GAS CHROMATOGRAPHY-MASS SPECTROMETRY ANALYSIS OF IRRADIATED FLUOXETINE AQUEOUS SAMPLES

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Abstract
The last decade witnessed the drastic increase in the use of antidepressant drugs, being fluoxetine the most prescribed worldwide. Conventional wastewater treatment is inefficient in removing fluoxetine and its accumulation in water bodies and water living organism is inevitable. Among several methods for contaminant removal from wastewater, electron beam irradiation is an efficient and green technology. This work presents the characterization of aqueous fluoxetine samples before and after irradiation. Gas chromatography coupled to mass spectrometry was used to identify the original compound and its irradiation products. Results indicate a drastic reduction in fluoxetine presence after the irradiation process. Radiolysis pathways were proposed based on mass fragments identification.

Introduction
The detection frequency of contaminants of emerging concern (CEC) has increased over the past decade [1]. Although their potential environmental hazard has been confirmed by many authors, toxicity data is still scarce. Among CECs, antidepressant drugs are usually a major contaminant found in different water matrices, from wastewater to agricultural irrigation systems [2] and groundwater [3]. According to the Organization for Economic Cooperation and Development (OECD), the consumption of antidepressants has increased 60% worldwide in the last decade [4].
Antidepressants are a category of psychiatric drug used in the treatment of depression, anxiety, panic disorder and obsessive-compulsive disorder. Among these, fluoxetine (**Figure 1**) is the most prescribed antidepressant in the world.
Approximately 10% of the parent compound is eliminated through urine, entering, thus, the water treatment facilities as human waste, mainly. Fluoxetine is a hydrolytic and photolytically stable drug with a long half-life, which accumulates in biological tissues [5].

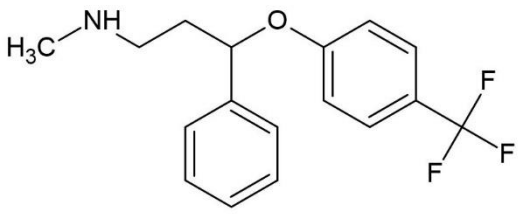

Figure 1 –Fluoxetine molecular structure

Since fluoxetine removal in wastewater treatment plants is inefficient, some alternative treatments have been developed. Several degradation methodologies for fluoxetine have been reported, such as sorption, biodegradation, photodegradation, oxidation and irradiation. Electron beam irradiation (EBI) treatment is a green technology, being efficient and safe. The

radiolysis of water molecules produces reactive species, as shown in Equation 1, which promote the degradation of compounds [6].

$$H_2O \xrightarrow{EB} e^-_{(aq.)} + H^\bullet + HO^\bullet + H_2O_2 + H_2 + H_3O^+ \quad \text{(Eq.1)}$$

Experimental

Irradiation of fluoxetine aqueous samples: Standard solution of pure fluoxetine was prepared at 100 ppm. Next step followed the batch scale irradiation that was carried out at a 1.4 MeV electron beam accelerator, by means of the variation of electric current. A Shimadzu Co. gas chromatograph/mass spectrometer model QP2020 NX was used, and the instrumental parameters were: Restek Rtx-5MS capillary column, injector temperature 250°C, column flow 0.9 mL/min, split ratio 5.0, oven temperature started at 140 °C and was raised to 300 °C (40 °C/min) and held for 2 minutes, ion source temperature 280 °C and interface temperature 280 °C, positive electron impact ionization mode.

Results and discussion

Chromatographic results (**Figure 2**) indicate the presence of only one irradiation product after 1 kGy.

