

Removal Techniques/ Treatment

Conventional treatment such as sludge dewatering, filtration or activated carbon adsorption is not sufficient to remove pharmaceuticals and personal care products (PPCPs) from wastewater. Advanced treatment technologies such as ozonation, granular activated carbon (GAC), and reverse osmosis (RO) are used for the removal of PPCPs. The effectiveness of GAC for removal of PPCPs depends on the type of PPCPs, the concentration of PPCPs, and the GAC characteristics. The adsorption capacity of GAC is affected by the type of PPCPs, the concentration of PPCPs, and the GAC characteristics. The adsorption capacity of GAC is affected by the type of PPCPs, the concentration of PPCPs, and the GAC characteristics.

Direct: Human Health Impacts

Direct human health impacts of PPCPs in the environment are a concern. Some PPCPs are known to be endocrine disruptors, which can interfere with the hormonal system. Other PPCPs are known to be neurotoxic, which can damage the nervous system. Some PPCPs are known to be carcinogenic, which can cause cancer. Some PPCPs are known to be mutagenic, which can cause mutations in DNA.

Indirect Effects: Aquatic

Indirect effects of PPCPs in the environment are a concern. Some PPCPs are known to be endocrine disruptors, which can interfere with the hormonal system of aquatic organisms. Other PPCPs are known to be neurotoxic, which can damage the nervous system of aquatic organisms. Some PPCPs are known to be carcinogenic, which can cause cancer in aquatic organisms. Some PPCPs are known to be mutagenic, which can cause mutations in DNA in aquatic organisms.

Fate of Pharmaceuticals

The fate of pharmaceuticals depends on the environment. In water, pharmaceuticals can be broken down by hydrolysis, photolysis, and biodegradation. In soil, pharmaceuticals can be broken down by biodegradation and sorption to soil particles. In air, pharmaceuticals can be broken down by photolysis and biodegradation.

Pharmaceutical	Concentration (ng/L)	Removal (%)	Residual (%)	Half-life (h)	Log K _{ow}	Water solubility (mg/L)	Biodegradability	Photolability	Hydrolyzability
Acetaminophen	100	95	5	1.5	1.5	100	High	High	High
Ibuprofen	100	90	10	2.0	3.5	10	High	Low	Low
Paracetamol	100	95	5	1.5	1.5	100	High	High	High
Amoxicillin	100	80	20	3.0	3.0	10	High	Low	Low
Cloxacillin	100	70	30	4.0	3.0	10	High	Low	Low
Fluoxetine	100	60	40	5.0	4.0	10	Low	Low	Low
Escitalopram	100	50	50	6.0	4.0	10	Low	Low	Low
Sumatriptan	100	40	60	7.0	4.0	10	Low	Low	Low
Valproic acid	100	30	70	8.0	4.0	10	Low	Low	Low
Phenobarbital	100	20	80	9.0	4.0	10	Low	Low	Low
Chlorzoxazone	100	10	90	10.0	4.0	10	Low	Low	Low
Propofol	100	5	95	11.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	12.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	13.0	4.0	10	Low	Low	Low
Propofol	100	5	95	14.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	15.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	16.0	4.0	10	Low	Low	Low
Propofol	100	5	95	17.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	18.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	19.0	4.0	10	Low	Low	Low
Propofol	100	5	95	20.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	21.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	22.0	4.0	10	Low	Low	Low
Propofol	100	5	95	23.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	24.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	25.0	4.0	10	Low	Low	Low
Propofol	100	5	95	26.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	27.0	4.0	10	Low	Low	Low
Etomidate	100	5	95	28.0	4.0	10	Low	Low	Low
Propofol	100	5	95	29.0	4.0	10	Low	Low	Low
Midazolam	100	5	95	30.0	4.0	10	Low	Low	Low

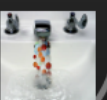


Biosorbents

Biosorbents are natural materials that can adsorb pharmaceuticals. They are often made from agricultural waste, such as yeast cells, algae, and bacteria. Biosorbents are a promising technology for the removal of pharmaceuticals from wastewater.

Outline

- What are pharmaceuticals?
- Pathway into the environment
- Transmission to Drinking Surface Water
- How are they an emerging issue?
- Exposure methods
- Effects on Species: Fish
- Concerns about Human Health
- Canadian/International standards and guidelines for water drinking water
- Removal techniques
- Future Drinking Water Research



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Pharmaceuticals in the Environment

Pharmaceuticals in the Environment

Pharmaceuticals in the Environment

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Pharmaceuticals in the Environment

Focus on Sources of Waste

Total concentrations (µg and daily dose) of pharmaceuticals in wastewater. Hospitals and pharmaceutical companies need to improve their control over the water resources pollution by the pharmaceuticals.

International Perspective

Pharmaceuticals in the Environment

Canadian Efforts to Monitor

Pharmaceuticals in the Environment

International Task Back Progress

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- Removal techniques
- Future Direction/Research

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What are PPCPs?
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- Human and veterinary pharmaceuticals are excreted by individuals, by animals, and by plants, and the products used in agriculture, industry, and the products used in household cleaning.
- PPCPs include hormones, antibiotics, and other drugs used in human and veterinary medicine.
- PPCPs are found in surface water, groundwater, and drinking water.
- PPCPs are found in the environment because they are not completely broken down by the body and are excreted in urine and feces.
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What are PPCPs?

