Larbi Hammadi
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Effect of physicochemical treatments on the characteristics of activated sludge

Larbi Hammadi[1]

1 Laboratory of Rheology, Transport and Treatment of the Complex Fluids, University of Science and Technology, Mohamed Boudiaf, B.P. 1505, El M'Naour, Oran 31000, Algeria Telephone: +213772657927 , adresse E-mail: or larbi.hammadi@univ-usto.dz

Abstract:

The treatment of wastewater in sewage plants usually results in the formation of a large amount of sludge. These appear at the outlet of the treatment plant as a viscous fluid loaded with a high concentration of dry matter. This sludge production presents environmental, ecological and economic risks. That is why it is necessary to find many solutions for minimizing these risks. In the present article, the effect of hydrogen peroxide, thermal treatment and quicklime on the characteristics of the activated sludge produced in urban wastewater plant were evaluated in order to avoid any risk in the plants. The study shows increasing of the dose of H2O2 from 0 to 0.4 g causes an increase in the solubilization rate of COD from 12% to 45% and a reduction in the organic matter content of sludge (VM/SM) from 74% to 36% . The results also show that the optimum efficiency of the heat treatment corresponds to a temperature of 80 ° C for a treatment time of 40 min is 47% and 51.82% for a temperature equal to 100 ° C and 76.30 % for a temperature of 120 ° C, and 79.38% for a temperature of 140 ° C. The treatment of sludge by quicklime gives the optimum efficiency of 70.62 %. It was shown the increasing of the temperature from 80°C to 140°C, the pH of sludge was increased from 7.12 to 9.59. The obtained results showed that with increasing the dose of quicklime from 0 g/l to 1g/l in activated sludge led to an increase of their pH from 7.12 to 12.06. The study shows the increasing the dose of quicklime from 0 g/l to 1g/l causes also an increase in the solubilization of COD from 0% to 70.62 %

Key Words*:* Activated sludge, hydrogen peroxide, thermal treatment , quicklime, COD, mineral matter, pH..

Effet des traitements physico-chimiques sur les caractéristiques des boues activées

Résumé

Le traitement des eaux usées dans les stations d'épuration conduit généralement à la formation d'une grande quantité de boues. Celles-ci se présentent à la sortie de la station d'épuration comme un fluide visqueux chargé à forte concentration en matière sèche. Cette production de boue présente des risques environnementaux, écologiques, sociaux, juridiques et économiques. C'est pourquoi il est nécessaire de trouver de nombreuses solutions pour minimiser ces risques. Dans le présent article, l'effet du peroxyde d'hydrogène, du traitement thermique et de la chaux vive sur les caractéristiques des boues activées produites dans les stations d'épuration urbaines a été évalué afin de minimiser la production des boues. L'étude montre que l'augmentation de la dose de H2O2 de 0 à 0,4 g provoque une augmentation du taux de solubilisation de la DCO de 12% à 45% et une réduction de la teneur en matière organique des boues (VM/SM) de 74% à 36%. Les résultats montrent également que l'efficacité optimale du traitement thermique correspond à une température de 80°C pour un temps de traitement de 40 min soit de 47% et 51,82% pour une température égale à 100°C et 76,30% pour une température de 120°C, et 79,38% pour une température de 140°C. Il a été montré que l'augmentation de la température de 80°C à 140°C le pH des boues a été augmentée de 7,12 à 9,59. Le traitement des boues par chaux vive donne une efficacité optimale de 70,62 %. Les résultats obtenus ont montré qu'en augmentant la dose de chaux vive de 0 g/l à 1 g/l dans les boues activées provoque une augmentation de leur pH de 7,12 à 12,06. L'étude montre que l'augmentation de la dose de chaux vive de 0 g/l à 1 g/l provoque également une augmentation de la solubilisation de la DCO de 0 % à 70,62 %.

