Policy brief on pharmaceuticals

Pharmaceuticals in the environment – the problem which is calling for urgent actions

Baltic Marine Environment Protection Commission

What are pharmaceuticals?

Pharmaceuticals are natural or synthetic substances of various chemical composition which are used in the diagnosis, treatment, or prevention of diseases and for restoring, correcting, or modifying organic functions. Most pharmaceuticals are designed to function at low concentrations so that they can be tolerated by the human or animal body, and to last long enough to have their intended effect. Pharmaceuticals are classified into different therapeutic groups according to their chemical characteristics, structure and how they are used to treat specific disease. Pharmaceuticals are vital for well-being of modern society as the treatment of many diseases in humans and animals relies on effective pharmaceuticals.

Industrial releases of pharmaceuticals can be major local sources of active pharmaceutical ingredients (APIs) to the environment (e.g. Fick et al. 2009), and industrial emissions can increase the API load received at wastewater treatment plants (WWTPs) (Scott et al. 2018). For the Baltic Sea region, comprehensive estimates on industrial emissions are currently lacking. WWTPs are considered as a major pathway of pharmaceuticals to the environment in the Baltic Sea region. Pharmaceuticals occur in municipal wastewater as they are excreted or washed off as well as intentionally thrown away into sinks and toilets. As pharmaceuticals are also widely used in veterinary medicine or even prophylactically in animal husbandry and fish farms, spreading manure or releases from aquaculture are important pathways to the environment. Potentially, pharmaceuticals can leak into the environment from landfills.

Since pharmaceuticals are designed to affect biological processes at low concentrations, their occurrence in the environment directly affects the ecological balance. Some of them are also persistent in the environment, spread through water and soil and accumulate in sediments, plants and wildlife. Furthermore, the metabolites of some pharmaceuticals can transform back into the active substance in WWTP conditions and in the environment. Some pharmaceuticals have toxic effects to biota, such as endocrine disruption properties which cause problems in e.g. reproduction. Antimicrobial (antibiotic and antifungal) pharmaceuticals may play a role in accelerating the development, maintenance and spread of resistant bacteria and fungi. However, in many cases environmental effects of pharmaceuticals are not well known. Also, the possible combined effects from exposure to many pharmaceuticals and other chemicals is not well known.

Pharmaceuticals are recognized as contaminants of emerging concern in the 2021 Baltic Sea Action Plan. It includes a number of actions aimed to improve existing knowledge on the occurrence and environmental effects of pharmaceuticals (HL22, HL24), make this knowledge available for broad expert society (HL22), identify priority substances (HL23) and undertake actions to mitigate the release of pharmaceuticals to the marine environment (HL25-27).

Observed facts

Data on pharmaceuticals in wastewater treatment plants in the Baltic Sea region was compiled through HELCOM data calls (2015 and 2018) and processed within the CWPharma project. The final dataset contained over 10 000 measurements from Denmark, Estonia, Finland, Germany, Latvia, Poland and Sweden, covering altogether over 100 WWTPs.

The reported data covers altogether 117 individual APIs, which were divided into 11 therapeutic groups. Two thirds of the reported data concern substances from three groups: anti-inflammatory and analgesic substances, antimicrobial and antiparasitic, and hormones and hormone antagonists.

Antimicrobial and antiparasitic APIs

Out of the 29 APIs classified as antimicrobial and antiparasitic, 24 were detected in at least one sample. Most of the data (more than 400 data points for each API) were reported for sulfamethoxazole, trimethoprim, triclosan and sulfamethizol, with detection frequencies ranging from 72% to 100%. The detection frequencies of erythromycin, ciprofloxacin, clarithromycin and azithromycin, included in the updated Water Framework Directive (WFD) watch list (DIRECTIVE 2013/39/EU), fall within the same range. Concentrations of the latter set of APIs in effluents is somewhat lower than in influents. However, the average concentrations of erythromycin, clarithromycin and azithromycin in effluent water exceed the proposed annual average Environmental Quality Standards (AA-EQSs). Concentrations in sludges vary widely between APIs but the highest are displayed by ciprofloxacin and tetracycline which were detected in sludge in all samples.

