Efficiency of the "*AndoF*" Filter in Presence of Pollutants: Methylene Blue, Copper Sulfate

C.H. Kouakou, M.O. Boffoué, A. A. Assandé, K. C. Kouadio, S. Ouattara, K.F.S. Ando, E. Emérwa

***Abstract*— In Côte d'Ivoire, as well as in all developing countries, clay is mostly used for house construction. In this article, clay from Dabou has been mixed with natural charcoal and sand to create a filter for the treatment of methylene blue and copper sulfate solutions. Then, chemical and mineralogical analysis and scanning electron microcopies (SEM) have been performed on these materials. In the same way, the collected filtrates have been submitted to tests for the measurement of pollutants concentration on the basis of their optical density, pH and electric conductivity. The results proved that charcoal is able to retain pollutants and that clay and sand are not harmful for health. Furthermore, the filter has helped purify methylene blue and copper sulfate solution for 15 days.**

***Index Terms*— filter, adsorption, purification, clay, charcoal**

I. Introduction

All living beings have great need for water in their day to day life. Unfortunately, since the years 60s, the entire biosphere has been undergoing drastic degradation due the negative influence of human activities. Today wastewaters from households and industries, as well as from chemical fertilizers used in agriculture, bring about serious pollutions that affect all elements of nature, and so pollute the environment.

Indeed, polluted waters have become threats to the lives of living beings on earth worldwide. The lack and the poor quality of drinking water are serious and disturbing phenomena against the effectiveness of development actions. The WHO estimates 80% of diseases in the world to be related to the bad quality of drinking water.

Manuscript received January 23, 2015.

C. H. KOUAKOU Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 05649397,

M. O. BOFFOUE, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07815997

A. A. ASSANDE, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07398397

K. C. KOUADIO, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07633532

S.OUATTARA, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07940921

K. F. S. ANDO, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07633532

E. EMARUWA, Laboratoire de Géomatériaux, Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières, Université Félix Houphouet Boigny, Abidjan, Côte d'Ivoire, 07088577

Here are some, among the solutions suggested to improve water quality:

- The conventional treatment process which includes coagulation, flocculation, sedimentation, rapid filtration and disinfection using products likely to result in an increase of formed disinfection byproducts when increasing the amount of disinfectant [1];

- Industrial filters and techniques for the treatment of dissolved industrial pollutants before they are discharged into the sewage systems, such as:

  - Biological techniques using biodegradable agents [2 ; 3];
  - Electrochemical techniques [4];
  - Adsorption techniques using activated carbon [5].

All these solutions have proved to be effective, but generally very expensive. This is why new researches have been directed towards methods of treatment using affordable and available natural materials such as clays, zeolites, agricultural materials (sawdust, natural charcoal and agricultural waste [6-11].[1]

But despite of all these purification techniques, the ground still remains the most natural system of water purification among these filters. An imitation of this system by the reconstitution of a sand and activated carbon based filter has been carried out by [1]. Let's note that this is only effective but when activated carbon is at least one meter thick. So, to reduce the thickness of layers, a filter is made out of sand, clay and natural charcoal. The purpose of this study is to test the effectiveness of that filter. This article then aims at showing the effectiveness of the filter in presence of methylene blue and copper sulfate in order to partially solve health problems related to the consumption of polluted water.

II. EXPERIMENTAL TECHNIQUE

A. *Filter arrangement*

From the bottom to the top, the *AndoF* filter is made of clay-sand-charcoal-sand in these respective weight proportions 1: 5: 1: 5. Before use, clay, sand and charcoal are submitted to a prior treatment. After extraction, clay is dried, crushed, ground and sieved using a sieve of 1 mm diameter; likewise the sand is washed and also sieved using a 1 mm diameter sieve. Similarly, charcoal is crushed, washed, dried and sieved using another sieve of 5 mm to 1 mm diameter. These are loops from the 1 mm sieve for clay and sand. Charcoal Particles are between 1 to 5 mm sized as a result of the use of the corresponding sieve. These different materials

constituting the filtering mass (FM), are submitted to characterization tests: sieve analysis, chemical analysis, X-ray diffraction and SEM observation.
The filtering mass (FM) is arranged in a 500 ml graduated cylinder perforated in its lower part and placed on a 100 ml sterilized flask serving as container (fig.1).

