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Evaluation of the Corrosion of Aluminum in Contact with a Biogas before and after Purification on Activated Carbon Based on Branches of *Borassus aethiopum*

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ABSTRACT

Biogas is a gas produced by the fermentation of organic animal or plant matter. It consists mainly of CO2 and methane, but contains trace amounts of hydrogen sulfide (H2S). H2S is a highly toxic gas that corrodes metals used in anaerobic digestion, in the petrochemical industry and elsewhere. The particularity of this work is to evaluate the performance of activated carbon prepared from *borassus aethiopum* branches in removing H2S from biogas and to assess the reduction of the corrosive effect of filtered biogas on aluminum metal. The aluminium-induced protective power of the filtered biogas was 87.63%.

INTRODUCTION

Biogas is a gas that mainly contains combustible methane (CH_4) and carbon dioxide (CO_2), but also contains other elements such as hydrogen sulphide (H_2S) in trace amounts [1]. Hydrogen sulfide, which is a highly toxic gas for humans and their environment, is one of the main causes of corrosion failure in the gas and petrochemical industry [2,3]. Thus, it can significantly decrease the useful life by cracking transmission pipelines; and processing facilities in the oil and gas industries [4,5]. The treatment of H_2S from biogas with local, available, and inexpensive materials is therefore necessary. The literature shows that activated carbon offers significant efficiency in the elimination of pollutants through efficient adsorbents [6,7]. Côte d'Ivoire is an agricultural country, we have therefore opted for *borassus aethiopum* which is very recurrent in certain localities of the country for the manufacture of our activated carbon in the purification of hydrogen sulphide from biogas to fight against corrosion. of our aluminum metal.

1. Material and Study methods

1.1.Material

As a precursor, we used the branches of *Borassus aethiopum* (palmyra) for the manufacture of activated charcoal because of its abundance and accessibility in several localities of the country. Figure 1 below shows the branches of borassus.

Figure 1: **Activated carbon raw material**

The aluminum metal used underwent a pre-treatment and was placed at 40°C for 5 min in an oven to dry before being transported to the experimental biogas site for the study of corrosion. Figure 2 below shows some samples of our aluminum metal.

Figure 2: **Aluminum samples**

The carbonization of the palmyra branches is done using a traditional oven.

The H2S concentration is determined using a portable biogas detector (Figure 3).

Figure 3: **biogas analyzer**

2.1 Methods

2.1.1 Activated carbon synthesis protocol

The preparation of activated carbon based on *Borassus aethiopum* intended for filtration was carried out in several stages [8,9]. The pieces of palmyra branches were sent to the traditional oven to be carbonized for 2 h 30 min at a temperature of 400 ± 10°C. After carbonization, the grains obtained were impregnated in a solution of copper sulfate at 1000 ppm for 24 h, then heated at 450 ± 10° C. for 3 h in the oven.

2.1.2 Characterization of activated carbon

2.1.2.1 Humidity rate

The humidity level is determined by drying the adsorbent in an oven. The adsorbent is dried in an oven at 105°C for 24 hours [10]. The humidity rate (% H) is calculated using the following formula:

$$\%H = \frac{(m_2 - m_3)}{m_1} \times 100 \qquad \text{Eq (1)}$$

Or:

m1: the initial mass of activated carbon (AC) used (in g)

m2: the mass of the crucible + activated carbon (AC) before drying (in g)

m3: The mass of the crucible + activated carbon (AC) after drying (in g).