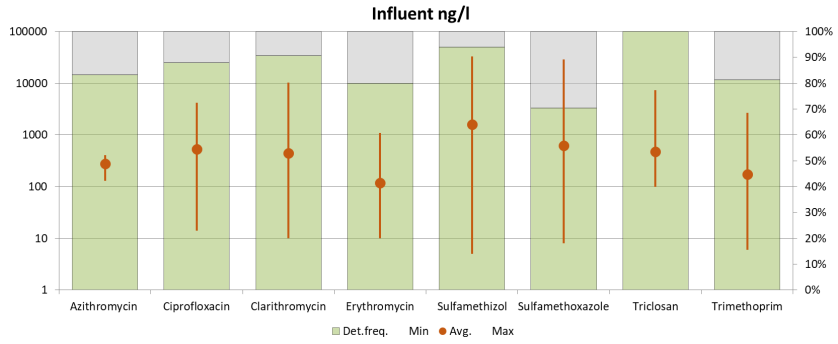
Anti-inflammatory and analgesic APIs

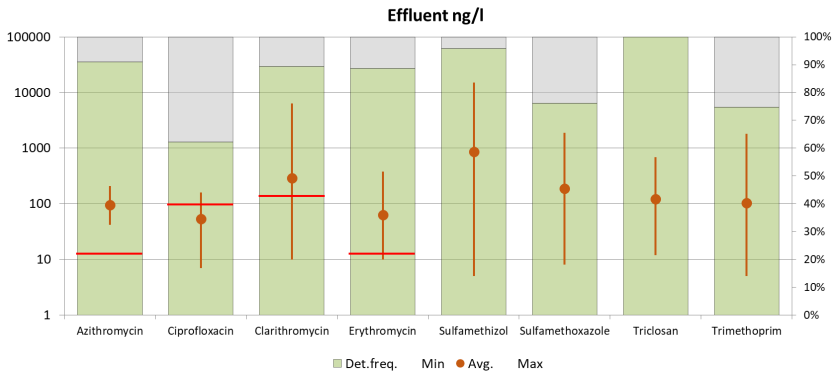
Out of the 17 APIs categorized as anti-inflammatory and analgesic substances 13 were found in at least one sample. Most of the countries reported data on ibuprofen, paracetamol, diclofenac, naproxen and ketoprofen. They were detected in about 80% of samples from influents, sludge and effluents. Average concentrations of ibuprofen, paracetamol and naproxen in effluents were tenfold lower than in influents. However, diclofenac and ketoprofen demonstrate reverse tendency. For example, average concentration of ketoprofen in effluents were several times higher than in inflowing sewage water. Average concentrations of ibuprofen, paracetamol and naproxen in sludge several times exceed 100 ng/g dry weight (dw). Concentration of diclofenac proposed as EQS for HELCOM pre-core indicator is exceeded in 93% of quantified samples, and in average is fifty times higher than the EQS while individual measurements reveal thousand-fold exceedances.

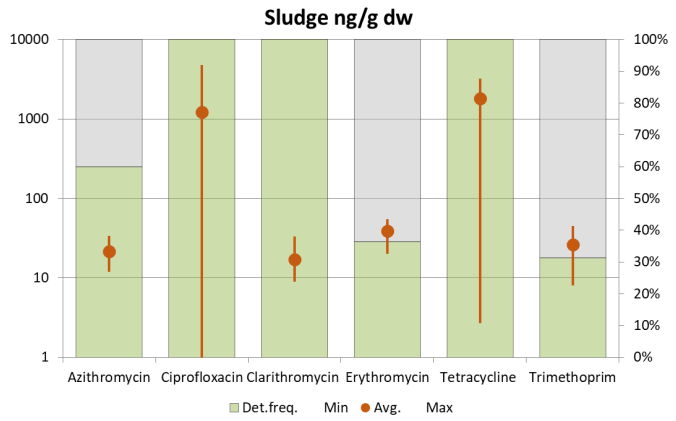
Hormones and hormone antagonists

Out of the 15 APIs classified as hormones and hormone antagonists, 11 were detected at least in one sample. The most frequently reported are 17β-estradiol, 17α-ethinylestradiol and estrone, detected in 54, 36 and 82 percent of samples respectively. These three hormones are in the Water Framework Directive watch list (DIRECTIVE 2013/39/EU). Average concentrations of these hormones in effluents are approximately one tenth of that in influents. However, their average concentrations in effluent samples still exceed AA-EQSs more than ten-fold, with individual samples showing over hundred-fold exceedances. The reported analytical detection limits for 17β-estradiol and 17α-ethinylestradiol are higher than their respective AA-EQSs.

