Aalto University

Emerging micropollutants in wastewater treatment

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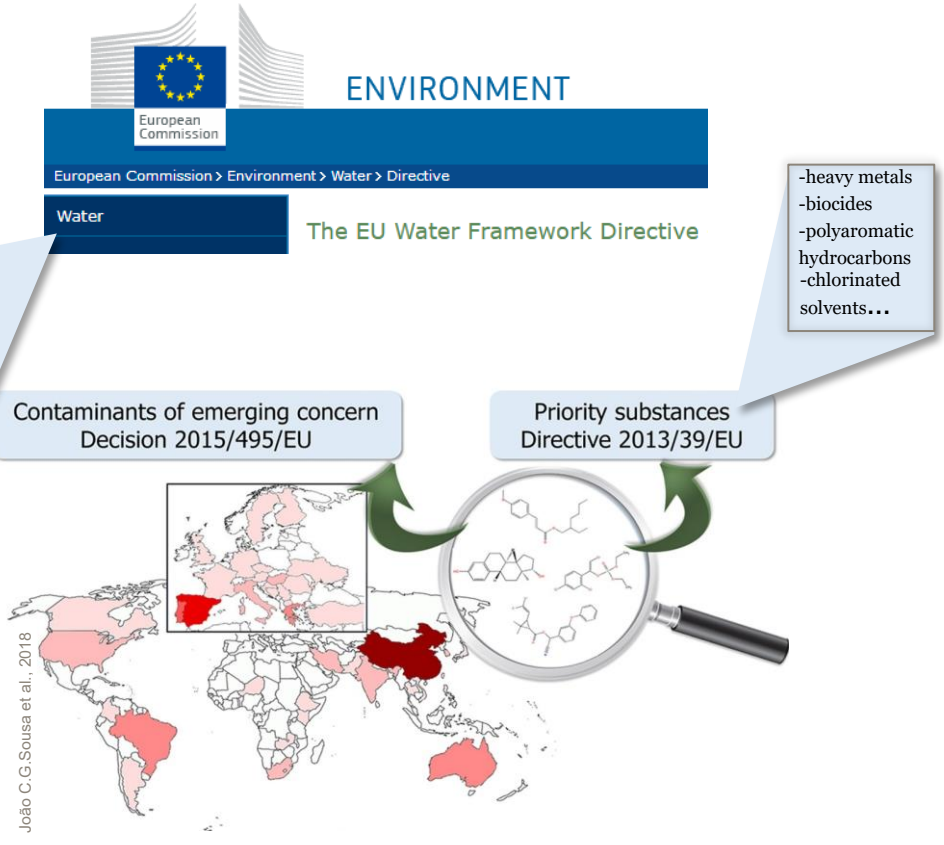
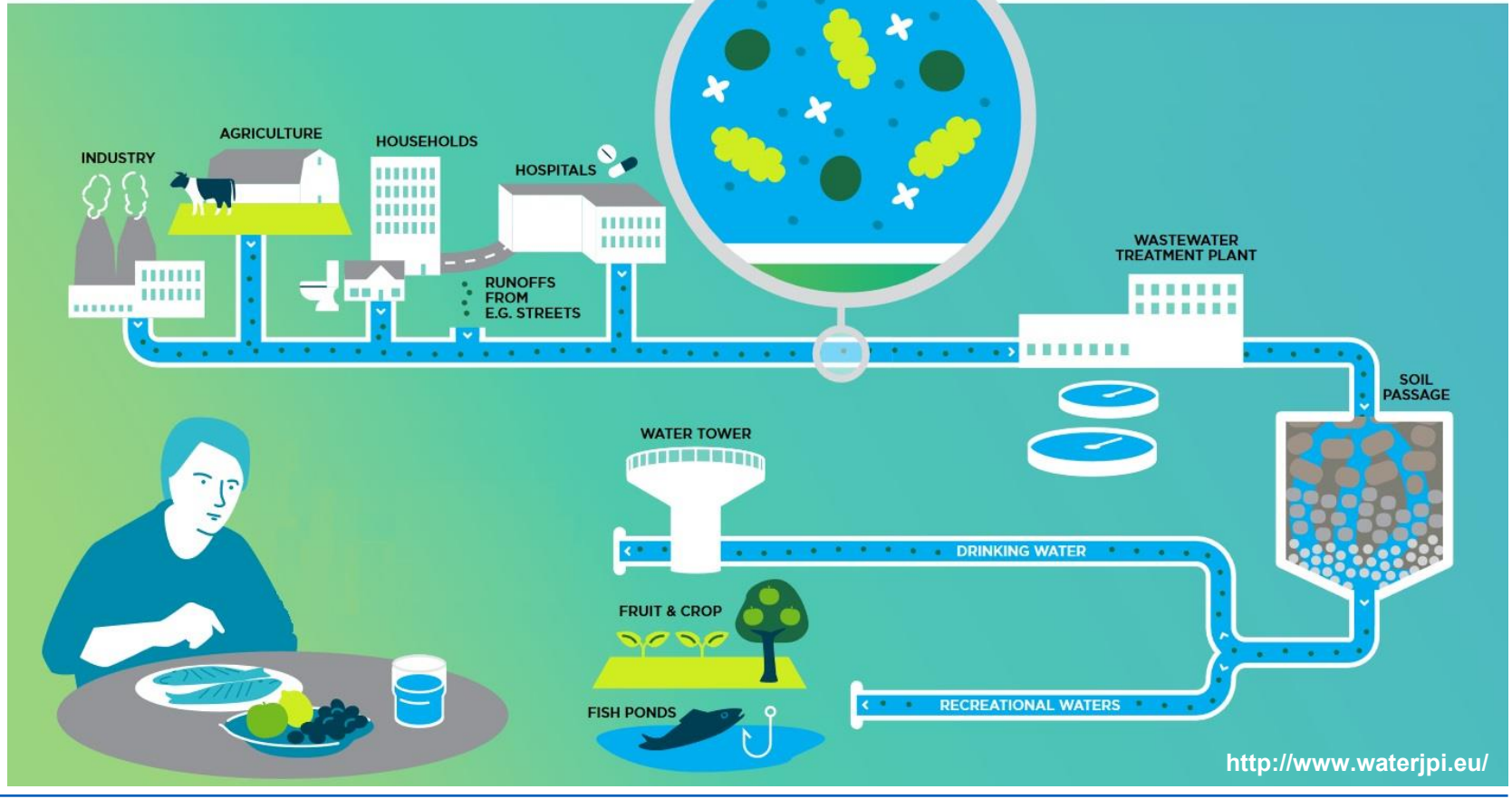
Terminology

- **Priority substances -** chemical pollutants that pose a significant risk to (or via) the aquatic environment
- **Environmental Quality Standards** - the concentrations, which should not be exceeded in order to protect human health and the environment
- **Contaminants of emerging concern** - contaminants that have been detected recently and have raised the concern about their ecological or human health impacts.



