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Nature of the degradation products of phenol which produce high levels of color in the wastewater oxidized in a photo-Fenton system

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ABSTRACT

This work completes the step of the mechanism of phenol oxidation, where the wastewater shows the maximum color levels, considering the formation of trihydroxybenzene rings and quinoidal compounds of hydroxylated nature as degradation intermediates. They have been determined experimentally by the stoichiometric ratios of oxidant to degrade phenol until the intermediate species generated during the oxidation (R = mol H_2O_2/mol C_6H_6O). Hence, catechol forms at R = 1.0, resorcinol at R = 1.3 and hydroquinone at R = 2.0. The addition of these ratios, R = 4.3, corresponds to the minimum dosage required to oxidize the initial phenol contained in the solution. p-benzoquinone is formed at R = 1.0. The formation of trihydroxylated rings with substituents in ortho-position (pyrogallol) and meta- (phloroglucinol), which makes them more unstable, needs a lower dosage of oxidant, R = 4.0, than the para-substituted (hydroxyhydroquinone), that requires R = 5.5. Muconic acid formation reaches its maximum at R = 6.0 while the formation of benzoquinones substituted by hydroxyl groups (dihydroxybenzoquinone) require R = 8.0. These results suggest that oxidation of p-benzoquinone would yield dihydroxybenzoquinone species, whereas muconic acid would be an oxidation byproduct of ortho- and meta-substituted species. The oxidation intermediates generated during the first steps of the oxidation pathway determine the color of oxidized wastewater, although iron species in solution may enhance its intensity. Maximum color is obtained at R = 4.0 and is produced by intermediates that are generated during the oxidation of pyrogallol and phloroglucinol-type compounds. A drastic decrease in color happens between R = 4.0 and 6.0 which corresponds to the formation of muconic acid. Finally, the color increases slightly at R greater than 7.0 which can be related to the formation of dihydroxylated benzoquinones. As the color and toxic compounds are degraded to biodegradable acids of colorless nature, the color intensity diminishes to colorless at R > 13.0.

Keywords: Dihydroxylated benzene; Hydroxylated benzoquinone; Phenol; Photo-Fenton; Trihydroxylated benzene

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