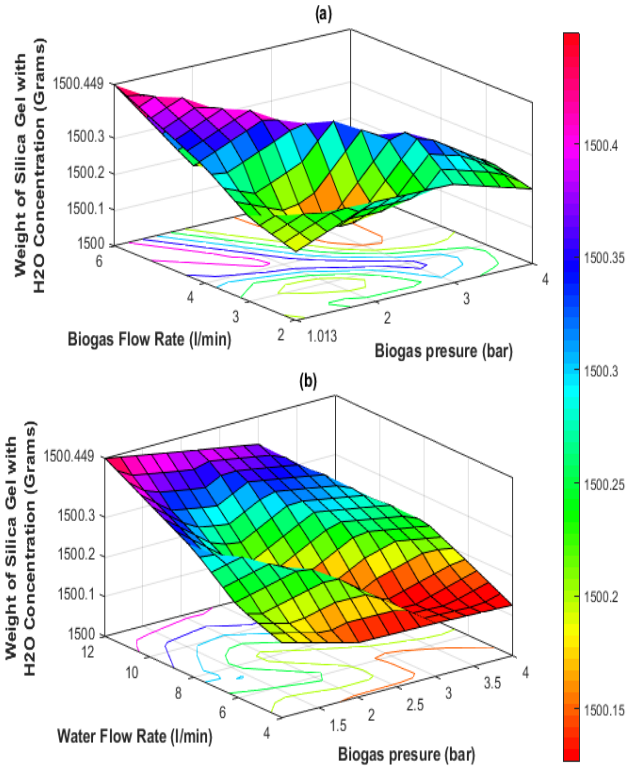

Figure.9. 3D Effect of biogas flow rate, water flow rate and biogas pressure on weight of removed water.

Fig.10 showed the highest weight of removed water of 0.449 g was obtained in run 4 at biogas pressure 1 bar, biogas flow rate of 6 *L*/min and water flow rate of 12 *L*/min, the ratio between water flow rate and biogas flow rate (L/G) was 2.0. While, the lowest weight of removed water of 0.127 g was obtained in run 16 at biogas pressure 4 bar, biogas flow rate of 6 *L*/min and water flow rate of 4 *L*/min, the ratio between water flow rate and biogas flow rate (L/G) was 0.7.

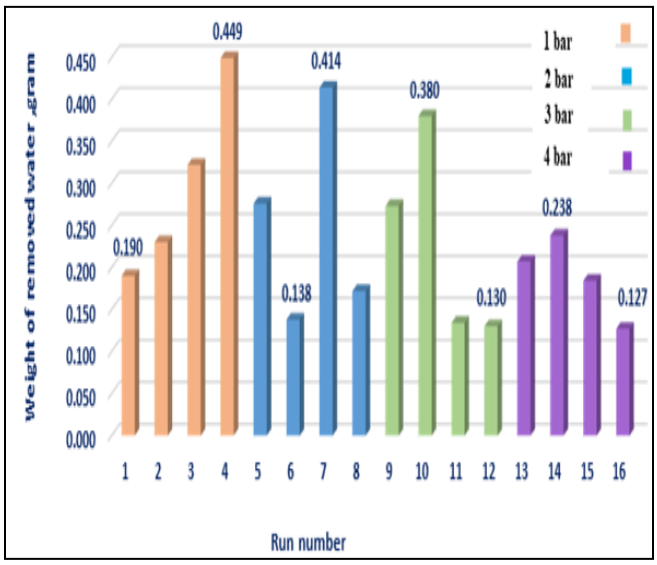

Figure.10. 3D Effect of biogas flow rate , water flow rate and biogas pressure on weight of removed water.

This result is consistent with **(Rohani, 2009)**, who demonstrated that the water content of a gas declines with increasing pressure, necessitating the removal of less water when a gas is dehydrated at a high pressure. According to the obtained Figure, it was found that the silica gel weight was increased when water and biogas flow rates increased along with the increase in the efficacy of silica gel removing water. High water flow rate results in an increase in the silica gel absorption of water because of the increase of water ratio in purified biogas which passing through silica gel after scrubbing with more washing water, the contact point between silica gel and the water will be wider. At the same time, high biogas flow rate also results in an increase in molecules of water which connected with molecules of biogas, so the silica gel absorption of water is increase.

3.3. Effect of biogas flow rate on biogas heating value:

Heating value is one of the most important indicators after biogas purification process to meet natural gas quality and to achieve a significant contribution to Egypt's energy requirements. Raw biogas has a heating value of 19.1 MJ/m^3 with methane content of 53.3%.Values of both the heating value from the integrated biogas cleaning system were estimated as shown in **Table (5)**.

It was noticed that higher values of both the heating value and the generated energy were associated with the percentage of methane obtained after purification process, according to **Badr (2019)**.

Table.5. Energy balance for purification system.