Micropollutants - contaminants which are found in the mg L^{-1}or ng L^{-1} concentration range in the aquatic environment

The pathways of emerging micropollutants



Emerging micropollutants in wastewater treatment

- Pharmaceuticals
  Hormones
  Antibiotics
- Household chemicals
- Cosmetics
  Personal care products
- Pesticides
  Herbicides

  and more…

~100 000

commercially registered compounds in Europe

Design Philippe Casse | Illustrations Alain Robert

- ✓ the scientific literature contains descriptions of over 80 million chemicals
- ✓ approximately 4,600 substances annually in quantities exceeding 1,000 tons
- ✓ data are also lacking for the estimated 30,000 substances, whose market volume in Europe exceeds one ton *(Federal office for the environment, 2015)*

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- accumulation in water and aquatic organisms
- chronical toxic effects in ng L^{-1} and µg L^{-1} range concentrations
- spread of antibiotic resistance
- micro- and nano- plastics

Pharmaceuticals

- almost 800 different pharmaceutical substances were measured worldwide in concentrations above their detection limits (**mostly in effluents of wastewater treatment plants**)*

- ~ **600** active substances detected above their detection limits in EU countries

- In surface water, groundwater and drinking water, **>500** substances detected globally

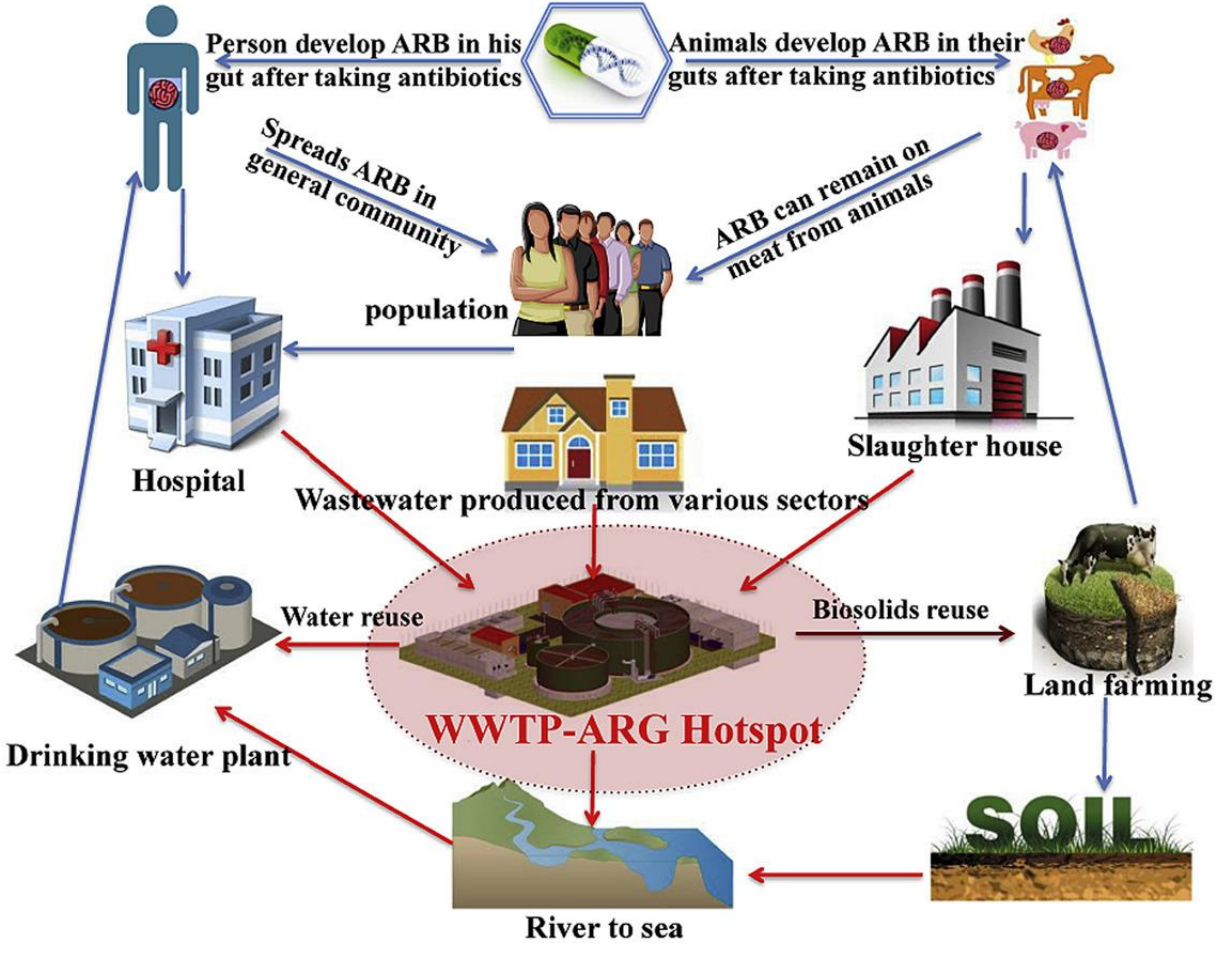
Dusi et al., 2019

**Pharmaceuticals defined as substances that are mainly used for therapeutic purpose*

Examples of adverse effects of pharmaceuticals on non-target organisms

