

# Adsorption of acetic acid on different carbons

K. Ouattara, M. Gouli, S. Ello, A. Yapo, A. Trokourey  
Laboratory of physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire.

## ABSTRACT

This study presents a double environmental aspect, on one hand, decline of the cost of the waste water treatment thanks to a cheap adsorbing, on the other hand, the valuation of coconut shells.

The acetic acid was used as adsorbent because the knowledge of the size of its molecule ( $21 \text{ \AA}^2$ ) allows characterizing studied carbons.

The model of Langmuir describes well the isotherms of adsorption on the various types of studied carbons.

It stands out in this study that the capacity of adsorption of inactivated carbon grain (CNAG COCO) doubles practically if this one is reduced in powder. Besides, the inactivated carbon powder (CNAP COCO) and the activated carbon grain (CAG COCO) have the same capacity of adsorption. So, the specific surfaces of the CNAP COCO and CAG COCO are identical:  $S_L = 77 \text{ m}^2/\text{g}$  while that of the CNAG is only  $32 \text{ m}^2/\text{g}$ .

The use of inactivated carbon powder can be thus recommended to treat waste water opposite the inactivated grain carbon which isn't of real interest.

**Key words:** Acetic acid ; adsorption ; carbon ; Langmuir.

## INTRODUCTION

The city of Abidjan gathers the majority of the Ivory Coast industries which still have no system to purge waste water. These industries, located generally in border of the Ebrié lagoon, reject thus many toxic matters which are not without relation with the lessening returns on the lagoon fishing (Dufour et al, 1994).

This study presents a double environmental aspect with on one hand, the decline of the cost of the waste water treatment thanks to a cheap adsorbing and on the other hand, the valuation of the waste stemming from the consumption of coconuts (Sekirifa and Hadj-Mahamed, 2005).

The acetic acid was used as adsorbent because it is organic pollutant which knowledge of the surface of its molecule ( $21 \text{ \AA}^2$ ) allows to characterize studied coals (Avom et al, 2001; Gouli et al, 2008). Besides, it allows facilitating the manipulation because the adsorbed quantity can be determined by a simple acido-basic dosage.

## MATERIALS AND METHODS

### Used carbons

The raw coconuts-based carbons were bought in Jacqueville (Southwest of Abidjan) at the local coalmen and reduce to grain of diameter between 1 and 3 mm in the laboratory with a mortar. We so obtained the inactivated coconuts-based carbon grain (CNAG COCO).

This carbon was afterward crushed to give the inactivated coconuts-based carbon powder (CNAP COCO) of diameter lower than 0.3 mm. Both aforementioned carbons underwent activation at Paul Verlaine University of Metz in a temperature of  $800 \text{ }^\circ\text{C}$  in presence of  $\text{CO}_2$  and  $\text{N}_2$ . The products of this activation are respectively the activated carbon grain (CAG COCO) and the activated carbon powder (CAP COCO).

The activated carbon grain called NORIT 830 (CAG NORIT 830), is a commercial carbon prepared by the Dutch company NORIT for the water treatment. It is characterized by grains of 1 mm in diameter.

The commercial activated carbon powder (CAP COM), wood-based carbon, was bought at Polychimie (Abidjan – Côte d'Ivoire).

### Methods

#### *Preparation of samples*

Samples were prepared by taking 100 mL of a solution of acetic acid of concentration  $C_o$  in a flask of 250 mL.

This solution of acetic acid is obtained from the acetic acid liquid of 96 % purity and density 1.06 supplied by the company PANREAC QUIMICA S.A (Barcelona - Spain).

#### *Determination of balance time*

Experiments will be realized at  $30^\circ\text{C}$  because the best rates of adsorption are observed at this temperature (Gouli et al, 2008).

The determination of time of balance or contact time tells about the necessary time to reach the balance of adsorption. This determination is realized by putting in contact during variable times, in various flasks, a mass of 0.5 g of carbon with a volume of 100 mL of solution of acetic acid of concentration  $C_o$ .

Flasks are maintained in the thermostat at the temperature of 30°C and shaken regularly. After very precise time included between 5 in 60 minutes, the mixture is removed from the thermostat and filtered.