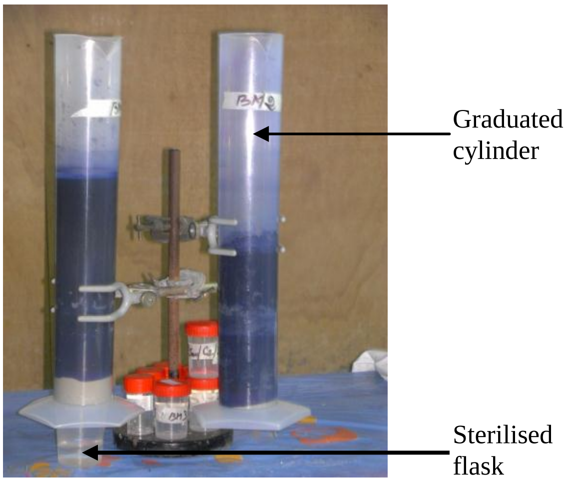

Figure 1: Filter device

B. Analysis of solutions

To test the *AndoF* filter, methylene blue and copper sulfate solution are used. Methylene blue is an organic pollutant widely used in industry, eg in the textile industry for dyeing, in biology and in pharmacy as an antiseptic. Its crude chemical formula is *C16H18ClN3S, 2H2O*. It is from the class of thiazine dyes which solubility in water exceeds 100 mg/l.
Copper sulfate is an inorganic pollutant like lead, cadmium and zinc. It releases in the solution, copper ions which are considered as an undesirable and toxic substance according to the standards of drinking water.
350 ml of these solutions to be filtered (5g/l of methylene blue concentration and 1.6 g/l copper sulfate) is added to the FM. Each day, the sterilized flask is removed and replaced and then the filtrate collected is tested. The solution to be filtered is renewed each time the volume of the remaining slurry is about 50 ml. The measurement of the pollutant concentration has been achieved with a HACH spectrophotometer (DR 4000). It allows to determine the optical density and to deduce the concentration of the pollutant.

In the case of methylene blue solution, a standard curve for methylene blue concentrations under 5 g/l has been drawn. Its equation OD = 0.1514 ° C (g/l) for 0 <OD <1. OD stands for the optical density read in the spectrophotometer. It also allows to calculate the concentration of methylene blue in the filtrate.
To test copper sulfate solution, CuVer1 reagents are used. These allow to measure copper in the collected filtrate and by a special setting of the spectrophotometer, to directly determine copper concentration. In addition, we can determine the pH and conductivity of the copper sulfate solution filtrate with a multiparametered multimeter, a Consort analyzer, model C861.

III. RESULTS AND DISCUSSION

A. Characterization of the materials used (adsorbents)

The analysis of characterization tests performed on clay, sand and charcoal indicates that clay taken from Dabou consists of 55% of clay particles and 45% of silt [12]. Its chemical content is respectively 56.2% of SiO2, 27.75% of Al2O3 and coloring oxides such as Fe2O3 and TiO2 respectively 6.60% and 1.19%. This clay does not contain toxic chemical elements such as copper and lead [13]. The mineralogical content of Dabou clay is composed of kaolinite and illite which are clay minerals and quartz that is an associated mineral [14]. Clay grains seen through the SEM are formed by a stack of crystallised micelles. Therefore, they can retain water and other substances by adsorption onto their surfaces (*Fig 2*).
Sand mined out from a quarry in the town of Marcory, consists essentially of quartz grains the granular distribution of which is 30% of fine sand, 66% of medium grained sand and 4% of coarse sand. Its fineness modulus equals 2 [15].
Charcoal obtained by natural wood calcination has a SEM structure made of large pores of about 20 to 150 microns diameter on the walls (*Fig.2*). There also are small pores of about 1 micron diameter on the walls of the sap pipe bundle as well (*fig.2*). These pores could trap water impurities.

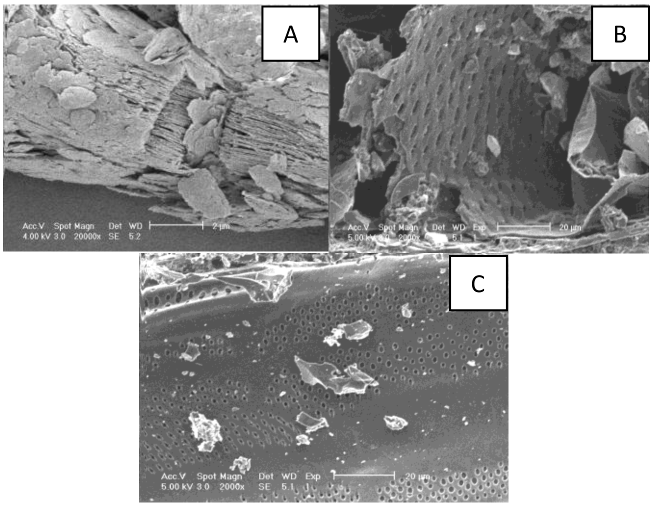

Figure 2: A structure of absorbents A: Clay; B: Charcoal cross-section; C: charcoal longitudinal section