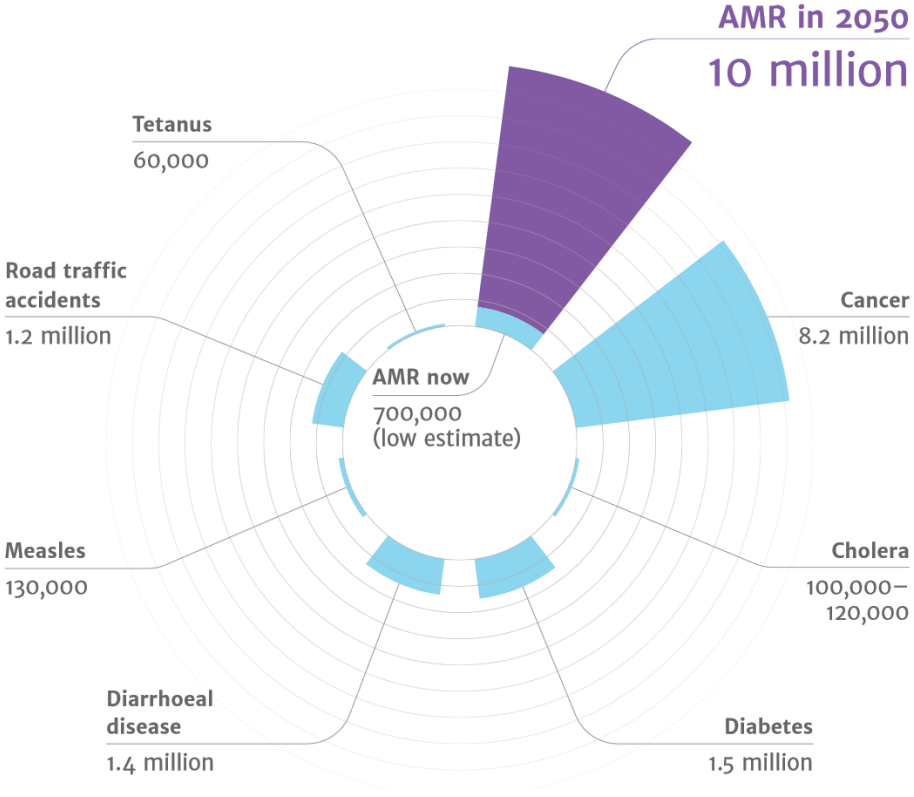
				
Pharmaceutical	Diclofenac	17α-Ethinylestradiol	Diclofenac	Sulfonamide
Therapeutic group	Analgesics	Synthetic estrogen	Analgesics	Antibiotic
Non-target organism	Vulture (*Gyps bengalensis*)	Fathead minnow (*Pimephales promelas*)	Rainbow trout (*Oncorhynchus mykiss*)	Maize (*Zea mays*) Willow (*Salix fragilis*)
Effects	Population collapse due to renal failure	Population collapse due to feminization of male fish	Strong reactions of liver, kidney, and gills	Adverse effects on root growth. Death of maize at high conc.
Study type	Wildlife	Whole-lake experiment	Laboratory	Greenhouse
Reference	Oakes et al. 2004	Kidd et al. 2007	Triebskorn et al. 2007	Michelini et al. 2012
				
Pharmaceutical	Fluoxetine	Oxazepam	Ivermectin	Enrofloxacin, Ciprofloxacin
Therapeutic group	Antidepressant	Anxiolytics	Veterinary parasiticide	Antibiotics
Non-target organism	Leopard Frog (*Rana pipiens*)	European perch (*Perca fluviatilis*)	Dung fly and beetle	Cyanobacterium (*Anabaena flosaquae*) Duckweed (*Lemna minor*)
Effects	Delayed tadpole development	Altered behaviour and feeding rate	Mortality of eggs and larvae	Growth inhibition
Study type	Laboratory	Laboratory	Laboratory and field	Laboratory
Reference	Foster et al. 2010	Brodin et al. 2013	Liebig et al. 2010	Ebert et al. 2011

Beek et al., 2016



Guo et al., 2017

Antimicrobial resistance (AMR)



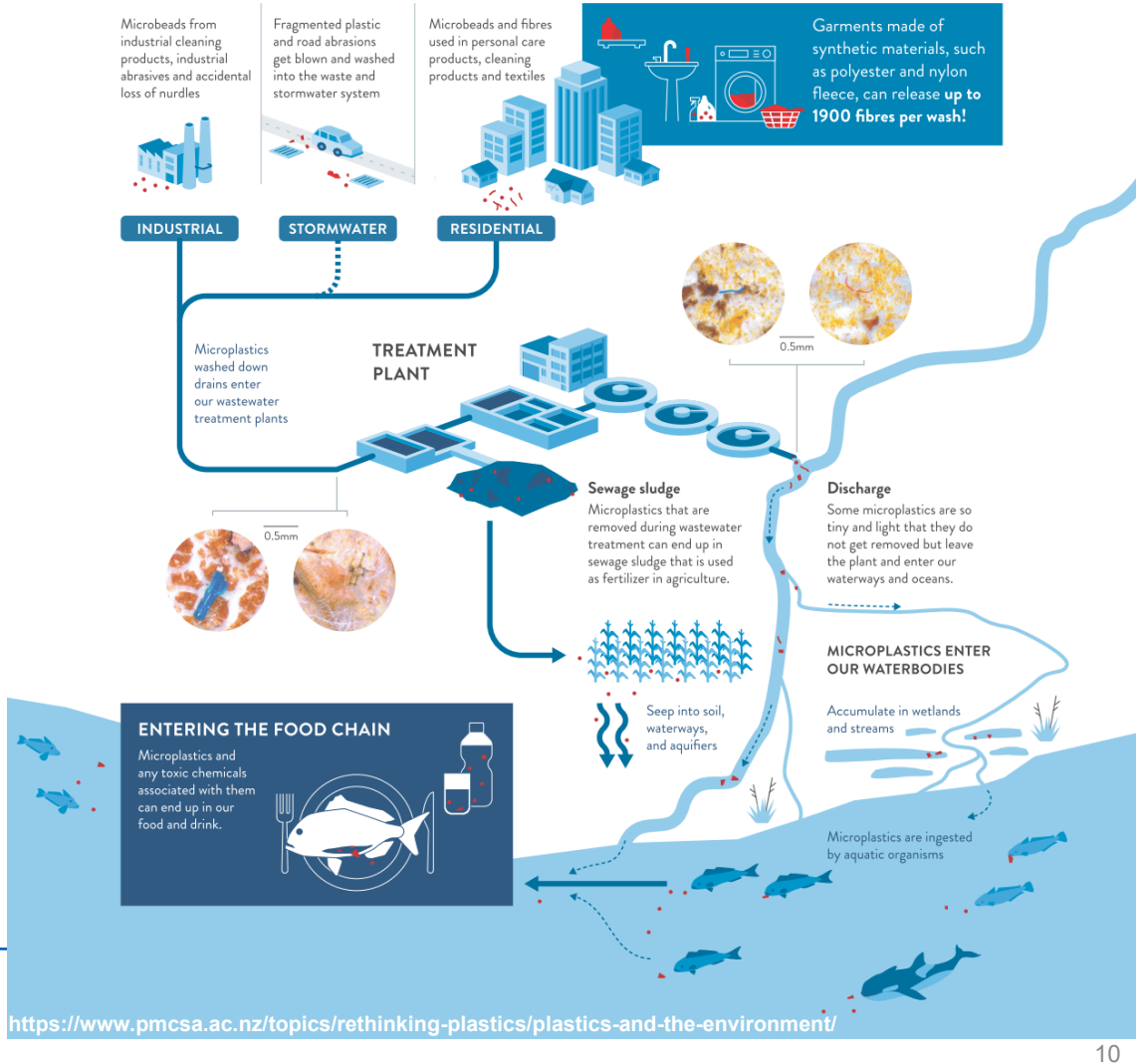
~ 700,000 people a year dying from antimicrobial-resistant infections.