A volume  $V_a = 10$  mL of the filtrate is measured out by a solution of soda of concentration  $C_b$  in the presence of some drops of phenolphthalein. The volume  $V_{eq}$  of the solution of soda, obtained at equivalence, is so found. At the conclusion of the dosage, is calculated the residual concentration  $C_r$  of the acid following the following formula:

$$C_b \times V_{eq} = C_r \times V_a \quad (1)$$

The time from which the residual concentration  $C_r$  remains constant is the time of balance. This time will be used as time of contact for the study of the isotherms of adsorption.

#### *Determination of isotherms adsorption*

Experiment is realized at 30°C. To determine the isotherms of adsorption, the operating mode is about the same as previously. Flasks always contain a volume  $V = 100$  mL of solution of acetic acid but the concentration  $C_o$  varies from a flask to another. A mass  $m = 0.5$  g of carbon is put in every flask. Flasks are placed in the thermostat and shaken regularly during the time of higher definite contact. The mixture is then filtered and measured by the solution of soda of concentration  $C_b$ . At the end of the dosage of the filtrate, the residual concentration  $C_r$  is calculated according to the equation (1) and the adsorbed quantity  $a$  is determined by the following formula:

$$a = \frac{C_o - C_r}{m} \times V \quad (2)$$

#### *Modeling by Langmuir Model*

Langmuir model is mathematically represented by the following equation:

$$a = \frac{a_m b C}{1 + b C} \quad (3)$$

There are two types of linear form of Langmuir equation:

$$\frac{1}{a} = \frac{1}{a_m} + \left( \frac{1}{a_m b} \right) \frac{1}{C} \quad (4)$$

$$\frac{C}{a} = \frac{1}{a_m b} + \frac{C}{a_m} \quad (5)$$

With  $b$  (without unit) the constant thermodynamics of Langmuir is linked to the adsorbing-adsorbent system,  $a$  (mol/g) the quantity of species adsorbed by one gram of solid in the balance and  $a_m$  (mol/g) the quantity of species adsorbed by one gram of solid necessary to cover the surface of the solid of a monomolecular coat.  $C$  (mol/L) represents the residual concentration of the liquid to the balance (Mohammed, 2002; Reed and Matsumoto, 1993).

The graphic representation of  $\frac{1}{a}$  in function of  $\frac{1}{C}$  gives a straight line in the case where Langmuir model is

applicable and allows calculating constants  $a_m$  and  $b$  (Pehlivan et al, 2008; Kenichiro and Kawamoto, 2005).

Knowing  $a_m$ , the specific surface of adsorbent  $S_L$  is calculated with the following formula:

$$S_L = a_m \omega_m N_A \quad (6)$$

$N_A$  and  $\omega_m$  ( $m^2$ ) respectively represent the number of Avogadro and the area occupied by a molecular of adsorbent (Kia et al, 2004).