2.1.2.2 Ash content

The ash content is the inorganic, inert, amorphous and unusable part present in activated carbon. Thus, a sample of 3 to 4 g of activated carbon is placed in a ceramic crucible. The whole is weighed and then placed in the oven set at 650°C for 3 hours. After cooling to room temperature, the whole is weighed again [11]. The ash content (C) is calculated using the following formula:

$$C\,\% = \frac{m_2 - m_0}{m_1 - m_0} \times 100 \qquad Eq\ (2)$$

with

m0: the initial mass of the AC used (in g).

m1: The mass of the crucible +CA before carbonization (in g)

m2: The mass of the crucible +CA after carbonization (in g)

2.2.2.3 Iodine value

For the determination of the iodine number, a mixture of 0.05 g of activated carbon and 15 mL of a 0.1N iodine solution is stirred for 4 min. After filtration, 10 mL of the filtrate is titrated with a 0.1N sodium thiosulfate solution in the presence of two drops of starch paste. A blank test was carried out under the same conditions in the absence of activated carbon. The iodine value can be calculated from the following formula:

$$I_d = \frac{(V_b - V_s) \times N \times 126{,}9 \times (\frac{15}{10})}{m} \qquad \text{Eq(3)}$$

with

Id: Iodine value (mg / g)

(Vb-Vs): difference between the titration results in the blank test and in the test with adsorbent (in mL of sodium thiosulfate)

N: normality of the sodium thiosulfate solution in (eq. g/L)

M: 126;9 the atomic mass of iodine (in g/mol) and m: the mass of activated carbon in (in g).

2. H2S elimination tests by adsorption on activated carbons

The H2S concentration is determined at the inlet and outlet of the filter filtration column using portable biogas detectors. Figure 4 below shows the adsorption test device.

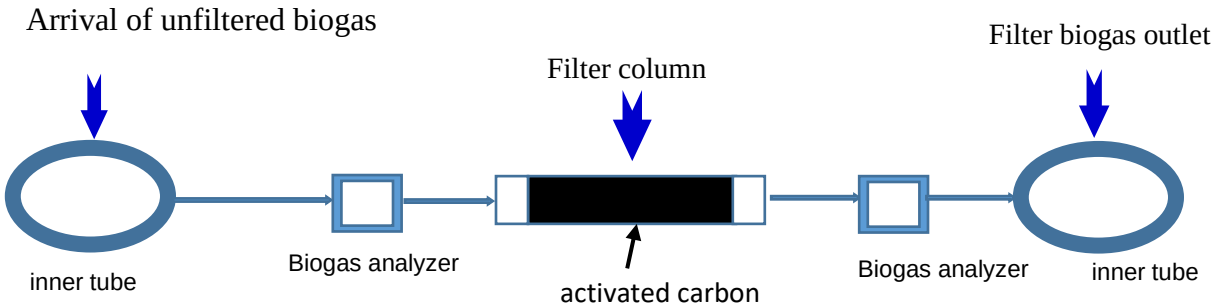

Figure 4: Diagram of the adsorption test

The biogas flow was kept constant during the test period with a value of 0.146 m3/min or 0.00244 m^3/s.

3. Results and discussion

3.1 Characteristics of activated carbon

The study of the characteristics of activated carbons is necessary to contribute to the understanding of several phenomena such as adsorption, desorption, exchange, etc. Table 1 shows some characteristics of activated carbon.

Table 1: characteristics of Borassus carbon

Iodine value (mg/g)	Yield(%)	Ash rate (%)	Humidity level (%)
958,09	39	2,38	11,15

The relatively low moisture content with 11.15% indicates a high superior calorific value (PCS) of our activated carbon [12]. The ash content of the activated carbon prepared on the basis of *Borassus aethiopum* is 2.38%. This content of less than 20% indicates a very good adsorption capacity of our synthesized activated carbon [13]. The iodine number value of our soda activated carbon is 958.09 mg/g. This value is largely greater than 500 mg/g, thus indicating that our adsorbent is microporous (0-2 mm) with a better specific surface [14].

3.2 Study of the efficiency of removal of hydrogen sulphide (H_2S) from biogas by activated carbon based on *Borassus aethiopum*

Changes in H2S concentration before adsorption were also monitored during working time and showed no change in the initial H_2S concentration (see Table 2). This means that the initial concentration of H_2S therefore remained constant during the working time.

Table 2: Composition of biogas

Constituents	Measure 1	Measure 2	Measure 3	Measure 4
CH_4	85-90 %	85-90 %	85-90 %	85-90 %
CO	10-15 ppm	85-90 ppm	85-90 ppm	85-90 ppm
H_2S	80 – 100 ppm	80 – 100 ppm	80 – 100 ppm	80 – 100 ppm

Figures 5 and 6 below respectively show the variation of H_2S concentration as a function of time and the removal efficiency (RE) of H_2S as a function of time.