B. Methylene blue absorption (M.B.)

The filter mass totally absorbs the methylene blue (Fig.3) .The layers of sand, clay and coal allow therefore to retain the organic pollutant that is methylene blue. However after 15 days, more than 50% of the contaminant concentration is found in the filtrate. The duration of this treatment is then, limited in time.
In fact, clayey particles are capable of absorbing onto their surface, some of the elements present on sites. The number of sites liable to be occupied by the pollutant is limited and depends on the nature of clay. That is why, after a certain time, the contaminant is found in the filtrate. Thus, the *AndoF* filter has a lifetime that depends on the nature of clay and on the pollutant concentration in the solution to be filtered. Indeed, according to [16; 17], the increase of the adsorbate concentration causes a reduction of the purification time. The

role of purification performed by clay is also supported by charcoal which traps the pollutant particles in its pores. However, for this role to be efficiently assured, the time of contact must be a pretty long because the longer it takes the more the charcoal is able to retain a significant amount of pollutants [6].

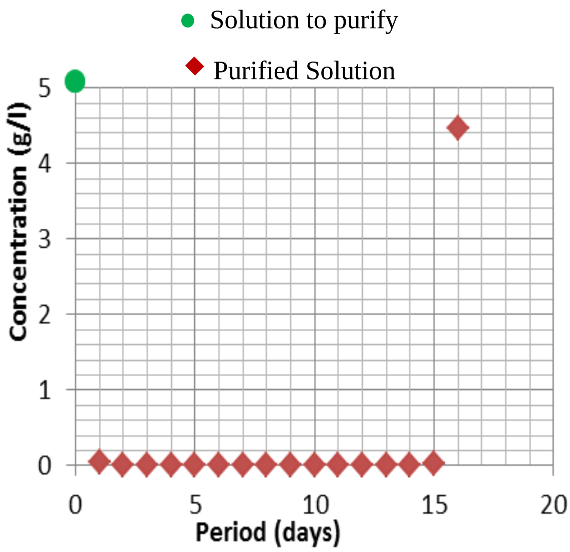

Figure 3: Methylene blue concentration in the collected filtrates

D-Absorption of copper ions

In the beginning, the copper ion concentration, the pH and the electrical conductivity are respectively 21.97 g/l; 7.34 to 2.17 ms/cm.

After crossing the *AndoF* filter, the copper ion concentration (Cu^{2+}) is 0g /l from the 1st to the 20th day. So, the filter completely retains copper ions. However, from the 20th to the 30th day of filtration, the copper concentration increases and becomes stable around 0.92 g/l until the 50th day. This can be explained by the saturation of the copper recovery systems (clay or charcoal) in the filter mass. Here is where copper ions start appearing in the filtrate until the 50th day. The filter has thence had a 20 days lifetime or adsorption time.

The pH of the collected solution has a slight increase along the time until the 50th day of filtration. This goes from 7.34 (before filtration) to 8.04 (40th day of filtration). The H^+ ions are co-selected with the Cu^{2+} ions [17] whereas the OH- ions are leached into the filtrate.

Furthermore, the conductivity of the collected solution increases until the 10th day from 2.17 to 8.1 ms/cm and then decreases until the 50th day. Water drops collected for the first ten days are much mineralized. This could be due to the increase in pH but also to the leaching of some chemical elements of the absorbent as the graph shows that Cu^{2+} ions are not responsible for this increase. Moreover, from the 20th day, the concentration of Cu^{2+} ions increases as the conductivity decreases.

The *AndoF* filter can absorb mineral pollutants such as copper, while maintaining the pH of the filtrate near to a neutral pH. It can be used without any risk for health in treating wastewater.

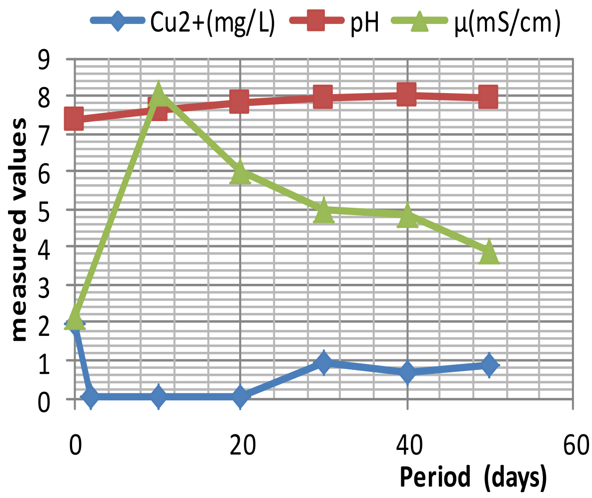

Figure 4: Concentration of Cu^{2+} in the filtrate

IV. CONCLUSION

A filter has been made out of a superposition of sand, clay and carbon layers. This filter named *AndoF* has enabled to purify methylene blue and copper sulphate solutions within 15 days. Similarly, the filter *AndoF* enriched the purified solution in mineral elements while keeping the pH at a neutral value. This filter then is not risky for health with regard to the variation of the pH and the conductivity of the collected filtrate.

