

Contaminants of Emerging Concern (CECs) in Treated Sewage Effluent

**What Are They? What is their
Environmental/Health Impact? How to
Best Remove them?**

White Paper

By [Rami E. Kremesti](#) M.Sc., CSci, CEnv, CWEM

August 2021

Abstract

In this white paper, author Rami Elias Kremesti, a UK chartered water treatment specialist, discusses a hot environmental topic that few people besides the specialists are aware of: Contaminants of Emerging Concern or CEC's. What we flush down the toilet ends up in a sewage treatment plant that removes the majority of contaminants from the waste water (In the form of SS, C, N and P), but a tiny fraction of contaminants make it through into our rivers and lakes. What are these contaminants? How do they harm our environment and our health? And how can we remove them from the waste water are the topics discussed in this paper. The Swiss and the Dutch already remove these CEC's from the their treated sewage effluent. The UK has fallen behind in this area. Finally, without deep knowledge of how we are polluting the planet, and how to mitigate this pollution, we will never live up to our responsibility, as the most intelligent species on planet Earth, to take care of our Environment.

Key words: contaminants of emerging concern, Endocrine Disrupting Chemicals, pharmaceuticals in waste water, CEC's, EDC's DBP's, water pollution, Ozone, GAC, AOP's.

What Are They?

Contaminants of Emerging Concern (CECs) are micro pollutants that include PPCPs (pharmaceuticals and personal care products), EDC's (Endocrine Disrupting Chemicals), pathogens, pesticides, biocides, cosmetics, nanoparticles, flame retardants, and trace organic compounds (including pharmaceuticals) that are found in treated sewage effluent. Classical sewage treatment technologies do not fully remove them either because they are Xenobiotics, the bacteria that break down BOD do not recognize them as a food source or because they don't adsorb to the sludge that settles at the bottom of settling tanks.

A full list of these chemicals is given below:

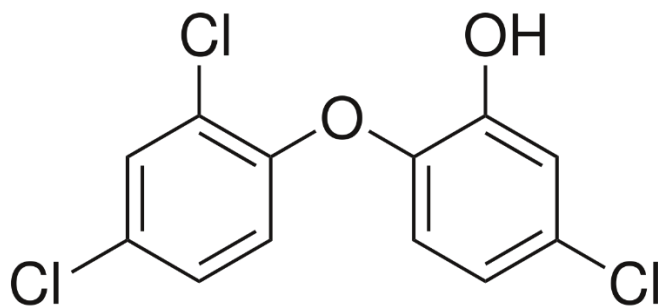
- 1.1 Organics - Pesticides, Herbicides, Biocides
- 1.2 Organic Contaminants from Industrial sources
 - 1.2.1 Flame retardants
 - 1.2.2 Fluorinated organic compounds (FOCs)
 - 1.2.3 MTBE
 - 1.2.4 Nonyl-phenols (NP)
 - 1.2.5 Phthalates
 - 1.2.6 Sulfonated organic compounds
- 1.3 Household and personal care products (PPCPs)
 - 1.3.1 Musk fragrances
 - 1.3.2 Sunscreen Agents (SSAs)
 - 1.3.3 Other PPCPs
- 1.4 Pharmaceuticals
 - 1.4.1 Antibiotics
 - 1.4.2 Antineoplastic drugs
 - 1.4.3 Diagnostic contrast media
 - 1.4.4 Estrogens
 - 1.4.5 General pharmaceuticals
- 1.5 Pesticides
- 1.6 Party drugs

1.7 X-Ray and MRI Contrast Media

The main EDCs include the following pharmaceuticals:

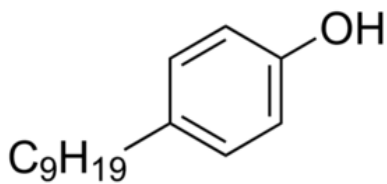
Triclosan, nonylphenol, nonylphenol ethoxylates, octylphenol, octylphenol ethoxylates, bisphenol A, phytoestrogens, and steroid hormones.