## RESULTS AND DISCUSSION

### Kinetic of adsorption: time of balance

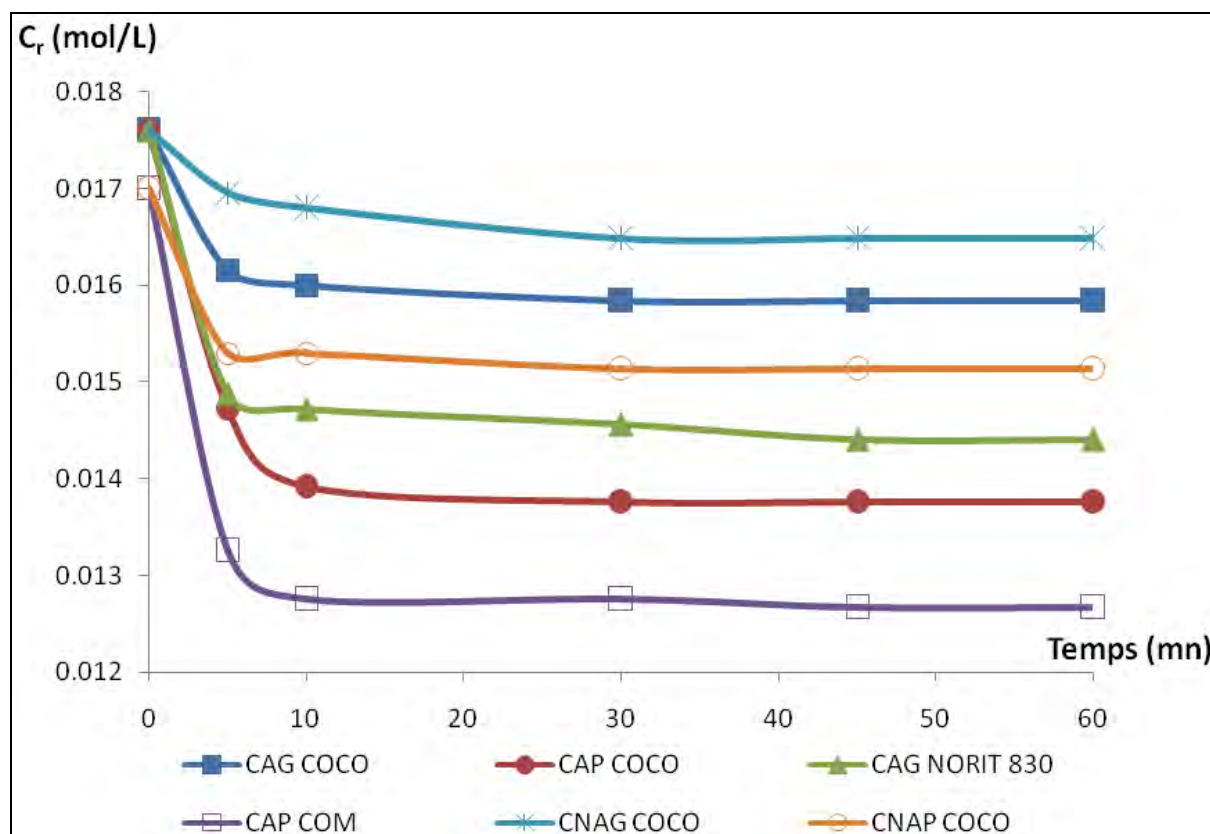


Fig. 1: Time of balance of acetic acid adsorption on various carbons

The study of the kinetics of the adsorption of the acetic acid was led on the carbons.

The purpose of this study is the determination of necessary time for every carbon to reach the balance of adsorption. The knowledge of this time of balance is indispensable for the study of the isotherms of adsorption (Pehlivan et al, 2008).

We notice on the figure 1 that after a time of contact of 30 minutes with various carbons, the residual concentration of the acetic acid does not vary practically any more. The time of the balance of physical adsorption is thus relatively high with studied carbons. This is probably due to the important porosity of carbon in general.

This result fits with the literature where the time of definite balance is often lower or equal to 30 minutes (Kifuani et al, 2004; Iqbal and Ashiq, 2007; Karim et al, 2006).

The difference of the characteristics of carbons, which is the origin, the size grading and the activation do not influence the time of balance of the adsorption.

A time of 30 minutes will thus be used as time of balance for isotherms study.

