Pharmaceuticals in hospital wastewater: Their ecotoxicity and contribution to the environmental hazard of the effluent

Orias Frédéric *, Perrodin Yves

University of Lyon, ENTPE, CNRS, UMR 5023 LEHNA, 2 Rue Maurice Audin, 69518 Vaulx-en-Velin, France

HIGHLIGHTS

- 197 Pharmaceuticals were sought in hospital wastewater.
- PNEC are available in bibliography for 150 of them.
- Calculation of 127 hazard quotients has been performed.
- Hazardousness of pharmaceuticals is greatly variable.
- 15 Compounds are very hazardous for the environment.

ARTICLE INFO

ABSTRACT

Nowadays, pharmaceuticals are found in every compartment of the environment. Hospitals are one of the main sources of these pollutant emissions sent to wastewater treatment plants (WWTP) that are poorly equipped to treat these types of compounds efficiently. In this work, for each pharmaceutical compound found in hospital wastewater (HWW), we have calculated a hazard quotient (HQ) corresponding to the highest concentration measured in HWW divided by its predicted no effect concentration (PNEC). Thus we have assessed the contribution of each compound to the ecotoxicological threat of HWW taken as a whole. Fifteen compounds are identified as particularly hazardous in HWW. In future more attention should be given to their analysis and replacement in hospitals, and to their elimination in WWTPs. This work also highlights the lack of knowledge of the ecotoxicity of certain pharmaceutical compounds found in HWW at high concentrations (mg L^{-1}). In order to extend this study, it is now necessary to investigate ecotoxic risks linked to various emission scenarios, focusing in particular on dilution in the aquatic environment and the production of metabolites, especially during transit inside WWTPs.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Nowadays, pharmaceuticals (PCs) are ubiquitous in the environment. Indeed, several ecosystemic compartments are contaminated by these substances: the hydrosphere (surface water (Heath et al., 2010), groundwater (Loos et al., 2010), drinking water (Gibs et al., 2007)); the geosphere (Silva et al., 2011a,b Yang et al., 2011) and the biosphere (Lajeunesse et al., 2011).

Among the different sources emitting these PCs into the environment, hospitals are particularly interesting. This is because the numerous care activities performed inside these establishments (anaesthesia, anticancer treatment, diagnosis, etc.) lead to the consumption of large quantities of PCs. This intensive activity at a single point leads to high concentrations of PCs (through

excretion) in hospital wastewater (HWW), sometimes greater than in urban wastewater (Verlicchi et al., 2010).

HWW is almost always untreated before being discharged into urban wastewater networks and then into municipal wastewater treatment plants (WWTP) (Emmanuel et al., 2004) despite the fact that these plants are not designed to remove complex compounds such as PCs (Ternes, 1998; Heberer, 2002; Joss et al., 2005). Although some PCs entering WWTPs are removed (e.g. biodegradation or adsorption onto sludge), a sizeable amount is released into the environment (Verlicchi et al., 2012b).

Some of these PCs present a considerable threat for aquatic organisms even at very low concentrations. Given the great number of compounds measured in HWW (Orias and Perrodin, 2013), it is necessary to characterize their respective contributions to the hazardousness of effluents discharged into the environment, in order to rank them. This will make it possible to identify the pharmaceutical compounds on which hospital managers must focus their efforts in order to decrease their release into the

---

* Corresponding author. Tel.: +33 4 72 04 70 58; fax: +33 4 72 04 77 43.
   E-mail address: frederic.orias@entpe.fr (O. Frédéric).

environment and their potential impacts on aquatic ecosystems and/or on the activated sludges of WWTP.

In order to establish the compounds most concerned by the environmental hazardousness of HWW, we compare concentrations measured in HWW (Orias and Perrodin, 2013) to the available ecotoxicity data (PNEC: Predictive No Effect Concentration). A hazard quotient (HQ) is calculated for each compound, characterizing its level of involvement in the environmental hazardousness of HWW.

Finally, we make proposals in this work to improve knowledge on the environmental hazard of these compounds, and to assess the environmental risks linked to various scenarios of releasing treated HWW into the environment.

2. Materials and method

2.1. Determination of PC concentrations in HWW

Two main approaches can be used to determine the concentration of PCs in HWW: (i) a theoretical approach (Mullot et al., 2010; Escher et al., 2011) consisting in assessing the quantity of PCs that could be present in HWW (Predictive Effluent Concentration), considering various parameters such as consumption and excretion. The advantage of this method is that it takes into account every compound used in a hospital, but considerable uncertainty remains due to the parameters considered. The other approach (ii) is experimental (Verlicchi et al., 2012a; Perrodin et al., 2013) and consists in measuring the concentration of PCs directly in HWW. However, measuring every PC potentially present in HWW is very expensive. Moreover, limits of detection (LOD) are often too high to assess all ecotoxicological hazards as PNECs are regularly higher than LODs. Nevertheless, this type of approach provides real information on concentrations in the effluent.