Triclosan is an ingredient added to many consumer products intended to reduce or prevent bacterial contamination. Soaps and Colgate toothpastes in the UK, for example, still contain Triclosan which is a chlorinated phenolic ether.



Chemical Structure of Triclosan

Nonylphenols are used in manufacturing antioxidants, lubricating oil additives, laundry and dish detergents, emulsifiers, and solubilizers. Alkylphenol ethoxylates (APEOs) are non-ionic surfactants widely used in agricultural, industrial, and domestic applications.



Nonyl-Phenol Chemical Structure

Switzerland is a world leader in removal of CECs. The Swiss authorities identified a broad range of micro pollutants, and specified 12 that are indicator species for the whole range. They then required the wastewater treatment plants to demonstrate 80% removal of 6, 9, or all 12 depending on what is present in the water. See a quick summary below with the 12 species indicated:

REGULATION IN CH

Clear treatment target

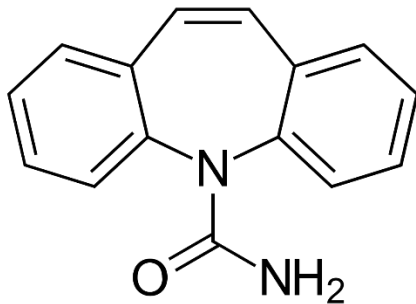
- List of 12 substances: Removal indicators for a large number of other substances (Eawag researches)
- Treatment target: 80 % average removal of the selected substances over the all treatment line (inlet WWTP / outlet WWTP) for 1 unique sample.
- Protocol:
 - 1-Screening of water matrix and selection of 12,9 or 6 substances from the list
 - 2-Treatment technology selection

Groupe de substances	Suisse
Substances médicamenteuses	Amisulpride*
	Carbamazépine*
	Candésartan*
	Citalopram*
	Clarithromycine*
	Diclofénaç*
	Hydrochlorothiazide*
	Irbésartan*
	Métoprolol*
	Venlafaxine*
	Agent anticorrosion

Some of the pharmaceuticals listed in the table above include:

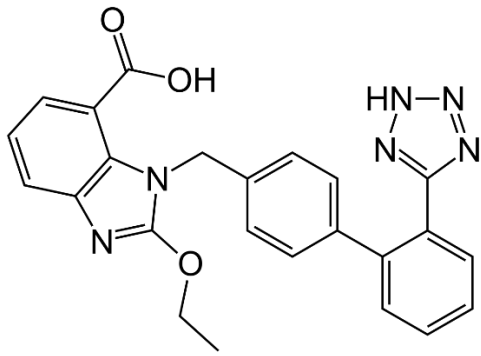
Amisulpride: an **antiemetic and antipsychotic medication** used at lower doses intravenously to prevent and treat postoperative nausea and vomiting; and at higher doses orally and intramuscularly to treat schizophrenia and acute psychotic episodes.

Carbamazepine: a medicine used to treat **epilepsy**. It can also be taken for nerve pain caused by diabetes (peripheral neuropathy) or if you have a painful condition of the face called trigeminal neuralgia. Carbamazepine is occasionally used to treat **bipolar disorder** when other medicines have not worked.



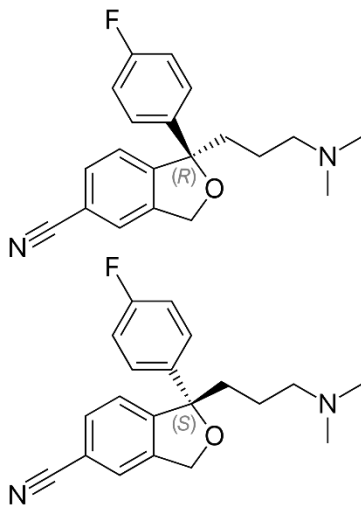
Carbamazepine

Candesartan: an angiotensin receptor blocker used mainly for the treatment of **high blood pressure** and congestive heart failure.