### Adsorption Isotherms

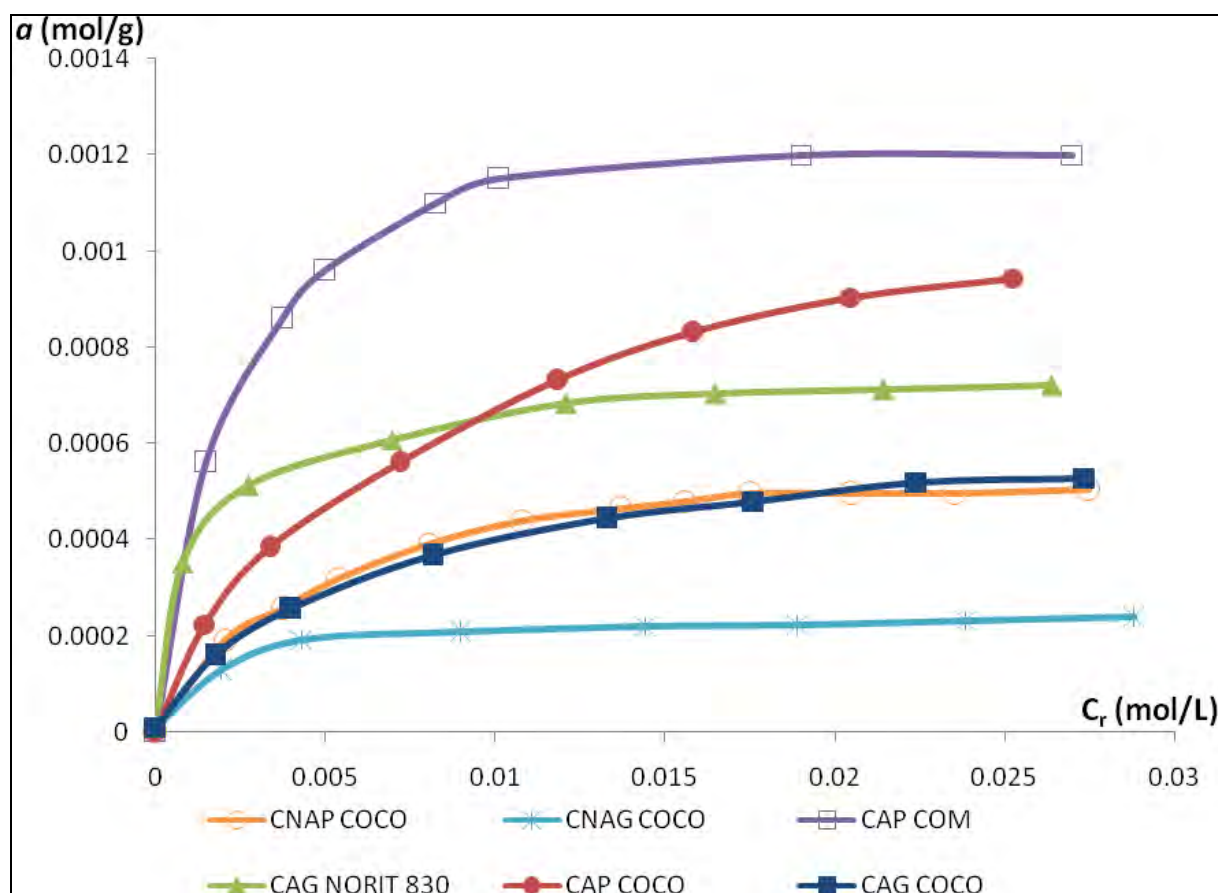


Fig. 2: Comparison of adsorption isotherms on various carbons

The figure 2 represents the isotherms of adsorption of the acetic acid on various coals of our study.

The isotherms of adsorption give indications on the nature of the interactions adsorbent-adsorbing and adsorbent-adsorbent, as well as on the characteristics of the adsorbent.

THE IUPAC classifies them in six categories. All the curves of the figure 2 are well similar to the isotherm of type I of this classification. This type of isotherms is observed in the case of a physical adsorption in the micro porous solids having pores of molecular dimensions (diameter lower than 2 nm). It is also observed in the case of an adsorption leading to the formation of a monocoat.

All the isotherms of adsorption of the figure 2 get closer to that of the type I of the classification of the IUPAC, they can thus be described by the model of Langmuir (Khezami and Capart, 2005; Mackay et al, 1985).

### Langmuir model's application

The figure 3 shows the linear representation of the isotherms of adsorption according to the model of Langmuir.

The table 1 indicates that the coefficients of correlation ( $R^2$ ) of each of the linear straights (figure 3) get closer to 1. The adsorption of the acetic acid on all these carbons can be thus described by the model of Langmuir.

