Fate of Pharmaceuticals in the Urban Hydrological cycle

Challenges of Prevention and Abatement in Developing Countries

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Abstract

Recently, a significant number of studies regarding the environmental occurrence and fate of pharmaceuticals and personal care products used in developed countries have been published. In developing countries, different therapeutic groups are frequently used without any knowledge of their behavior in the aquatic and terrestrial ecosystems.

This study, with the support of a pharmaceutical company in Nairobi, Kenya, analyzed the biodegradation potential of 19 selected pharmaceuticals typical for the developing world. The test method was based on the OECD 301 guidelines, and OxiTop-C system was employed in the measurement.

Only 3 drugs of the19 were readily biodegradable. All of the tested anti-HIV drugs, antimalarials, antiparasitics, antifungals, antituberculotics, antibacterials, antiulceratives and antiepileptics were found non-degradable, potentially persistent in the environment, or affecting the efficiency of WWTP.

Introduction

Pharmaceuticals and Personal Care Products (PPCPs) in the urban hydrological cycle have been recognized as a potential environmental problem. The research on the occurrence and fate of PPCPs in the aquatic and terrestrial ecosystems have been particularly active in Europe and the USA. Futhermore, the pressure to develop innovative methods to improve the removal efficiencies of the anthropogenic pollutants from the hydrologic cycle is increasing. Recent studies provide sufficient knowledge on the PPCPs commonly used in developed countries. However, the use, occurence, fate, biotic and abiotic degradation of therapeutics used in developing countries has not been widely studied. In other words, the ecotoxicological knowledge on PPCPs such as antimalarials, antiretrovirals, antituberculotics and antiparasitics is incomplete.

The main objective of the study was the biodegradability analysis of selected pharmaceuticals in order to identify refractory compounds. These refractory compounds with low biodegradation are suspected potentially persistent pollutants.

Method

The Closed Bottle Test (CBT) was used to measure the Biological Oxygen Demand of activated sludge bacteria for complete oxidation of the tested compound.

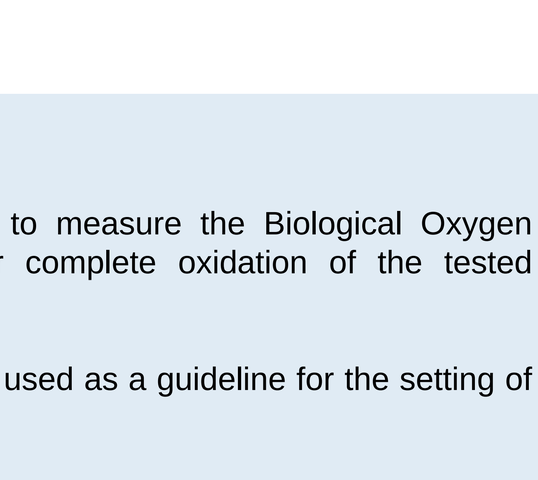
The OECD 301 B – CO_2 evolution test was used as a guideline for the setting of test conditions.

Each pharmaceutical compound was tested in 3 replicates in a solution of artificial wastewater (OECD 301) and compound concentration of 50mg/l. The resulting values were corrected to the blank BOD, which presents the endogenous BOD value caused by organic matter other than the tested compound.

As inoculum, 0,5ml of filtered activated sludge sampled from Viinikanlahti wastewater treatment plant, Tampere, Finland was used. Nitrification bacteria were inactivated by addition of ATU (N-Allylthiourea) in a concentration of 20drops/l. Tests were performed at 20±1°C in the dark for a time period of 7 and 28 days. Carbamazepine and dextrose monohydrate were used as system reference compounds.

Measured BOD values were compared to calculated Theoretical Oxygen Demand (ThOD) to obtain the degradation percentage.

OxiTop – C® system was used to measure the evolved carbon dioxide, and the results were presented as Biological Oxygen Demand (O_2mg/l).