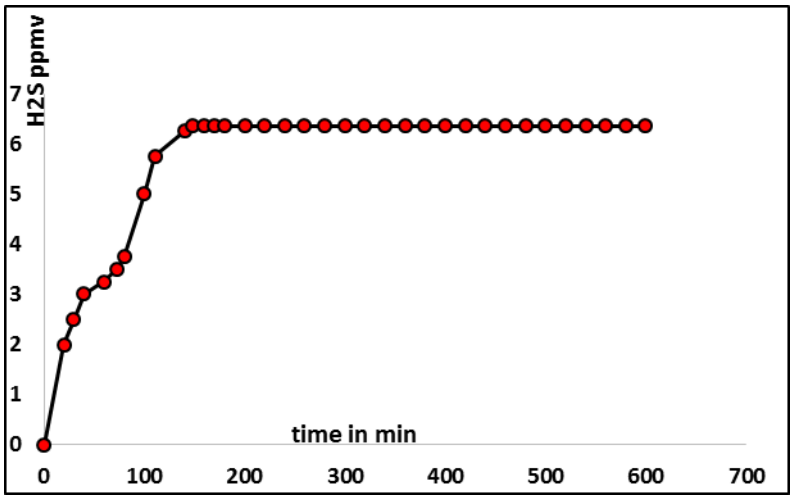

Figure 5: The variation of H_2S concentration as a function of time

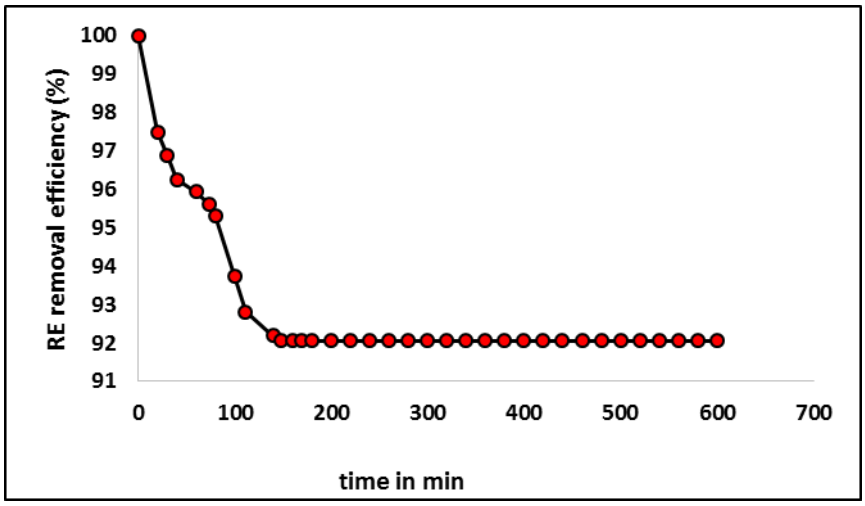

Figure 6: The removal efficiency (RE) of H_2S as a function of time.

Activated carbon samples have an H_2S removal efficiency (RE) greater than 97% (Figure 6). This indicates the development of pores essential for adsorption [15,16].

3.3 Study of aluminum metal corrosion in biogas

3.3.1 Comparative study of the evaluation of the loss of mass of aluminum (Al) as a function of time (t) in unfiltered biogas (BNF) and in filtered biogas (BF).

Figure 7 below presents a comparison on the evaluation of the loss of aluminum mass in the unfiltered biogas (BNF) and in the filtered biogas (BF) according to the residence time.