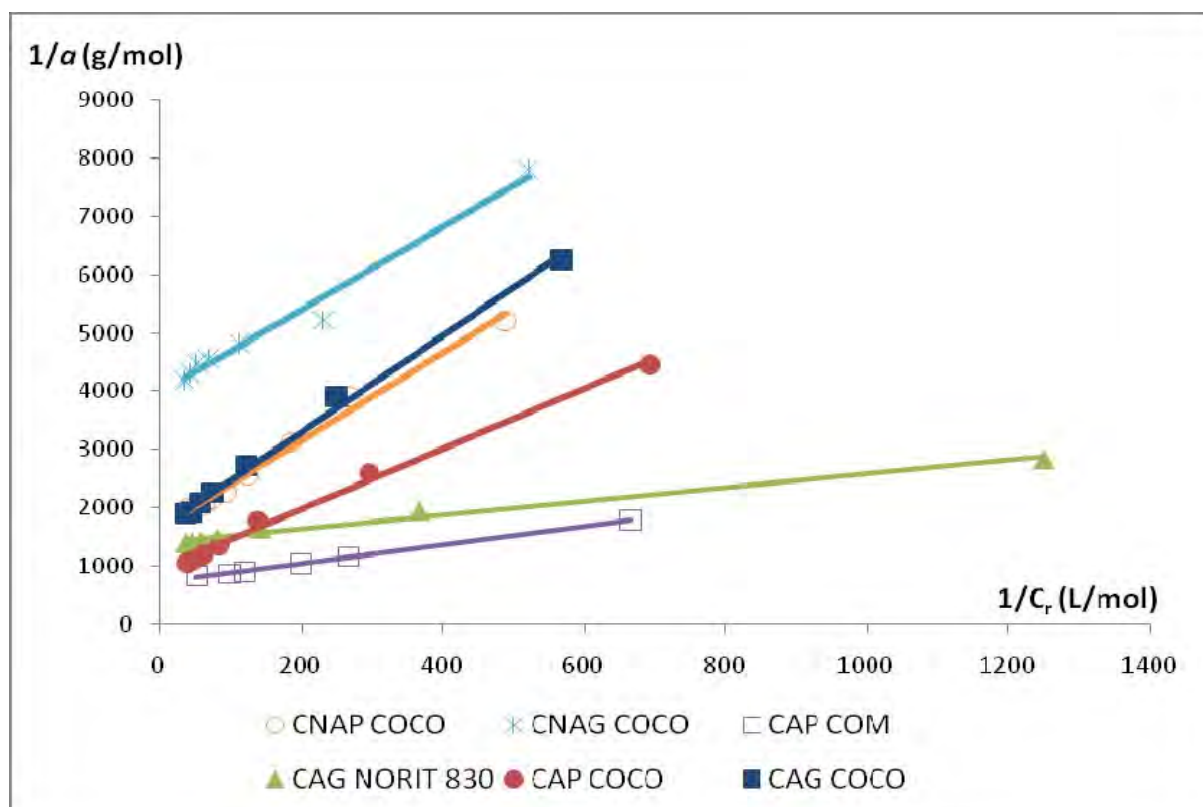


Fig. 3: Langmuir model's application on various carbons

The application of the model of Langmuir allows us to calculate the capacity of maximal adsorption  $a_m$  necessary to cover the surface of the solid of a monomolecular coat and the constant of Langmuir thermodynamics  $b$ .

A high coefficient  $a_m$  guarantees a good adsorption. The determination of  $a_m$  allows us to calculate the specific surface  $S_L$  offered by every carbon. The table 1 gathers the values of  $S_L$  calculated in 30°C.

Table 1: Parameters of Langmuir's linear representation at 30°C

	$R^2$	$a_m \times 10^4$ (mol/g)	$b$	$S_L$ (m <sup>2</sup> /g)
CNAP COCO	0.990	6.07	218.77	77
CNAG COCO	0.978	2.52	555.67	32
CAP COM	0.998	13.72	459.46	174
CAG NORIT 830	0.981	7.18	1170.73	91
CAP COCO	0.994	10.79	178.42	136
CAG COCO	0.995	6.09	198.57	77

The rank order of decreasing value of  $S_L$  for different coals is:

CAP COM > CAP COCO > CAG NORIT 830 > CAG COCO = CNAP COCO > CNAG COCO.

The activation or the powder reduction of the carbon can double its specific surface. For example, the specific surface of the CNAG coconut is only 32 m<sup>2</sup>/g, while that of the CAG coconut and the CNAP coconut is 77 m<sup>2</sup>/g.

## CONCLUSION

Experiments of adsorption of the acetic acid were led on various types of the following carbons: CNAG COCO, CNAP COCO, CAG COCO, CAP COCO, CAG NORIT 830 and CAP COM.

The balance of adsorption of the acetic acid on all these carbons is reached after 30 minutes. The adsorption of the acetic acid on studied carbons is thus relatively slow, because of the porosity of carbons.

The isotherms of adsorption of the acetic acid on used carbons correspond to the type I of the classification of the IUPAC.

A classification of the capacity of adsorption of our various types of carbons is deduced from the study of the model of Langmuir CAP COM > CAP COCO > CAG NORIT 830 > CAG COCO = CNAP COCO > CNAG COCO.

It results from this classification that an inactivated carbon powder can have the same capacity of adsorption as an activated carbon grain.

The use of the inactivated coconuts-based carbon powder can be thus recommended to treat waste water stemming from the industry before their discharge in the nature.

On the other hand, the inactivated coconuts-based carbon grain (CNAG COCO) does not present interest because of its low capacity of adsorption.