Mots clés : Boues Activées, Peroxyde d'hydrogéné, Chaux vive, DCO, Matière minimale, pH

[1] Corresponding author: hammadi7280@yahoo.fr

1. INTRODUCTION

Wastewater from various urban activities cannot be discharged as such which in the environment, because they contain various organic pollutants and minerals. They must therefore undergo, before their release into the natural environment, a treatment of purification which drives the production of sludge [1-3]. The sludge produced on the water supply chain is composed of water and materials containing mineral and organic substances. This sludge presentedan environmental, ecological and economic risks [4-6]. For this reason many solutions proposed to reduce the production of sludge by treatment and valorisation. But the treatment and valorisationof sludge are dependent on the cost of installation, origin of sludge and the impact of treatment on the environment. For example thecost of treatment and disposal of an excess sludge byconventional treatment requires for approximately 50 to70% of the whole operation cost of a wastewater treatmentplants [7,8] . However the methods ofthe elimination of sludge by incineration causes pollution problems and the incineration plant is quite expensive [9,10]. According to Wójcik et al [11] theusing the sludge in agriculture has a positive impacton fertilization of soils dueto their wealthin organic matter, nitrogen, phosphorus and other microelements. Butusing the sludge in agriculture is now restricted in Algeria. Therefore, giving importance to methods to reduce the volume and mass of excess sludge has been increased by various studies that reported the use of different physical, chemical and biological processes to reduce a sewage sludge production. Several disintegration methods have been investigated such as mechanical treatment using ultrasounds [12-14].

2. SAMPLING AND METHODS

2.1. Sampling of activated sludge

The sludge sample was collected from the secondary settling tank of a municipal wastewater treatment plant located in Mostaganem (Algeria) after activated sludge treatment process (Fig.1) . The samples were stored at 4°C in a refrigerator. They were then transported to the laboratory within 10 min and put them in the freezer at -20°C in order to avoid changes in the characteristics of the sludge.

Fig.1- Sampling of activated sludge for treatment.

2.2 Experimental set up

2.2.1. Treatment the sludge by hydrogen peroxide

The hydrogen peroxide is generally used for the treatment of organic wastes (agricultural residues, sludge of different origins, organic acids, aromatic compounds, etc.) The hydroxyl radical (•OH) is a very reactive chemical species in aqueous solution in the presence of Fe^{+2}, this reaction are efficient in acid solution [15]. For this reason weadapted the following experimental conditions:

- 1000 ml of activated sludge is introduced in glass beaker

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-The initial pH of the solution was adjusted to 3 by sulfuric acid
- 0.137 g/l of Fe^{+2}
-The dose of hydrogen peroxide range between 0 and 0.45 g/l
- The time of agitation 60 min at 120 ramp
- Ambient temperature and pressure

2.2.2. Thermal treatment of the sludge

The thermal treatment of the sludge was carried out in batch using a magnetic induction plate (Figure 2), adapted with a borosilicate glass beaker of one liter capacity with a cover comprising two orifices, the first oneis to measure the temperature of the treated sludge and the second one is to collect the treated sludge. The sludge was agitated mechanically at a speed of 300 rpm and kept at the set temperature for 1 hour. The sludge is placed in the treatment beaker when the set temperature is reached on the plate. A 100 ml of treated sludge are then withdrawn every ten minutes with a syringe and the chemical oxygen demand (COD), the pH, the ratio between volatile matter (VM) and suspended matter (SM) are determined.