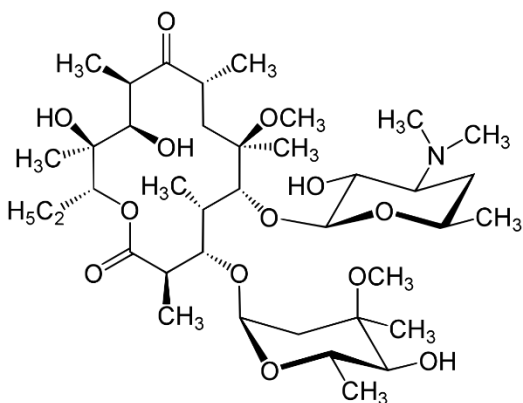
Candesartan

Citalopram: an anti-depressant



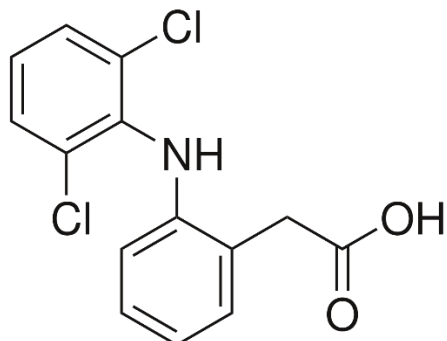
Citalopram chemical structure

Clarithromycin: an **antibiotic** used to treat various bacterial infections. This includes strep throat, pneumonia, skin infections, H. pylori infection, and Lyme disease, among others.



Clarithromycin chemical structure

Diclofenac: a **nonsteroidal anti-inflammatory drug** (NSAID) used to treat pain and inflammatory diseases such as gout.

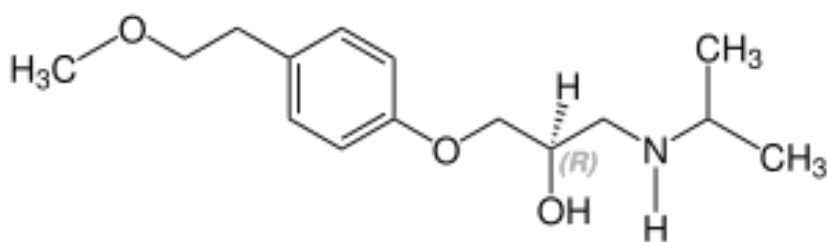


Diclofenac sold under the brand name Voltaren among others

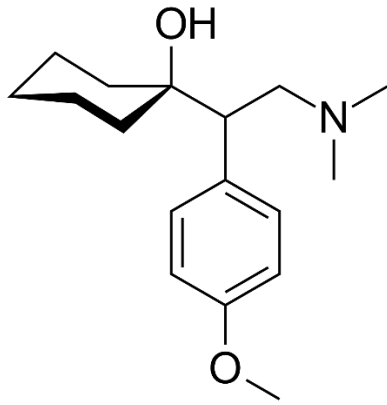
HydroChloroThiazide: diuretic medication often used to treat **high blood pressure** and swelling due to fluid build-up. Other uses include treating diabetes insipidus and renal tubular acidosis and to decrease the risk of kidney stones in those with a high calcium level in the urine.

Irbesartan: a medication used to treat high blood pressure, heart failure, and diabetic kidney disease.

Metroprolol: is a selective β_1 receptor blocker medication. It is used to treat high blood pressure, chest pain due to poor blood flow to the heart, and a number of conditions involving an abnormally fast heart rate.

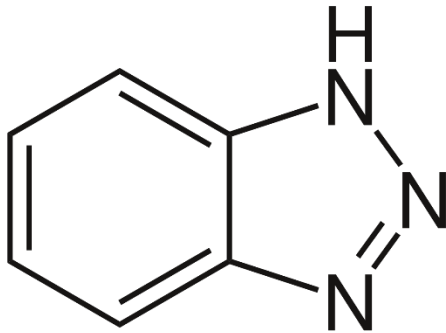


Venlafaxine: sold under the brand name **Effexor** among others, is an **antidepressant** medication of the serotonin-norepinephrine reuptake inhibitor class. It is used to treat major depressive disorder, generalized anxiety disorder, panic disorder, and social phobia. It may also be used for chronic pain.



