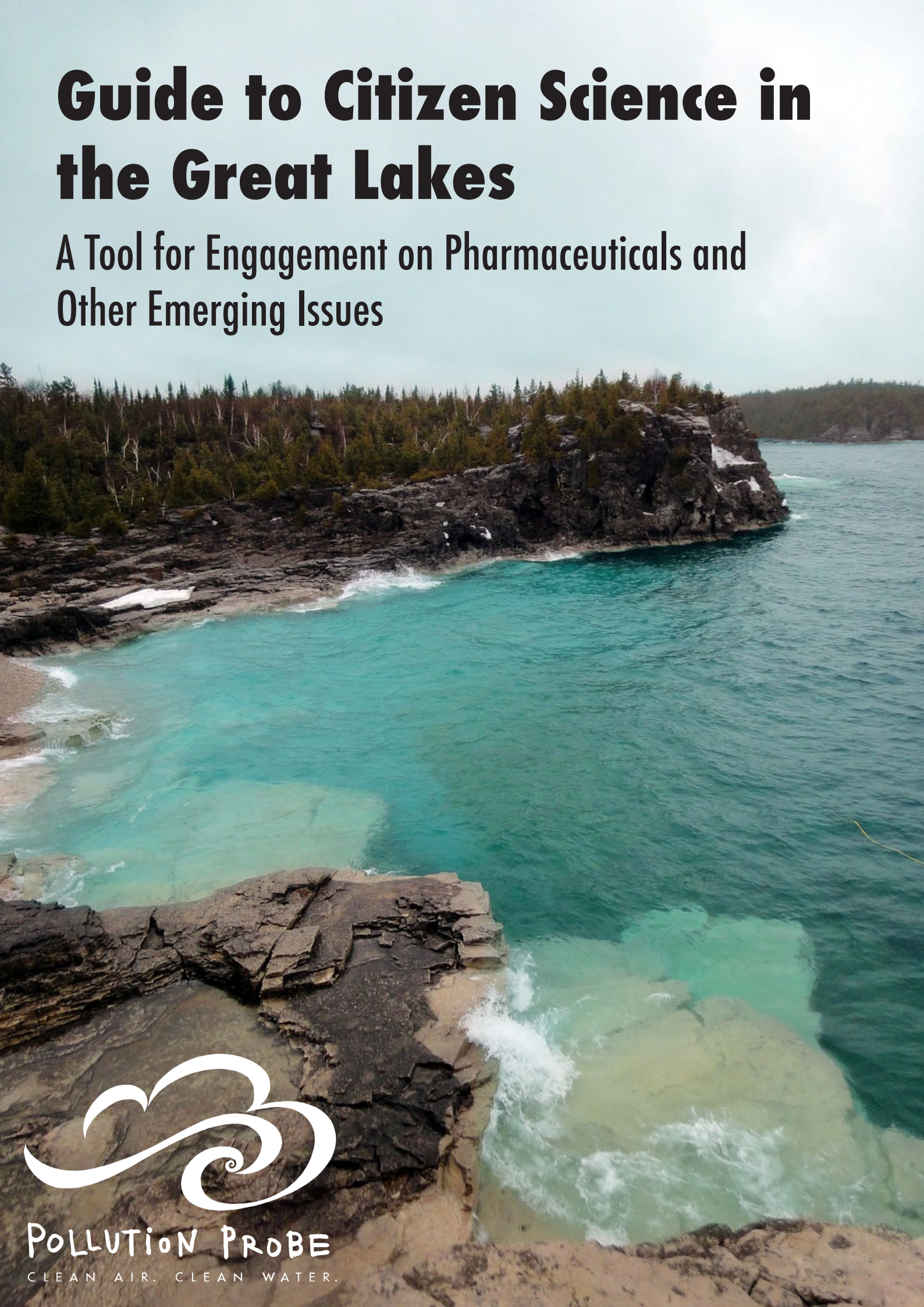
Guide to Citizen Science in the Great Lakes

