Science of the Total Environment 572 (2016) 508–519

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Evaluation of human pharmaceutical emissions and concentrations in Swedish river basins

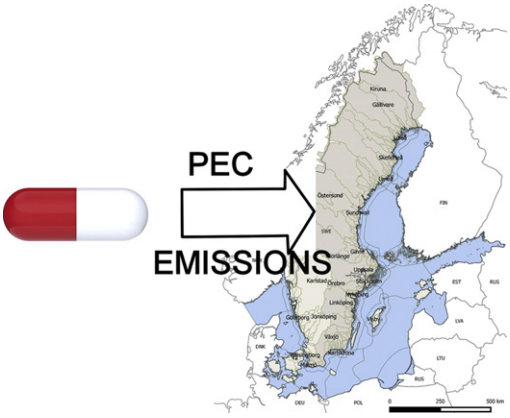
C. Lindim [a,*], J. van Gils [b], D. Georgieva [c], O. Mekenyan [c], I.T. Cousins [a]

[a] ACES - Department of Environmental Science and Analytical Chemistry, Stockholm University, SE-10691 Stockholm, Sweden
[b] Deltares, PO Box 177, 2600 MH Delft, The Netherlands
[c] Laboratory of Mathematical Chemistry, University "Prof. As. Zlatarov", 8010 Bourgas, Bulgaria

HIGHLIGHTS

- An emissions inventory of 54 human pharmaceuticals was done for Sweden.
- The top ten emitted pharmaceuticals are emitted in loads >0.5 ton/y.
- Metformin, Gabapentin and Atenolol had the highest emissions to both water and soil.
- Concentrations in water of the most consumed pharmaceuticals were predicted.
- Predicted water concentrations were >100 ng/L for 4 substances in Stockholm area.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 1 July 2016
Received in revised form 10 August 2016
Accepted 11 August 2016
Available online 24 August 2016

Editor: D. Barcelo

Keywords:
Pharmaceuticals
Swedish basins
Emissions
PEC
Wastewater

ABSTRACT

An emissions inventory for top consumed human pharmaceuticals in Sweden was done based on national consumption data, human metabolic rates and wastewater treatment removal rates. Concentrations of pharmaceuticals in surface waters in Swedish river basins were predicted using estimated emissions from the inventory and river discharges. Our findings indicate that the top ten emitted pharmaceuticals in our study set of 54 substances are all emitted in amounts above 0.5 ton/y to both surface waters and soils. The highest emissions to water were in decreasing order for Metformin, Furosemide, Gabapentin, Atenolol and Tramadol. Predicted emissions to soils calculated with the knowledge that in Sweden sludge is mostly disposed to soil, point to the highest emissions among the studied drugs coming from, in decreasing order, Metformin, Paracetamol, Ibuprofen, Gabapentin and Atenolol. Surface water concentrations in Sweden's largest rivers, all located in low density population zones, were found to be below 10 ng/L for all substances studied. In contrast, concentrations in surface waters in Stockholm's metropolitan area, the most populous in Sweden, surpassed 100 ng/L for four substances: Atenolol, Metformin, Furosemide and Gabapentin.

* Corresponding author.
E-mail addresses: claudia.lindim@aces.su.se (C. Lindim), Jos.vanGils@deltares.nl (J. van Gils), denitsa_georgieva@btu.bg (D. Georgieva), omekenya@btu.bg (O. Mekenyan), ian.cousins@aces.su.se (I.T. Cousins).

http://dx.doi.org/10.1016/j.scitotenv.2016.08.074
0048-9697/

1. Introduction

Surveys show that there is global contamination of water resources by pharmaceutical compounds (IWW, 2014; Hughes et al., 2012) with their major source cited as wastewater treatment plants (WWTPs). A 2014 review shows that >600 pharmaceuticals have been detected in surface waters of 71 countries worldwide (IWW, 2014). The Baltic Sea and the rivers discharging to it are no exception, with water contamination by pharmaceuticals found in all countries in the basin (Borecka et al., 2015; Beck et al., 2009; Bendz et al., 2005; Helcom, 2010).

Pharmaceuticals are a diverse group of substances used to prevent or treat diseases. After intake, these compounds are metabolized with significant fractions of the compound excreted and entering WWTPs. Currently, urban wastewater treatment is not efficient enough to remove most pharmaceuticals from wastewater and sludge (Deblonde et al., 2011). As a result these contaminants are continuously discharged to waterbodies or are distributed to sewage sludge, often later used as soil fertilizer (Kasprzyk-Hordern et al., 2009). Many pharmaceutical substances have already been shown to produce adverse effects on aquatic and terrestrial organisms (Schnell et al., 2009). In particular, synthetic estrogens have

Fig. 1. Swedish basins discharging to the Baltic Sea and the Danish Strait (dark grey).