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
- Pharmaceuticals and Personal Care Products are substances used by individuals for personal health or cosmetic reasons and the products used by agribusiness to boost growth or health of livestock.
- PPCPs in water have received growing attention from environmental and health agencies all over the world and have become one of the emerging pollutants due to their frequent detection.
- They should be treated as hazardous compounds and removed from municipal effluents because not only is it harmful to the environment but also to human health.

Controversial Emerging Issue

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- In 2008, pharmaceutical sales totaled US \$602 billion
- consumption of pharmaceuticals is likely to increase given the fact that people are living longer and using more drugs as they age
- Some pharmaceuticals are more prevalent than others
- eg. Meprobamate
 - one study detected in more than 50% of drinking water samples
 - difficult to be governed by the degree of wastewater influence in source water and removal during treatment.

Meprobamate
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- Anti-anxiety pharmaceutical
- Minimum therapeutic dose is 200 mg/day
- Maximum concentration ever discovered in drinking water (0.00042 mg/L)
- A person would need to consume at least 4.7 million L of water in a single day to ingest the therapeutic dose.
- Perspective: Drinking 10L of water in an hour can be fatal

Pharmaceuticals are
Ubiquitous
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Table 1. Concentration of pharmaceuticals found in European water systems

Substance	Concentration (µg/L)	Frequency (%)	Number of samples (%)	Number of stations (%)
Acetylsalicylic acid	20000	100	100	100
Chloramphenicol	10000	100	100	100
Doxycycline	10000	100	100	100
Erythromycin	10000	100	100	100
Fluoxetine	10000	100	100	100
Paracetamol	10000	100	100	100
Salicylic acid	10000	100	100	100
Sulfamonomethoxazole	10000	100	100	100
Trimethoprim	10000	100	100	100

Studies have shown that pharmaceuticals in fresh drinking water do not pose a significant health risk. However, they do occur at low frequencies and concentrations.

mg = 1,000,000 µg
kg = 1000 g

Pharmaceuticals are Ubiquitous

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Table 3. Concentrations of selected pharmaceuticals found in European surface waters

Compound	Median (maximum) concentrations (ng/l)				
	Austria	Finland	France	Germany	Switzerland
Bezafibrate	20 (160)	5 (25)	102 (430)	350 (3100)	—
Carbamazepine	75 (294)	70 (370)	78 (800)	25 (110)	30–150
Diclofenac	20 (64)	15 (40)	18 (41)	150 (1200)	20–150
Ibuprofen	nd	10 (65)	23 (120)	70 (530)	nd (150)
Iopromide	91 (211)	—	7 (17)	100 (910)	—
Roxithromycin	nd	—	9 (37)	< LOQ (560)	—
Sulfamethoxazole ^a	nd	—	25 (133)	30 (480)	—

LOQ, limit of quantification; nd, not detected (below the detection limit)

^a Includes the human metabolite *N*⁴-acetyl-sulfamethoxazole.

Source: Ternes et al. (2005)

Studies have shown that pharmaceuticals in trace amounts are ubiquitous in surface water, but occur at low frequency and concentration.

1mg = 1 000 000 ng

1mg = 1000 ug

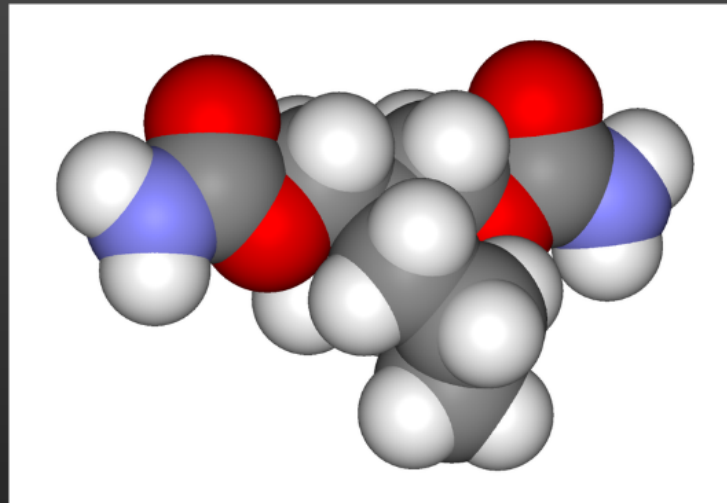
**At what levels do
these chemicals
occur in the surface
water?**

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- Study conducted by U.S Geological Survey report published in 2002 found detectable quantities of PPCPs in 80% of a sampling of 139 susceptible streams in 30 states.
- Most common pharmaceuticals detected were steroids and nonprescription drugs; detergents, fire retardants, pesticides, natural and synthetic hormones, and an assortment of antibiotics and prescription medications.

Meprobamate

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Pathway into the Environment

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- Through human activity
- Residues from manufacturing agribusiness, hospital and community use
- Waste excretion
- Disposal of unused medication to septic tank, sewers/trash

