MICROPLASTICS!
The threat is NOT just large fragments!

BlueGreen Innovations Group
Queen's University

THE HIDDEN THREAT OF PLASTIC POLLUTION

IN THE GREAT LAKES

An Overview of Current Research, Potential Impacts & Recommendations Moving Forward

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TEAM

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Dedication

LAROCQUE Joseph Norman "Shaun", B.Com.

This project is dedicated to Shaun Larocque, of Sarnia Ontario, who passed away on Thursday July 18th, 2019 at the tragically young age of 52.

Shaun was formally educated in accounting and economics at the University of Western Ontario. He had more than 20 years of business experience including as the Vice President of Finance at BlueGreen Innovation Group and as Credit Union board director with Mainstreet Credit Union (formally Lambton Financial).

Shaun had a longstanding career with the Canadian Coast Guard for over 26 years most recently as a Marine Communications supervisor. He was passionate about marine safety and the environment especially regarding pollution in the Great Lakes.

Shaun was also an entrepreneur/inventor and co-owner of Ayess Industries. He made valuable contributions to the science and engineering aspects of innovation as well as finance and administration.

He will be greatly missed by all especially his colleagues at BlueGreen Innovation Group.

THE LAURENTIAN GREAT LAKES

18 % OF THE WORLD'S FRESHWATER

is held in the Laurentian Great Lakes System.

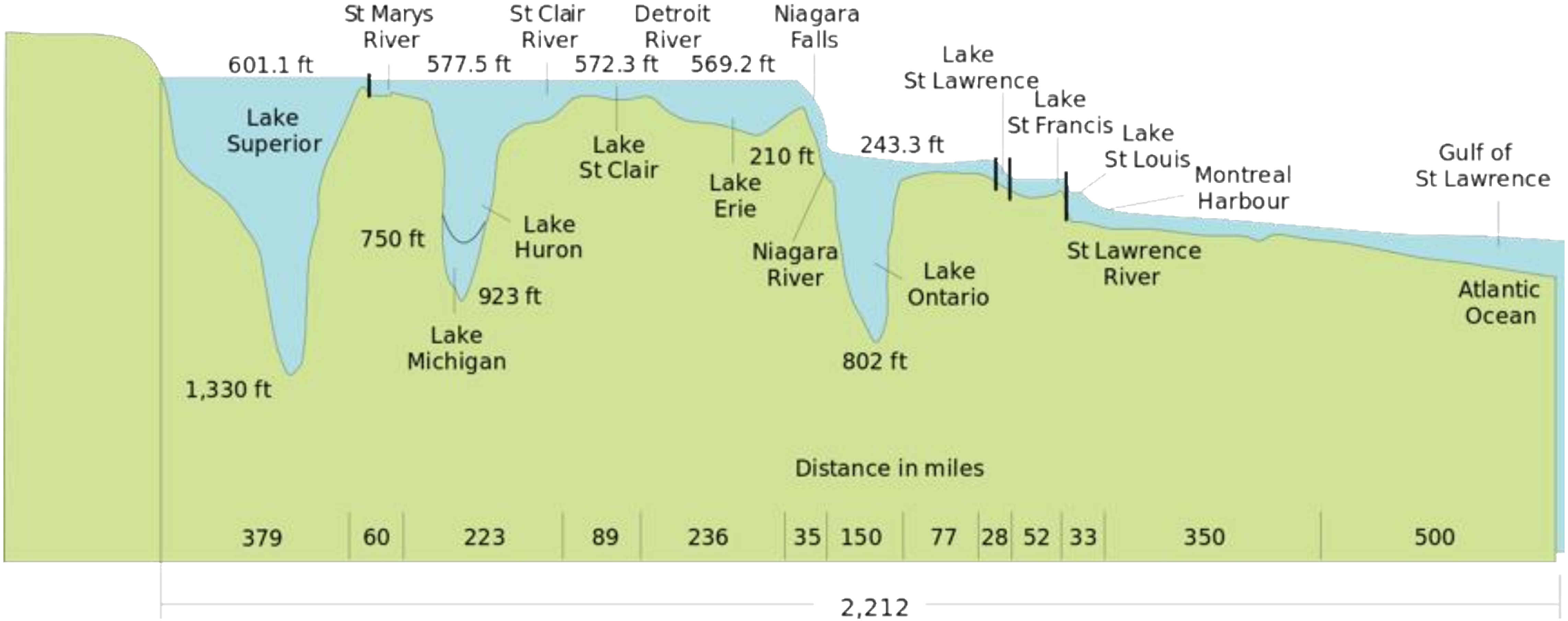
NORTH AMERICA'S CONNECTION TO THE ATLANTIC OCEAN

through the St. Lawrence River.

