Removal of niflumic acid during ozonation and identification of its transformation products by LC-QToF-MS

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EXTENDED ABSTRACT

Recent studies have demonstrated the occurrence of pharmaceuticals in the aquatic environment, from ng to μg per litter, depending on their physicochemical properties and biodegradability. Among pharmaceuticals, nonsteroidal anti-inflammatory drugs (NSAIDs), including compounds used as analgesics, is one of the most important groups of pharmaceuticals due to their wide use [Coelho (2010)]. NSAIDs were detected in numerous secondary treated wastewater samples worldwide indicating their incomplete removal by the conventional processes applied in waste water treatment plants (WWTPs) [Loos (2013), Kasprzyk-Hordern (2009)]. Niflumic acid (NA) was detected in various environmental samples of Greece, recently. In particular, it was detected a) in concentration levels ranging from 420 to 675 ng/L in samples obtained from the main wastewater treatment plant (WWTP) in Athens in 2011 [Dasenaki and Thomaidis (2015)], b) in twenty-four hour flow-proportional samples of secondary wastewater samples, with 100% frequency detection, collected from the same WWTP in 2014 [Ibanez (2016)], c) in all treated sewage sludge samples collected from five WWTPs of Santorini in July 2013 in a mean concentration of 40.9 ng/g d.w. [Gago-Ferrero (2015)] and d) in samples collected from seawater of Eastern Mediterranean Sea, Saronikos Gulf and Elefsina Bay during December 2013 with frequency detection ≥ 50% [Alygizakis (2016)].

Although ozonation is a promising tertiary treatment technique for the elimination of micropollutants, the reactivity of ozone towards organic compounds may lead to the formation of structurally-related compounds called transformation products (TPs). The identification of these compounds is essential not only to provide a comprehensive risk assessment on micropollutants fate in the environment, but also to design improved technologies for the removal of persistent contaminants.

In this study, the removal of NA during ozonation was investigated and the identification of its TPs was realized through suspect and non-target screening approaches. The influence of different initial ozone concentrations and different pH values of the reaction mixture on NA's removal was tested. After analysis by reversed-phase liquid chromatography quadrupole-time-of-flight mass spectrometry (RPLC-QToF-MS) in both positive and negative electrospray ionization mode, detection and identification of TPs was realized. Structure elucidation was based on accurate mass, isotopic pattern measurements and interpretation of the acquired MS/MS spectra. Moreover, an in-house retention time prediction model [Aalizadeh (2016)] was used as a supporting tool for their identification.

Results indicated the highly reactivity of NA with the molecular ozone, since the reaction was extremely fast and was completed within the first minute. Initial ozone concentration and aqueous solution's pH were proven to be crucial experimental parameters. An initial ozone concentration of 5 mg/L led to total NA elimination, while 70% of removal was achieved at acidic pH when 2 mg/L of ozone were added. A total of thirteen TPs of NA were identified. The structure elucidation of the TPs showed that the oxidation occurred in the heterocyclic ring of the molecule, while the aniline-like part remained intact by ozone attack due to the presence of the three fluoride atoms, which act as electron withdrawing groups. The most abundant identified TP was 2-aminopyridine-3-carboxylic acid (NA-138), formed by the breakdown of NA structure during ozonation. This TP was confirmed through the analysis of the corresponding reference standard. The high reactivity of the pyridine-like moiety of the parent compound with ozone was proven in ozonation experiments in which NA-138 was used as parent compound. It was completely removed when 5 mg/L of ozone were added and three ozonation TPs of NA-138, and thus second generation TPs of NA were detected. A probable structure based on diagnostic evidence was proposed for the one of them, while only an unequivocal formula was assigned to the other two.

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