Venlafaxine

Benzotriazole (BTA): extensively used as a corrosion inhibitor in the atmosphere and underwater. Also can be used as antifreezes, heating and cooling systems additives, hydraulic fluids and vapour phase inhibitors as well.



Benzotriazole

Σ 4+5 Methyl Benzotriazole: used in the following products: lubricants and greases, **washing & cleaning products**, heat transfer fluids, anti-freeze products and coating products. Other release to the environment of this substance is likely to occur from: indoor use in close systems with minimal release (e.g. cooling liquids in refrigerators, oil-based electric heaters), indoor use as processing aid, outdoor use as processing aid and outdoor use in close systems with minimal release (e.g. hydraulic liquids in automotive suspension, lubricants in motor oil and break fluids).

Estrogens

The most studied endocrine disruptors are those organic compounds which mimic the hormone estrogen. Estrogenic steroids such as the synthetic steroid hormone 17 α -ethynylestradiol (EE2) prescribed as **oral contraceptive for birth control** or estrogen substitution therapies and the natural hormone 17 β -estradiol (E2) and its main metabolite estrone (E1) are among the most potent EDCs causing effects in aquatic organisms.

MRI Contrast Media

In May 26, 2020, Researchers from Tokyo Metropolitan University surveyed the amount of **gadolinium** found in river water in Tokyo. Gadolinium is contained in contrast agents given to patients undergoing medical magnetic resonance imaging (MRI) scans, and it has been shown in labs to become toxic when exposed to ultraviolet rays.

What is their Environmental and Health Impact?

There are many CECs and PPCPs that act as so-called endocrine disruptors (EDCs). EDCs are compounds that alter the normal functions of hormones resulting in a variety of health effects. EDCs can alter hormone levels leading to **reproductive effects** in aquatic organisms. Evaluating these effects may require testing methodologies not typically available along with endpoints not previously evaluated using current guidelines.

The emerging contaminants may also demonstrate low acute **toxicity** but cause **significant reproductive effects** at very low levels of exposure. In addition, the effects of exposure to aquatic organisms during the early stages of life may not be observed until adulthood. Therefore, traditional toxicity test endpoints may not be sufficiently comprehensive for criteria derivation for these chemicals and the chemicals may also have specific modes of action that may affect only certain types of aquatic animals (e.g., vertebrates such as fish).

Authors of a three year study in Canada found that the makeup and number of bacteria, phytoplankton, and zooplankton in fresh water lakes dosed with estrogen were not affected, but this EDC increased the number of rotifers, glassworm, and insects, while **decreasing the population of most fish**. Small fish like fathead minnow, pearl dace, and sculpin were directly affected by estrogen. It disrupted the development of their sexual organs leading to failure in breeding. This caused their populations to crash.

Another environmental/health impact of CEC's is development of microbial resistance. With the ever-increasing threat of **antibiotic resistance**, it is essential to ensure that as little antibiotic residues as possible make their way through the wastewater treatment plants. The emergence of super-bugs is every pathologist's worst nightmare. The overuse of antibiotics in recent years means they're becoming less effective and has led to the emergence of "superbugs". These are strains of bacteria that have developed resistance to many different types of antibiotics.

Another undesirable effect of CEC's could be infertility in men. According to an article published in The Guardian in Mon 18 Mar 2002, the steady **drop in male fertility** in Britain could be caused by men ingesting female hormones in drinking water drawn from rivers containing recycled sewage, according to government researchers.

Finally, one side effect of chlorination of sewage effluent is the formation of DBP's. When chlorine reacts with organic chemicals, it forms new chemicals that remain in the water. These are called chlorination by-products or Disinfection By Products. The International Agency for Research on Cancer (IARC) classifies some chlorination by-products as possible causes of **cancer**, specifically bladder cancer.