## REFERENCES

- [1] Avom, J.; Ketcha, M.J.; Matip, M.R.; Germain P., (2001). Adsorption isotherme de l'acide acétique par des charbons d'origine végétale. *African Journal of Science and Technology (AJST). Science and Engineering*, 2 (2), 1-7.
- [2] Dufour, P.; Kouassi, A.M.; Lanusse, (1994). Les pollutions. Dans *Environnement et ressources aquatiques de Côte d'Ivoire: Les milieux lagunaires*. Tome 2. Orstom. 309-334.
- [3] Gouli, B.I.M.; Yapo, A.J.; Ello, S.A.; Diabaté, D.; Trokourey, A., (2008). Adsorption of acetic and benzoic acids from aqueous solutions on activated carbon. *J. Soc. Ouest-Afr. Chim.*, 26, 53-57.
- [4] Iqbal, M.J.; Ashiq, M.N., (2007). Adsorption of dyes of aqueous solutions on activated charcoal. *J. Hazard. Mater. B.*, 139, 57-66.
- [5] Karim, M.M.; Das, A.K.; Lee, S.H., (2006). Treatment of colored effluent of textile industry in Bangladesh using zinc chloride treated indigenous activated carbons. *Analytica Chimica Acta.*, 576, 37-42.
- [6] Kenichiro, I.; Kawamoto, K., (2005). Fundamental adsorption characteristics of carbonaceous adsorbents for 1,2,3,4-tetrachlorobenzene in a model gas of an incineration plant. *Environ. Sci. and Technology.*, 39, 5844-5850.
- [7] Khezami, L.; Capart, R., (2005). Removal of chromium (VI) from aqueous solution by activated carbons: Kinetic and equilibrium studies. *J. Hazard. Mater. B.*, 123, 223-231.
- [8] Kia, M.; Kifuani, W.M.; Mukana, V.; Noki, V., (2004). Adsorption de bleu de méthylène en solution aqueuse sur charbon actif obtenu à partir des sciures végétales. Préparation et caractérisation du charbon actif. *Rev. Cong.Sci. Nucl.*, 20 (1/2), 215-224.
- [9] Kifuani, K.M.; Noki, V.; Musibono, E.; Ndelo, D.P.; Nzuzi, P.; Kunyama B., (2004). Adsorption sur charbon actif Ntola de la quinine bichlorhydrate en solutions aqueuse ou chlorhydrique. *Rev. Cong. Sci. Nucl.*, 20 (1/2); 209-214.
- [10] Mackay, G.; Bino, M.S.; Altamemi, A.R., (1985). The adsorption of various pollutants from aqueous solutions onto activated carbon. *Wat. Res.*, 19, 491-495.
- [11] Mohammed, A. S. (2002). Modélisation de l'adsorption par les charbons microporeux : Approches théorique et expérimentale. Thèse de doctorat, Université de Neuchâtel. Suisse.
- [12] Pehlivan, E.; Yanik B.H.; Ahmetli, G.; Pehlivan, M., (2008). Equilibrium isotherm studies for the uptake of cadmium and lead ions onto sugar beet pulp. *Bioresource Technology.*, 99, 3520-3527.
- [13] Reed B.E.; Matsumoto M.R., (1993). Modeling cadmium adsorption by Activated carbon using Langmuir and Freundlich isotherm expressions. *Sep. Sci. and techn.*, 28, 2179-2195.
- [14] Sekirifa M.L.; Hadj-Mahamed M., (2005). Etude comparative de la capacité adsorbante d'un charbon actif issu de noyaux de dattes et un charbon actif commercial. *Sciences et Technologie.*, 23, 55-59.

## AUTHOR (S) BIOSKETCHES

Ouattara, K., M.Sc., student in physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire. Email: okph2000@yahoo.fr

Gouli, B.I.M., M.Sc., student in physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire. Email: goulibitra@yahoo.fr

Ello, S., Ph.D. in chemistry, Lecturer in Laboratory of physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire.

Email: serge\_ello@yahoo.fr

Yapo, A., Ph.D. in chemistry, Researcher in Laboratory of physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire.

Email: yapoaboua@yahoo.fr

Trokourey, A., Ph.D. in chemistry, Professor, Chief of Laboratory of physical chemistry, University of Cocody, Abidjan, Côte d'Ivoire.

Email: trokourey@gmail.com