INTEGRAL TO SEVERAL INDUSTRIES

including shipping and tourism.

THE LAURENTIAN GREAT LAKES



PLASTICS - KEY DEFINITIONS

Fragments	plastic broken off from previously larger piece
Fibers	thread or filament; from synthetic materials
Pellet	aka "nurdle" plastic intentionally manufactured into spherical shape for manufacturing of other plastic items

Pelagic plastic pollution within surface waters

PLASTICS - KEY DEFINITIONS

MACROPLASTIC - GREATER THAN 5MM IN SIZE

MICROPLASTIC - LESS THAN 5MM IN SIZE

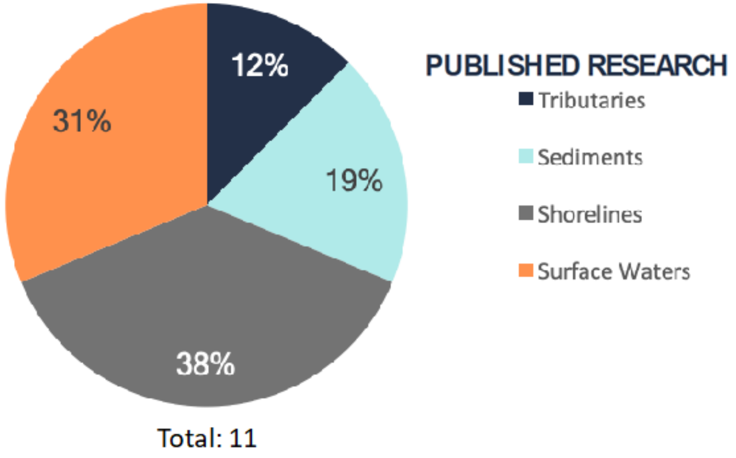
NANOPLASTIC - LESS THAN 0.1 UM IN SIZE

PRIMARY

PLASTIC MANUFACTURED IN SMALL SIZE, USUALLY USED AS RESIN PELLETS IN MANUFACTURING OR IN PRODUCTS

SECONDARY

FORMED FROM THE DISINTEGRATION OR DEGRADATION OF LARGER PLASTICS



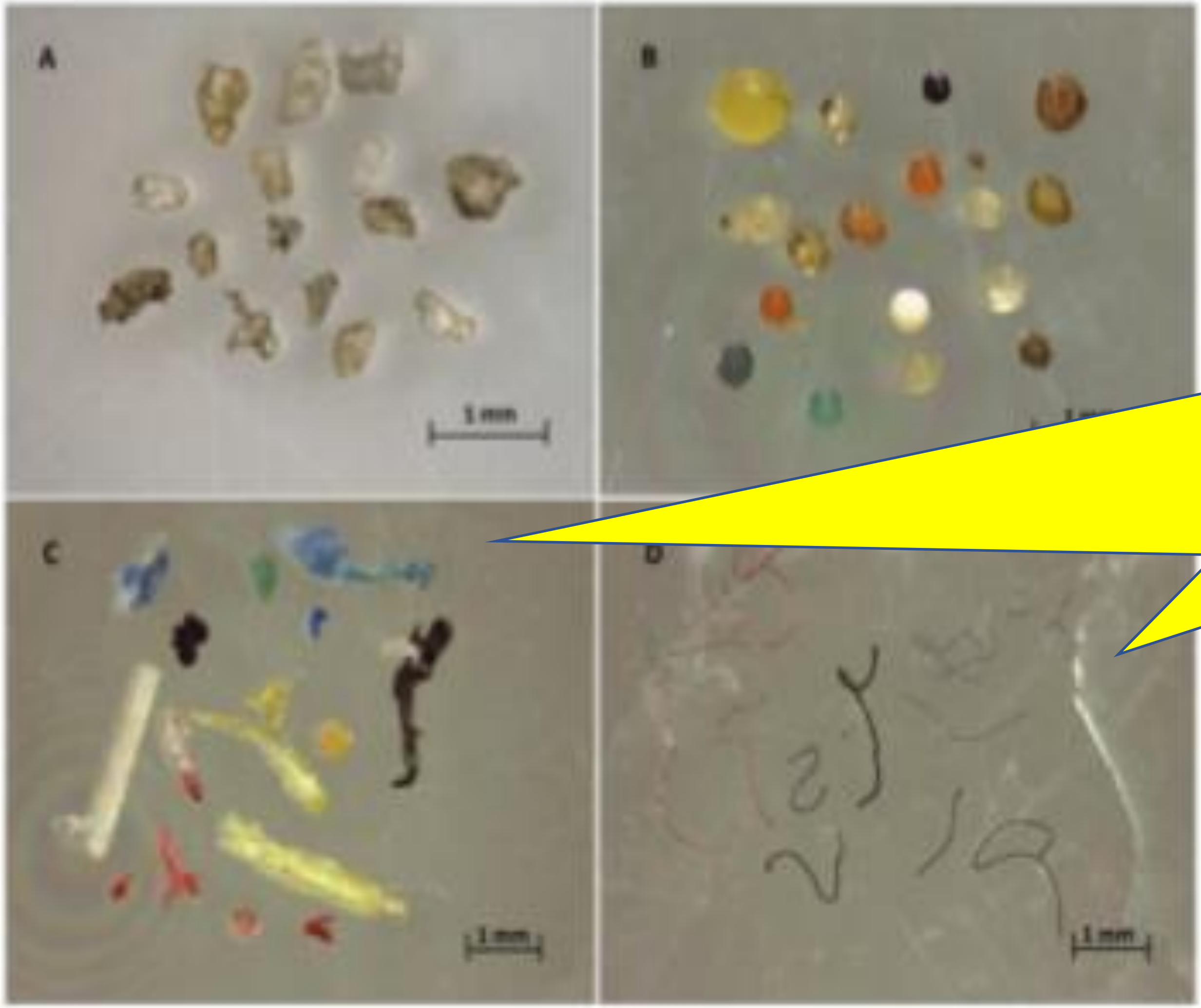


Figure 5: Example microplastic shapes: A and B are microbeads in the shape of fragments and spheres derived from personal care products. C and D are in the shape of fragments and fibres, respectively and are from break-down of larger plastics and synthetic textile fibres. [20].

Washing Clothes

Particles detected in

EASTERN ARCTIC

(Dr Chelsea Rochman Lab at U of T -CBC- 2020)

Table 1: As found in [21], the main kinds of microplastics found in different stages of the WWTP which were identified by micro-FTIR and micro-Raman.

Polymer	Description	Percentage of All MP Collected
Polyester	Fibres - Cross-section: Round, oval, flat - End: Cut, frayed, thickened - Appearance: Shiny or dull Particles - Shape: flat, angular fragment - Hardness: medium - Appearance: Shiny	79.1% *Mostly fibres