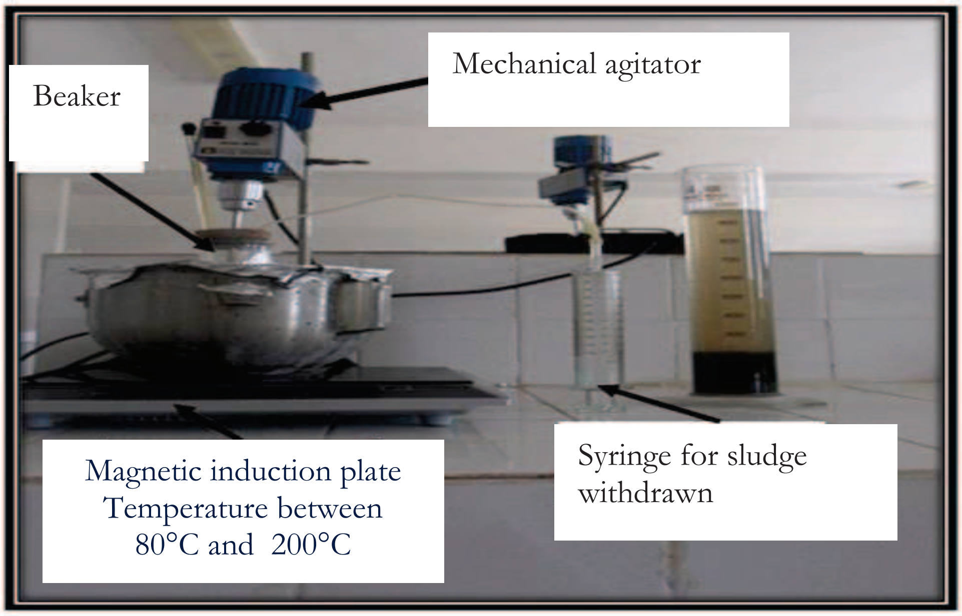

Fig.2- Mounting used for the heat treatment of activated sludge.

2.2. Treatment the sludge by quicklime

The sludge sample was poured into ten separate beakers of one litre and quantity of 0 to 1 grams of quicklime (CaO) per litre of sludge was added. Then the samples were mixed for an hours by magnetic agitation at 200 ramp in ambient temperature and pressure.

2.3. *Determination of mineral matter*

The mineral matter contained in the various fractions was determined according to standardized method NFT 90.105. A volume of liquid (V_e) sample was centrifuged for 10 min at 4000 rpm. The pellet was recovered, transferred to a porcelain capsule (W_1) and then placed in a drying oven at 105°C for 24 hours in order to obtain the suspended matter. This dried sample was cooled at room temperature, and then placed in desiccators, before being weighed (W_2). Subsequently, it was heated in a furnace for 2 hours to burn the volatile matter in suspension. After cooling, the sample was again weighed (W_3). The suspended matter (SM) is related to the volatile matter (VM) by:

$$SM = \frac{W1-W2}{Ve} \quad (1)$$

$$VM = SM - \frac{W2-W3}{Ve} \quad (2)$$

3. RÉSULTATS ET DISCUSSION

3.1. *Effect of hydrogen peroxide on COD of sludge*

3.1.1. *Effect of hydrogen peroxide dosage on COD of sludge*

Fig. 3 shows the variation of COD as a function of dose of hydrogen peroxide in sludge. We observed a decrease in COD as a function of hydrogen peroxide dosage on sludge. This can be explained by the solubilization of organic matter in the form of CO_2 and H_2O [16]. The stability of COD at high dose of hydrogen peroxidecould is explained by interaction of hydroxyl radical with sludge organic matter. Also at high dose of hydrogen peroxide, the hydrogen peroxide decomposing to molecular oxygen decreases the potential of hydroxyl radical oxidation caused the stability of COD [17].

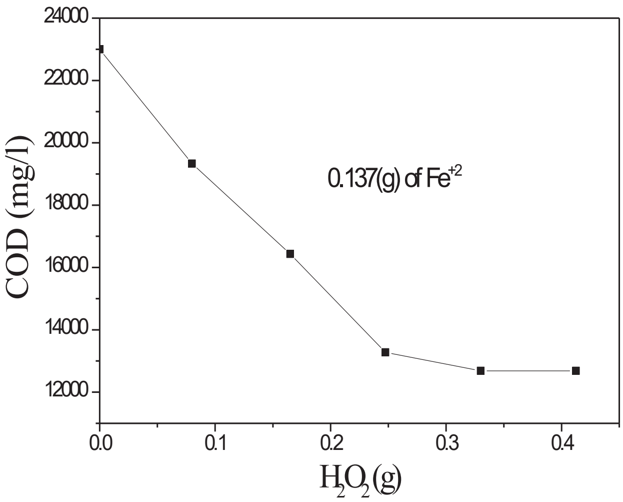

Fig.3 -Effect of hydrogen peroxide dosing on COD of activated sludge.

