

How do organic micropollutants affect fish?

Wastewater treatment plants remove contaminants and pollutants from water before releasing it back into the surrounding aquatic ecosystems. Unfortunately, these treatment facilities are not designed to remove all pollutants, and some chemicals end up being released in local rivers and waterways. **Dr Kelly Munkittrick** from the **University of Calgary** and **Dr Maricor Arlos** from the **University of Waterloo** are combining their expertise to monitor organic micropollutants in Canadian aquatic ecosystems and reduce their impacts.



Dr Kelly Munkittrick

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Fields of research

Aquatic toxicology, environmental
engineering

Research project

Studying the effects of organic
micropollutants on aquatic organisms and
ways of minimising the occurrence of these
micropollutants in wastewater

Funders

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Talk like an ... aquatic toxicologist and environmental engineer

Bioaccumulation —
the gradual accumulation of
substances (e.g., chemicals) in
the tissues of an organism

Effluent — treated
wastewater (from water
treatment facilities or industry)
discharged into the environment

Invertebrate — an animal
without a backbone (e.g.,
molluscs, insects, worms)

Micropollutants —
chemicals from human
activities that can have negative
environmental impacts, even at
very low concentrations

Personal care products
— substances used for hygiene
and beautification such as
shampoo, toothpaste, sunscreen
and hair dye

Pharmaceuticals —
substances used to treat illnesses
or diseases, which can be
released from the body through
urine

Toxicology — the study of
the harmful effects of chemicals
or other substances on living
organisms or ecosystems

When we flush
the toilet, take
a shower or do
the washing up,
the water we use usually ends up in
a wastewater treatment plant. Here,
solid wastes and other materials
are treated or removed before the
water is allowed to re-enter rivers
or the sea. However, wastewater
treatment is not able to remove all
traces of every contaminant. For

example, pharmaceutical chemicals,
such as medicines, and personal care
products that we use to clean and
beautify ourselves, often end up as
micropollutants in aquatic ecosystems
where they may have profound effects
on the organisms living there.

Dr Kelly Munkittrick, an aquatic
toxicologist from the University of
Calgary, played an important role in
developing the Environmental Effects



Kelly and Maricor's team and other researchers working on the Bow River project.

Monitoring (EEM) framework which is used to examine how waste discharges affect organisms living in freshwater environments in Canada. At the University of Waterloo, environmental engineer Dr Maricor Arlos is using the EEM framework to study the effects of micropollutants from wastewater on freshwater environments.

While aquatic toxicologists like Kelly research the effects of pollutants on aquatic organisms, environmental engineers like Maricor develop and design innovative ways of treating effluents to reduce micropollutant concentrations. When combined, these two disciplines can protect aquatic ecosystems and the organisms that live in them.

Environmental Effects Monitoring

Many industrial sites, such as mines, paper mills and wastewater treatment plants, release effluent into their surrounding freshwater habitats. Regulators test this effluent using environmental monitoring programmes like EEM to ensure that it is safe and causing minimal harm to the local environment. "Even if local industries meet effluent regulations, EEM can help establish whether there are still concerns about water quality," says Kelly. "Using EEM, we monitor how fast the local fish grow, how long they live, how many eggs they produce and the health of their tissues. We also monitor populations of different invertebrates, which gives an indication of habitat health."

"If measurements indicate fish populations are healthy, monitoring continues in a 'surveillance' mode," continues Kelly.

"If there are indications of changes in fish health, monitoring ramps up to a 'confirmation' mode, where we repeat our measurements to confirm the observed changes." If measurements suggest significant cause for concern, monitoring moves to a 'focused' mode which involves intensive monitoring to establish the scale and nature of the negative impacts. The data generated from this framework set the stage for identifying potential causes and coming up with effective solutions.

Organic micropollutants

Pharmaceuticals, personal care products and industrial chemicals are typically only present in waterways in ultra-low concentrations – but this can still be enough to have an impact. "We call these substances organic micropollutants and measure their concentration in parts per trillion – which equates to about one drop of water in twenty Olympic-sized swimming pools," says Maricor. "Organic micropollutants originate from our homes as well as agricultural and urban runoff." Even if these micropollutants enter a wastewater treatment plant, most treatment systems are not equipped to remove them, so they tend to pass straight through.

Organic micropollutants can interact with animals by mimicking hormones, which interferes with their physiology. "Researchers have found intersex fish – male fish with some female characteristics – downstream of wastewater treatment plants," says Maricor. "They have also found that antidepressants can affect fish behaviour, affecting their ability to survive and reproduce." While it is rare that these

chemicals directly kill the fish, impacts on their lifespan and ability to reproduce put their populations at risk.

Monitoring micropollutants

Maricor is using an artificial streams facility to study what happens to micropollutants when they enter a freshwater environment. "This facility has twelve replicate streams which are linked to different types of wastewater treatment technologies," she says. "We monitor the levels of micropollutants in the water, sediments, invertebrates and fish to understand where they end up after leaving the treatment plant." New, highly sensitive technologies that can detect and measure very low concentrations of these micropollutants are making this research possible.

