WATER REUSE MANAGEMENT

IS PHARMACEUTICAL POLLUTION A REAL PROBLEM?

INTRODUCTION

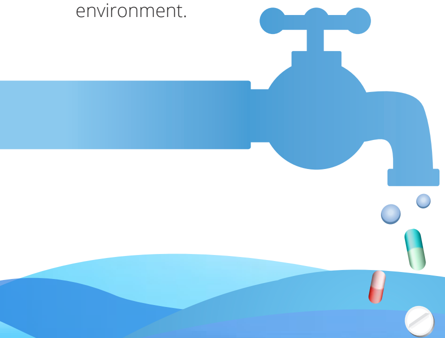
Water scarcity and droughts currently affect many European regions.[1] Statistics show that by 2007, at least 11% of European citizens and 17% of Europe's territory had been affected by a scarcity in water supply. It is estimated that droughts in Europe over the past thirty years have incurred costs of up to €100 billion. This situation is expected to worsen due to climate change but water reuse could pose a possible solution, if properly explored.[1,2]

Water reuse refers to the use of treated wastewater to increase the available water supply in communities while ensuring high quality, especially in times of drought.

In 2012, the European Commission (EC) announced its intention to tackle the issue of water scarcity and reuse, and supported the need for increasing water reuse in its Communication, A Blueprint to Safeguard Europe's Water Resources.[3]

At present, the EC is working to develop minimum quality requirements for water reuse in the EU, taking into consideration the fate of emerging contaminants* after irrigation with reclaimed wastewater.[4] Pharmaceuticals are among the long list of emerging contaminants that show persistence and can bioaccumulate in different environmental compartments. Their presence in treated wastewater should therefore be accurately addressed.

* Emerging contaminants include substances that are persistent, bioaccumulative, and toxic (PBTs), persistent, mobile and toxic (PMTs), very persistent and very bioaccumulative, as well as substances affecting endocrine-related functions. These chemicals are not commonly monitored in the environment, but can enter the environment and cause predictable or unpredictable side effects to both human health and the environment.



WASTEWATER TREATMENT EFFLUENTS ARE PARTICULARLY PROBLEMATIC

The presence of emerging contaminants, particularly pharmaceuticals, in effluent from wastewater treatment plants (WWTPs) has been extensively described in the recent scientific publications.[5,6,7]

Current wastewater treatment methods can only partially remove pharmaceuticals, meaning residues are still present in effluent. Examples of residues detected in effluent include:

- Lipid regulators, anti-inflammatories, and antibiotics, which have been found in influents and effluents of WWTPs in Portugal.[8]
- Anti-inflammatories such as ibuprofen and diclofenac, the antibiotics erythromycin and oxytetracycline, and the female sex hormone 17b-estradiol have all been found in the final effluent of WWTPs in the UK.[9]

In both cases, the concentrations of these drugs were high enough to potentially cause harm to ecosystems.

Even low concentrations of pharmaceuticals have harmful effects on animal and plant life. Some of the effects of pharmaceuticals in the environment described in research are:

- Residues of diclofenac, an anti-inflammatory drug, can cause renal failure in vulture populations feeding on carcasses of cattle treated with the drug. As a consequence the vulture population in the Indian subcontinent declined by 80-99% between 2003-2004[10]
- The contraceptive drug ethinylestradiol can impair reproduction in fish population[11]
- The antibiotics enrofloxacin and ciprofloxacin have toxic effects and can inhibit the growth of aquatic species such as cyanobacterium and duckweed[12]

Disinfection processes at WWTPs cannot completely inactivate local microorganisms, which are able to regrow post treatment when they find favourable conditions.[13,14,15]

In addition, very little is known about the fate of antibiotic resistant bacteria and antibiotic resistance genes in soil after irrigation with wastewater. Scientific evidence suggests that some antibiotic resistant bacteria can proliferate in soil or plants, behaving as an invasive species and some antibiotic resistance genes can be transferred** from wastewater bacteria to soil or plant bacteria.[16]

WHAT FACTORS DETERMINE THE EFFICIENCY OF REMOVING PHARMACEUTICALS FROM WASTEWATER?