Fig. 4 shows the effect of hydrogen peroxide dosing on the abatement of COD of sludge. The results obtained show that the optimal hydrogen peroxide dose corresponds to 0.35g. The abatement rate of COD is in the range of 45%. According to Mahdad et al ([18] the increase of efficiency of treatment is occurred due to oxidation of H_2O_2 to O_2 and hydroxyl radical recombination by H_2O_2.

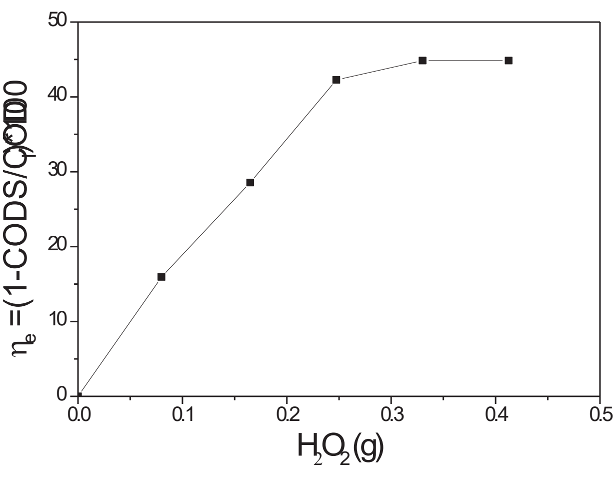

Fig. 4 -Effect of hydrogen peroxide dosage on efficiency of sludge.

3.1.2. *Effect of hydrogen peroxide dosage on mineral matter of sludge*

Figure 5 shows the evolution of the MV/SM ratio as a function of the dose of hydrogen peroxide in sludge. From the figure we can see that the more the dose of peroxide increases, the more the MV/SM ratio decreases. This decrease in MV/SM ratio can be explained by the increase in the solubilization of the particulate matter. The addition of H_2O_2 will oxidize the organic matter in the form of CO_2 and H_2O, so the amount of organic matter has been reduced.

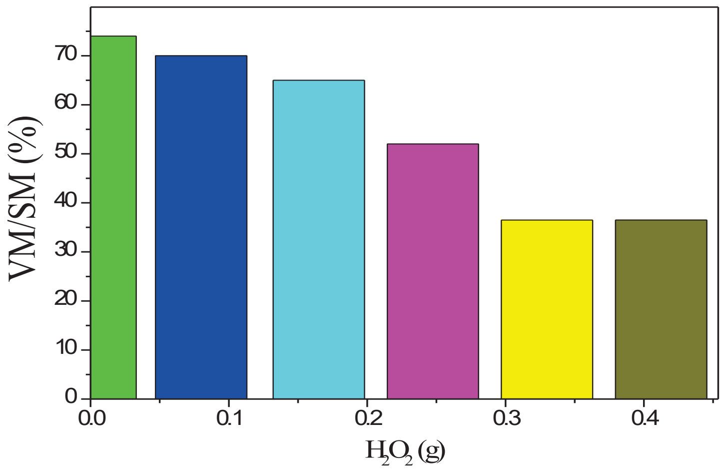

Fig. 5- Effect of hydrogen peroxide dosage on mineral matter of sludge.

3.2. Effect of thermal treatement

3.2.1. Effect of thermal treatement on COD of sludge

The effect of thermal treatment on total COD is shown in fig.6. We observed in fig 6 solubilisation of total COD depending on the treatment on temperature and time of treatment. Thus, for a temperature of 140°C, it remained constant after 40 min of treatment whereas for the other temperatures there was a consistent reduction in the COD within time. According to Biswal et al [19] this decreasing of the COD can be explained by solubilisation of organic materials of sludge by temperature.

