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Limit of Sulfamethoxazole in wastewater

Contents

Foreword

The Standard Student Society (SSS) is a newly formed federation of student standard bodies. Each member body interested in a subject in which a technical committee has been established, has the right to be represented in the committee.

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Introduction

Water is the most valuable and the most sensitive resource in the world. The pollution of surface water becomes a global problem and pollution of drinking water reservoirs is a rising threat. Pharmaceuticals in the water are currently not cleaned out in most municipal wastewater treatment plants worldwide. Pharmaceutically active compounds were found to have ecotoxic effects on aquatic organisms. Furthermore specific compounds have a high persistence in certain aquatic organisms and bear the risk of bioaccumulation. Besides other risks antibiotic substances released over the effluent wastewater treatment plant can lead to antibiotic resistances in microbial populations.
Due to not standardized no effect concentrations in the water and non standardized detection methods the base for international regulations is missing. This standard addresses the common understanding of threatening concentrations of antibiotics in wastewater in particular Sulfamethoxazole.
With this standard the authors address the following sustainability goals:

Limit of Sulfamethoxazole in wastewater

1. Scope

This document specifies a standard no effect limit of sulfamethoxazole in the wastewater treatment plant effluent.

2. Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

3. Terms and definitions

For the purpose of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at electropedia.org/
- ISO Online browsing platform: available at iso.org/obp

3.1
persistance
residence time of a chemical species in a specifically defined compartment of the environment

[SOURCE: ISO 15473:2002(en), 3.5]

3.2
nitrification
oxidation of ammonium salts by bacteria where usually the intermediate product is nitrite and the end product nitrate

[SOURCE: ISO 11733:2004(en), 3.9]

3.3
denitrification
reduction of nitrate and nitrite to the end product nitrogen (in the form of the gas) by the action of bacteria

[SOURCE: ISO 11733:2004(en), 3.6]

3.4
bioaccumulation
process of accumulation of a substance in organisms or parts

[SOURCE: ISO/TR 19057:2017(en), 3.1]

3.5
retention time
tR
time between injection of the solute and the vertex of the supposed symmetrical peak

[SOURCE: ISO 8974:2002(en), 4.5]

3.6
PNEC
predicted no-effect concentration
concentration of a substance determined from hazard assessment by applying a suitable assessment factor, below which no adverse effect to a defined environment is anticipated

Note 1 to entry: It is calculated by dividing toxicological dose descriptors by an assessment factor (4.1).

Note 2 to entry: The typical units are mg/L or mg/kg.

[SOURCE: ISO 13073-1:2012(en), 2.16]

3.7
NOEC
no observed effect concentration
highest tested concentration of a test substance at which no statistically significant lethal or other effect is observed when compared with the control

[SOURCE: ISO 13073-1:2012(en), 2.14]

4. Consequences of Sulfamethoxazole in the environment

Sulfamethoxazole (SMX) has been documented as a contaminant in wastewater streams, surface water and groundwater. Besides the detection in the water SMX also has been detected in sludge as well as in fish (P. Hallgren, P. Wallberg). River water samples were analysed in Germany, where concentrations up to 10 mg/L of SMX was detected (UNESCO and HELCOM, 2017).
Antibiotics are designed not to degrade easily, which is why they will accumulate in the environment. The water streams with antibiotics will be highly diluted, and therefore the antibiotics will occur in low concentrations. Due to their persistent occurrence in low concentrations, the toxic effects on the environment are more likely to be chronic rather than acute (Ferrari et al.).
Concerning the persistence of SMX, it has been shown that antibiotic resistance is promoted in the time frame of natural degradation of SMX in the environment (Patrolecco et al. 2018). In the study performed with SMX in river water, it was found that the shortest time for total degradation of the antibiotic was 28 days in the presence of active microorganisms and UV-light, where after 21 days 70% of the initial antibiotic concentration was measured (Patrolecco et al. 2018). It was further found that at a concentration of 500 µg/L, the resistance of natural bacterial populations is promoted in the time frame of 28 days.
SMX belongs to the group of sulfonamides, which have been found to induce a change in microbial diversity by reducing not only microbial biomass but also the relationship between bacteria and fungi [92]. As regards the nitrogen cycle, it is known that several prokaryotes perform denitrification and nitrification by ammonium-oxidising Bacteria and Archaea (AOB and AOA) [79]. Environmentally significant concentrations of fluoroquinolones and sulfonamides could partially inhibit denitrification, and the application to the soil of swine manure containing the antibiotic tylosin has been shown to change the behaviour of nitrogen mediated by these microbial communities [79,111]. Overall, the lack of standardised tests hinders generalisations about the effects of antibiotics on biogeochemical processes.