World Health Organization (WHO):

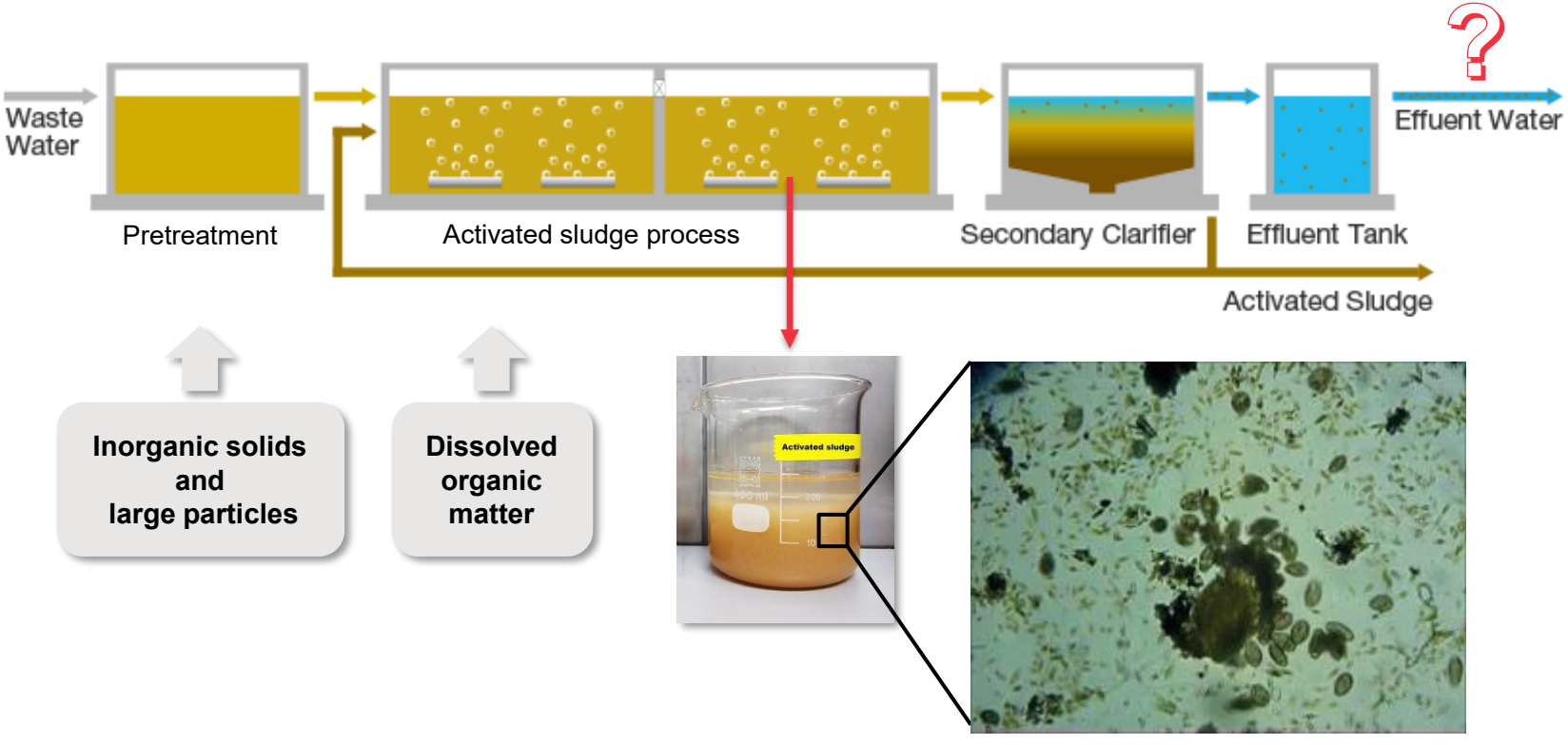
antibiotic resistance as one of the most important public health problems of the 21st century, which needs to be immediately resolved