Polyethylene	Particles - Shape: uneven flakes and fragments, spherical - Hardness: medium to soft - Appearance: Dull or a bit shiny	11.4%
Polyamide, nylon	Fibres - Cross-section: Round, oval, flat - End: Cut - Appearance: Shiny	3.7%
Polypropylene	Particles - Shape: uneven fragments - Hardness: medium - Appearance: Dull	Negligible

Washing Clothes: major source!

1.2.2 Types of Microplastics Commonly Found in Water

There are many existing types of polymers. The polymers that were the most abundant in tested water throughout several research articles were polyester, polyethylene, polyamide and polyethylene terephthalate (PET) [18] [20]. These polymers are frequently used in common items such as clothing and food packaging. The common use, structure, general properties, and likely source at which they enter the

THE DOWNSIDE OF PLASTICS

1

ADSORPTION OF TOXIC CHEMICALS

- Can adsorb harmful environmental pollutants
- Smaller particles have larger adsorption capacity from increased surface area to volume ratio

2

HARMFUL MONOMERS

- Can be carcinogenic and mutagenic (ex. PVC)
- BPA, a known endocrine disruptor, is now banned

3

SLOW DEGRADATION

- Persistent in the environment
- Disintegrates into fragments as degradation occurs
- Toxic chemical are released to the environment

IMPACTS OF PLASTIC ON MARINE LIFE

ENTANGLEMENT

BIOACCUMULATION

INGESTION

Conservation Corps,

Dr Chelsea Rochman, University of Toronto scientist published her research in the journal Facets.