5. Test methods to determine the concentration

The emerging problem of pharmaceutical residues found in aquatic environments demands the development of both fast and sensitive analytical methodologies. These analytical methods are needed to screen not only for SMX but also for different kinds of pharmaceuticals found in wastewater. Among the recent methods developed different types of Liquid Chromatography (LC) to determine concentrations are used. This section aims at summarizing some of the recent advances made in this field.
From the most recent methods is the use of Liquid Chromatography–Tandem Mass Spectrometry (LC-MS). Eleni Botitsi (2017) and her team in the General Chemical State

Laboratory exploited the analytical method of LC-MC in which the identification of the target compounds was determined by its LC retention time(tR) along with the transitions states ratio. This was followed by MS detection of the target with the two most intense peaks. In order to quantify the concentration of the compounds, a calibration plot ranging between 0.1 µg/L–100 µg/L (2 pg–2000 pg injected) was then used to extrapolate the results using the most intense transition state analyte.
A second method in reference to *M.Sharfshir & D.Avisar (2012*), employs solid phase extraction prior to determining the concentration using HPLC–MS/MS. The antibiotic was firstly extracted using ultrasonic solvent extraction. This was then followed by tandem-solid-phase extraction for cleanup then performing a strong anion exchange plus hydrophilic–lipophilic balance. Thereafter for quantifying the antibiotic concentration, HPLC-MS/MS was used with an electrospray ionization source. The noted recoveries for sulfonamides, which includes SMX were 11-31%.
The third method, developed by Teixeira (2008) and her team, directly injected samples using HPLC with diode array detection (DAD). The advantage stated is an added ability of fast screening a large number of samples. This in turn reduced the complexity employed by other methods through significantly reducing sampling. Recovery was also notably higher, ranging from 90 to 109%.

6. Limits of Sulfamethoxazole in wastewater

The predicted no effect values (PNECs) in current publications shall serve as standard values for the limit of SMX in the effluent of wastewater treatment plants. Based on the NOEC of the most sensitive organism namly the cyanobacterium a chronic-based aquatic deterministic PNEC of 520ng/L of SMX in the effluent shall be set as a standard limit (Straub, 2015).
Although the effect of SMX on antibiotic resistance in aquatic bacterial populations are still a research objective the following section gives an overview about risks and the need for further regulations.

7. Regulations, needs and alternative solutions

SMX has seen to be present in high concentrations in water effluents in the Baltic Sea. SMX is thought to be persistent in the environment due to its capability to avoid degradation by conventional biological treatments of wastewater (Vidales et. al, 2012).
SMX is shown to promote antibiotic resistance in bacterial populations in river samples (dose 500 µg/L), emphasizing the importance of reducing the levels in water effluents (Patrolecco, 2018).
Due to the lack of monitoring of pharmaceuticals in Europe, with Switzerland being the only country in Europe regulating the measuring of pharmaceuticals in wastewater, there has been a limited numbers of studies investigating the occurrence of SMX in water effluents (Johansson, 2014). As a matter of fact, SMX presence has been detected and described in

environmental samples in these few studies, being always ranked among the top 5 antimicrobial compounds found (UNESCO and HELCOM, 2017). For example, the UNESCO report detected SMX in all matrices analyzed: SMX concentrations were detectable in 50% of the tested sediments, in 25% of the tested biota samples and in 9% of the water samples.
This is a problem that is arising also for other pharmaceuticals. This year, The European Commission updated the watch list of pharmaceuticals in surface waters, based on the report made by Joint Research Centre (JRC). On this watch-list, other antibiotics such as ciprofloxacin and macrolide antibiotics could be found, stressing the importance of regulating and degrading antibiotics in the marine environment. However, other classes of pharmaceuticals were also of interest, such as the steroid hormones 17-Alpha-ethinylestradiol (EE2), 17-Beta-estradiol (E2) and estrone (E1) (Loos et. al, 2018).
The JRC report is not only pointing out the importance of monitoring the pharmaceuticals according to abundance in waters, but the damage that they can do. Steroid hormones have shown to be potent in causing breast cancer in the environment. However, as Adeel et. al. mentions, there is a lack of knowledge within the topic to draw strong conclusions about the direct effect of estrogens in the environment, and the impact that they lead to (Adeel et. al, 2017). This further highlights the importance of regulations of pharmaceuticals in waste waters, and what the lack of knowledge could mean to the food chain, from marine life to human.
In addition, there is still a gap to standardize protocols for sampling and for analytically determining the pharmaceuticals found in water. First there is a need to fill this first gap in the beginning of this process and acquire comparable and informative data (WHO, 2011). Risk assessments are essential in the process and there should be standardized protocols to accurately assess the current risk.

As a prospective project, take-back procedures have been implemented by private and government organizations in some countries to decrease the quantity of pharmaceuticals being introduced in the environment (Teleosis Institute, 2009). One example is the Return Unwanted Medicines (RUM) Project in Australia: funding was used to create a new system for the collection and disposal of unused pharmaceuticals, which were subsequently incinerated in accordance to established guidelines (RUM, 2011). Additionally to these programs, rising awareness in the customers through different commercial campaigns could indirectly help in the solution of this problem.

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