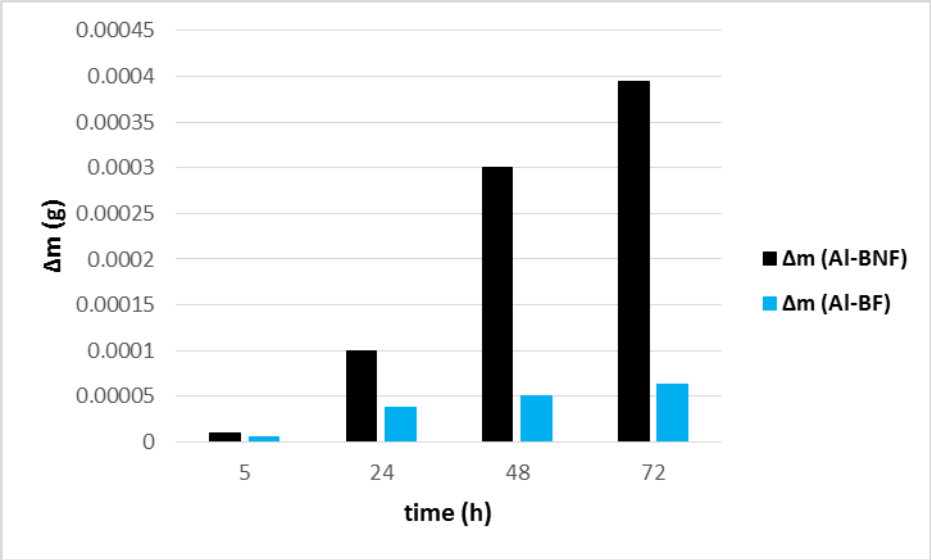

Figure 7: **Mass loss of aluminum in unfiltered biogas (BNF) and in filtered biogas (BF) of trace BORASSUS-based activated carbon as a function of residence time.**

The histograms in Figure 7 above clearly indicate an increasing trend of mass loss with increasing time for the aluminum metal used in the case of unfiltered biogas (BNF) and in filtered biogas (BF). A greater mass loss is also observed in the different cases with the longer exposure time, which is 72 hours. For unfiltered biogas, the growing trend is higher than for filtered biogas. This could be explained by the presence of hydrogen sulfide (H_2S) in a very high concentration of 80 ppm in unfiltered biogas and 6.5 ppm in filtered biogas.

Moreover, in the BF, the corrosion process exists but is slowed down. The slowing down of aluminum corrosion in BF could be explained initially by the low H_2S content, but also secondarily by the low water content, due to the adsorption of H_2S molecules. water and H_2S by activated carbon during filtration. This would indicate the formation of a surface layer acting as a protective layer, thus preventing the corrosion process from spreading.

3.3.2 Study of the corrosion rate of aluminum metals (Al) as a function of time (t) in unfiltered biogas and in filtered biogas

Figures 8, 9 and 10 below show the evolution of the corrosion rate of aluminum as a function of time in unfiltered biogas (control) and in biogas filtered by activated carbon and also a comparative study.

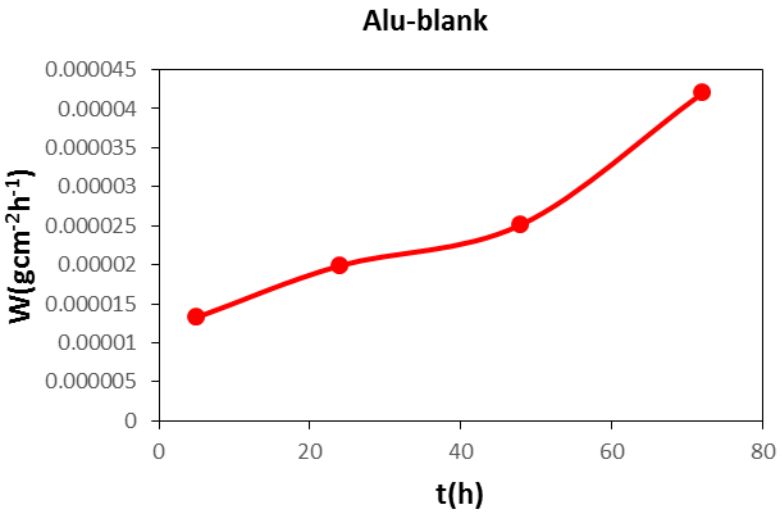

Figure 8: **Evolution of the corrosion rate of aluminum as a function of time in unfiltered biogas (control) by BORASSUS activated carbon**