Dr Peter Ross, vice-president, environmental research, Ocean Wise, associate professor University of Victoria.

TOXICITY

- More research required into toxicity – may not necessarily be the plastic which is toxic, but the additives adhered to the particle such as:
    - pharmaceutical residues
    - cosmetic products
    - hygiene products

Micro & Nano Particle Hazards:

- Maybe small enough to cross blood- brain barrier & into organs.
- Toxins & pathogens concentrated by adsorption & absorption.
- WHO: " No proven hazards" but many hypothesize and concerns!
- EU: 14 ongoing health studies (Nederland's).

Measurement methods currently need an R & D lab and trained technicians

Measurement Methods

Typical measurement method:

- Collect and dry samples
- Count & classify with microscope or electron microscope
- Apply identification methods to determine type of plastic

Common identification methods:

- Raman spectroscopy
- Fourier-transform infrared spectrometry
- Focal plane array-based systems

Size

- Most common microplastic particle size is between 20 to 100 µm
- Particles less than 20 µm are currently not detectable

THE PLASTIC INDUSTRY

GLOBALLY AND IN CANADA

348 million tonnes produced globally (2017)

2% of plastic production occurs in Canada

1/2 of Canadian Plastic Industry is Located in Ontario

91%

Percentage of the 6.3 billion tonnes of global plastic waste that have not been recycled

9%

The average recycling rate for plastics in the United States

26 MILLION TONNES

The estimated amount of plastic sent to landfills and the environment by the United States in 2015

11%

The estimated average recycling rate for plastics in Canada

ECONOMICS OF RECYCLING

A $200B GLOBAL INDUSTRY

Plastic is a petroleum product, and thus is impacted by the price of oil.

EXCHANGE RATES

Foreign currency exchange rates also greatly affect the profitability of recyclers.

RECYCLING INFRASTRUCTURE

As Asian countries have refused to become the world’s “dumping grounds”, this has forced developed countries to invest in their own recycling capacity.

COMPARISON TO OCEANIC STUDIES

Freshwater systems may share similarities to oceanic systems regarding the impact of plastic on marine life, and potential methods of remediation.

AROUND 60% OF PLASTICS ARE LESS DENSE THAN SEAWATER.

ALL 5 MAJOR GYRES THROUGHOUT THE GLOBE CONTAIN SIGNIFICANT BUILDUP OF PLASTICS.

THE GREAT PACIFIC GARBAGE PATCH MAY CONTAIN UP TO 129,000 TONNES OF PLASTIC WITHIN 1,600,000 KM^2.

SOURCES OF PLASTIC

CONSUMER USE

- Population
- Consumer goods and urban waste
- Wastewater treatment

INDUSTRIAL ACTIVITY

- Industrial spills
- Effluent wastewater

Photo: CBC Thunder Bay, 2019

Research shows that wastewater and water treatment plants are expected to remove more than 90% of the MPs. The remaining 10% of particles fall under 100 µm in size. The majority of the 90% of MPs and fibres are removed in pre-treatment and secondary treatment [20].

OVERVIEW: LAKE SUPERIOR

PHYSICAL DATA

- **Volume:** 12,100 km^3
- **Average Depth:** 183 m
- **Retention Time:** 191 years
- **Shoreline Length:** 4,385 km

MAJOR CITIES AND POPULATED REGIONS

- Thunder Bay, Ontario
- Sault Ste. Marie, Ontario
- St. Clair, Michigan
- Superior, Wisconsin

SUMMARY OF STUDIES: LAKE SUPERIOR

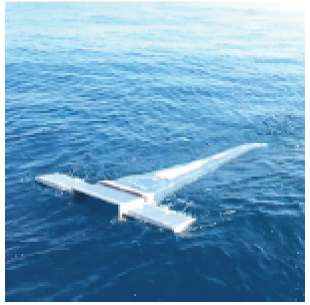
Microplastic pollution in the surface waters of the Laurentian Great Lakes

Eriksen et al. 2013

Methodology

3 week expedition collected 21 samples from Lake Superior (5), Lake Huron (8), and Lake Erie (8)

Rectangular manta trawl dragged along the surface of the water aside the ship over a defined surface area, allowing particle abundance per square kilometer to be determined.



