DIATOMITE PELLETS TO REMOVE ORGANIC DYE AND LEAD IONS FROM WASTEWATER DISCHARGE

Evelyn Loures de Godoi, Maira Cardoso Monje, Nilce Ortiz

Abstract — *A low cost treatment process was developed using pellets of diatomite and bentonite as adsorbent bed to adsorb and remove dye organic compound and lead ions from wastewater. The study provides information about the use of diatomite as adsorbent in batch process to obtain the maximum removal percentage and the adsorption rate. The obtained results for adsorption rate are similar with those related in the literature for non conventional adsorbents with 56 % removal percentage for organic dye and the lower removal percentage was 33%, obtained for lead ions in solution. The study shows the possibility of the use of diatomite with low cost mainly composed by non aggressive silica to treat chemical effluents and sewage water.*

Keywords — lead, organic dye, diatomite, adsorbent, wastewater.

I – INTRODUCTION

The treatment of industrial effluents and domestic discharge is an important factor to the sanitation control and health of any community [1]. In the past the common method of sewage discharge were the dilution, the sewage was discharged in the near surface water, as streams, rivers or lakes, where the presence of oxygen will promote the decomposition of the organic matter. Nowadays this process is not considered adequate mainly because most of the water bodies as streams, rivers and lakes near the cities can not dilute the larger amount of sewer discharges generates from the population and the industrial activity [2].

The adsorption process using non conventional adsorbents to remove lead ions and organic dye of industrial discharges have showed promising results for utilization. The use of natural adsorbent diatomite as adsorbent material to remove soluble toxic metals from industrial effluents represent a possibility to solve those problems in a practical and not costly manner[3][4][5].

The diatomite, as natural adsorbent, can also be used as a tool for water quality monitoring (as ceramic monitor) applying the adsorption properties to adsorb and fix toxic compounds presents at surface water bodies.

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The ceramic monitor will be placed at the contaminated water body and after the saturation time, it will be chemically analyzed to determine the toxic contaminants and their concentrations, it will be similar with those found at the analyzed water body. This study was developed trying to improve the adsorption properties of the diatomite to be used as adsorbent material to fix lead ions and dye compounds from wastewater discharges at the beginning for further to be applied on water bodies monitoring.

A. Adsorption Processes Calculations

The first step to study the adsorption processes is usually on batch process performed by the variation of the initial concentrations and the determination of the equilibrium time and concentration [6] [7]. In the equilibrium condition the adsorption system is considered stable and in spite of the continuity of the shaking process it will not verify any concentration changes. The experimental results allow to calculate the removal percentage of the adsorption process to remove toxic compound on solution with the Equation 1.

$$R = (Co - Ce)/ Ce \qquad (1)$$

Where:

C_o - Initial concentration (mg L^{-1}),

C_e - Equilibrium concentration (mg L^{-1}),

R – Removal Percentage (%)

The study of the adsorption rate is important for the designer of the adsorbent material. The adsorbent material to be used to fix and remove toxic compounds from solution can not be slower than acceptable values for others non convention material in use commercially. When the adsorbent will be used as tool for water quality monitoring the adsorption rate should be enough to represent all the monitoring period. The experimental data's and the calculation of the adsorption rate will help to design the adsorbent diatomite accordingly with the adsorption velocity needs.

The adsorption rate is calculated considering the adsorption as a first-order reaction. The calculations are based on the placement of the experimental results in the graph of log (C_e-C) for t (agitation time). The linear regression was obtained and the equation is used in the calculation of K_{ab}. This value represents the mass of organic dye or lead ions adsorbed for the adsorbent in a certain interval of time [8] [9] [10].

Adsortion Rate Equation

$$\log(Ce - C) = (- K_{ab}/2{,}303)t + \log qe \qquad (2)$$

Where:
Ce - Equilibrium Concentration ($mg.L^{-1}$);
Co -Initial Concentration ($mg.L^{-1}$);
C - Concentration in time t ($mg.L^{-1}$);
t - Time of agitation (min.);
K_{ab} - Constant of adsorption rate ($mg.g.min^{-1}$);
qe -The mass of adsorbed compound for adsorbent material after the equilibrium time ($mg.g^{-1}$);
R^2 - Correlation Coefficient of the experimental data with the line equation.

The adsorption rates can be calculated using the experimental data plots in the graph with linear regression, the angular coefficient of the linear equation obtained is correspondent to $–K_{ab}/2{,}303$. In Table I there are some constant of adsorption velocity values for non conventional adsorbents found in literature.

TABLE I
ADSORPTION RATE FOR NON CONVENTIONAL ADSORBENTS

Non Conventional Adsorbent Material	Adsorbed Toxic Compound	Kab (10^{-3}) ($mg.g^{-1}.min^{-1}$)
FeIII and CrIII Sludge	Cd II	7 to 25
	Ni II	10 to 28
Iron Hydroxide	Cr VI	75 to 87
	Paraquat	5 to 18

B. The Diatomite

The diatomite is a natural product used as filter aid on liquids clarification process. The most common commercial applications are in filtration processes of beer, wine, distilled drinks, juices, vegetal, animal and mineral oils, waxes, fluid oils for dry laundry and the treatment of metallurgic sewers, effluent and sewage sludge.

The diatomite material usually shows white color and sometimes it can be considered as montimorilonite, but a microscopic examination with 100 to 500 percent of enhancement can help to easily identify the diatomite carcass content. The carcass of algae as unicellular vegetal organisms present at continent aquatic environment, sea or mangrove seaweed called diatomaceous earth. The algae carcass is composed essentially for amorphous silica (which make difficult for crystalline characterization with X rays difraction). The chemical analyzes of three types of commercial diatomite can be observed at Table 2 The diatomite is main composed by silicon, aluminum and iron oxide.