Maricor's research is generating intriguing results. They indicate that substances like antidepressants bioaccumulate in the tissues of fish and invertebrates. "We are not yet sure how this bioaccumulation might affect these animals," says Maricor. "But we have strong evidence that these micropollutants are building up within aquatic organisms."

These findings will help researchers like Kelly and Maricor figure out what concentrations of micropollutants can be considered acceptable in these environments, and find new ways to treat effluents to remove these pollutants. "Governments need the information that we're generating to develop new regulations that limit the amount of these chemicals that are allowed to be released," says Maricor. "This stimulates optimisation and modernisation in our wastewater treatment systems."

About aquatic toxicology and environmental engineering

Aquatic toxicology is the study of how materials and activities, in particular, the release of man-made chemicals, affect aquatic organisms. It is a field with important implications for environmental and human health, helping define regulations and recommendations around chemicals in effluents from industry, agriculture and domestic sources. “The world is being exposed to ever-increasing numbers of chemicals, many of which have very subtle long-term consequences on organisms that we are only just beginning to understand,” says Kelly. “New chemicals of potential concern are always being created, so there are always new issues to study.”

The explosion of new technologies over the last couple of decades has opened new doors for aquatic toxicology, as costs of emerging technologies fall and the precision and quantity of data increases. “In particular, ‘omics’ technologies, that can analyse DNA, RNA and proteins at a large scale, are accelerating our analyses,” says Kelly. He also notes that advances in environmental DNA technologies, where DNA shed by organisms can be detected in water samples without ever needing to find the organisms themselves, have been a huge help to ecosystem analyses. “Technologies for tagging animals have also dramatically improved, not to mention drones and satellite imagery, all of which really widen the kinds of studies that we can do,” Kelly continues.

Environmental engineering involves collaborating with specialists from a variety of disciplines. “While I am an environmental engineer, I work closely with biologists to help prioritise monitoring efforts and potential remediation options,” says Maricor. “Others in the field work on water economics, public health and public policy.” Coordinating research priorities and their application to policy and legislation involves strong collaboration between everyone involved. “The common reward for all is building an understanding of the causes of an environmental problem and working to develop a solution,” says Kelly.

Pathway from school to aquatic toxicology and environmental engineering

For careers in environmental engineering, Maricor recommends getting a good grounding in biology, chemistry, physics and mathematics. At university, civil or environmental engineering courses represent the most direct route into this field.

For a career in aquatic toxicology, Kelly agrees that biology, chemistry and mathematics are valuable subjects to study at school. At university, he suggests biology courses that cover or specialise in biochemistry and physiology.

Explore careers in aquatic toxicology and environmental engineering

The Environmental Careers Organization of Canada (eco.ca) is a great starting point for exploring the range of environmental careers available in Canada, as well as a resource hub for training and events.

Environmental Science provides an overview of careers in environmental toxicology (which can include aquatic toxicology) environmentalscience.org/career/environmental-toxicologist

Watch these videos on Maricor’s lab website to learn more about her research: arloslab.com/outreach

Watch this video from Oak Ridge National Laboratory to learn more about aquatic toxicology research: youtube.com/watch?v=qIWG1k0-HmE



Meet Kelly

As I was growing up, I fished in our local river as much as I could. I was fascinated to observe the fishes' habits, what they ate and where they lived. At university, I studied fish biology and wanted to find a career where I was outside on the water as much as possible.

I get to work in wonderful places. My work has taken me to rivers in more than 20 countries including Chile, Uruguay and Bhutan. In Uruguay, one river may hold as many as 200 species of fish, and we only know the biology of a small percentage of them. Creating the information needed to develop monitoring programmes is

exciting, as a lot of what we learn is new to science.

Outside of work, I still like to fish! I also love playing golf and riding my bike.

Kelly's top tips

1. Be curious. Learn to ask good questions and accept that you might not understand the answers as well as you think.
2. Learn to work well with others. Embrace diversity and the benefits it brings.



Meet Maricor

I grew up in the Philippines. Initially, I wanted to become a medical doctor, but my sister studied engineering and I became fascinated by what she was learning. Now, as an environmental engineer, I feel that I have a duty to develop technologies and frameworks that protect public and environmental health.

Being able to make contributions to science and engineering around the world is pretty neat! In 2022, I was able to go back to the Philippines for a project, and I am still collaborating with this project now. I hope to become a contributor to environmental protection in the Philippines.

I am still in the relatively early stages of my career. I have a lot to learn from folks that walked the path before me, including Kelly. I also pass on my knowledge to those more junior than me - I am very proud of the students that I have trained so far, and I love seeing them grow as young researchers.

Working in water research has taught me humility. It's important to recognise that I don't have all the answers and can learn from other people's points of view. No matter our discipline and perspective, we all want the same thing for water: to protect it and ensure that it is protected for years to come.

In my spare time, I do yoga and read a lot of fantasy novels. I grew up reading books like Harry Potter and Lord of the Rings, and they remain among my favourites!

Maricor's top tips

1. Embrace authenticity and stay true to yourself. When you align with your true self, opportunities and doors naturally open.
2. Pursue projects and activities that reflect your evolving values. As our values change, it's a chance to explore fresh, meaningful ventures.