

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 membrane filtration (MF) are used for the removal of PPCPs. The effectiveness of GAC for removal of PPCPs depends on the type of PPCP, the concentration of PPCPs, and the GAC bed depth. MF is a physical process that removes PPCPs from wastewater by passing it through a membrane. MF is effective for removing PPCPs from wastewater, but it is not a perfect process. Some PPCPs can pass through the membrane. MF is a physical process that removes PPCPs from wastewater by passing it through a membrane. MF is effective for removing PPCPs from wastewater, but it is not a perfect process. Some PPCPs can pass through the membrane.

Direct: Human Health Impacts

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Endocrine-disrupting chemicals (EDCs) are a class of chemicals that can interfere with the body's endocrine system. EDCs can be found in many products, including pesticides, plastics, and pharmaceuticals. EDCs can cause a variety of health problems, including reproductive problems, developmental problems, and cancer.

Indirect Effects: Aquatic

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Pharmaceuticals in the environment can have indirect effects on aquatic life. For example, pharmaceuticals can act as endocrine-disrupting chemicals (EDCs), which can interfere with the reproductive system of fish and other aquatic organisms. This can lead to reduced fertility, abnormal development, and even death.

Fate of Pharmaceuticals

The fate of pharmaceuticals depends on the environment in which they are released. In water, pharmaceuticals can be broken down by sunlight, bacteria, and other natural processes. However, many pharmaceuticals are resistant to these processes and can persist in the environment for long periods of time. Some pharmaceuticals can also be taken up by plants and animals, which can then pass them on to other organisms in the food chain.

| Pharmaceutical | Removal (%) | Concentration (µg/L) | Half-life (h) | Log K _{ow} | Water Solubility (mg/L) | Biodegradability | Photolability | Volatility | Adsorption |
|----------------|-------------|----------------------|---------------|---------------------|-------------------------|------------------|---------------|------------|------------|
| Acetaminophen | 100% | 100 | 1.5 | 0.5 | 1000 | High | High | Low | Low |
| Ibuprofen | 100% | 100 | 1.5 | 3.5 | 10 | High | High | Low | Low |
| Paracetamol | 100% | 100 | 1.5 | 0.5 | 1000 | High | High | Low | Low |
| Aspirin | 100% | 100 | 1.5 | 2.0 | 100 | High | High | Low | Low |
| Amoxicillin | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Cloxacillin | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Penicillin G | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Vancomycin | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Fluoxetine | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Escitalopram | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Sumatriptan | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Propofol | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Midazolam | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Etomidate | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Propofol | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Midazolam | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |
| Etomidate | 100% | 100 | 1.5 | 3.0 | 10 | High | High | Low | Low |

Biosorbents

Biosorbents are natural or synthetic materials that can adsorb pharmaceuticals from wastewater. They are often made from agricultural waste, such as wheat bran, and are effective for removing a wide range 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
- Controversy about Health Effects
- Canadian/International standards and guidelines for safe drinking water
- Removal techniques
- Future Research



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Canadian Efforts to Monitor

The environmental drug regulator publishes data on the pharmaceuticals in Canada. CDTO regularly releases information about the levels of pharmaceuticals in the environment. This helps to identify areas where there is a high concentration of pharmaceuticals and where there is a need for further action.

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 TSP Back Ground

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Pharmaceuticals in the Environment