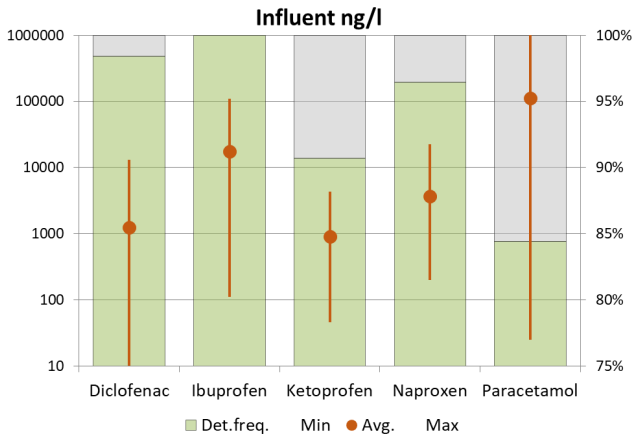
A. Antimicrobial and antiparasitic APIs



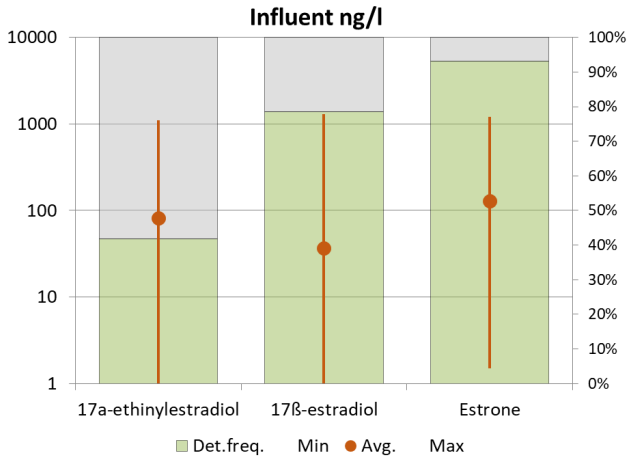


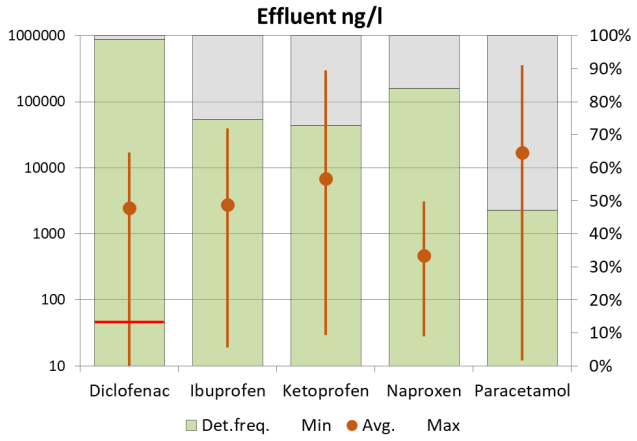


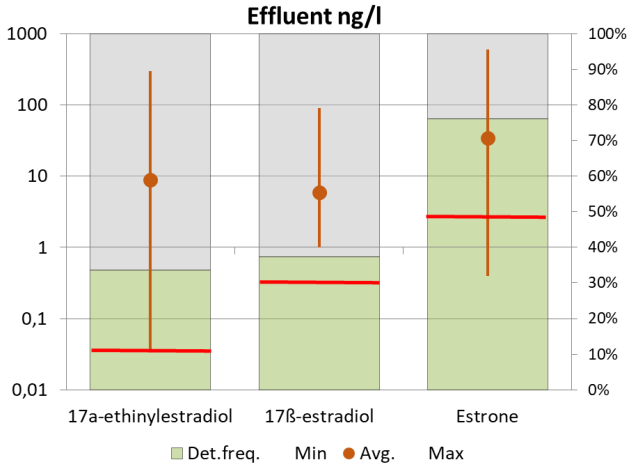
B. Anti-inflammatory and analgesic APIs

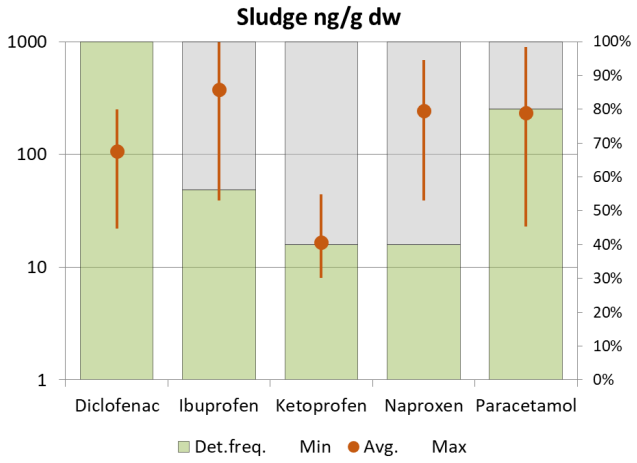


C. Hormones and hormone antagonists









Concentrations of antimicrobial and antiparasitic APIs (A), anti-inflammatory and analgesics (B) and hormones (C) in WWTP influent, effluent and sludge samples. Only concentrations above limit of quantification (LOQ) are reflected. Red lines in graphs A and B indicate AA-EQSs for inland waters given in DIRECTIVE 2013/39/EU, red line in graph B indicates threshold for HELCOM pre-Core indicator on diclofenac. Note the different scales of y axis in influent, effluent and sludge in some of the graphs. EQS values are used here for indicative comparison but not for the assessment of contamination level.

Key messages

The collated and analysed data on pharmaceuticals in WWTPs – derived from influents, effluents and sludge – is the most comprehensive compilation of this type of data in the Baltic Sea region. However, the analysis demonstrates that large knowledge gaps still exist. For example, several active pharmaceutical ingredients are only analysed in one of the three matrices, but to assess the environmental impact of the micropollutants, and the need for measures to remove them, a holistic overview on their presence and concentration levels in influents, effluents and sludge alike is needed, as well as better geographical coverage.

A database containing information on the occurrence and concentrations of APIs in wastewater, inland surface waters, ground waters and in the marine environment is to be established and made available for expert community. This would help creating a scientifically sound basis for strengthening the management cycle for this group of hazardous substances. This database would also serve as the main source of information for the development of respective indicators of the state of the Baltic Sea or advancement of existing ones (e.g. diclofenac).