O'Neill, J., 2016

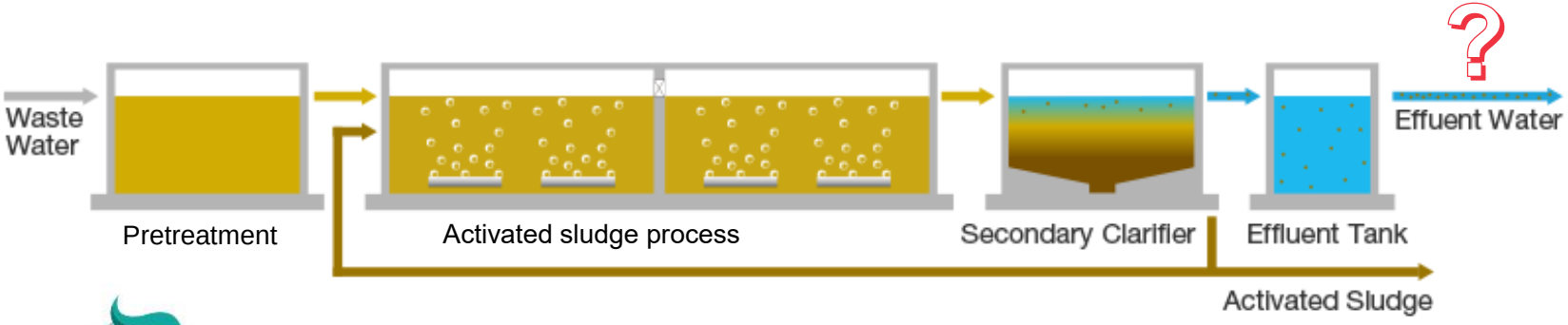
Microplastics in wastewaters



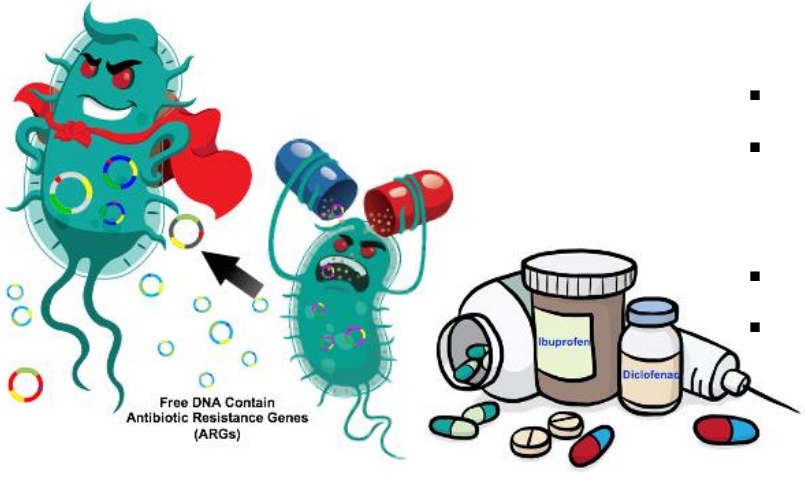
Typical wastewater treatment process



Typical wastewater treatment process

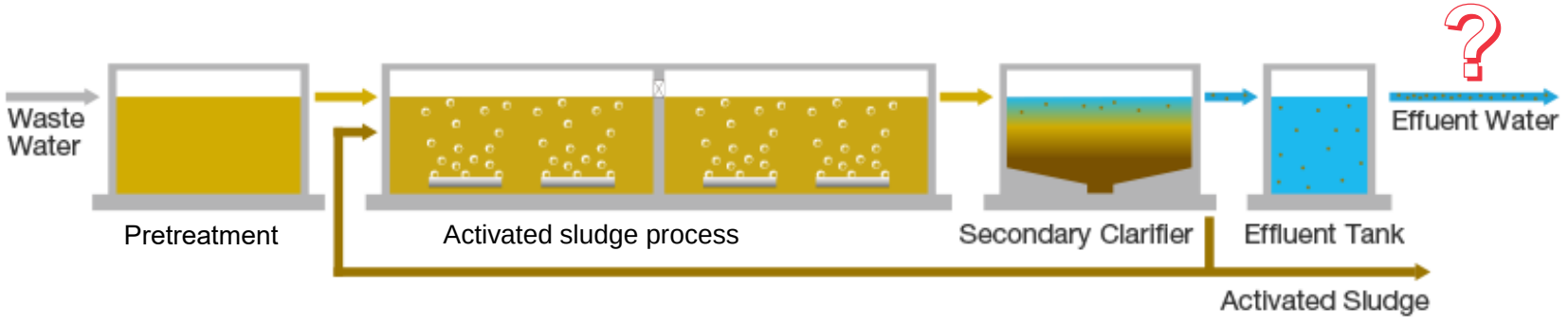


kubota.com



- High concentration of bacteria from different sources
- Different antibiotics excreted by humans (low concentrations don't kill bacteria but promote antibiotic resistance)
- Presence of other urban chemicals and micropollutants
- Bacteria excreted by humans meet water and soil bacteria

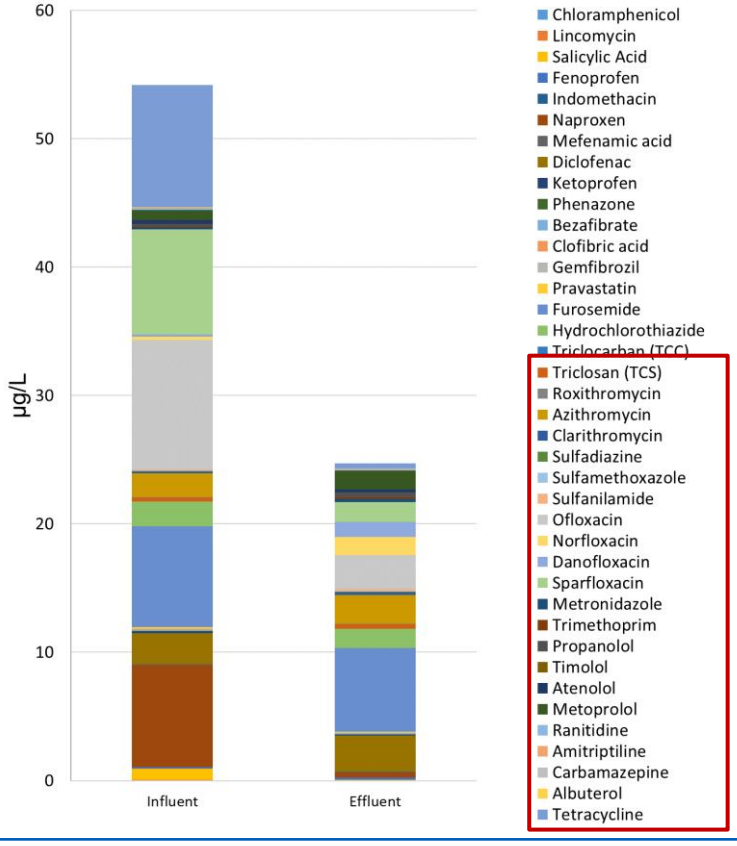
Removal of dissolved micropollutants in activated sludge



- The removal rates depend on micropollutant characteristics:
  - biodegradability
  - hydrophobicity
  - chemical transformation (hydrolisis, acid based, photocatalytic…)

- Biological removal rates are highly dependent on temperature and noticeably lower during cold seasons

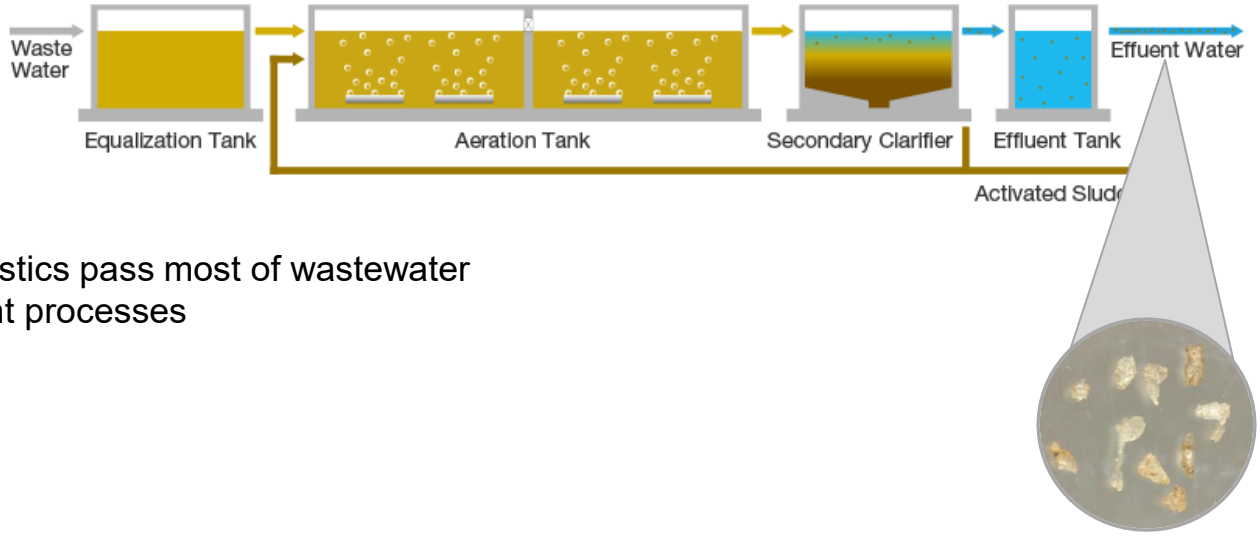
Emerging micropollutants in Finnish wastewaters



