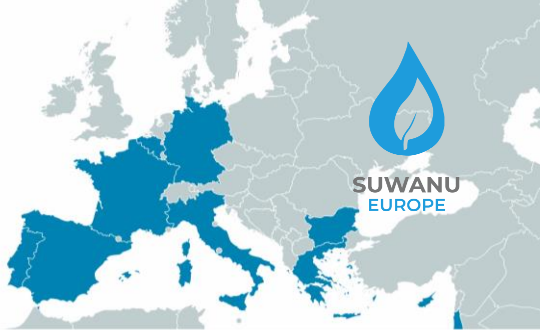
Sustainable **Water treatment** and
Agricultural reuse options in Europe



Info-package 3
Water Reclamation Operators

Fact Sheet 3.2 – **Contaminants of emerging concern (importance, fate in the environment, technologies to remove them, ecological impacts)**

Reclaimed water quality requirements → **Contaminants of emerging concern** → Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water → Key for success in Israel (and Cyprus?) → Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describes the importance of contaminants of emerging concern (CECs) in reclaimed water as well as their fate in the environment, ecological consequences and treatment options for their removal from effluent wastewater.

1. Contaminants of emerging concern in reclaimed water–why are they important?

The presence of contaminants of emerging concern (CECs) in raw wastewaters and reclaimed water, is an important issue to address when assessing hazards to human health and ecosystems during the practices of reclaimed water disposal and reuse. According to the NORMAN network (NORMAN network, 2017), a CEC is “a substance currently not included in routine environmental monitoring programs and may be candidate for future legislation due to its adverse effects and/or persistency”. Currently, there is not a standardized categorization of CECs, and generally examined categories in reclaimed water include chemical compounds, such as pharmaceuticals (including antibiotics), personal care products, micro/nanoplastics, Per- and Polyfluoroalkyl Substances (PFAS), pesticides and certain microbial contaminants such as antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs). Among CECs, pharmaceuticals belong to a group of increasing interest due to their pharmacological activity, their rising consumption deriving from their use in human and veterinary medicine and their ubiquitous environmental presence (Kümmerer, 2008).

The COST Action ES1403: ‘New and Emerging challenges and opportunities in wastewater REUSe’ (NEREUS) has provided the platform for a systematic consolidation of data and standardization of methods for assessing emerging hazards associated with wastewater reuse, in particular the most concerning ones from both the public health and environmental perspectives and how these can be overcome (http://www.nereus-cost.eu/).

2. How CECs reach the environment

Wastewater treatment plants (WWTPs) often reduce the emission of CECs, primarily by phase separation during which some of the CECs are removed into the sludge. This process, however, does not fully eliminate the presence of CECs in effluents produced by the WWTPs. Many pharmaceuticals remain in the produced effluent, some undergo partial metabolism that produces transformation products (TPs) (Radjenović et al., 2009). These TPs can be just as persistent and toxic as their parent compounds, and as such their presence in effluent only contribute to the risk associated with effluent reuse (Escher and Fenner, 2011). When reused, effluent may be seen as a source of CECs, introducing them to receiving water bodies due to the incomplete removal of CECs in common wastewater treatment technologies.

Another main source of CECs to the environment is through the disposal of treated effluents and sludge from plants that produce chemicals considered as CECs such as pharmaceuticals, flame retardants and personal care products. Due to the fact that a wide spectrum of chemical and microbial contaminants with different physicochemical properties and toxicological characteristics must be managed, requiring suitable responses by the applied wastewater treatment process, the abovementioned premises give an idea of the complexity of the issues arising from the presence of CECs in raw wastewater and reclaimed water.

3. Ecological impacts of the presence of CEC in reclaimed water

The presence of CECs in reclaimed water may have a variety of ecological impacts, including among others, endocrine disruption in higher order organisms (e.g., fish, amphibians) and the development of antimicrobial/antibiotic resistance in lower order organisms, such as bacteria. The accumulation of CECs in organisms through direct/indirect contact with these residual compounds, may exacerbate abnormal hormonal control leading to impairments of the reproductive system, decreased fertility, increased cancerous cell prevalence, effects which may be preserved through future generations of impacted organism (Belhaj et al., 2015). Antibiotic compounds have been recognised as an important category of CECs, due to their adverse effects on aquatic ecosystems (Kümmerer, 2009). The greatest concern of the release of antibiotic residues in reclaimed water, is associated with the potential development and spread of antibiotic resistance among bacteria in receiving aquatic environments, which potentially leads to a reduction of the therapeutic potential of antibiotic compounds against human and animal bacterial pathogens.

New evidence suggests that CECs such as pharmaceutical residues might be accumulated in agricultural produce grown using reclaimed water (Malchi et al., 2014). The same research also shows that to consume pharmaceuticals in levels approaching those used for therapeutic purposes, one must consume unrealistic amounts of vegetables on a daily basis. On the other hand, biochemical and molecular evidence by Christou et al. (2016) highlighted that various pharmaceuticals in reclaimed water may act as an emerging abiotic stress factor of alfalfa plants, as alfalfa plants were shown to employ detoxification mechanisms once exposed to high pharmaceutical concentrations (Christou et al., 2016). Another study by Christou et al. (2017), has shown that concentrations of pharmaceutical residues in soil and tomato fruits vary, depending on the duration of irrigation and the origin of the wastewater applied, as well as the physicochemical properties of pharmaceuticals, with acidic pharmaceutical uptake and bioconcentration increasing with long-term irrigation with reclaimed water.

4. Treatment options for the removal of CEC from reclaimed water

The refractory nature of pharmaceutical residues found in WWTP effluents and reclaimed water has driven the development of technological solutions whose aim is to overcome the inability of their adequate removal by conventional WWTP processes. Membrane BioReactor (MBR) technology and Advanced Oxidation Processes (AOPs) have exhibited enhanced removal capacity of pharmaceutical microcontaminants from WWTP wastewater matrices and are proved to be powerful treatment processes for the removal of organic persistent and biologically-recalcitrant pharmaceutical compounds (Karaolia et al., 2017). These processes include homogeneous solar-driven photocatalytic processes such as UV/H_2O_2 and photo-Fenton oxidation and the heterogeneous photocatalysis process (Rizzo et al., 2019). Additional methods for CECs removal from effluent involve filtration using biologically active media, and effluent desalination combining ultrafiltration and reverse osmosis. Various combinations of the abovementioned processes can be seen in facilities applying such advanced treatment to effluents. Technology selection at each WWTP is determined based on a combination of scientific and local considerations, including regulatory requirements, cost, water quality goals among others. The removal of CECs and their TPs is the focus of many groups in academia, industry, and policymakers, and is an important driver for an active field of science full of new, interesting and ground-breaking innovations.

Reference/further readings

Reference/further readings

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THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT N. 818088