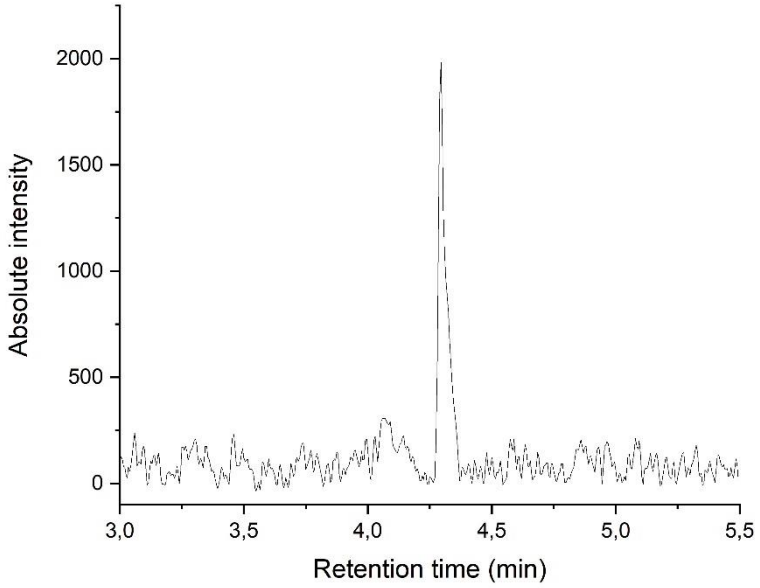

Figure 2 – Chromatogram of irradiated fluoxetine

As indicated by Shao [7], this dose (1kGy) degrades 98% of the active fluoxetine. **Figure 3** presents a comparison of the same sample, before and after irradiation. The peak area of the irradiated sample is negligible (10^3 times less intensity).

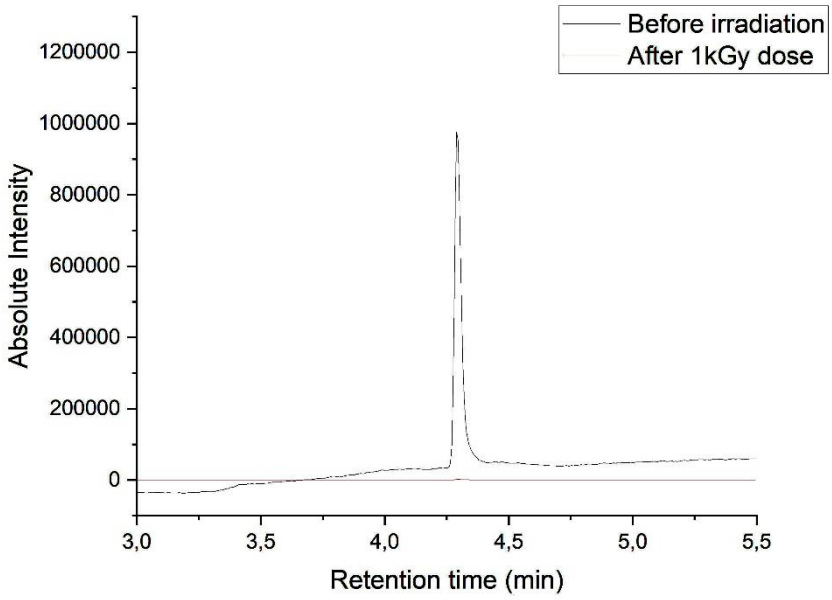

Figure 3 – Chromatogram before and after irradiation

Shao *et al.* [7] proposed degradation pathways for fluoxetine under EBI, using liquid chromatography coupled to tandem mass spectrometry (LC/MS-MS) using electrospray ionization (ESI) mode. Similarly, Silva *et al.* [8] used direct injection on an ultra-high resolution Qq-time-of-flight (UHR-QqTOF) mass spectrometer on ESI mode as well. Despite employing the same characterization technique (MS), this work differs from both Shao and Silva for the ionization mode. Electron (impact) ionization is a 'hard' ionization mode, since the high energy provided by electron at 70 eV generates several fragments. Electrospray is considered a 'soft' ionization mode. Therefore, fragments should not be generated the same way for the different ionization modes. Also, some fragments might be the product of fragment recombination, which makes their identification much more complicated.

The mass spectrum of fluoxetine presents 4 characteristic fragments (44, 104, 148, 162, 309) Mass spectrum of the irradiated product (**Figure 4**) indicates the presence of 8 fragments (44, 73, 143, 207, 253, 281, 327, 341). The only fragment present on both samples, before and after irradiation, is the base peak (*m/z* 44).