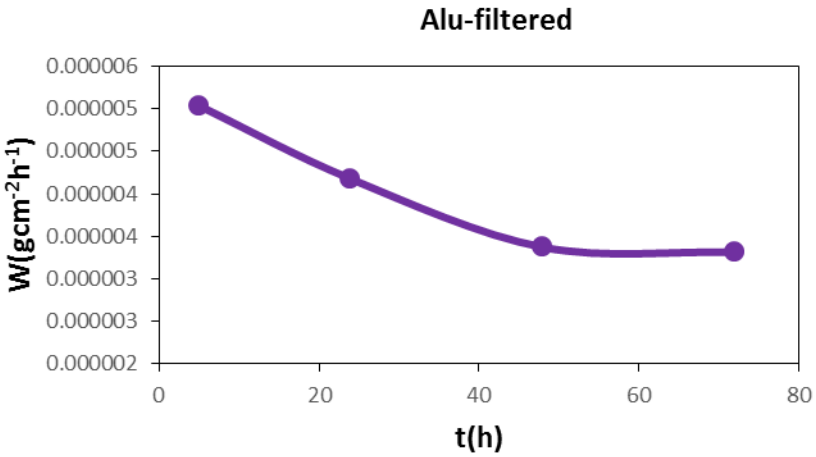

Figure 9: **Evolution of aluminum corrosion rate as a function of time in biogas filtered by BORASSUS activated carbon**

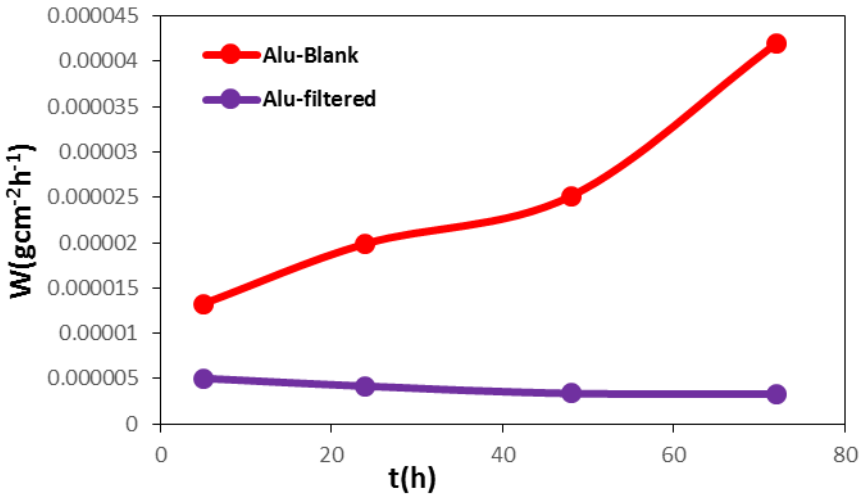

Figure 10: Evolution of aluminum corrosion rate as a function of time in unfiltered biogas (control) and in biogas filtered (BF) by BORASSUS activated carbon.

The best interpretation of the corrosion process is by the corrosion rate. It is an indicator of stability (with a constant corrosion rate), aggressiveness (with a higher corrosion rate), or softness (decrease in the corrosion rate) [17,18]. A process that has a corrosion rate equal to or close to zero indicates that the corrosion process is inactive [17,18]. Figure 10 above gives the variation of the corrosion rate of aluminum as a function of time in unfiltered biogas (control) and in biogas filtered by Borassus activated carbon. The analysis of this comparative figure shows that the corrosion rate increases with residence time in the case of aluminum (control), i.e. in unfiltered biogas (BNF). The high rate of corrosion, characterized by an increase in mass loss, indicates a more aggressive corrosion process [18]. This could be explained by the continuous loss of the element Aluminum (Al) due to its weakening due to the high concentration of humidity and hydrogen sulfide H_2S present in the medium. Moreover, with aluminum in the presence of filtered biogas (BF), the curve of the evolution of the corrosion rate as a function of time has a decreasing trend over time. In this case, we speak of a milder corrosion process during the contact time [18-20]. This could be explained by the presence of activated carbon based on Borassus in a trace state in the environment.