Pelagic plastic pollution within surface waters

SUMMARY OF STUDIES: LAKE SUPERIOR

Microplastic pollution in the surface waters of the Laurentian Great Lakes

Eriksen et al. 2013

Results

Higher microplastic density

than in Lake Huron,

but likely because samples were collected closer to shore

Results

Most common particles:

fibers

OVERVIEW: LAKE MICHIGAN

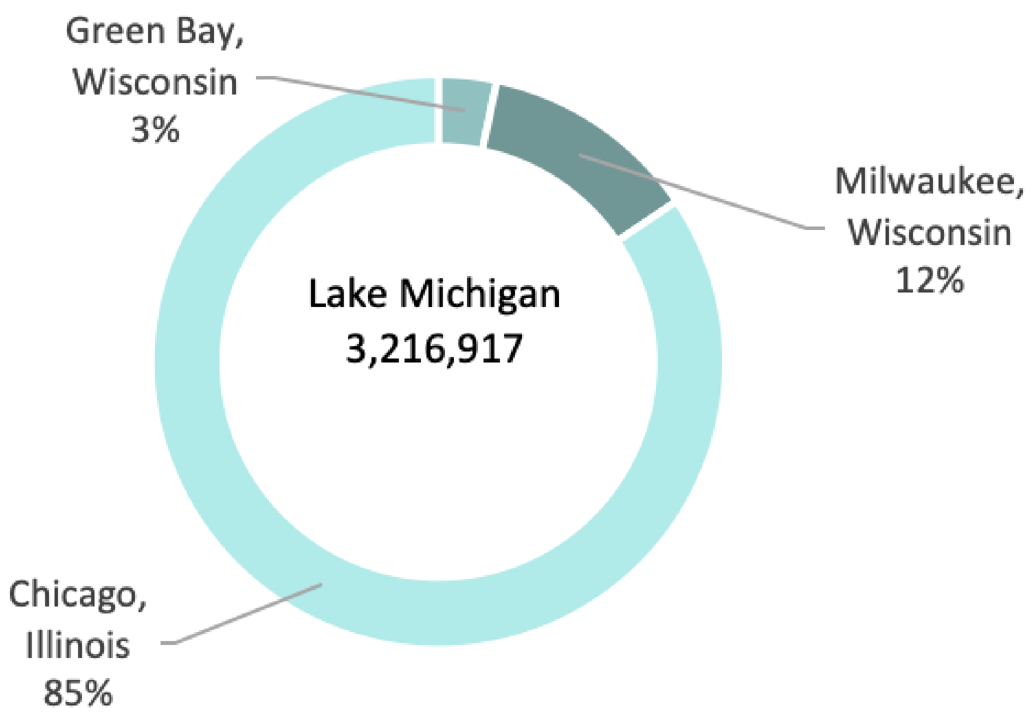
PHYSICAL DATA

- **Volume:** 4,920 km^3
- **Average Depth:** 85 m
- **Retention Time:** 99 years
- **Shoreline Length:** 2,633 km

FLOW PATTERNS

- Water enters from Lake Superior and slowly flows into Lake Huron
- Anticyclonic gyre develops within southern basin over Summer months