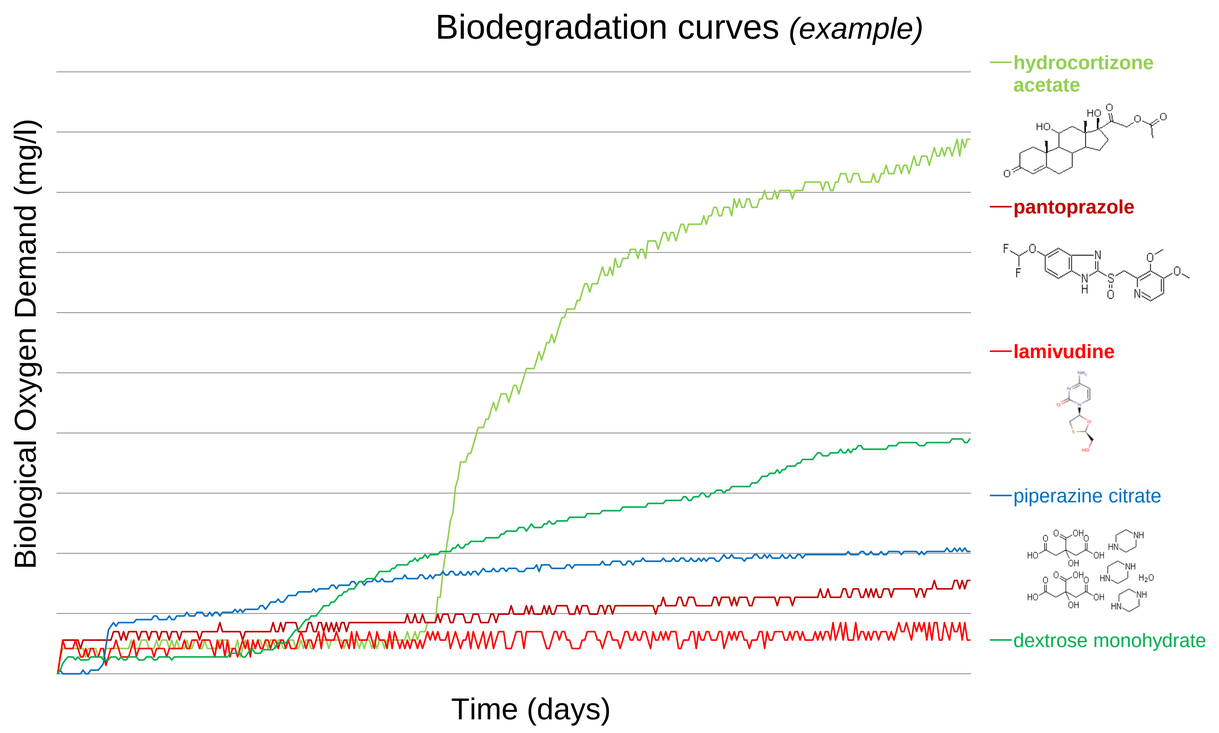


Evaluation

Based on OECD, a readily biodegradable compound has to reach a BOD greater than 60% within 28 days.

Biodegradation during wastewater treatment (WWT) is the main process of organic matter removal. Therefore, biodegradation is assumed to be a main removal process for pharmaceuticals as well. OxiTop - C measurement in a closed bottle simulates the biological processes of WWT. Any disturbance in the simulated process or low BOD value points to possible disturbances in the WWT processes, inhibition of bacteria, toxic effects and potentially persistent compounds.

Results



Readily biodegradable
Degradable
Non-degradable (inhibitory and toxic compounds)

Antiepileptic	Carbamazepine (ref.)
Anti-HIV drugs	Lamivudine Nevirapine Zidovudine
Antimalarial	Amodiaquine Quinine Sulphate Pyrimethamine
Anthelmintic	Piperazine Citrate
Antibacterial	Mebendazole Levamisole Ethambutol Metronidazole Benzoate Ofloxacin
Antifungal	Ketoconazole
Antitubercular	Isoniazid
Anti-inflammatory	Aspirin
Antiulcerative	Pantoprazole
Other	Hydrocortisone acetate Dextrose monohydrtate (ref.)

Conclusions

19 selected pharmaceuticals used frequently in developing countries were tested on their biodegradability. The OxiTop-C measuring system simulating the biological processes during WWT was used as a test method.

3 tested pharmaceuticals were found readily biodegradable (aspirin, hydrocortizone acetate, and dextrose monohydrate (ref.)).

Degradation of 2 compounds ranged between 25-35% (piperazine citrate, metronidazole benzoate).

14 compounds were found inhibitory or toxic to activated sludge bacteria. These compounds are expected to pass WWTP and enter the environment. Furthermore, these chemicals are used in large quantities, and resistant strains of target organisms have been found. Finally, inhibitory and toxic compounds can decrease the efficiency of the WWTP and cause secondary pollution due to low bacterial activity.

14 compounds were found to be refractory compounds posing a large risk to the aquatic and terrestrial ecosystems.

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