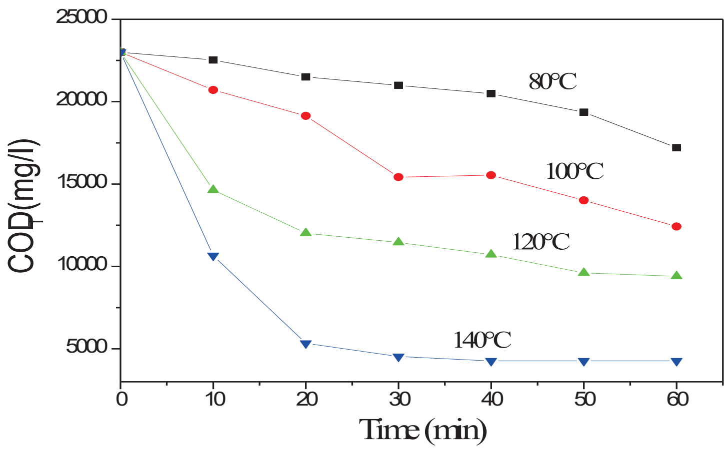

Fig.6- Effect of thermal treatment on COD of activated sludge.

Fig. 7 shows the removal efficiency of the COD of the sludge by thermal treatment.It is clearly determined that the efficiency of thermal treatment dependant on time of treatment and the temperature. We observed in fig 7 the efficiency increased with increasing of time and temperature and this efficiency stabilized after 40 min of treatment for temperature of 140°C. According to Kim et al [20] the stability of COD is happened due to a transformation of organic particles in sludge into carbohydrates, lipids and proteins.

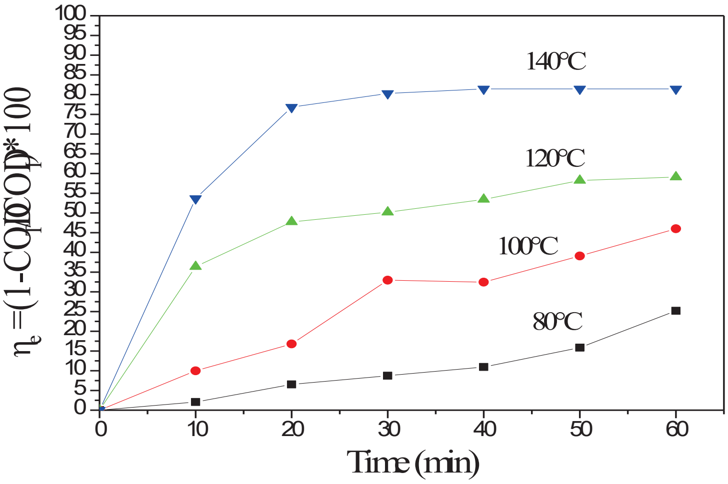

Fig.7- Efficiency the reduction of COD in activated sludge as a time function of thermal treatment at different temperatures (80°C, 100°C, 120°C and 140°C).

3.2.2. Effect of thermal treatement on pH of sludge

For these tests, pH was not measured during heat treatment of the sludge but rather before and after treatment at room temperature. Whatever the temperature of heat treatment is, the pH increases with time (Fig.8). However this increase is much softened for the highest temperature (140°C). Morgan et al [21] explained this increase of pH by protein desorption, which results in the ionization of carboxyl groups. Also the increase of pH by temperature could be explained by acidic compounds volatilisationor CO_2 [22].

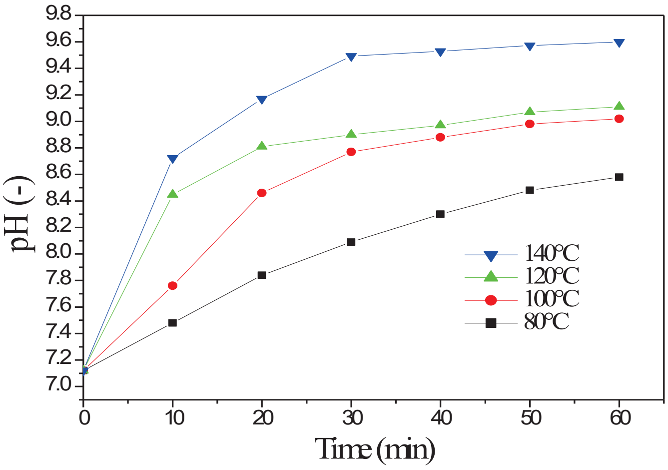

Fig.8- Variation of pH of activated sludge as a function of the time of thermal treatment at different temperatures (80°C, 100°C, 120°C and 140°C).