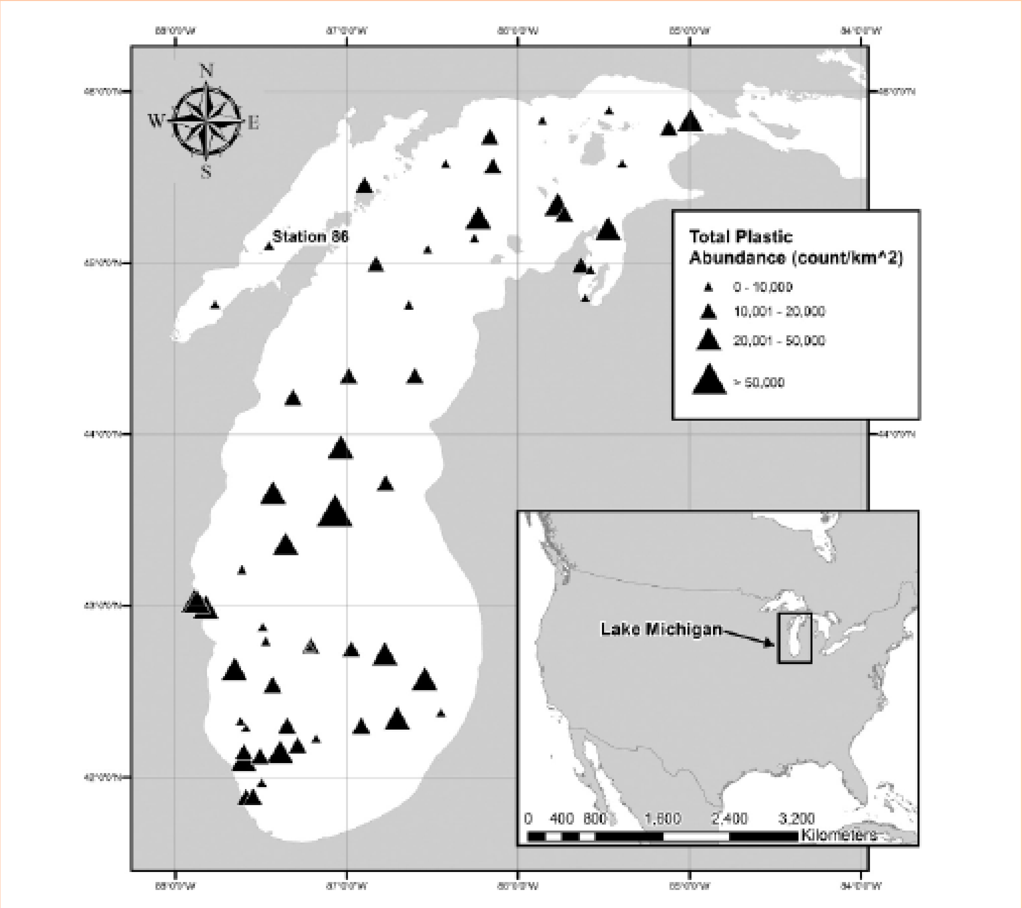
MAJOR CITIES AND POPULATED REGIONS



SUMMARY OF STUDIES: LAKE MICHIGAN

Pelagic plastic pollution within the surface waters of Lake Michigan, USA

Mason et al. 2016



Results

pelagic plastic obtained from Lake Michigan:

79% Fragments

OVERVIEW: LAKE HURON

PHYSICAL DATA

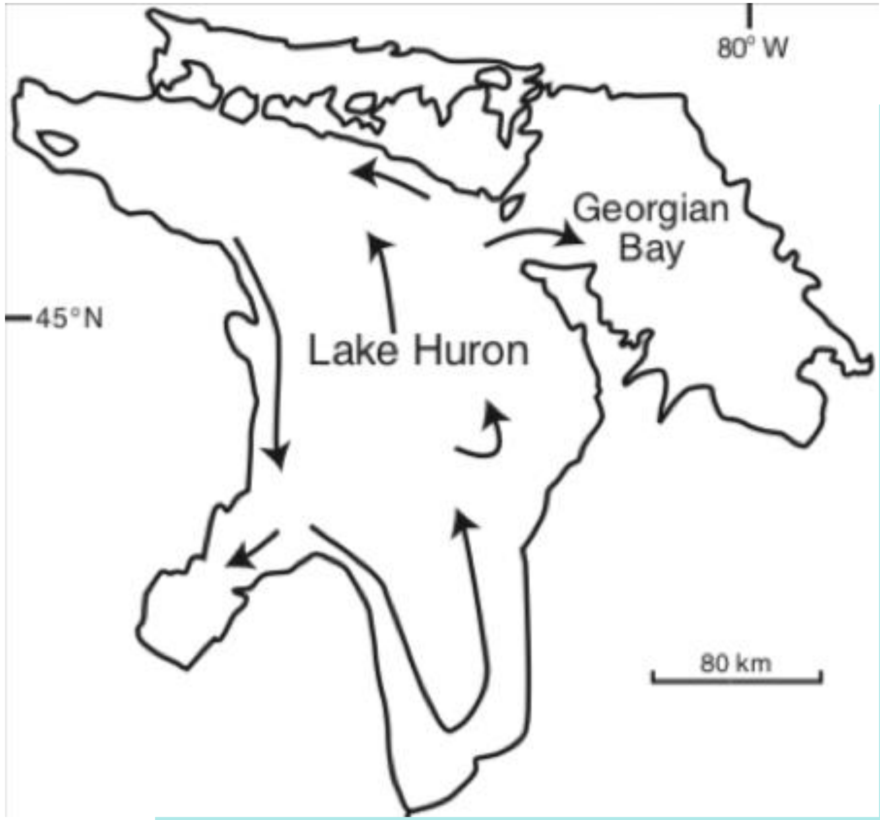
- **Volume:** 3,540 km^3
- **Average Depth:** 59 m
- **Retention Time:** 22 years
- **Shoreline Length:** 6,157 km

