Pharmaceutical residues in hospital and urban wastewaters: Occurrence, removal and potential risk assessment

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Abstract
The presence of ten pharmaceutical compounds (bupropion, venlafaxine, mirtazapine, sertraline, citalopram, caffeine, triclosan, carbamazepine, diazepam, clozapine) which belong to different treatment categories was studied in one hospital and three urban WWTPs in north and northwestern Greece. The pharmaceuticals have been selected due to their high usage rate but also because of their proven presence in both wastewater treatment plants and the aquatic environment. Analytical methodology was based on gas chromatography coupled to mass spectrometry (GC-MS) detection after the application of a solid phase extraction (SPE) step. In addition, elimination of these compounds in the WWTPs was assessed as well as their ecotoxicological impact on the aquatic environment was estimated by means of risk quotient (RQ). The results showed that the most often detectable compounds were caffeine, triclosan and venlafaxine. High concentration levels of caffeine, up to 22142.1 ng/L were found, while removal rates were up to 99 %. In addition, high levels of acute and chronic toxicity were observed for triclosan (RQ>1).
Keywords: Pharmaceuticals, wastewaters, risk quotient, SPE, GC-MS

1. Introduction

Pharmaceuticals are a broad group of chemical compounds, including complex molecules with a variety of different functional groups, physicochemical and biological properties. Until the early 1990s, there had been no research for their existence in the environment. Pharmaceuticals can enter the environment through many streams, including the outflows of sewage treatment plants and the drainage of waste from sources such as livestock breeding units. An additional source of pharmaceuticals in urban wastewater is the inappropriate disposal of unused or expired drugs. In addition, the presence of pharmaceuticals in the water may be a result of the drainage of landfills in which household wastes or industrial wastes containing such substances are buried or by the direct discharge of waste water into pits [Daughton et al., 2007; Fent, 2008]. A great number of toxicity studies have been carried out with the aim of assessing the potential risk that pharmaceuticals pose to the aquatic environment. For human health, the resistance in bacteria due to the continuous presence of antimicrobials in the aquatic ecosystem is gaining concern. In addition, we are still far from knowing the toxic effect of the complex mixture of pharmaceuticals and their metabolites [Kosma et al., 2014; 2019; Nannou et al., 2015]. In the present study the categories that were studied were: antidepressants, psychochomotor stimulants, disinfectant-antiseptic, antiepileptics, anxiolytics and antipsychotics. Taking into consideration all the above, this study aims : Firstly to determine the occurrence of ten pharmaceuticals (bupropion, venlafaxine, mirtazapine, sertraline, citalopram, caffeine, triclosan, carbamazepine, diazepam, clozapine) in influent and effluent wastewaters of one University hospital and three urban WWTPs in north and northwestern Greece. The pharmaceuticals were chosen by their high usage rate and also by their proven presence in wastewater treatment plants and aquatic environment. Secondly to estimate the removal efficiencies of these compounds in WWTPs and finally to assess the environmental risk of the target compounds in the aquatic environment, providing important information concerning their distribution and fate.

2. Experimental procedure

2.1. Standards and reagents

Pharmaceutical analytical standards were purchased from Sigma-Aldrich (Darmstadt, Germany), TCI (Zwijndrecht, Belgium) and LGC (Wesel, Germany) and were of high purity grade (>95%). Methanol and water (LC–MS grade) were received from Fisher Scientific (Leicestershire, UK). Hexane (GLC pesticide residue grade) was purchased from Fisher Scientific. Oasis HLB (200 mg, 6 cm^3) cartridges were purchased from Waters Corporation (Milford, MA, U.S.A.). A GC-MS, QP2020 Shimadzu equipped with capillary column MEGA-5MS (30m x 0.25 mm, 0.25 μm) system was used for the determination of the analytes in wastewaters.

2.2 Sample collection and preparation

The samples were collected from the University hospital of Ioannina and three urban wastewater treatment plants in north and northwestern Greece (Ioannina city, Grevena city and town of Chalastra). The samples were immediately transported to the laboratory and filtered

through 1 μm glass fiber filters GF/B (Whatman, UK) prior to analysis, in order to eliminate suspended solid matter. Afterwards, the samples were stored in the dark at 4 °C and extracted within 48 h in all the cases. Isolation of the pharmaceuticals from the water samples were performed off-line, using a standard SPE-system connected to a vacuum pump. The sorbent was activated by adding 5 mL of acetone and was conditioned with 5 mL of LC-MS methanol and 5mL of H_2O LC-MS and then, 250 mL of aqueous sample was loaded into the cartridge with vacuum application. Next the cartridge was washed with 5 mL of H_2O LC-MS and was dried under vacuum for 15 minutes. The analytes were eluted with 2x5 mL MeOH LC-MS. Finally, the extract was concentrated under a gentle stream of nitrogen and reconstituted to a final volume of 1ml of hexane.

3. Results and discussion

The method presented excellent linearity with the correlation coefficient being over 0.9990 for all substances. Recoveries for samples were over 63% in all cases. Limits of detection and quantification ranged from 16.4-53.2 ng/L and from 50.6-163.2 ng/L, respectively. The most often detectable compounds were caffeine, triclosan and venlafaxine. High concentration levels of caffeine up to 22142.1 ng/L, were found. Removal rates were up to 99 %. Finally, high levels of acute and chronic toxicity were observed only for triclosan (RQ>1).

4. Conclusions

In conclusion, the SPE method followed by chromatographic analysis in a gas chromatograph coupled to a mass spectrometer applied to this task seems to be simple, fast and reliable for the determination of pharmaceutical residues in wastewater samples. The most commonly detected substances were caffeine, triclosan and venlafaxine. Removals were up to 99%. Only triclosan showed high acute toxicity and high chronic toxicity value. Therefore, triclosan is the most critical substance for chronic and acute toxicity.

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