A Tool for Engagement on Pharmaceuticals and Other Emerging Issues



POLLUTION PROBE

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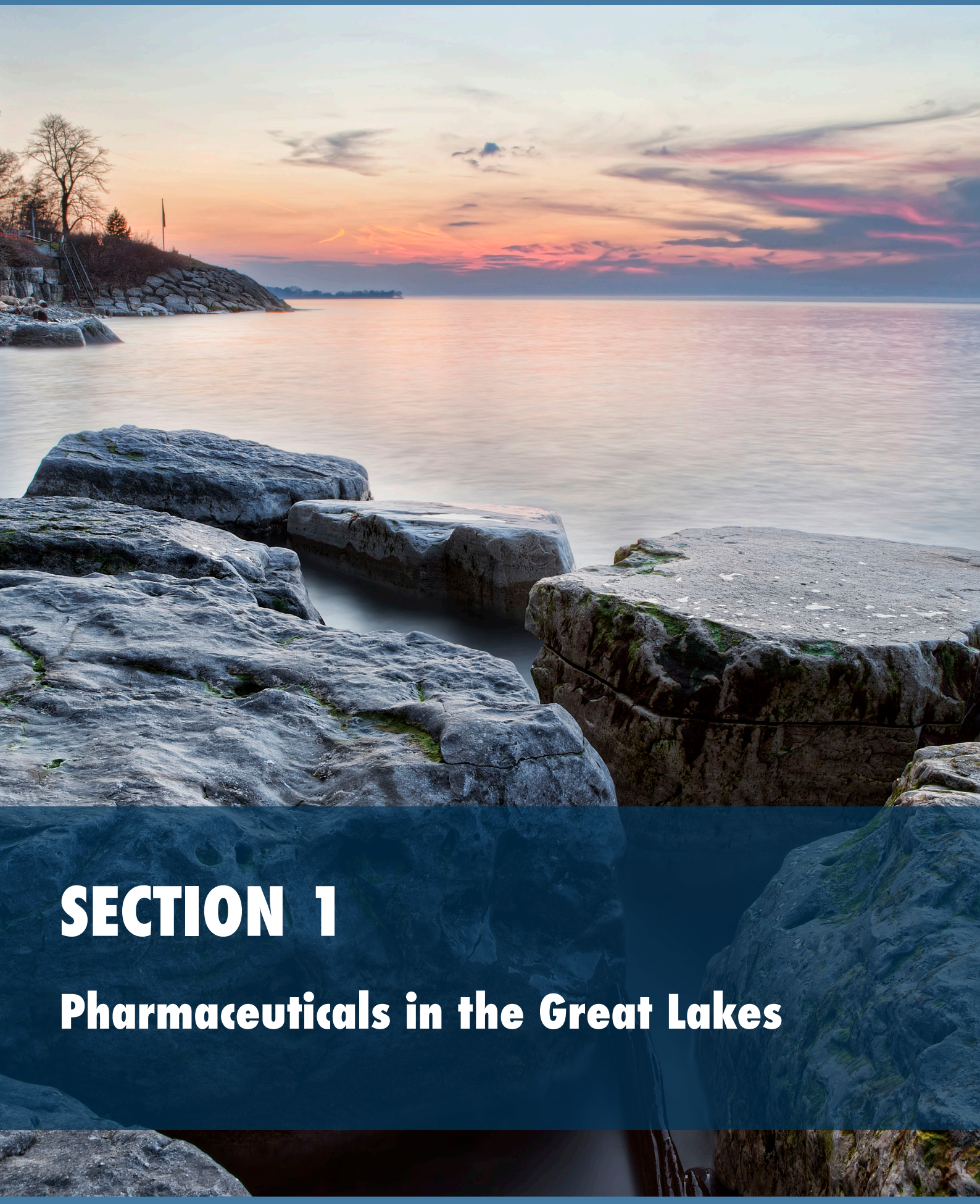
Pollution Probe is a Canadian charitable environmental organization (established in 1969) that is a leading agent of change at the intersection of communities, health and environment. Its approach is to define environmental problems through research, to promote understanding through education and to press for practical solutions through advocacy. Pollution Probe seeks to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change.