~**50** micropollutants were found in final effluents of wastewater treatment plants in Finland, including **>20** antibiotics

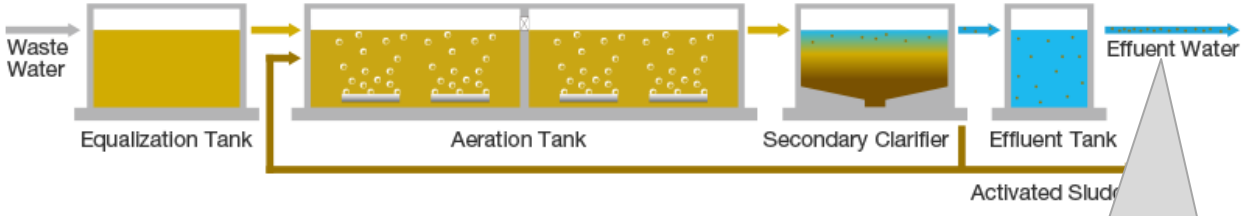
**ibuprofen and acethaminophen concentrations are not presented in the picture*

Microplastics in Finnish wastewaters

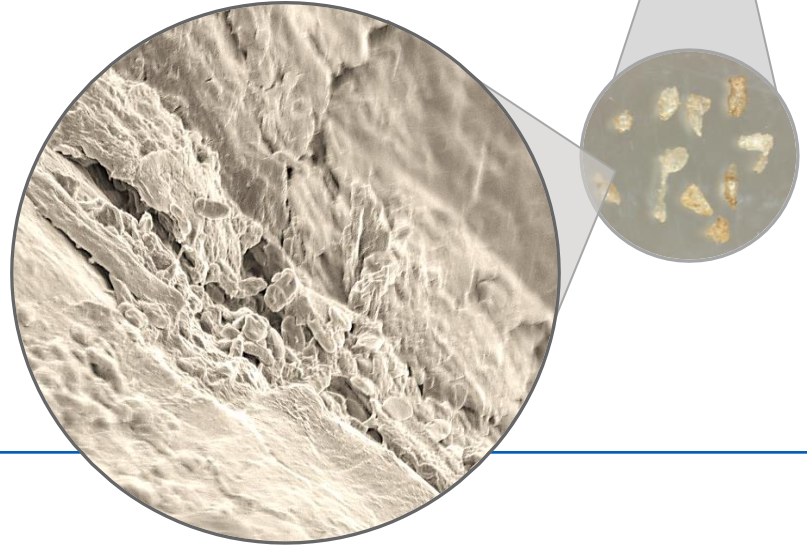


- Microplastics pass most of wastewater treatment processes

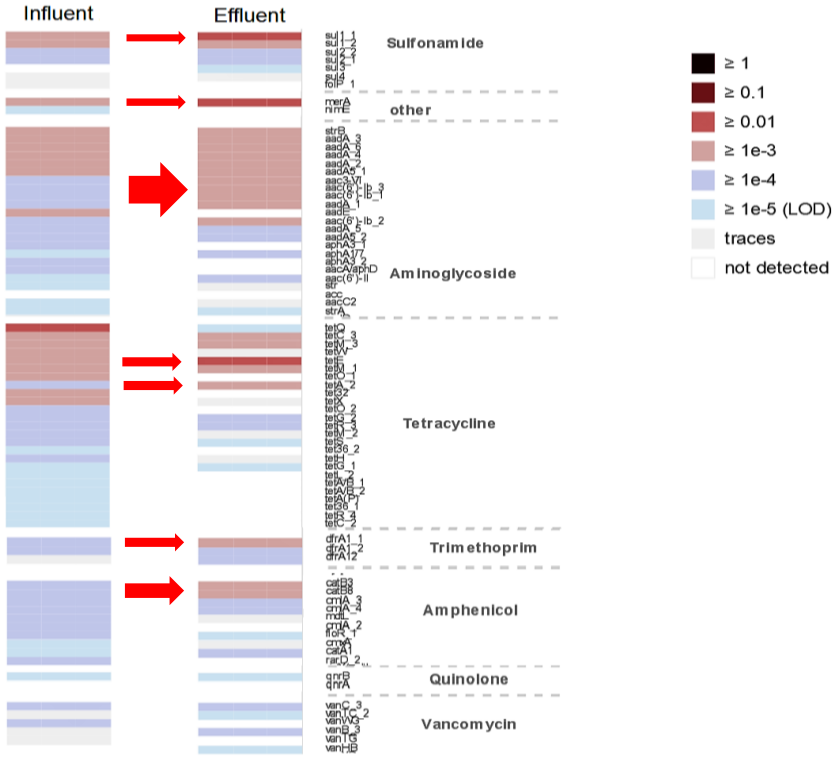
Microplastics in Finnish treated wastewaters



- 40-97% of plastic particles removed
- rest of microplastics pass most of wastewater treatment processes
- microplastics can carry attached bacteria and chemical pollutants from wastewaters to the effluents