1. **The chemical composition profile of a pharmaceutical** – for example, the size of the molecule, the chemical structure of both the active pharmaceutical substance, and the excipients (i.e. the substances with no medicinal effects which are also added to pharmaceuticals)
2. **The specific wastewater treatment process applied**
3. **The initial concentration of pharmaceuticals in the influent**[4] - for example, the influent from hospitals has high concentrations of pharmaceuticals, so their removal at WWTPs can be very challenging

To give just one example of the difference in efficacy of pharmaceutical removal - after wastewater treatment ibuprofen has a removal rate of >90%, while carbamazepine has a rate of <10%.[17]

** This is achieved through a mechanism called horizontal gene transfer, which is the main mechanism for the spread of antibiotic resistance in bacteria.

THE ADDED PROBLEM OF TRANSFORMATION PRODUCTS

Some pharmaceuticals can have a high removal rate, but their transformation products*** are of particular concern. For example, metformin - the most commonly prescribed drug in the treatment of diabetes - can theoretically be removed with a potential >98% success rate in sewage treatment plants. During water treatment, however, metformin can be transformed to guanylurea, its transformation product. In this form, 82% of the metformin initially present in wastewater can be detected in effluent after treatment.[18]

*** Most pharmaceuticals undergo changes to their chemical structure before excretion, while passing through human or animal bodies, resulting in metabolites. After excretion, both active pharmaceutical ingredients and their metabolites will be present in the environment where they can further undergo changes to their chemical structures due to naturally occurring processes and technological processes (i.e. effluent treatment). These changes result in what are known as transformation products.

WASTEWATER TREATMENT TECHNOLOGIES ARE NOT YET ADVANCED ENOUGH TO DEAL WITH THE PROBLEM

Although some recent research has been conducted into wastewater treatment technologies and the factors that influence the removal of pharmaceuticals, innovation is needed in this field in order to minimise pharmaceuticals entering into the environment.

For example, one method of wastewater treatment used for drinking water that combines ozone and granular activated carbon was proved effective in removing most antibiotics.[19] This treatment, however, is not as effective at removing other drugs, such as the antiviral drug acyclovir. The oxidation of acyclovir and its biotransformation product carboxy-acyclovir by ozone actually results in a stable but toxic transformation product called COFA.[20] COFA was shown to be toxic for Vibrio fischeri sp. - a bacteria that can be naturally found in seawater and fresh water.[20]

PHARMACEUTICAL POLLUTION IN WASTEWATER AND SOIL

In order to provide the nutrients essential to support plant life, manure and sludge are added to soil during the so-called "amending process". In areas with high water scarcity, irrigation in agriculture is achieved using reclaimed wastewater.[4] This is particularly problematic, however, as sludge, manure, and wastewater have all been shown to contain a series of contaminants, including pharmaceuticals.[21]

Irrigation with reclaimed wastewater may result in high levels of pharmaceutical pollution, particularly from pharmaceuticals that have relatively high solubility in water.

