Attenuation of emerging contaminants by wetland systems

Dr. Víctor Matamoros

Institute of Environmental Assessment and Water Research

The Universe of Chemicals: Globally
- 73,000,000 organic + inorganic substances (2013)
- Commercially available: 19,184,000
- In commerce in USA, EU, Japan, China
- ~150,000
- Production > 1 tonne/year ~ 30,000

<500 of them are routinely measured in the aquatic environment

Emerging pollutants can be defined as pollutants that are currently not included in routine monitoring programmes at the European level, and which may be candidates for future regulation, depending on research on their (eco)toxicity, potential health effects and public perception and on monitoring data regarding their occurrence in the various environmental compartments.

In some cases, release of emerging chemical or microbial contaminants to the environment has likely occurred for a long time, but may not have been recognized until new detection methods were developed.

Contaminants of emerging concern

Personal care products
- fragrances (galaxolide, celestolide or tonalide), sun filters (oxybenzone)
- cosmetics (parabens, siloxanes)

Plasticizers
- Phthalates (Di-, mono- and phthalate), plastic additives (bisphenol A, bisphenol F, bisphenol S...)

Pharmaceuticals
- antiinflamatory/analgesics (ibuprofen, naproxen, diclofenac), diuretics (furosemide), antibiotics (erythromycin, sulfonamides)

Microplastics
- sorb and concentrate persistent organic pollutants (POPs), which can increase exposure to contaminants when these plastics are ingested

Disinfection by-products (except THMs)
- iodo-THMs, N-nitrosamines...

Personal care products
- Surfactants/detergents
- PFOA & PFOS (Perfluorooctanoic acid and Perfluorosulfonates)
- Flame retardants
- Polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), organophosphates (tris-2-chloroethyl)phosphate)
- Pesticides
- Herbicides (mecoprop, 2,4-D, MCPA...)
- Antimicrobials
- Fungicides, bactericides, bacteriostatic
- Nanoparticles (1-100 nm)
- Silver nanoparticles added to socks to kill the bacteria
- Anticorrosives
- Benzotriazoles, chlorophenol

Anticoagulants
- warfarin, dicumarol

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Ecoxicological effects of the presence of ECs in the aquatic environment

Triclosan (antiseptic)
Negative effects on frog metamorphosis

Effects on fish gills and liver (0.5-1 µg/L)

DCP consumption as a human and veterinary pharmaceutical drug is >1000 tons/year

17β-Estradiol (EE2) (birth control pill)

Feminization of male fishes: 5-6 ng/L (Fathead minnows)
Collapse of fish populations after exposure to a synthetic estrogen

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Contaminants of emerging concern

- Reduction of macroinvertebrate diversity in rivers
- Behavioural changes in mosquito fish
- Reproductive disruption in fish

Ecosystem (structural and functional changes)

Example of a Pareto distribution
Vilfredo Pareto (1848-1923), Italian economist who stated in 1906 the so-called "80:20" (Pareto Principle)
Sociology: "20% of the people own 80% of wealth"
Quality Control: "20% of the causes account for 80% of the failures"
"Few compounds are responsible for most of the risk"

Watch list

- Estrogens
- NSAID
- Personal care products
- Antibiotics
- Pesticides

Some are more recalcitrant and toxic than the parental compounds

Crop's uptake and human health risk

- Intake of crops irrigated with reclaimed water

Carbamazepine

The threshold of toxicological concern for a child is of 80 g/day (half a carrot)

Contaminants of emerging concern - high amount of unknown transformation products (TPs) are discharged or produced in the surface water bodies

Elodie Passeport's Lab

Contaminants of emerging concern - Wetland systems

- Activated sludge
- Membrane biological reactors
- Advanced oxidation processes (ozone, TiO₂...)
- Membrane-based treatments

Wetland systems

Conventional treatments

- Urban and industrial wastewater
- Surface and agricultural run-off water effluents
Factors affecting the attenuation of CEC in CWs

1. CW configuration (HFCW, VFCW vs. SFCW)
2. Water depth (HFCW)
3. Clogging (HFCW and VFCW)
4. Surface area (HFCW and SFCW)
5. Plant effect (VFCW)
6. Seasonality (SFCW)
7. Sorption material (HFCW)

Factors affecting the attenuation of EOCs in CWs

1. CW configuration
2. Water depth effect
3. Clogging effect
4. Surface area effect

Attenuation processes/mechanisms

1) Biodegradation
2) Hydrolysis
3) Photodegradation
4) Sorption
5) Phytoremediation
6) Hydrolysis
7) Adsorption
8) Plant uptake
9) Increase of biodegradation

Factors affecting the attenuation of CEC in CWs

1-CW configuration

Factors affecting the attenuation of CEC in CWs

3-Clogging effect

The accumulation of different type of solids and biofilm, leading to a reduction of the infiltration capacity of the gravel bed

Factors affecting the attenuation of CEC in CWs

4-Surface area effect

High surface area dependence.
The presence of plants increases the attenuation of microcontaminants and their TPs.


In the year 2000, with the aim of re-naturalising the River Besòs, 60 HFCWs were built along a 3.3 km stretch of the Besòs basin, each with a width of 50 m and between 20 and 35 m long. 30% of the WWTP effluent (432,000 PE) is diverted to the CWs.

Use of HFCW as a wastewater tertiary treatment for water reuse (Spain)


In the year 2000, with the aim of re-naturalising the River Besòs, 60 HFCWs were built along a 3.3 km stretch of the Besòs basin, each with a width of 50 m and between 20 and 35 m long. -30% of the WWTP effluent (432,000 PE) is diverted to the CWs.

Use of HFCW as a wastewater tertiary treatment for water reuse (Spain)


Average removal was 34% in May and 44% in July.

Poster 33
The presence of vegetation increases the attenuation rate of emerging contaminants.

Mediterranean streams are dry almost of the year upstream of the WWTP. The only water that flows is the treated wastewater.

The water flows from the bed of the wetland body through sand and gravel aquifers into wells or filtration galleries adjacent to the river.

Highly integrated in the landscape.

Are they capable of removing CEC?

Recharge basin with vegetation (treated wastewater from Tossa Mar WWTP)

The presence of vegetation increases the attenuation rate of emerging contaminants.
Aquifer recharge (from WWTP effluent to extraction well) was manifested as a useful way for the removal of high amount of emerging contaminants (>90%).

Average concentration of 25 Emerging Contaminants tetrode (n=5)

Concluding remarks
- The attenuation of CEC in CWs depends on different factors (CW configuration, clogging, surface area, presence of plants, seasonality, sorption material...).
- The use of Hybrid CWs improves attenuation of CEC.
- CWs used as tertiary treatment technology are able to remove CEC more efficiently than conventional tertiary systems.
- Reed bed sludge systems, restored wetlands, recharge basins and buffer strips are useful for attenuating the discharge of CEC into the aquatic environment.
- The presence of vegetation enhances the attenuation of CEC.

Future trends
- Include other CEC and toxicological studies of both influent and effluent waters. For example only some of the pollutants included in the EU watch list have been studied until now.
- Assessment of TPs, some of them can be more toxic than the parental ones.
- Understand removal mechanisms, interactions soil-plant (rhizosphere). Explore the capacity of plant exudates and uptake for removing pollutants.