Antibiotic resistant genes in Finnish wastewaters

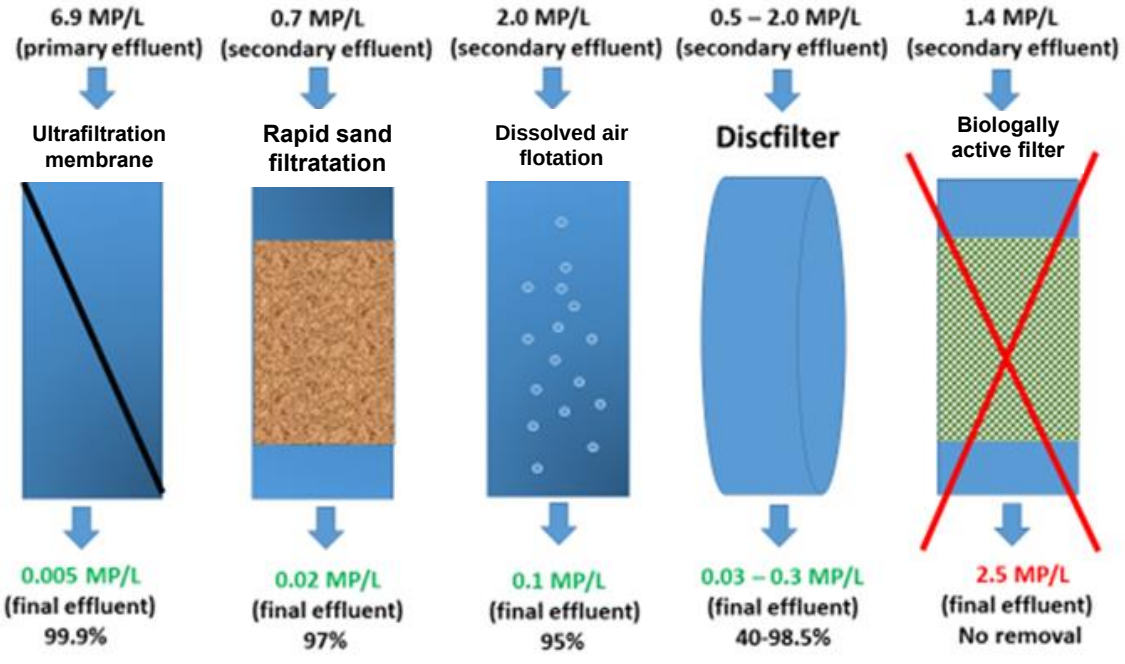


>120 genes

Genes of **multi drug resistance** were found in effluents

Important process bacteria are among the potential hosts of multiple ARGs

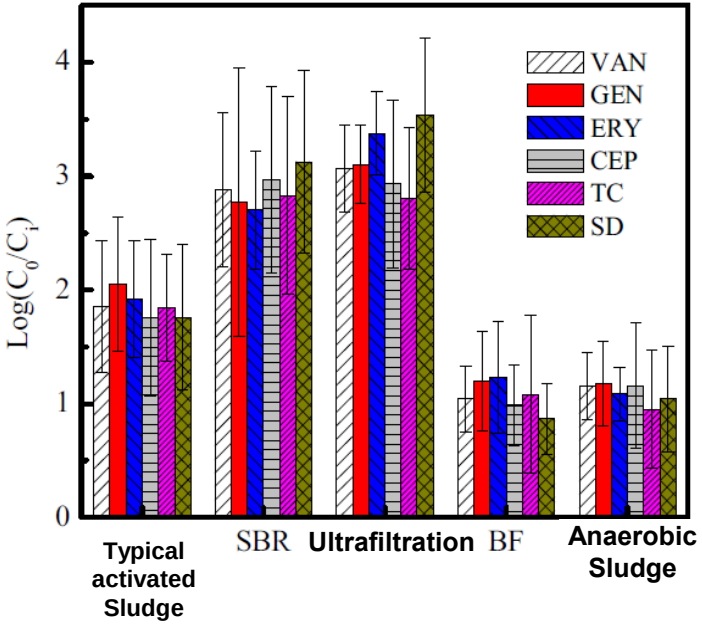
Removal of microplastics in advanced wastewater treatment processes



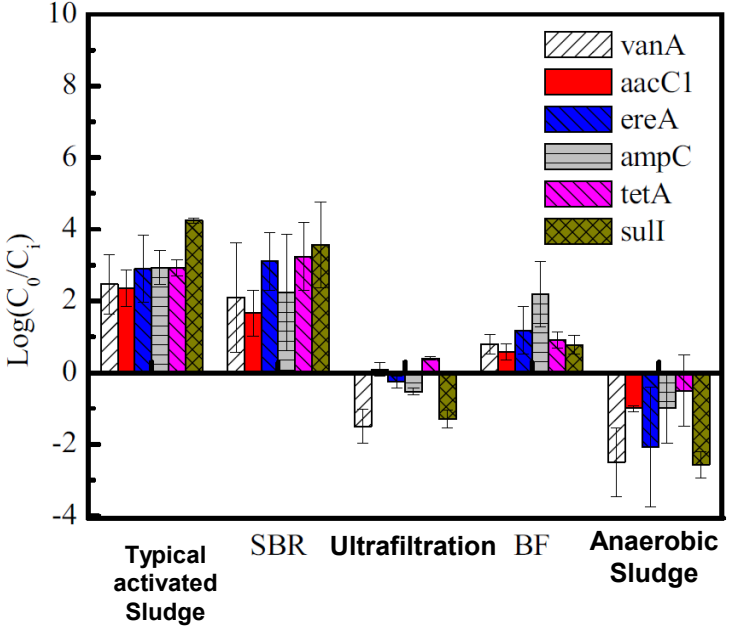
Talvitie et al., 2018

Removal of antibiotic-resistant bacteria and antibiotic resistance genes by ultrafiltration