3.2.3. Effect of thermal treatement on mineral matter of sludge

To characterize the evolution of the mineral and organic fractions of the sludge, we analysed the time evolution of the ratio of volatile matter (VM) in suspension by suspended matter (SM) computed from equations (1) and (2) respectively for the different temperatures of heat treatment. The results are shown in Fig. 9.

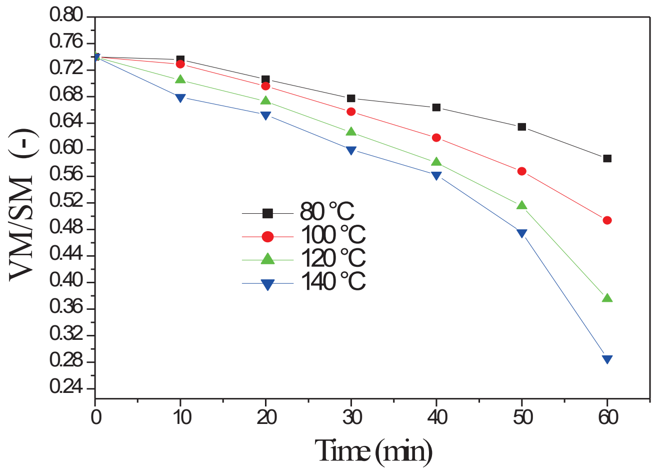

Fig.9-Variation of the ratio VM/SM of activated sludge as a function the time of thermal treatment at different temperatures (80°C, 100°C, 120°C and 140°C).

The ratio VM/SM was approximately 0.74 for the initial sludge, in which the percentage of mineral matter is high, during the thermal treatment, the ratio VM/SM decreases to 0.28, so the thermal treatment gave a great advantage for solubilisation of the mineral matter in sludge.

3.3. Effect of quicklime

3.3.1. Effect of quicklime on pH of sludge

Figure 10 shows the increase in pH of the sludge as a function of the dose of added quicklime, it is clearly shown that the increase of lime in the sludge caused the increase of their pH, this increase of pH can explain by the conversion of CaO to $CaCO_3$. In fact, up to a dose of quicklimetransferred from 0.8 g per litre of activated sludge the pH is almost constant. The stability of pHis possibly due to the reaction of calcium ions with atmospheric carbon dioxide. According Bina et al [(23] the increasing of pH by the quicklime caused elimination of pathogenic microorganisms and microbiological quality on sludge. The increase of pH caused the transformation of HCO_3^- to CO_3^{2-}this transformationblocks biological activity of sludge so improve their stability [24]. It is noted the high pH lead to the increase of alkalinity in sludge this results a problem of use the sludge in agriculture [25].

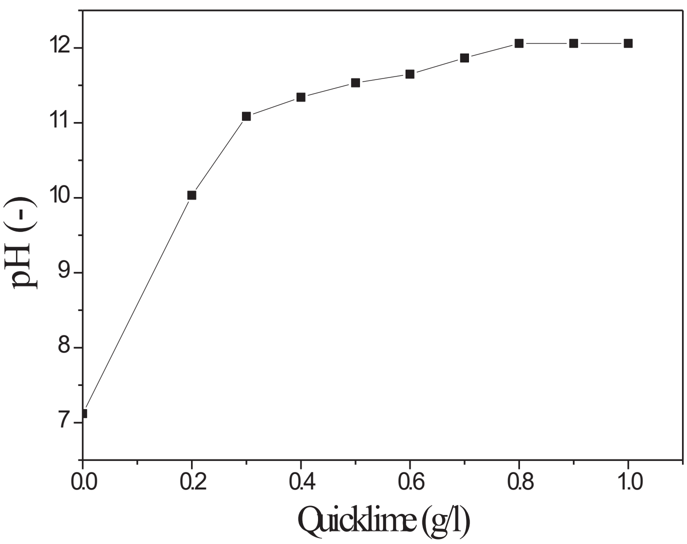

Fig.10- Effect of quicklime on pH of activated sludge.