How to Remove them from Tertiary Sewage Effluent?

SUEZ use Ozone and GAC. GAC is basically a filter than contains Granulated Activated Carbon.

AOP's = Advanced Oxidation Processes can also be used using H_2O_2/UV and Ozone and any combination thereof.

Fenton's Reagent = Iron activated Peroxide.

Fenton's reagent is a solution of hydrogen peroxide (H_2O_2) with ferrous iron (typically iron(II) sulfate, $FeSO_4$) added as a catalyst that is used to oxidize contaminants or waste waters. Fenton's reagent can be used to destroy organic compounds such as trichloroethylene (TCE) and tetrachloroethylene (perchloroethylene, PCE).

One strategy to combat the emergence of pharmaceuticals in waste water is to **treat them at the source**. The amount of pharmaceuticals in hospital wastewater is on average 13 times higher per person than for a normal household. Antibiotics are more than 300 times higher per person in hospital wastewater and x-ray contrast media 25 times higher.

Needless to mention, the best way to remove CEC's from waste water is to eliminate their getting in the waste water to begin with. This can be done by raising awareness in consumers to avoid buying Personal Care Products for example that may have CEC's. To respond to this need, many "Environmentally Friendly" washing/cleaning agents have appeared on the market.

References/Further Reading:

<https://www.epa.gov/wqc/contaminants-emerging-concern-including-pharmaceuticals-and-personal-care-products>

https://en.wikipedia.org/wiki/Contaminants_of_emerging_concern

Unraveling the riverine antibiotic resistome: The downstream fate of anthropogenic inputs - Water Research, Volume 197, 1 June 2021, 117050: <https://www.kwrwater.nl/en/projecten/opkomende-stoffen/>

Municipal Waste Water Treatment Plant (WWTP) Effluents - a Concise Overview of the Occurrence of Organic Substances. RIWA July 2007

Fish exposed to even small amounts of estrogen produce fewer males - <https://www.sciencedaily.com/releases/2020/10/201023123100.htm>

Direct and indirect responses of a freshwater food web to a potent synthetic oestrogen. - Kidd KA, Paterson MJ, Rennie MD, Podemski CL, Findlay DL, Blanchfield PJ, Liber K. 2014 *Phil. Trans. R. Soc.* B 369: <https://envirobites.org/2019/05/10/how-hormones-in-lakes-harm-aquatic-life/>

Fish clue to human fertility decline: <https://www.theguardian.com/society/2002/mar/18/research.medicalscience>

There's something in the water: the shocking contents of the River Thames: <https://www.standard.co.uk/lifestyle/esmagazine/contents-of-the-thames-pollution-river-a4191461.html>

Removal of pharmaceutical residues at the source

https://www.nijhuisindustries.com/assets/uploads/NEWS/Focus-paper-Removal-of-pharmaceutical-residues-at-the-source_ENG_final.pdf

MRI's Environmental Impact: <https://www.itnonline.com/content/mris-environmental-impact>

Biography



Rami Elias Kremesti with a KEE Process RBC rotor.

Rami Elias Kremesti is a UK chartered water treatment specialist with over 15 years of experience in water treatment. Rami earned his M.Sc. in industrial chemistry from the USA in 1998. He started his water treatment career in 2005 in Saudi Arabia working for Nalco. Afterwards, he worked for many years on power stations specializing in boiler chemistry and ultra-pure water production. He loves reverse osmosis and he also knows his cooling tower chemistry. Afterwards he worked in the building services industry treating the cooling towers in large commercial buildings in the UK using environmentally friendly Ozone as a biocide and reverse osmosis for water recycling. He currently works as a sewage treatment specialist for KEE Process based out of Aston Clinton where he manages contracts and advises clients on water chemistry issues. Rami has two daughters that live in Bulgaria and he spends his working time in the UK and his vacations mostly in Bulgaria to be with his girls. Rami is passionate about the poetry of Rumi and published his first book *The Other Cheek of Islam* in December 2020. He is a peace activist and passionate environmentalist.