Disclaimer

The contents of this guide are based on Pollution Probe's report entitled *Citizen Science in the Great Lakes: A Tool for Engagement on Pharmaceuticals and Other Emerging Issues*, prepared for Environment and Climate Change Canada. Pollution Probe would like to acknowledge the project advisory group, comprised of subject-matter experts, for their guidance on the overall direction of the study and their contribution of important resources and data. For more information on citizen science, the impacts of pharmaceuticals in the Great Lakes, or other emerging water issues, please visit our website at www.pollutionprobe.org/water



SECTION 1

Pharmaceuticals in the Great Lakes

Intro to Pharmaceuticals

Pharmaceuticals play an important role in the treatment of disease and are widely used to improve the quality of life for humans and animals. However, they have been identified as substances of emerging concern based on evidence that a wide variety are finding their way into water bodies, including the Great Lakes.[1]

Commonly used pharmaceutical groups include:

- **Painkillers (e.g., acetaminophen)**
- **Birth control pills containing synthetic hormones**
- **Antidepressants**
- **Antimicrobials**
- **Anti-inflammatories (e.g., ibuprofen)**
- **Anti-diabetics**
- **Beta-blockers**

Even in extremely low concentrations, the detection of pharmaceutical compounds has the potential to spark public concern about risks to human health and the environment.

People may worry that:

- **They are being unknowingly medicated**
- **Wastewater treatment plants (WWTPs) are somehow ineffective**
- **There will be human health impacts from exposure**

These concerns point to a need to better educate the public around pharmaceuticals in an effort to replace misinformation with facts and provide context based on science. For example, while pharmaceuticals have been detected in aquatic environments, the majority are in very low concentrations, typically in the microgram (one millionth of a gram) to nanogram (one billionth of a gram) per litre range.

What can you do to prevent pharmaceuticals from ending up in the Great Lakes?[2]

1. Avoid the overuse of medications.
2. Finish using prescriptions as directed by your physician.
3. Take unwanted and waste medications to your local pharmacy for disposal—**do not flush!**
4. Share your concerns with Pollution Probe and we will engage the appropriate decision-makers.

Main Sources and Pathways

Pharmaceuticals can end up in the aquatic environment via **agricultural runoff**, **discharges from pharmaceutical plants**, **wastewater effluents from human excretion** and **improper disposal** of unused or expired medications.[3]

WWTPs are the primary pathway for human pharmaceutical compounds to enter the aquatic environment. Treatment processes may remove some but WWTPs were not designed to remove most synthetic compounds, including pharmaceuticals.[4]

The Great Lakes Basin acts as a repository for a number of pollutants because the water replenishes slowly, and persistent substances are not readily flushed from the system. Pharmaceuticals generally enter the lakes at low levels, but their supply can be continually replenished in the aquatic environment, leading to an accumulation even if they degrade easily. Once pharmaceuticals enter the lakes, they can be absorbed by other media (e.g., soil, suspended particles, sediment), organic matter (e.g., plants), and biological organisms (e.g., algae, fish).[5] Some pharmaceuticals may degrade rapidly or transform into other substances, which may be more or less harmful than the original form, and more or less available to media in the aquatic environment.

While pharmaceuticals in the Great Lakes have been found primarily in effluent or surface water downstream from WWTPs, compounds have also been detected in open waters, fish tissues, and drinking water treatment plants.[6]

Environmental and Human Health Impacts

ENVIRONMENTAL	HUMAN HEALTH
◆ Studies have shown impacts on the environment, even at low concentrations.[7]	◆ Questions remain related to the impact of low levels of pharmaceuticals on human health.
◆ Pharmaceuticals can **bioaccumulate** in the food chain.	◆ Cumulative exposure over a long period of time can lead to potentially harmful effects.