3.3. Effect of quicklime on COD of sludge

The figure 11 shows the decrease in COD with the increase in dose of quicklime, this decrease in COD stabilized for doses of lime higher than 0.8 g / l. This stability of the COD can be explained by the adsorption of organic matter on the quicklime which causes saturation of the specific surfaces of the quicklime.

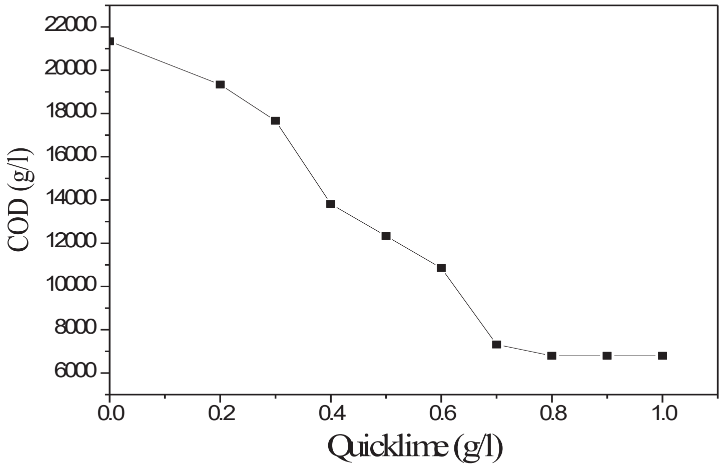

Fig.11- Effect of quicklimedosing on COD of activated sludge

Fig. 12 shows the efficiency of the treatment of the sludge by quicklime. It is clearly the efficiency of reduction of COD dependant of quantity of quicklime added to sludge. The increase of the quicklime dose in sludge causes a COD solubilization rate from 10% to 68% and then it stabilizes.

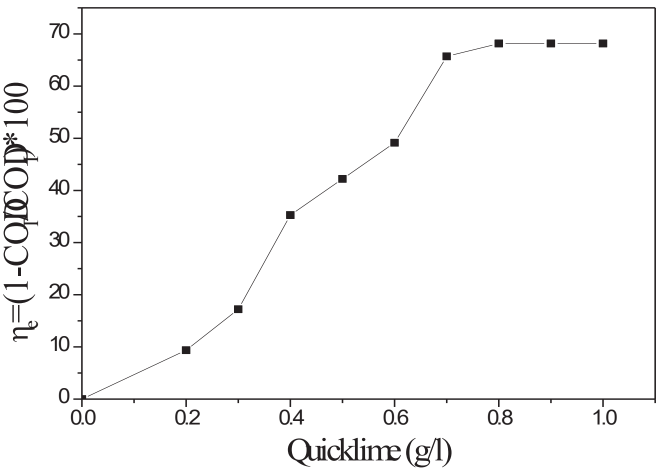

Fig.12- Efficiency the reduction of COD as a function of quicklime dose in activated sludge.

CONCLUSION

In order to find a solution to the problem caused by sludge from sewage treatment plants, we studied the effect of three physicochemical treatments on the characteristics of activated sludge from the Mostaganem sewage treatment plant. We have demonstrated that thermal treatment, the addition of lime, and hydrogen peroxide lead to a decrease in chemical demand of chemical oxygen demand (COD) associated with a decrease in mineral matter (ration volatile matter/ suspended matter) and increase in pH of activated sludge.The results obtained, showing that the reduction in COD is significant in the case of heat treatment (79.38%), then comes that of treatment with quicklime (68%) and finally that of treatment with hydrogen peroxide (45%). Finally, the quicklime treatment is the effective process, the economic from of cost and the best chemical sludge stabilizer.

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