Log removal of antibiotic-resistant bacteria



Log removal of antibiotic resistance genes



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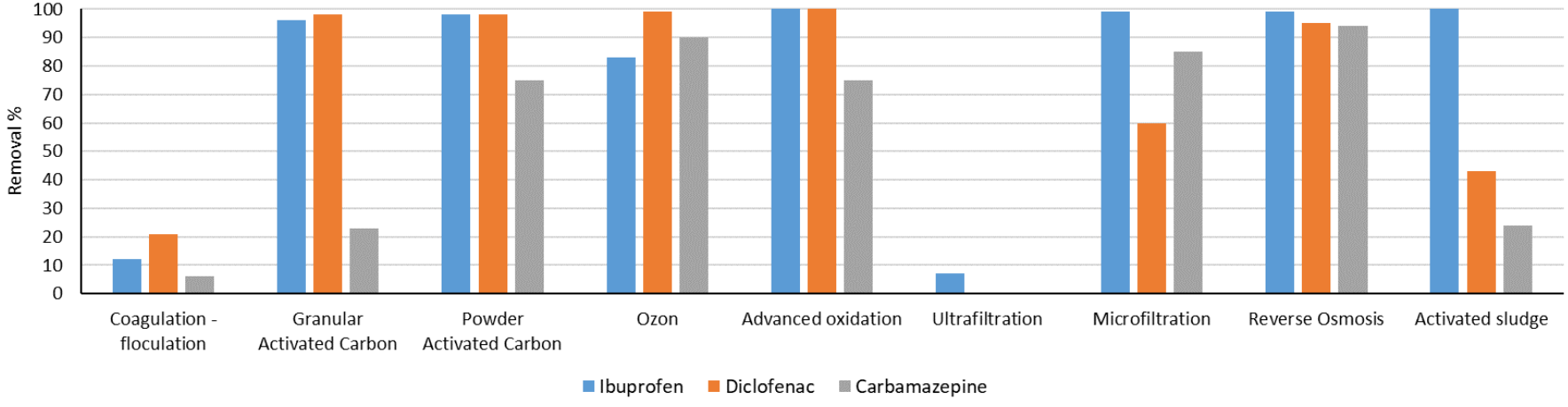
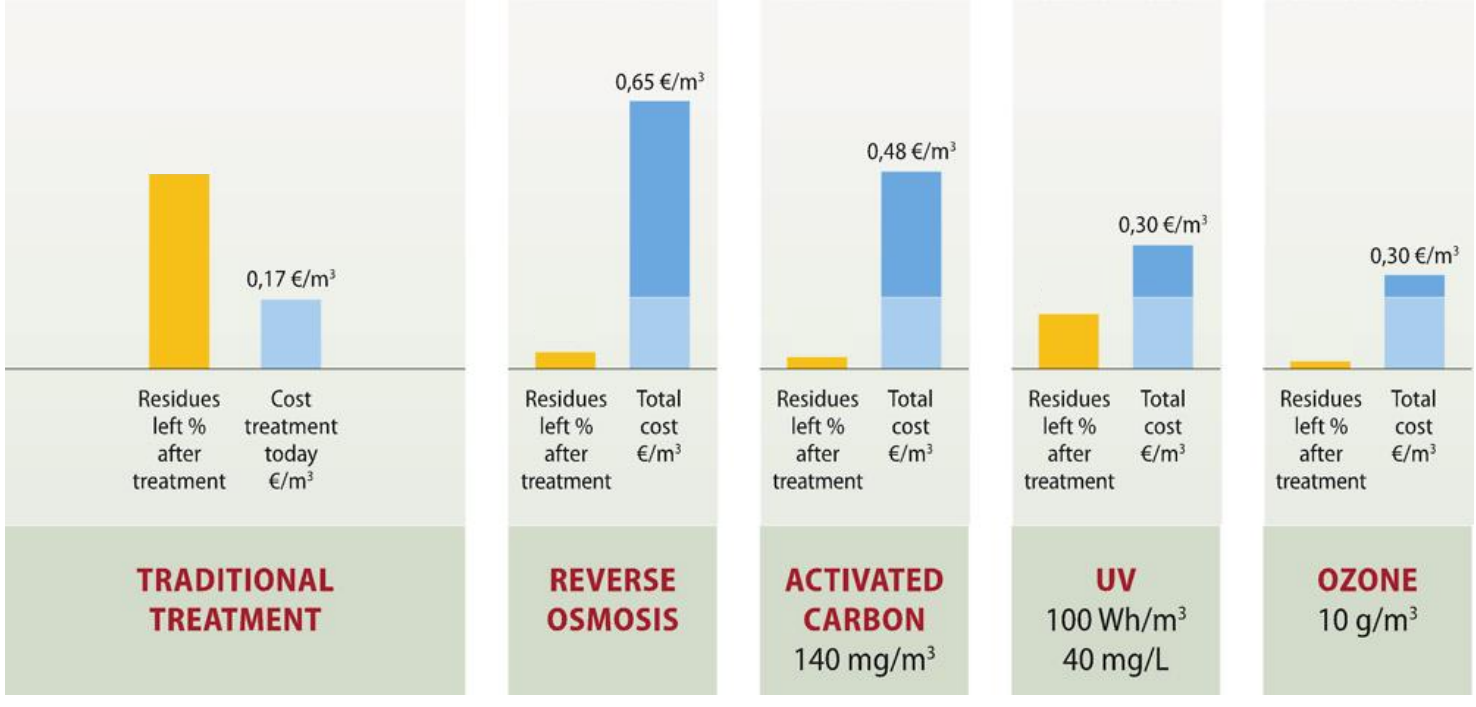
Yuan et al., 2016

Removal of dissolved micropollutants in advanced wastewater treatment processes



Yunlong et al. 2014, Nagy et al 2014

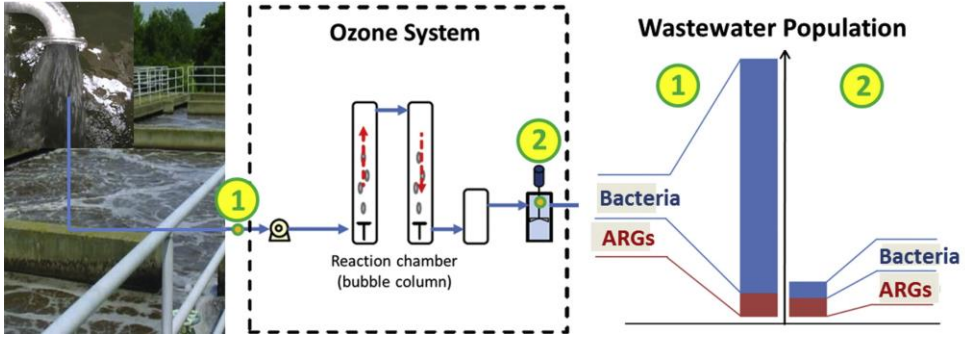
Cost of wastewater treatment



Bui et al., 2016

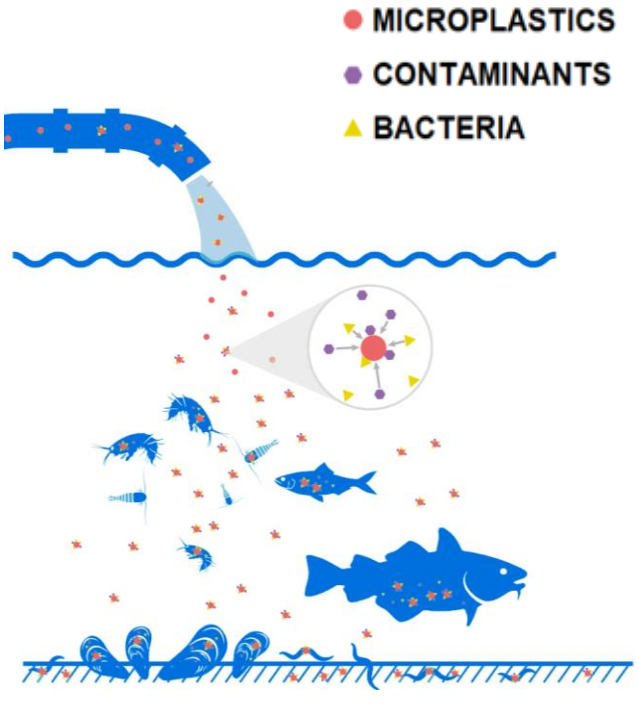
Removal of micropollutants and antibiotic resistance by ozonation

- Ozone treatment selects vancomycin- and imipenem- resistant bacteria
- Ozone impact depends on bacterial species
- Possible effluent toxicity (ozonation by-products)



Alexander et al., 2016

Summary



su.se/ostersjocentrum

- Raising concern on emerging micropollutants passing all wastewater treatment processes
- No perfect technology to remove emerging micropollutants from wastewater

What should we do?

https://www.oecd-ilibrary.org/sites/4781cb74-en/index.html?itemId=/content/component/4781cb74-en

Group task

https://flinga.fi/s/FT3PP29