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Environmental Application of Carbon Nanomaterials

Ovejero G, Delgado JA, Agueda VI, Álvarez-Torrellas S, Serra E, Hernández AB and García J*

Department of Chemical Engineering, Avda Complutense s/n, Universidad Complutense, Spain

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***Corresponding author:** García J, Group of Catalysis and Separation Processes (CyPS), Department of Chemical Engineering, Faculty C.C. Chemistry, Avda Complutense s/n, Universidad Complutense, Spain, Email: jgarciar@ucm.es

Abstract

The use of carbon nanomaterials as adsorbents and catalytic support to remove organic pollutants presents in wastewaters have been mini-reviewed. These materials appear as a good adsorbent and catalytic support, because of its excellent textural and physic-chemical properties. It is known that the surface functionalization can change the reactivity and selectivity of carbon surface, which plays an important role on the adsorption and the catalytic process for specific organic molecules.

Keywords: Adsorption; Carbon nanomaterials; Catalytic support; Catalytic wet air oxidation; Organic contaminants

Introduction

The number of organic compounds detected in streams and source waters is very high and continuously increasing. Studies about these compounds have documented a large class of chemical contaminants including pharmaceutical active compounds, personal care products, dyes, endocrine disrupting compounds, surfactants, pesticides, plasticizers, and numerous other industrial pollutants [1].

Some recent researches indicated that the low concentrations of these contaminants present in drinking water are not harmful to humans from a toxicological point of view, but their presence is still not desirable as a precautionary principle [2].

Pollutants are usually released into the environment via wastewater discharges or leakage from conventional methods of wastewater treatment and they can contaminate the water sources that are used as drinking water resources. Up to date, due to the inadequate analytical methods and the lack of accurate information about the effects of these compounds and their metabolites in the aquatic environment, there has been a relevant lack of studies on this field [3].

In this mini review, two processes were revised: the adsorption and the catalytic wet air oxidation (CWAO) under several conditions using these carbon nanomaterials (CNM). Extensive experimental and modeling studies on CNM adsorption of a broad spectrum of hazardous compounds from aqueous solution have been reported. In this sense, the adsorption of different specific organic compounds (as pharmaceutical, dyes, etc) has become one of the aims of researchers in the world.

On the other hand, CWAO represents a promising technique for removal of toxic and non-biodegradable organic compounds from wastewaters. The CWAO of a variety of organic pollutants has been studied over supported noble metal catalysts, metal oxides, mixed metal oxide systems and cerium-based composite oxides. Several studies regarding CWAO of various organics have been performed in the presence of CNM-based catalysts. The specific metal-support interactions in carbon based solids can directly affect the catalytic activity and the selectivity.

Discussion

Adsorption

Psychoactive drugs are of ubiquitous nature and persistence in the aqueous environment due to their general low removal in wastewater treatment plants. In these cases, for carbamazepine, it could be established a correlation between the equilibrium adsorption capacity and the specific surface area of the adsorbents, since when surface area increased, carbamazepine adsorption capacity increased too. Thus, large carbamazepine adsorption capacities were obtained for the mostly microporous carbons, 260mg g–1, for activated carbon from peach stones. Likewise, it was observed a high decreasing in the adsorption capacity when the mesoporosity of the adsorbent increased, namely 43.9mg g–1 for carbamazepine onto carbon nanofibers or 39.5mg g–1 for ciprofloxacin onto

multi walled carbon nanotubes. The correlation between the efficiency removal and the specific surface area of the adsorbents has already been observed in the literature. This term is very important in presence of natural organic material in wastewater samples, because the organics compete with the target compounds for the active sites, directly or by pore blocking [4].

For example, using carbon nanotubes and carbon nanofibers for diclofenac and isoproturon adsorption, it was found that the adsorption capacity of single compounds is higher than the capacity of the compounds in the real wastewater, suggesting that the background natural organic material had a greater impact on the adsorption process. It was observed that the adsorption capacity was lower at higher temperatures. The process was hence concluded to be exothermic.

Several works have been conducted in order to elucidate the mechanism of adsorption of many molecules on different adsorbents. Those publications reveal that adsorption of organic molecules from dilute aqueous solutions on carbon materials is a complex interplay between electrostatic and non-electrostatic interactions and that both interactions depend on the characteristics of the adsorbent and adsorbate, as well as the solution chemical properties [5].

Catalytic wet air oxidation

In Spain, synthetic dyes often receive considerable attention from researchers interested in textile wastewater treatment processes. Initial environmental efforts with dyes dealt with color pollution, which has a strong psychological effect. In this sense, when considering the Basic Yellow dye removal concentration and total organic carbon after three reaction hours, it can be observed that a higher amount of dissolved oxygen gave slightly faster abatement of TOC; so, some differences of removal ratios were detected between 30 and 50 bar of total pressure of oxygen. In all cases, the final removal value of TOC achieved after 3h of oxidation was between 16.2 and 31.4%, with selectivity to CO2 between 16.9 and 33.5% for this dye removal using platinum support on multiwall carbon nanotubes [6].

On the other hand, among the noble metal catalysts used, supported platinum catalysts would seem to be particularly interesting because they are highly effective in the oxidation of organic compounds. This CWAO process applied to the oxidation of several pharmaceuticals dissolved together in ultra-pure water yielded, for a catalyst loading of 0.025g at 140ºC and 20 bar (platinum support on multiwalled carbon nanotubes), the following best final removals: 98.3%, 96.7%, and 24.0% for amoxicillin, naproxen, and phenacetin, respectively [7].

Finally, Ovejero et al. [8] based on the results of catalytic wet air oxidation of aniline in a trickle bed reactor using Pt catalysts support on multiwall carbon nanotubes, confirmed the assumption made by Oliviero et al. [9], that in the degradation mechanism of aniline produce hidroquinone and benzoquinone as intermediaries compounds, and carboxylic acids.

Conclusion

It seems that the low-range temperature functionalities control the adsorption mechanism of several organic compounds as caffeine, diclofenac and carbamazepine from aqueous solutions. The determination of the physicochemical properties of the organic compounds, as hydrophobicity, water solubility, molecular size and others provides a better understanding of the removal of the adsorbates in the aqueous phase.

Noble metals supported on carbon nanomaterials as multi walled carbon nanotubes exhibits an excellent catalytic activity in the CWAO processes. Also, these catalysts are very active for organic matter as TOC, and toxicity removal in industrial wastewater. In absence of the catalyst, significant differences are observed in comparison with the catalytic process. Noble catalyst showed a good stability in the reaction conditions, as no leachate was observed.

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