3.4 Study of the protective power induced by filtration as a function of time

Figure 11 below gives the evolution of the protective power of aluminum induced by filtration as a function of time in the filtered biogas.

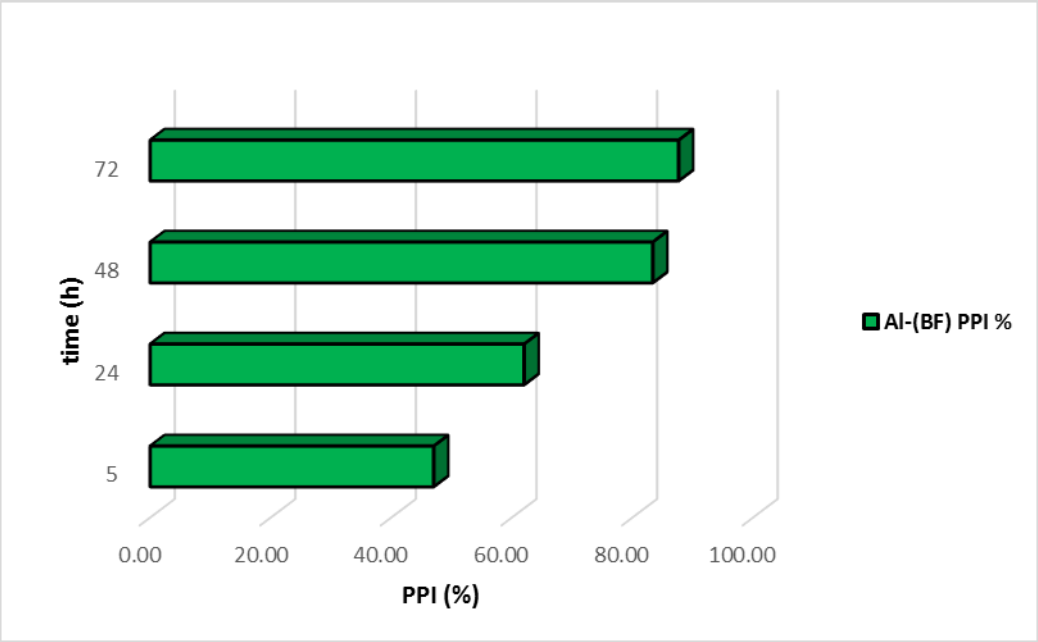

Figure 11: **Evolution of the protective power induced in the filtered biogas as a function of time (case of aluminum).**

Figure 11 above also shows that the protective power induced by filtration increases over time to 87.63%. This would indicate the presence of a physical barrier which will gradually spread and which will cause a significant rate of recovery of the surface of the aluminum metal by traces of activated carbon. Thus, a large part of our metal would therefore be isolated from the aggressive environment [21]. The crystalline structure of aluminum therefore helps the aluminum to better resist corrosion in the filtered biogas. Therefore, activated carbon based on *Borassus aethiopum* would have a good aluminum protective power.

4. Conclusion

The parameters of the palmyra-based activated carbon such as the iodine number, the yield, the ash content and the humidity content were respectively 958.09 mg / g, 39%, 2.38%, and 11.15%. These results indicate that the prepared activated carbon is microporous (0-2 mm), of good quality and light. Furthermore, the samples of activated carbon prepared have an efficiency of elimination (RE) of H_2S, during the working time (8 h), greater than 90% with output concentrations of H_2S less than 10 ppm which is the threshold. tolerance for prolonged exposure. Borassus-based activated carbon can therefore be used to remove hydrogen sulfide from biogas.

The value of the induced protective power (therefore the surface coverage rate) of aluminum in the filtered biogas is 87.63%. Activated charcoal based on Borassus has a good protective power.

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