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Contribution of hospital effluents to the load of pharmaceuticals in urban wastewaters: Identification of ecologically relevant pharmaceuticals

Lúcia H.M.L.M. Santos [a], Meritxell Gros [b], Sara Rodriguez-Mozaz [b,*], Cristina Delerue-Matos [c], Angelina Pena [d], Damià Barceló [b,e], M. Conceição B.S.M. Montenegro [a]

[a] REQUIMTE, Faculty of Pharmacy, University of Porto, Rua Jorge Viterbo Ferreira 228, 4050-313 Porto, Portugal
[b] Catalan Institute for Water Research (ICRA), H_2O Building, Scientific and Technological Park of the University of Girona, Emili Grahit 101, 17003, Girona, Spain
[c] REQUIMTE, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto, Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal
[d] Group of Health Surveillance, Center of Pharmaceutical Studies, University of Coimbra, Health Sciences Campus, Azinhaga de Santa Comba, 3000-548 Coimbra, Portugal
[e] Water and Soil Quality Research Group, Department of Environmental Chemistry, IDAEA-CSIC, Jordi Girona 18-26, 08034, Barcelona, Spain

HIGHLIGHTS

- In-depth monitoring of pharmaceutical presence in hospital effluents of four different types of hospitals
- Evaluation of contribution of hospital wastewater into urban wastewater influent in terms of pharmaceutical loads
- Environmental Risk Assessment regarding presence of pharmaceuticals in hospital effluents and wastewater effluents
- Prioritization of 10 selected pharmaceuticals in hospital and WWTP effluents based on the Environmental Risk Assessment performed

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ABSTRACT

The impact of effluent wastewaters from four different hospitals: a university (1456 beds), a general (350 beds), a pediatric (110 beds) and a maternity hospital (96 beds), which are conveyed to the same wastewater treatment plant (WWTP), was evaluated in the receiving urban wastewaters. The occurrence of 78 pharmaceuticals belonging to several therapeutic classes was assessed in hospital effluents and WWTP wastewaters (influent and effluent) as well as the contribution of each hospital in WWTP influent in terms of pharmaceutical load. Results indicate that pharmaceuticals are widespread pollutants in both hospital and urban wastewaters. The contribution of hospitals to the input of pharmaceuticals in urban wastewaters widely varies, according to their dimension. The estimated total mass loadings were 306 g d^{-1} for the university hospital, 155 g d^{-1} for the general one, 14 g d^{-1} for the pediatric hospital and 1.5 g d^{-1} for the maternity hospital, showing that the biggest hospitals have a greater contribution to the total mass load of pharmaceuticals. Furthermore, analysis of individual contributions of each therapeutic group showed that NSAIDs, analgesics and antibiotics are among the groups with the highest inputs.
Removal efficiency can go from over 90% for pharmaceuticals like acetaminophen and ibuprofen to not removal for β-blockers and salbutamol. Total mass load of pharmaceuticals into receiving surface waters was estimated between 5 and 14 g/d/1000 inhabitants.
Finally, the environmental risk posed by pharmaceuticals detected in hospital and WWTP effluents was assessed by means of hazard quotients toward different trophic levels (algae, daphnids and fish). Several pharmaceuticals present in the different matrices were identified as potentially hazardous to aquatic organisms, showing that especial attention should be paid to antibiotics such as ciprofloxacin, ofloxacin, sulfamethoxazole, azithromycin and clarithromycin, since their hazard quotients in WWTP effluent revealed that they could pose an ecotoxicological risk to algae.

1. Introduction

Over the last decades, the worldwide consumption of pharmaceuticals has increased as well as their detection in wastewaters and surface waters, which represents a major concern in terms of their potential impact on the environment and human health. Wastewaters have been pointed out as the main route of entry of pharmaceuticals into the environment (Daughton and Ruhoy, 2009), since they gather the residues excreted after ingestion, which are excreted in urine and feces, either as unchanged compounds or metabolites. Several studies pointed out that Wastewater Treatment Plants (WWTPs)

* Corresponding author. Tel.: +34 972 18 32 55; fax: +34 972 18 32 48.
E-mail address: srodriguez@icra.cat (S. Rodriguez-Mozaz).

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are not able to completely remove pharmaceuticals (Behera et al., 2011; Gracia-Lor et al., 2012; Jelic et al., 2011; Kosma et al., 2010; Zorita et al., 2009). Besides urban wastewaters, hospital wastewaters have also stood up as an important environmental exposure pathway of pharmaceuticals (Verlicchi et al., 2010b).

Due to their specific nature, it is expected that hospital effluents present a mixture of compounds, including not only pharmaceuticals and their metabolites, but also diagnostic agents, disinfectants, among others, resulting from diagnostic, laboratory and research activities and principally from medicine excretion from patients (Verlicchi et al., 2010b). Consumption, use and application of pharmaceuticals in a hospital may vary over the year and from country to country (Schuster et al., 2008), due to the predominance of diseases and to the hospital activity, as well as to the local list of pharmaceuticals suggested for the treatment of different diseases. These changes will have impact on pharmaceuticals detected in hospital effluents, since they are closely related with the substances that are being administered in a certain hospital as well as their quantities. Several authors have shown the presence of pharmaceuticals in hospital wastewaters (Gómez et al., 2006; Lin and Tsai, 2009; Sim et al., 2011; Verlicchi et al., 2012a; Weissbrodt et al., 2009). Furthermore, hospital effluents also play an important role in the introduction of pathogens into public wastewaters, especially concerning multi-resistant bacteria, contributing to the spread of antibiotic resistance into the environment (Kümmerer, 2009).