ACKNOWLODGMENT

This work was supported by "Programme d'Appui Stratégique à la Recherche Scientifique" (PASRES). The authors thank these authorities.

REFERENCES

[1]Thibault D., Desjardins R., Prévost M., Niquette P. et Lachelle J., "Exploitation des filtres bicouches au sable et charbon actif biologique", Can. J. Civ. Eng., 24, pp 250-262, 1997.
[2]Souabi S. and Belkebir M., "Elimination of surfactants in water treatment by adsorption onto activated carbon", J. Soc. Mar.Chim., 2, pp53-65, 1993.
[3]Altinbas T., Dökmeci S. and Baristisran A., "Treatability study of waste water from textile industry", Envir. Techn., 16 pp 389-394,1995.
[4]Lin S.H. and Peng C.F., "Treatement of textile waste water by electrochemical, method", wat. Res. , 28, pp. 277-282, 1994.
[5]Huckins J. N., Manuweera G.K., Petty J.A., Mackay D. and Lebo J., "Lipid containing Semi-permeable membrane devices for monitoring organic contaminant in water",Environ.Sci.Technol., 27, pp 2489-2496, 1993.
[6]Gupta G. S., Prasad G. and Singh V. N., "Removal of chrome dye from aqueous solutions by mixed adsorbents flash and coal", wat. Res., 24, (1), pp 45-50, 1990.
[7]El Guenddi M. S., "Adsorbents for Industrial Pollution Control", Adsorption Sci. andTech., 15 (10) pp 777-787, 1997.
[8]Kay G. Mc and Alduri B., "Multicomponents dye adsorption onto carbon using asolid diffusion mass transfer model", Ind. Eng. Chem. Res., 30, (2), pp 385-395, 1991.
[9]Convey F. Mc, Gordan and Kay G. Mc.,"Mass transfer model for the adsorption of basic dyes on wood mead in agitated batch adsorbers", Chem. Eng. Proces, n°19, pp 267-275, 1985.
[10] Bagane M. et Guiza S., "Elimination d'un colorant des effluents de l'industrie textile par adsorption", Ann. Chim. Sci. Mat., 25 pp 615-626, 2000.

[11] Oumam M., Abourriche A., Adil A. et Hannache H., "Elaboration et caractérisation d’un nouveau matériau adsorbant à partir des schistes bitumineux du Maroc", Ann. Chim. Sci. Mat., 28, pp 59-74., 2003.
[12] Ouattara S., "Recherche de briques légères : Etude de la stabilisation à froid de l’argile de Dabou avec un déchet industriel (la sciure de bois)", Mémoire de DEA des Sciences de laTerre, Université d’Abidjan Cocody, Côte d’Ivoire, 59 p., 2005.
[13] Kouakou C. H., "Valorisation des argiles de Côte d'Ivoire, Etude de la stabilisation à froid de l'argile de Dabou avec un liant hydraulique (le ciment portland)", Thèse unique Sc. de la terre option Géomatériaux, 195 p., 2005.
[14] Kouadio K. C., "Elaboration et caractérisation de blocs d’argile comprimée et stabilisée au ciment", Mémoire de DEA des Sciences de la terre, Université de Cocody, 57 p., 2003.
[15] Mamery S., "Recherche de substitut du gravier dans le béton : utilisation de déchets non biodégradable (ciment durci, bouteille, pneu usage)", Mémoire de DEA des Sciences de la Terre, Université d’Abidjan Cocody, Côte d’Ivoire, 49 p., 2007.
[16] Bakhti A., Larid M., "Etude des facteurs contrôlant l’élimination des ions Chromate par une argile anionique de synthèse", revue Eurodeur – ecgp’6 2007 – france – marseille, 2007.
[17] Naïma G., "Etude expérimentale et identification du processus de rétention des cations métalliques par des matériaux naturels", Thèse de Doctorat en Sciences de Génie des Procédés. Université de Constantine, Algérie, 140 p., 2008.