◆ There are concerns that the release of antibiotics into the aquatic environment may have the potential to contribute to the development or spread of antibiotic resistance, another issue of emerging concern.[8]

Bioaccumulation refers to the gradual accumulation of a substance in an organism. It occurs when organisms take up a chemical substance more rapidly than they can eliminate it, so that the contaminant accumulates in their bodies. For example, antidepressants have been shown to bioaccumulate in some fish.[9]

A Tool for Addressing Pharmaceuticals in the Great Lakes

Clearly, there is a need for additional research to better understand the presence and impacts of pharmaceutical pollution, and to monitor and report on concentration changes and the effects of potential chronic exposure over the long-term. A targeted **citizen science program** could help to provide a more complete picture of the extent of pharmaceutical presence and impacts in the Great Lakes, while helping to support a coordinated approach to research, analysis and action on pharmaceutical pollution.

This guide explores what citizen science is and the role it can play in further understanding the impact of pharmaceuticals in the Great Lakes.

SECTION 2

Citizen Science & Water Quality Monitoring in the Great Lakes

What is Citizen Science?

Public participation in the science process is known as citizen science. Its origins date back thousands of years, with some of the earliest examples organized around the monitoring and recording of insect, bird, and animal sightings.[10] Today, citizen science has come to describe an ever-broadening range of activities and approaches, including public science, crowdmapping, community citizen science, participatory sensing, popular epidemiology, and participation in scientific research.

Pictures from the early days (right) and a recent session (left) of the Audubon Society's annual Christmas Bird Count - the world's longest-running contributory citizen science project.

Citizen Science can:[11]

- Increase scientific knowledge;
- Raise awareness about environmental issues;
- Allow like-minded people to share knowledge;
- Allow governments and other institutions to interact with the general public;
- Provide unique opportunities for individuals and communities to generate their own questions, collect their own data, and advocate for the change they wish to see!

Citizen science promotes environmental stewardship by engaging those involved in activities that connect them with their land, air, and water. It provides individuals and communities with an opportunity for hands-on, experiential learning, which is an effective educational tool.

Citizen Science & Water Quality Monitoring in the Great Lakes

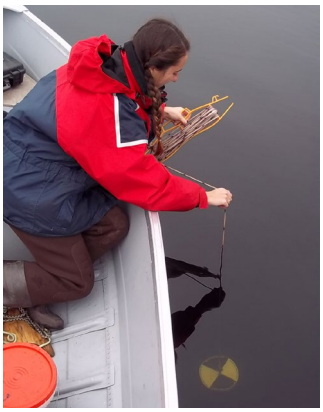
Water quality is a term used to encompass how the physical, chemical, and biological characteristics of a water sample measure up to a set of standards. Water quality monitoring has been used to verify whether water is suitable for its intended uses, to determine trends in the quality of the aquatic environment and to see how ecosystems may be affected by human activities.

Who Monitors Water Quality?

Water quality in the Great Lakes is monitored by governments, researchers, academic institutions, and environmental and citizen science groups. The federal and provincial governments regularly monitor the physical, chemical and biological conditions in the Great Lakes, allowing them to measure any natural changes to the condition of the water, determine the presence of contaminants, support the development of science-based guidelines for water, fish and sediment, and **identify emerging issues and threats**.

The following are two examples of established citizen science programs in the Great Lakes region:

Ontario Lake Partner Program



Coordinated by the Ontario Ministry of the Environment, Conservation and Parks, the Ontario Lake Partner Program is a volunteer-based, water quality monitoring program in collaboration with the Federation of Ontario Cottagers' Association. Water is sampled primarily to determine total phosphorus concentrations, but also the presence of chloride from road salt.