Hospitals generate different quantities of wastewaters depending on factors like number of beds, hospital age, general services present inside the structure (kitchen, laundry, etc.), number and types of wards and units, institution management policies, cultural and geographical factors, among others (Verlicchi et al., 2010b). Usually hospital effluents are directly discharged into public sewer network, being co-treated with domestic wastewaters in municipal WWTPs. This practice has been questioned by some authors (Pauwels and Verstraete, 2006; Verlicchi et al., 2012a), who suggested the adoption of a more dedicated treatment for hospital effluents before being discharged into public wastewaters and then both urban and hospital wastewaters would be subsequently treated in WWTPs (Pauwels and Verstraete, 2006; Verlicchi et al., 2010a). This approach has benefits like avoiding the dilution of hospital wastewaters with urban wastewaters, which may result in the inhibition of biomass and reduction of removal efficiency in WWTPs, as well as to avoid losses into the environment due to sewer leakage and combined sewer overflows (Kovalova et al., 2012). At the same time, it is possible to avoid the spread of multi-antibiotic resistant bacteria (Kümmerer, 2009) and the input of chemical substances (pharmaceuticals, diagnostic agents, etc.) that in some cases are genotoxic (Gupta et al., 2009).

Several monitoring studies have reported the presence of pharmaceuticals in urban wastewaters (Al-Rifai et al., 2007; Brown et al., 2006; Bueno et al., 2012; Gracia-Lor et al., 2011; Gros et al., 2006; Pedrouzo et al., 2011) and surface waters (Daneshvar et al., 2010; González Alonso et al., 2010; Kolpin et al., 2002; Martín et al., 2011; Spongberg et al., 2011; Vystavna et al., 2012). Nevertheless, few data is available on the contribution of hospital effluents towards the load of pharmaceuticals in WWTPs (Beier et al., 2011; Langford and Thomas, 2009; Ort et al., 2010; Thomas et al., 2007; Verlicchi et al., 2012a). At the same time, available data regarding the environmental risk posed by hospital effluents to aquatic organisms is still sparse and often limited to predicted (Escher et al., 2011; Souza et al., 2009) rather than measured concentrations (Verlicchi et al., 2012a).

Due to their bioactive intrinsic properties, pharmaceuticals are recognized as being able to cause potential effects in aquatic organisms; therefore environmental risk assessment (ERA) studies are recommended, in order to consider the potential effect of pharmaceuticals at their exposure levels (von der Ohe et al., 2011). According to the guidelines set out by the European Medicines Agency (EMA), new pharmaceuticals require an ERA, which is assessed in a step-wise approach, divided in two phases. In Phase I, environmental exposure of the pharmaceuticals is estimated and if their predicted environmental concentration (PEC) exceeds a threshold safety value of 10 ng L^{-1}, Phase II studies are required, in order to assess their ecotoxicological potential (EMEA, 2006).

In this context, the aim of the present work was to monitor the occurrence of 78 pharmaceuticals of major human consumption in four hospitals located in Coimbra (Portugal) with different capacities, wards and units, namely a university hospital (1456 beds), a general hospital (350 beds), a pediatric hospital (110 beds) and a maternity hospital (96 beds), as well as in the influent and effluent wastewaters of the WWTP that receives and co-treats their wastewaters. The impact and individual contribution of each hospital to the load of pharmaceuticals into the receiving urban wastewaters was evaluated, being one of the few studies that embraced a high number of compounds belonging to several therapeutic classes. In addition, removal efficiency for all target compounds was also evaluated in WWTP. Finally, the potential ecotoxicological risk posed by pharmaceuticals to aquatic organisms when exposed to the studied hospital and WWTP effluents was assessed and prioritization lists of potentially hazardous pharmaceuticals that should be included in monitoring programs and that might be considered for inclusion in future regulations were established.

2. Materials and methods

2.1. Sampling site, sample collection and sample pre-treatment

Effluents from four hospitals with different dimensions, units and wards located in Coimbra (Portugal) were sampled in this study, together with the influent and effluent of the receiving WWTP. Studied hospitals included:

- University hospital: large hospital with 1456 beds and with a broad range of clinical and services and medical specialities as well as a center of research. It serves a population of approximately 430,000 inhabitants and it is also a reference hospital for the center region of Portugal;
- General hospital: medium-sized hospital with 350 beds and thirteen main wards. It serves a population of approximately 369,000 inhabitants;
- Pediatric hospital: small hospital with 110 beds and nine main wards. It serves a population of approximately 90,000 inhabitants and it is a reference hospital that supports pediatric units of hospitals located in the center region of Portugal;
- Maternity: small hospital with 96 beds, not including the baby unit, and three main wards, namely gynecology, obstetrics and neonatology. It serves a population of approximately 507,000 inhabitants (women).

The WWTP is designed for 213,000 population equivalent and it has a primary and secondary treatment operating with trickling filters. The WWTP receives urban wastewaters (including domestic wastewaters and hospital effluents — from the four mentioned hospitals) combined with rain waters. The biological treatment is performed by four trickling filters that work in parallel. They are 3 m high and 36 m in diameter, having a unitary volume of 3030 m^3.

Sampling campaigns were performed between February 2011 and May 2011, embracing a total of nine sampling periods for hospitals and seven for WWTP (influent and effluent). Samples from hospital effluents and WWTP wastewaters were collected in the same days, with the exception of two days where it was only possible to collect samples from hospital wastewaters (namely 28th March 2011 and 4th April 2011). Wastewater samples were collected in amber glass bottles previously rinsed with ultra-pure water as grab samples to hospital effluents, which were all collected at the same time frame (10–11 a.m.), and time proportional 24-h composite samples to WWTP influent and effluent. Samples were kept refrigerated (± 4 °C)