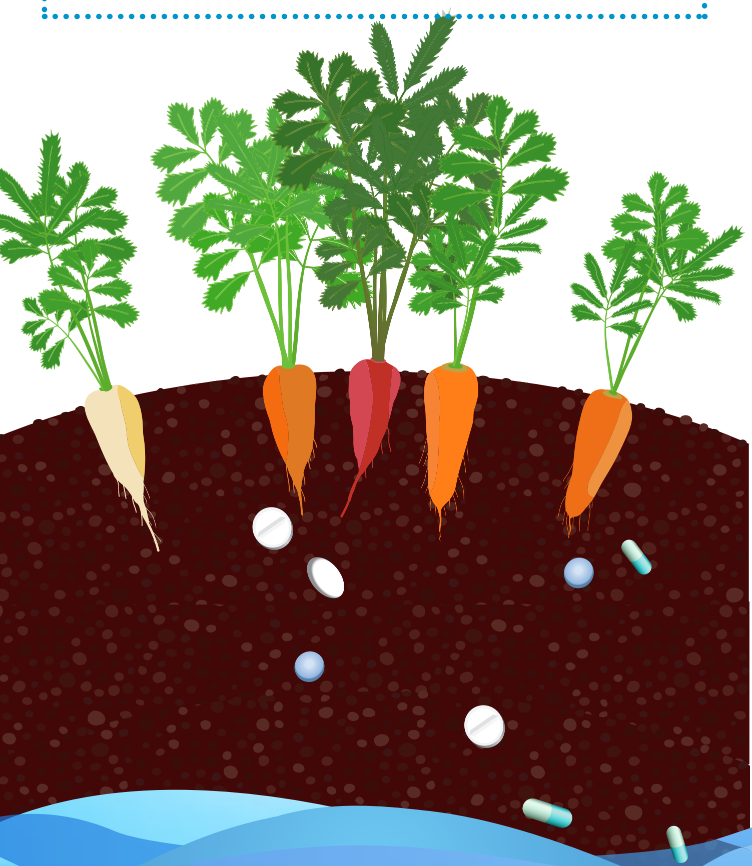
In recent years, scientists have explored the accumulation of pharmaceuticals in plants growing in amended soil or soil irrigated with reclaimed wastewater; research has shown that plants accumulate pharmaceuticals from the media where they grow. [4,21]

Crop plants grown on land that has been irrigated with reclaimed wastewater have higher levels of exposure to pharmaceuticals than those grown on land to which manure or sludge has been added.[4,21]

PHARMACEUTICALS IN PLANTS

The veterinary medicines florfenicol, levamisole, and trimethoprim have been shown to accumulate in lettuce leaves, and enrofloxacin, florfenicol, and trimethoprim in the roots of carrots grown in contaminated soil. Scientists have concluded that measurable residues of these medicines are likely to occur in soils for at least five months following application of manure containing these compounds.[22]

Furthermore, a research study investigated whether 20 frequently occurring pharmaceuticals could accumulate in four plants species (lettuce, spinach, cucumber, and peppers) grown in a nutrient solution containing low concentrations of the above pharmaceuticals. All pharmaceuticals were detected in the roots of the plants and 13 were also present in the leaves of the plants.[23]



Furthermore, exposure during irrigation can take place during the entire life cycle of the plant, and the plants' capacity to accumulate pharmaceuticals from the soil increases over time. On the contrary, the exposure of plants to pharmaceuticals via manure or sludge decreases over time as plants naturally reduce their uptake of fertiliser.[4,21]

How should pharmaceutical pollution in water reuse be addressed?

Water reuse can be beneficial in regions suffering from water scarcity, however, to ensure high water quality and protect human and environmental health, legislative measures should consider pharmaceutical pollution and the spread of antimicrobial resistance when proposing minimum quality requirements for water reuse.

RECOMMENDATIONS FOR EU POLICY MAKERS

- Establish quality standards/requirements to ensure that pharmaceuticals and antimicrobial resistant microorganisms in irrigation water, manure, and sewage sludge are controlled and limited in order to protect the environment
- Develop guidelines for EU Member States to carry out targeted monitoring of pharmaceuticals in water reuse
- Provide EU funding for innovative water treatment technologies that would reduce the level of pharmaceuticals in wastewater, including antibiotics and other antimicrobial resistant microorganisms

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HCWH Europe
Rue de la Pépinière 1,
1000 Brussels, Belgium

E. europe@hcwh.org
T. +32 2503 4911

@HCWHEurope HCWHEurope

www.noharm-europe.org

Authors: Adela Maghear, Pharmaceuticals Policy Officer, HCWH Europe

Design: prinzdesign Berlin

Published: December 2017

Photos: hxdyl@istockphoto (Title), Thinglass@istockphoto (P.5), zabava_t@istockphoto (P.6), SteveMcsweeny@istockphoto (P.7), Lora-Sutyaginaœ istockphoto (P.8)

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Printed on 100% recycled paper using vegetable based ink.

HCWH Europe gratefully acknowledges the financial support of the European Commission (EC). HCWH Europe is solely responsible for the content of this publication and related materials. The views expressed do not reflect the official views of the EC.