Swim Drink Fish

Swim Drink Fish is a non-profit organization using citizen science to connect people with water. With four water quality monitoring hubs on the Great Lakes and in Vancouver, volunteers collect water samples to inform the public about the water quality status of their local waters.[12]

Designing a Citizen Science Program

The following section provides guidance on considerations for the initial development of a citizen science program that could be applied to support a better understanding of pharmaceuticals in the Great Lakes.[13]

1. Program Objectives

In order to determine whether citizen science can play a role in helping meet a program's overall objectives, it is important to understand the purpose of its use. The U.S. Environmental Protection Agency (EPA) suggests three high-level project purposes as a starting point for shaping the design process and associated quality assurance requirements. The following purposes are organized from least to most rigorous:[14]

1. Increasing public understanding
2. Scientific studies and research
3. Legal and policy action

2. Program Planning

A good starting point is for program organizers to determine the target audience and overall goals of the program. Determining how data that has been collected will be used, and by whom, is also a key consideration early on in the planning process. Other questions to be answered during the program planning phase include:

1. How and where will samples and other information be gathered?
2. What training is required of participants?
3. What procedures should be followed for sampling?
4. How will potential errors be controlled for?
5. Who will be analyzing the samples collected?
6. How will data be reviewed to determine if it is scientifically relevant, consistent and useful?
7. How long will the program run?
8. How will participant engagement be maintained?
9. Is there an opportunity to embed the program within existing research and monitoring programs?[15]

3. Quality Assurance & Quality Control

As with any science-based initiative, citizen science programs should use specific strategies aimed at improving the credibility of data and use the highest level of quality assurance (QA) — a system of activities designed to ensure that the data meet defined standards of quality — and quality control (QC) — a system of maintaining standards by testing a sample of the output against the specification — required in order to meet the program's intended purpose. Such measures ensure the data meet the expected quality. Additionally, some labs and programs may have QA/QC requirements that should be consulted before designing the program to ensure their standards are met.

4. Financial Considerations

Available budget will also help to determine the scope of a citizen science program. The use of more sophisticated analysis to ensure precision and accuracy is often associated with greater costs due to the types of equipment, procedures, necessary expertise, laboratory fees and time required.

Ways of finding cost savings may include:

1. Analyzing numerous compounds together as a group
2. Partnering with a local academic institution with their own laboratory
3. Partnering with an existing monitoring program

5. Program Management & Administration

Training

An important step in designing a citizen science program is the development of a set of training protocols that can be tested and implemented.

Training programs play an important role in improving the scientific literacy of participants so that they can inform and train new volunteers or help educate members of their communities.

Documentation & Records

It's important that citizen science programs provide participants with clear instructions, descriptions of procedures, and checklists to be used when performing tasks.

SECTION 3

The Role of Citizen Science in Better Understanding Pharmaceuticals in the Great Lakes

Citizen Science Monitoring of Pharmaceuticals in the Great Lakes

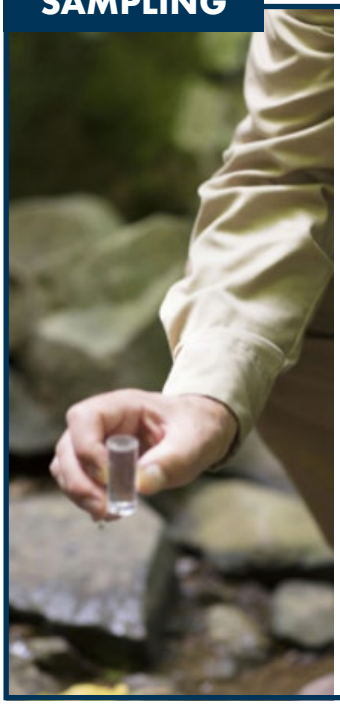
Citizen science can play an important role in helping individuals and communities better understand the nature of potential risks associated with the detection of pharmaceuticals in the Great Lakes through opportunities for first-hand learning, which can be a direct way to sort fact from fiction.[16]

A targeted citizen science program can contribute to a more complete picture of the extent of pharmaceutical presence and impacts in the Great Lakes, while helping to support a coordinated approach to research, analysis, education and action on pharmaceutical pollution. There is great potential for citizen science to reinforce the message that detection of pharmaceuticals does not always mean there is a risk to human health.[17] However, given the complexity of analysis required in testing for pharmaceuticals, a citizen science program is likely to be of greatest value as a means of educating and building science literacy while encouraging stewardship in the Great Lakes.