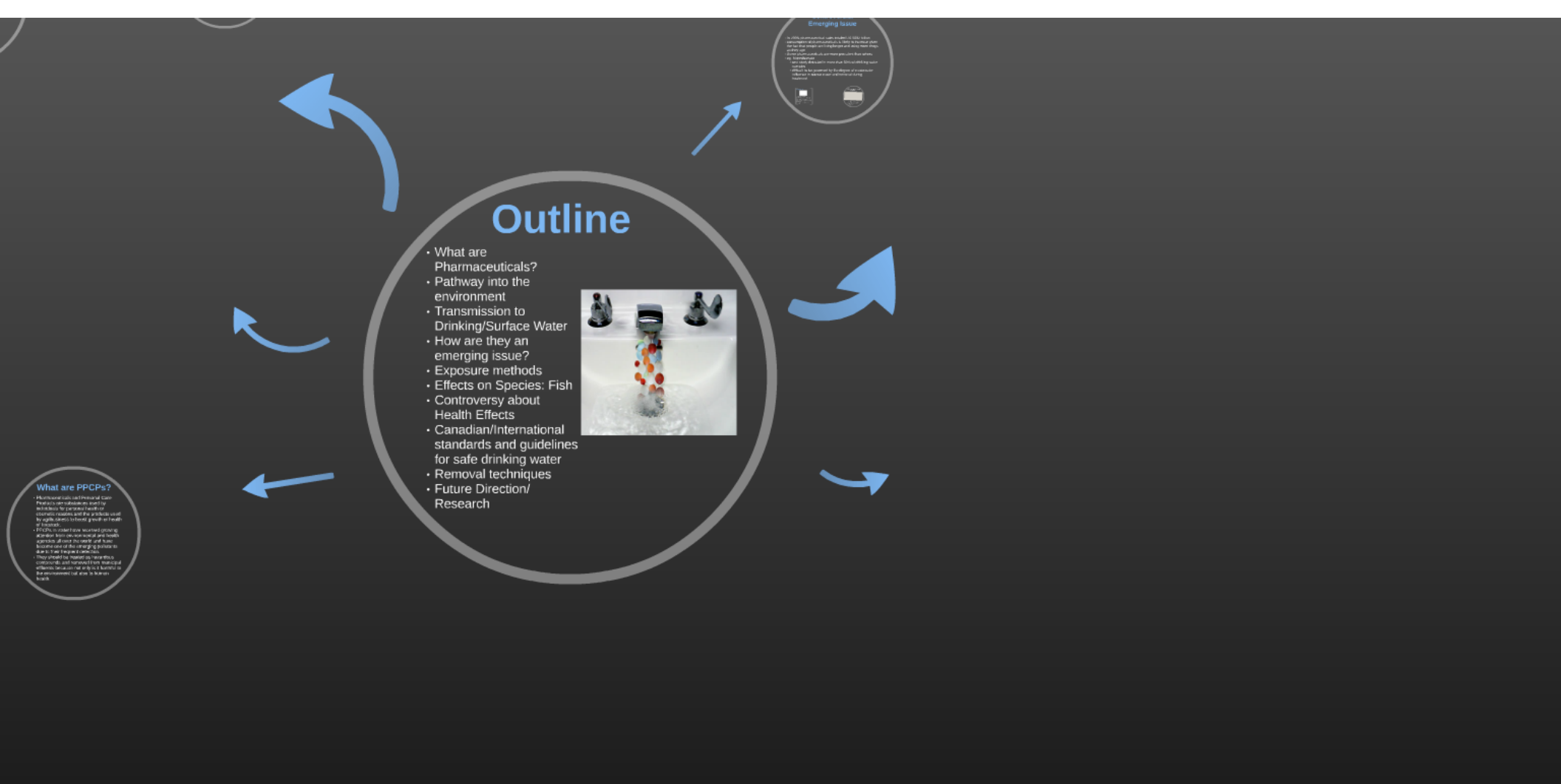
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Observation

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Takeaway

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- Exposure methods
- Effects on Species: Fish
- Controversy about Health Effects
- Canadian/International standards and guidelines for safe drinking water
- Removal techniques
- Future Direction/ Research



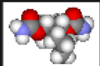
What are PPCPs?

- 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

- 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



- Anti-anxiety pharmaceutical
- Minimum therapeutic dose is 200 mg/day
- Maximum concentration ever discovered in drinking water (0.000042 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

Table 1. Concentration of pharmaceuticals in surface water in the United States

| Pharmaceutical | Concentration (ng/L) | Concentration (µg/L) | Concentration (mg/L) | Concentration (ppb) |
|--------------------|----------------------|----------------------|----------------------|---------------------|
| Albuterol | 2.0 | 0.002 | 0.000002 | 2.0 |
| Aspirin | 100 | 0.1 | 0.0001 | 100 |
| Clonidine | 100 | 0.1 | 0.0001 | 100 |
| Diazepam | 100 | 0.1 | 0.0001 | 100 |
| Fluoxetine | 100 | 0.1 | 0.0001 | 100 |
| Levamisole | 100 | 0.1 | 0.0001 | 100 |
| Phenacetin | 100 | 0.1 | 0.0001 | 100 |
| Phenol | 100 | 0.1 | 0.0001 | 100 |
| Salicylic acid | 100 | 0.1 | 0.0001 | 100 |
| Sulfamonomethoxime | 100 | 0.1 | 0.0001 | 100 |
| Tylenol | 100 | 0.1 | 0.0001 | 100 |
| Valproic acid | 100 | 0.1 | 0.0001 | 100 |

Studies have shown that pharmaceuticals in fresh surface water are ubiquitous in surface water, but occur at low frequency and concentrations.

mg = 1,000 µg
µg = 100 ng

Pharmaceuticals are Ubiquitous

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.

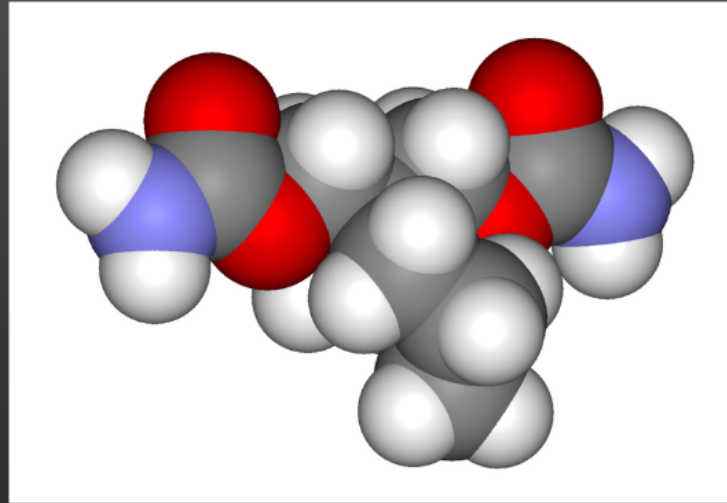
1mg = 1 000 000 ng

1mg = 1000 ug

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

- 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.

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