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Study of dye adsorbtion from water on silica materials using an optical fiber sensor

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Abstract

The adsorption process on aqueous phase can be described as the exchange between a solvent molecule eletrostatically attracted to a solid surface and the molecule of a given solute. In this research the capability of three different silica materials in removing a dye from water was evaluated using an optical fiber sensor. Despite the better results, the nanomaterials data showed higher dispersion due to the presence of dynamic light scattering on particles which got stably suspended, and crystalline quartz showed the lowest manufacturing cost.

Key words:

Adsorption, silica, optical fiber sensor.

Introduction

The use of ceramic materials in water-purifying processes is a promising alternative for the removal of dyes[1] by adsorption, when a molecule of solvent electrostatically attracted to the solid surface is exchanged by a given solute molecule, due to the higher attraction between surface and solute[2]. In this context, the objective of this study was to compare the performance of three different sources of silica previously studied in removing a mixture of methylene blue and ethanol from water, by adsorption: amorphous and spherical nano silica (soot) and active silica (110 nm and 243 nm of mean diameter, respectively), and crystalline quartz (0.66 µm of mean diameter)[3].

A commercial dye was used due to the fact it can be easily analyzed visually and presents different industrial and laboratory applications and environmental impacts regarding the misdirected disposal. Besides qualitative analyses, we used an optical sensor based on the Fresnel principle for a quantitative study of the removal process: the signal was modulated by the refractive index of the sample, so as the refractive index rises with the concentration of the mixture of dye and ethanol, the reflected intensity of the light gets progressive lower. The use of optical sensor provides data with low interference of the environment – due to the fact that it is inside the solution – and more accurate data with low cost. This optical fiber sensor is described in further details in References [4] and [5].

Results and Discussion

Methylene blue (MB) was diluted in water to a concentration of 10.1 mg.L^{-1} followed by the addition of an equal volume of ethanol, and finally water was added again, maintaining the molar ratio of ethanol to MB fixed (5.4 x 10^{5} mol/mol) to prepare solutions with concentrations ranging from 1 to 5 mg.L^{-1} of MB. It is important to highlight that the calibration curve relating the intensity of signal detected by the sensor was best described by a non-linear sigmoidal curve, presenting two sensor saturation baselines. The adsorption tests, on their turn, were conducted using masses of silica material ranging from 4 to 12 grams, and a solution with initial concentration of MB of 3.03 x 10^{-3}g.L^{-1}.

Figure 1 shows the final concentration of dye detected after the equilibrium was reached for each mass and material tested (temperature of 30 ºC). The temperatures of 20 and 40 ºC were also tested but showed poor results.

The use of soot provides the best results in terms of dye adsorption and less deviation in the data. Also, the presence of active silica changed the color of the solution and rised its turbidity, indicating the presence of silica particles that got stable suspension. Since the diameters of both soot and active silica nanoparticles are comparable to the wavelength of the sensor laser, they can dynamically scatter the light and rises the data dispersion, affecting the quality of the evaluation by the sensor. In fact, the MATLAB routine used for the evaluation of the sensor signals showed, for these cases, the decay of the autocorrelation function of the light intensity characteristic of the dynamic light scattering (DLS) phenomenon[4]. Then, deviations from expected results can be partially explained by the presence of DLS, when using this methodology.

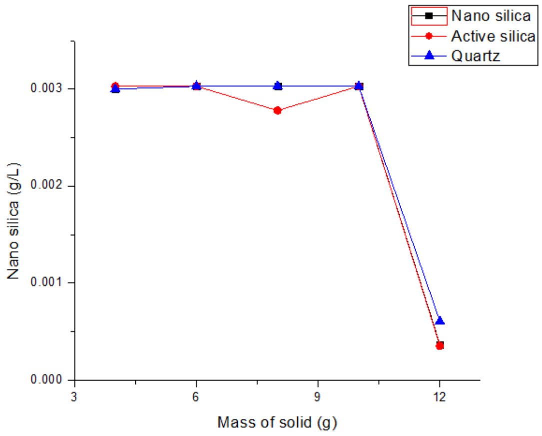

Figure 1: Final concentration of MB for the tests under 30 ºC.

Conclusions

Amorphous silica nanoparticles showed the best results in terms of dye removal from water. However, the use of this silica material for purification devices may be not economically viable due to its high cost of production. In order to solve this problem, future tests using cheaper materials, such as common and microstructured silica should be done. Besides that, the use of different types of coloring materials allows the determination of the robustness of both the fabrication and the performance evaluation method and the feasibility of the use of the material. Finally, the last consideration that should be done is about the use of alcohol in the solution for simulating the composition of commercial dyes. Future studies should be conducted to analyze the proportion of alcohol and dye adsorbed, evaluating the possible presence of preferential adsorption of dye or alcohol from the aqueous suspension. This procedure could probably affect the quality of the results. A parallel methodology must be used for such studies, and an interesting technique that could be tested is the colorimetry.

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