Considerations for Designing a Citizen Science Program

A range of considerations specific to the development and implementation of a citizen science pharmaceutical program in the Great Lakes are outlined below. The processes and methods described relate to the collection and transport of water samples, and to a lesser extent, any related analysis. The purpose of introducing these methods is to provide general, high-level guidance and should not act as a substitute for following approved standards and protocols for the specific processes required to meet the program's objectives.

SAMPLING



It is important to establish standard methods/operating procedures for the field and for laboratory analyses.

Sampling protocols should consider the following:

- Sampling design
  - Who will collect what data, where, when, and how?
- Sampling location
- Sampling frequency
- Sampling methods (e.g., grab, composite or passive sampling)
- Financial considerations (e.g., supplies, equipment)

The most appropriate method for sampling depends on the overall objective of the program. For more information on determining program objectives, see Section 2: Citizen Science & Water Quality Monitoring in the Great Lakes.

SHIPMENT AND STORAGE

The proper handling and transportation of samples from the field site to the lab are integral to ensuring data validity and reliability.

Shipment and storage should consider the following:

- Does the sample need to be analyzed within a certain timeframe? This will depend on the pharmaceuticals chosen to be analyzed and their degradation behaviour.
- What modes of transport are necessary or available?
- Will the sample's integrity be affected by outside influences (e.g., temperature, pressure, humidity)?

A chain of custody form should also be included to ensure that the samples have not been altered or tampered with.

ANALYSIS

It is well beyond the scope of a citizen science program to conduct their own analysis on pharmaceuticals. A reputable laboratory should be consulted as the process for testing for trace amounts of pharmaceuticals is analytically complex, requiring highly trained professionals using precise instruments and exact settings.

PROGRAM EVALUATION

It is important that citizen science programs undertake continuous tracking and reviewing of progress and performance over time to determine what is working well and what processes or methods may need to be updated.

Program evaluation should consider the following:

- Are the right types of data being collected?
- Are data being collected from the most appropriate locations?
- Can the results be compared statistically?
- Did all datasets meet QC criteria and, if not, what is the impact on the study or program?

OPPORTUNITIES FOR EDUCATION

Citizen science sampling programs provide excellent opportunities for individuals and communities to get out in the field, to experience the Great Lakes firsthand, and to better understand how to care for them. It is also a great opportunity to provide further educational resources.

By combining experiential learning and the provision of further information, participants can make a personal connection to what they see firsthand. This can empower citizen scientists to make changes in their own lives.[18]

Key Recommendations

1. The program should increase the public's understanding about pharmaceuticals.

2. Citizen science programs related to pharmaceuticals should emphasize educational and science literacy opportunities and encourage stewardship in the Great Lakes.

3. There are many contributions individuals can make to increasing understanding of pharmaceuticals in addition to collecting samples, including helping to communicate messages within their communities.

Conclusion

Citizen science initiatives have been shown to be one of the most effective means of increasing environmental awareness, education, stewardship and support for conservation efforts because they build goodwill and provide opportunities for participants to feel like an important part of the solution. A number of challenges associated with the feasibility of citizen scientists undertaking a monitoring program specific to pharmaceuticals exist, including the complex and costly analytical methods required to analyze trace amounts of pharmaceutical compounds. However, the public has shown concern about the potential risks that these substances may pose for human health and the environment, pointing to a need to better educate and engage around the science in a way that can help to replace fear with facts.

Given the complexity of the analysis for pharmaceuticals, the greatest value of developing a citizen science program is in its ability to effectively educate the public about the difference between what they may hear in the media and the reality of pharmaceutical presence and impacts in the Great Lakes. A program focused on education would ideally involve a combination of data collection methods in order to build a more complete picture of pharmaceutical presence in the Great Lakes, and an awareness-building element to improve scientific literacy and understanding.

The purpose of this guide is to provide an overview of important considerations for the monitoring of pharmaceuticals that can be explored or adopted by those looking to utilize citizen science as a tool for engagement and awareness-building, particularly in the Great Lakes. Participation in citizen science programs will engage the community as active participants in positive change, armed with a better understanding of how to contribute to the preservation and sustainability of their environment.

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