Run	CH_4 content, %	Gas flow rate, m^3/h	Heating value, MJ/m^3
1	53.9	0.12	19.3
2	54.4	0.18	19.5
3	54.1	0.24	19.4
4	54.9	0.36	19.7
5	54.0	0.12	19.4
6	56.3	0.18	20.2
7	55.8	0.24	20.0
8	56.7	0.36	20.3
9	55.7	0.12	20.0
10	58.9	0.18	21.1
11	55.9	0.24	20.0
12	58.2	0.36	20.9
13	54.2	0.12	19.4
14	57.3	0.18	20.5
15	53.6	0.24	19.2
16	55.7	0.36	20.0

4. CONCLUSION:

In order to significantly contribute to Egypt's future energy needs, experimental work was done to investigate a more effective method for biogas cleaning that would using inexpensive material. It is essential to clean and upgrade raw biogas in order to improve its calorific value, increase its usability, and remove pollutants. These contaminants were removed using steel wool, water, and silica gel. H_2S is removed through chemical mechanism as it reacted with steel wool to form iron sulphide. Water vapour is reduced in the purified biogas by using silica gel. Therefore, the important results could be summarised in the following points:

- According to the desulfurization results, the highest H_2S removal efficiency was 95.40% at a steel wool bed depth of 500 mm and a biogas flow rate of 6 *L*/min.
- The highest value of heating value of desulphurised biogas of 21.1 MJ/ m^3.
- In run 4 with a biogas pressure of 1 bar, a biogas flow rate of 6 *L*/min, and a water flow rate of 12 *L*/min, the greatest weight of removed water was measured at 0.449 g.
- These chemical methods are a feasible method for cleaning biogas given the successful elimination of H_2S and H_2O.

FUNDING:

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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الملخص العربى

تنظيف الغاز الحيوي لإزالة H_2S و H_2O عن طريق الامتصاص الكيميائي

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تهدف تكنولوجيا البيوجاز إلى إعادة استخدام المخلفات العضوية كمخلفات المحاصيل وروث الماشية بطريقة اقتصادية وآمنة صحيا لإنتاج طاقة جديدة متجددة وكبديل للطاقة التقليدية مع إنتاج سماد عضوي جيد وحماية البيئة من التلوث. الغاز الحيوي هو مخلوط غازي ناتج من تخمر المخلفات العضوية بمعزل عن الهواء "تخمرلاهوائى" وذلك بفعل مجموعة متخصصة من البكتريا لينتج خليط من غاز الميثان و ثاني أكسيد الكربون وكبرتيد الهيروجين.
يستخدم الغاز الحيوي في الطهي والإنارة والتدفئة وتشغيل المحركات و ماكينات الري وتوليد الكهرباء. يهدف هذا البحث إلى تنظيف الغاز الحيوى من كبريتيد الهيدروجين والماء ورفع القيمة الحرارية للغاز الناتج ، حيث أن وجود كبريتيد الهيدروجين مع الغاز يعمل على تآكل الآلات وقصر عمرها الافتراضي ، وتواجد الماء يقلل من القيمة الحرارية للغاز الحيوى و يسبب تآكل المعادن أيضا .
تم تصنيع وحدة تنظيف الغاز الحيوي في ورشة خاصة بمدينة دمياط وتم إجراء التجارب العملية في قسم الهندسة الزراعية، كلية الزراعة، جامعة دمياط في عام 2021 م، وذلك لتقييم أداء هذه الوحدة في عملية تنظيف الغاز الحيوي .
أجريت التجارب الرئيسية لوحدة تنظيف الغاز الحيوى كالتالى:

- **المرحلة الاولى (إزالة كبريتيد الهيدروجين):** تتم بإستخدام تقنية الامتصاص الكيميائي الجاف لإزالة الكبريت ويترسب الكبريت على أكسيد الحديد (الصوف المعدنى).
- **المرحلة الثانية (تجفيف الغاز الحيوى):** حيث يتم إزالة الماء بإستخدام تقنية الامتصاص الكيميائي الجاف التى تعتمد على امتصاص الماء بواسطة بلورات السيليكا جل ، وتمتاز المواد الخام المستخدمة بأنها رخيصة ومتوفرة محلياً.

- **وتحددت أهداف الدراسة الرئيسية فيما يلي:**
  - تصميم وتصنيع وحدة محلية الصنع لتنظيف الغاز الحيوى.
  - اختبار أنسب عوامل التشغيل التي تؤثر على أداء وحدة تنظيف الغاز الحيوى.
  - تقييم أداء وحدة تنظيف الغاز الحيوى للحصول على أعلى كفاءة تنظيف للغاز الحيوى.
  - تحقيق 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): 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 الماء): 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:

1. نسب مكونات الغاز الحيوى قبل وبعد عملية تنقية كبريتيد الهيدروجين.
2. وزن السيليكا جل قبل وبعد عملية تجفيف الغاز.
3. كفاءة تنظيف 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 أن أعلى وزن للمياه المزالة كان ٤٤٩,٠ جرام في المعاملة رقم ٤ وذلك عند ضغط ١ بار ، ومعدل تدفق الغاز الحيوي ٦ لتر / دقيقة ومعدل تدفق المياه ١٢ لتر / دقيقة ، وأن النسبة بين معدل تدفق المياه ومعدل تدفق الغاز الحيوي كانت ٢.

- أظهرت النتائج أن أقل وزن للمياه المزالة ١٢٧,٠ جرام في المعاملة رقم ١٦ وذلك عند ضغط ٤ بار ، ومعدل تدفق البيوجاز٦ لتر / دقيقة ومعدل تدفق المياه ٤ لتر / دقيقة ، وأن النسبة بين معدل تدفق المياه ومعدل تدفق الغاز الحيوي كانت ٧,٠ .

الكلمات المفتاحية: تنظيف الغاز الحيوي ;الامتصاص الكيميائي ;الصوف الصلب; جيل السيليكا; كبريتيد الهيدروجين (H_2S); بخار الماء (H_2O).

DJAS., Volume (2) , Issue (II) , 2023