Low removal level of APIs from wastewater, limited capacity to restrict their use and their continuous input to the aquatic environment prominently show the need of more measures to minimize their release. These measures should not only be focused on improving technologies at WWTPs to increase their removal efficiency but also target pharmaceuticals at their source (e.g. prescription, consumption reduction, responsible handling and disposal, pretreatment for large hospitals and pharmaceutical manufacturers) (e.g. Thisgaard et al. 2020).

The assessment of risk caused by pharmaceuticals to the environment requires comparison of their concentrations in environmental samples to relevant ecotoxicological data. This demands further investigation of environmental effects of various APIs and identification of their non-effect concentrations. Since distribution of manure or the use of sewage-based recycled products might be a pathway for some pharmaceuticals to the aquatic environment, respective safety standards are to be developed.

Detection limits and analysis methods should be aligned among countries. Analytical methods sufficient to detect APIs at concentrations close to respective environmental quality standards should be applied throughout the region.

Concentrations of almost all most frequently reported pharmaceuticals, for which environmental quality standards (EQS) in river waters have been proposed, demonstrate high level of exceedance of these EQSs in WWTPs effluents. Even the limited data compiled proves that active pharmaceutical substances, including those with scientifically proven environmental effect, are continuously released.

In general, many substances rom all 11 studied therapeutic groups are frequently detected, demonstrating concentrations in effluents at similar level as in influents. In some cases, such as diclofenac and ketoprofen, concentrations in effluents are even higher than in influents. It demonstrates that conventional wastewater treatment is not efficient for removing pharmaceuticals from wastewater.

References

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PLATFORM BSR WATER

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