The diatomite is processed industrially to produce three types of materials: natural, calcined and calcined with the addition of melting agent. The natural product obtained from mineral deposits is usually found on layers with more than 21 m of thickness. After the mineral extraction the diatomite is dried and calcined to be sail to the market. The sedimentary diatomite is usually darker than the mineral one. Some of the minerals are prepared in the shape bricks or blocks, dried at 260°C, calcined in oven tunnel on 1000°C. The calcination process modifies the filter properties and many impurities are transformed into composites as calcium and aluminum silicate. The calcinations with melting agent is performed by addition of carbonate or sodium chloride end after that the calcinations on oven at 1200°C, this treatment increases the surface area and improve its filter properties.

TABLE 2
THE CHEMICAL COMPOSITION OF COMERCIAL DIATOMITE

Composition (%)	Manville	Dicalite
SiO_2	89,6	88,92
Al_2O_3	4,0	3,12
Fe_2O_3	1,5	1.01
TiO_2	0,2	0,16
CaO	0,5	0,40
MgO	0,6	0,78
Na_2O	3,3	4.91

Adapted from [9]

II - MATERIALS AND METHODS

The diatomite powder was sent by the producer with technical description of the product and it was characterized using the X ray fluorescence and X ray diffraction.

The diatomite pellets were prepared manually and it was necessary to mix with bentonite clay of the raw material for pelletization. The mixture was necessary due the low plasticity of the diatomite. Two different formulations were used the D1 composed by 50% of diatomite plus 50% of bentonite clay and the D2 composed by 75% of diatomite plus 25% of bentonite clay. The obtained pellets were dried and calcined at 800°C.

The adsorption process adopted was in batch with mechanical agitation for organic dye and lead ions adsorption. The magnetic stirring was also applied trying to reduce the influence of the mechanical shock in removal percentage and adsorption efficiency.

The diatomite pellets were submitted to adsorption experiments as non-conventional adsorbent material to the removal of the organic dye and lead ions in several concentrations. In each experiments a diatomite pellet with approximated mass of 1g and 500mL of the organic dye and the lead ions solution were used. The adsorption processes were controlled by the collect of aliquots of 10 mL at 2, 10, 30, 60, 120, 240 and 300 minutes of continuous stirring. The determination of the concentration of organic dye where performed by adsorbance measurements with an espectrophotometer Varian Carry1E and the concentration of lead ions on solution were performed by complex titration with EDTA.

III – Results and Discussion

Diatomite is compound predominantly by silica according with the technical report the chemical analyses and the diffraction analyses don't give any more details about the crystalline structure.

The mechanical resistance of the diatomite pellets D1 were verify by the comparison of weigh loss on two different ways of stirring, the mechanical with a steel bar and the magnetic with a magnetic bar. The mechanical stirring had 44.70 % of mass loss and the magnetic stirring were about 0.06 % .

The removal percentage of organic dye and lead ions in solution were calculated using the experimental data's and the Equation 1. The percentages can be observed at Table 3.

TABLE 3

REMOVAL PERCENTAGE, CI, CE AND QE FOR ORGANIC DYE AND LEAD IONS ADSORPTION

ORGANIC DYE R (%)	Ci (mg L^{-1})	Ce (mg L^{-1})	qe (mg L^{-1})
56	12,01	5,26	4,03
50	51,59	26,0	17,9
40	14,16	8,57	5,39
37	14,6	9,22	5,18
LEAD IONS R (%)	Ci (mg L^{-1})	Ce (mg L^{-1})	qe (mg L^{-1})
42	19,68	11,4	11,2
42	12,01	6,96	5,13
33	10,11	6,79	5,40
30	58,01	40,4	15,7

The adsorption velocities were calculated using the experimental data's and the determination of linear equation on Figure 1 and Equation 2 with log (qe-q) at y and t at x.

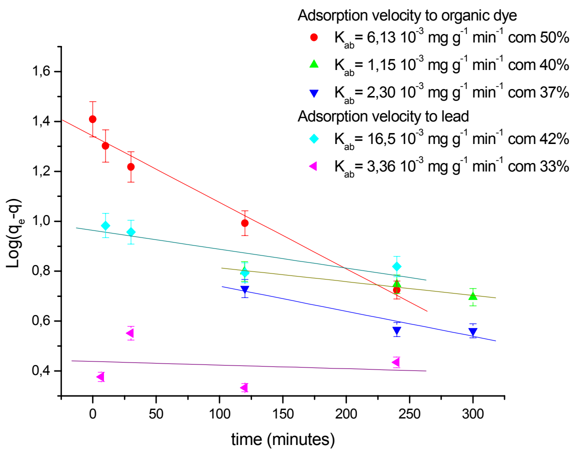

FIGURE 1: THE ADSOPRITON VELOCITY CALCULATED USING LINE EQUATION.

The Figure 1 shows the adsorption velocity values K_{ab} obtained using the linear equations; The values are similar with those related by literature and higher for the lead ions on concentrated solutions.

IV - CONCLUSION

The study provides information about the use of diatomite as adsorbent in batch process to obtain the maximum removal percentage and the adsorption velocity. The obtained results for adsorption velocity were similar with those related in the literature for non conventional adsorbents with 56 % removal percentage for organic dye and the lower removal percentage was 33%, obtained for lead ions in solution. The study shows the possibility of the use of diatomite with low cost mainly composed by non aggressive silica to be used as a tool for water quality monitoring and to fix and remove toxic metals and organic dye of chemical effluents and sewage water.

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