In this work, we kept the highest concentrations of each PC already measured in HWW from a previous study (Orias and Perrodin, 2013), in order to obtain the "worst case" scenario. It should be noted that only one measure was made for several PCs. In the future, when more data is available, it could be relevant to study median values to evaluate "typical" concentrations of each PC in HWW.

2.2. Ecotoxicity of PCs in HWW (PNEC calculation)

In a previous study (Orias and Perrodin, 2013), PNEC's of PCs were calculated according to modelled ecotoxicological data using the ECOSAR method (Sanderson et al., 2003), experimental data from international databases (e.g. EPA ECOTOX, Wikipharma (Molander et al., 2009)) and also from the literature. These results are used in this study.

2.3. Involvement of each PCs in hazardousness of HWW (HQ calculation)

The involvement of PCs in the environmental hazard of HWW depends not only on its concentration in HWW but also on its ecotoxicity.

In order to identify and rank these PCs, a hazard quotient was calculated for each compound according to the equation below:

$$HQ = HWW_{max}conc./PNEC$$

With: HWW_{max} conc.: highest concentration ever measured in HWW in $\mu g\,L^{-1}$. PNEC: Predictive No Effect Concentration in $\mu g\,L^{-1}$.

The PC with the highest HQ will be considered that most involved in the hazard of HWW.

It is noteworthy that 172 of the 198 PCs sought in the HWW were detected. Of the 172 PCs detected, data was insufficient for 34 to calculate their PNEC. Finally, only 127 HQs were calculated.

3. Results

3.1. Type of available data

In the following paragraphs, the PCs are analysed according to their distribution in therapeutic classes (Table 1). These classes are those of the ATC (Anatomic Therapeutic and Chemical) classification proposed by the World Health Organisation Collaborating Center for Drug Statistics Methodology (WHOCC, 2011).

3.1.1. PC detection in HWW (Fig. 1)

PCs from classes J (antibiotic and antiviral) and N (anaesthesia compound, antidepressants, etc.) were those most sought for and detected in HWW, with 47 and 46 PCs detected out of 60 and 47, respectively. Furthermore, 22 of the 22 compounds of class C sought (Cardio-vascular system) in HWW were detected. We also found 12 anticancer PCs (class L) of the 16 sought, 11 compounds linked to the musculoskeletal system (class M) of the 14 sought and 9 sex hormones (class G) of the 10 sought. For each group V (various), A (Alimentary and tract metabolism) and D (Dermatologicals), 7 compounds were sought with 7, 6 and 5 detected, respectively. Finally, we found 5 compounds linked to the respiratory system (class R) of the 6 sought. It is noteworthy that among the PCs sought for in HWW, no compounds from classes B (Blood and blood forming organs), H (Systemic hormonal preparations, excluding sex hormones and insulins), P (Antiparasitic products, insecticides and repellents) and S (Sensory organs) were found.

3.1.2. Available PNECs

Of the compounds detected in HWW, considering every class, not enough or no ecotoxicological data was available for 22% of them, making it impossible to calculate a PNEC. Class N contained the most compounds for which no or insufficient data was available. Indeed, 14 PCs detected in class N (of 47) did not have a calculable PNEC. Two other therapeutic classes, i.e. classes V and G, drew attention due to the lack of ecotoxicological data. In class V, 7 out of 7 compounds were detected, but sufficient experimental and modelled data for calculating a PNEC could only be found for one of them. For 3 others, only modelised data were available. Moreover, for 2 compounds of this class, detected at concentrations ranging from a hundred $\mu g\,L^{-1}$ to a mg L^{-1}, there was no data on their ecotoxicity. Concerning 22 compounds classed as veterinary compounds sought in HWW, only 5 were detected. Indeed,

Table 1
Classes and codes of Anatomic Therapeutic and Chemical classification.

Code	Content
A	Alimentary tract and metabolism
B	Blood and blood forming organs
C	Cardiovascular system
D	Dermatologicals
G	Genito-urinary system and sex hormones
H	Systemic hormonal preparations, excluding sex hormones and insulins
J	Antiinfectives for systemic use
L	Antineoplastic and immunomodulating agents
M	Musculo-skeletal system
N	Nervous system
P	Antiparasitic products, insecticides and repellents
R	Respiratory system
S	Sensory organs
V	Various