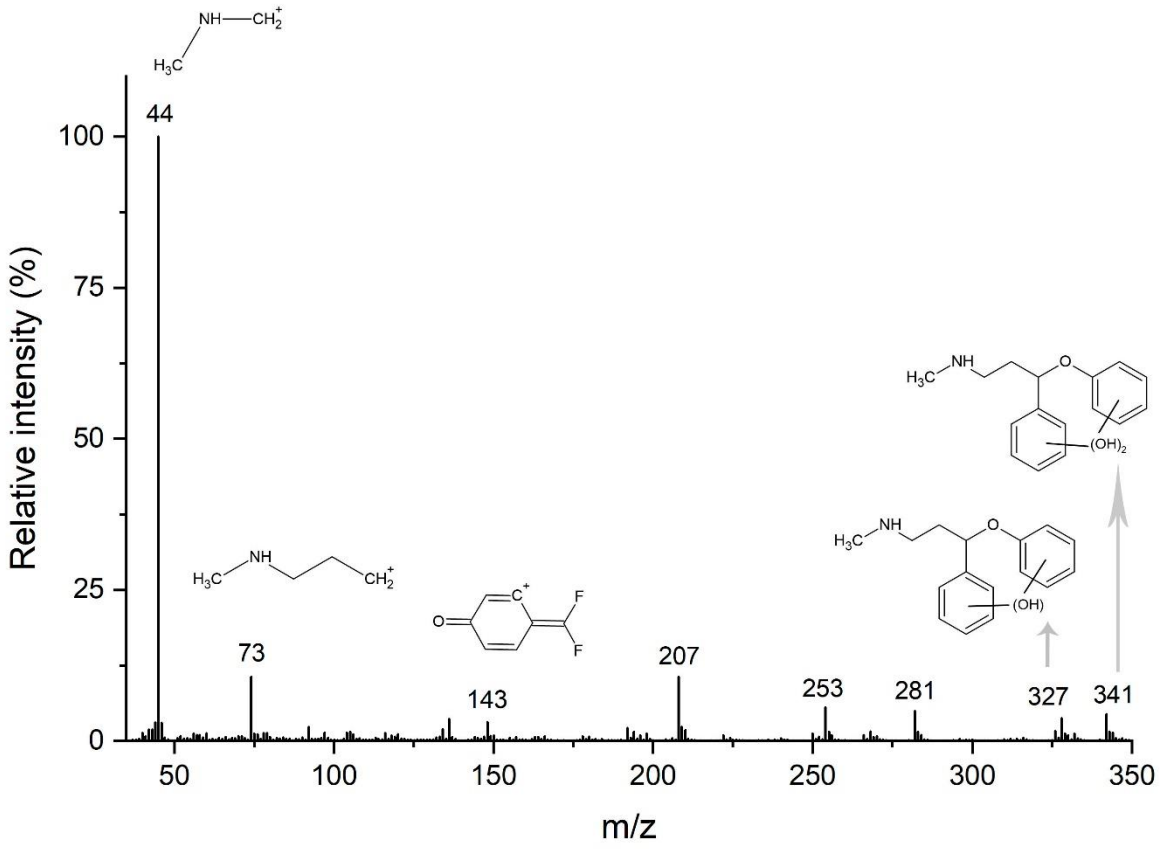

Figure 4 – Mass spectra of irradiated fluoxetine

Based on fragments presented on **Figure 4**, we propose that OH• is the most reactive species, attacking both the carbon oxygen bond, yielding fragment *m/z* 73, and the aromatic ring, yielding fragment *m/z* 327 and 341. The last reaction if the defluorination, yielding fragment *m/z* 143.

Conclusion

Mass spectrometry is a ubiquitous characterization technique in the field of environmental analysis. Nonetheless, the coupling with gas chromatography (GC) is ever less usual in comparison to liquid chromatography (LC), a more sensible yet highly expensive. This work established a methodology for the characterization of irradiated fluoxetine samples by GC/MS, a cheaper and more commonly employed analytical technique.

Acknowledgements

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