MAJOR CITIES AND POPULATED REGIONS

- Sarnia, Ontario
- Midland, Ontario
- Parry Sound, Ontario
- Owen Sound, Ontario
- Saginaw, Michigan

FLOW PATTERNS

- Occupied by counterclockwise circulation in western portion of lake, and clockwise circulation in northern basin
- Predominantly cyclonic surface circulation pattern



Pickett, 1980

SUMMARY OF STUDIES: LAKE HURON

Distribution and Degradation of Fresh Water Plastic Particles Along the Beaches of Lake Huron, Canada

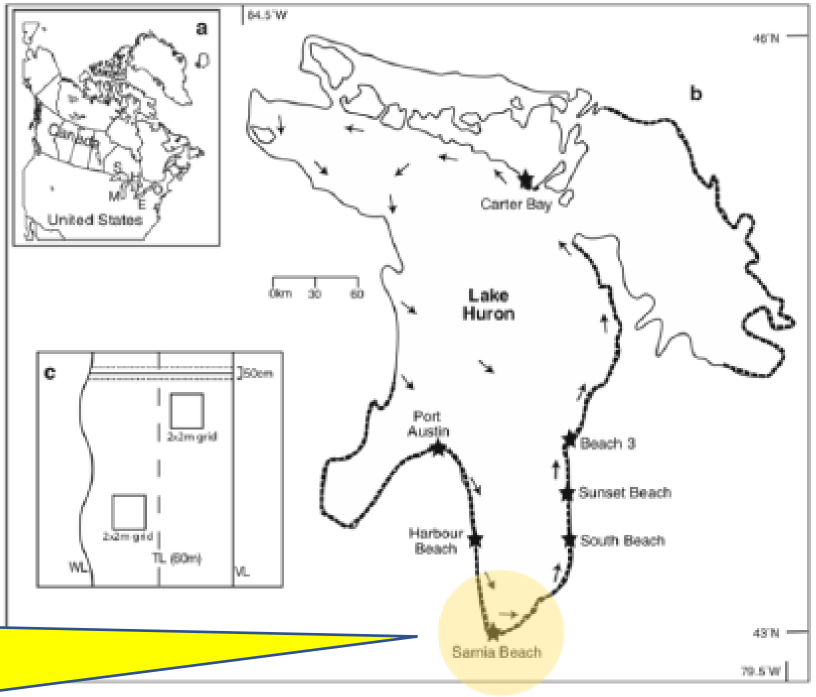
Zbyszewski et al, 2011

e surface
reat Lakes

Sarnia Beaches 94% of total plastic pellets in L. Huron.

Results

- 4 of the 7 beaches yielded 3,209 plastic pieces
- The beach located in Sarnia, ON, yielded over 94% of the total plastic pellets



In the 1990s, a train carrying nurdles was derailed near Lake Superior, and millions of pellets were released into the lake. Almost three decades later, these pellets are still in the surface waters and shorelines of Lake Superior. and Lake Huron!

The University of Western Ontario recently investigated the origin of pellets in southern Lake Huron. Significant sources include water-bourn transportation north along Perch Creek, which exits into Lake Huon at Bright's Grove. This watercourse drains a catchment area adjacent to a number of polymer manufacturing plants situated in Corunna and Mooretown.

SUMMARY OF STUDIES: LAKE HURON

Distribution and Degradation of Fresh Water Plastic Particles Along the Beaches of Lake Huron, Canada

Zbyszewski et al, 2011

Microplastic pollution in the surface waters of the Laurentian Great Lakes

Eriksen et al. 2013

Results

samples showed significant variability

ranged from **<480 particles/km^2** to **10,001-25,000 particles/km^2**

OVERVIEW: LAKE ERIE

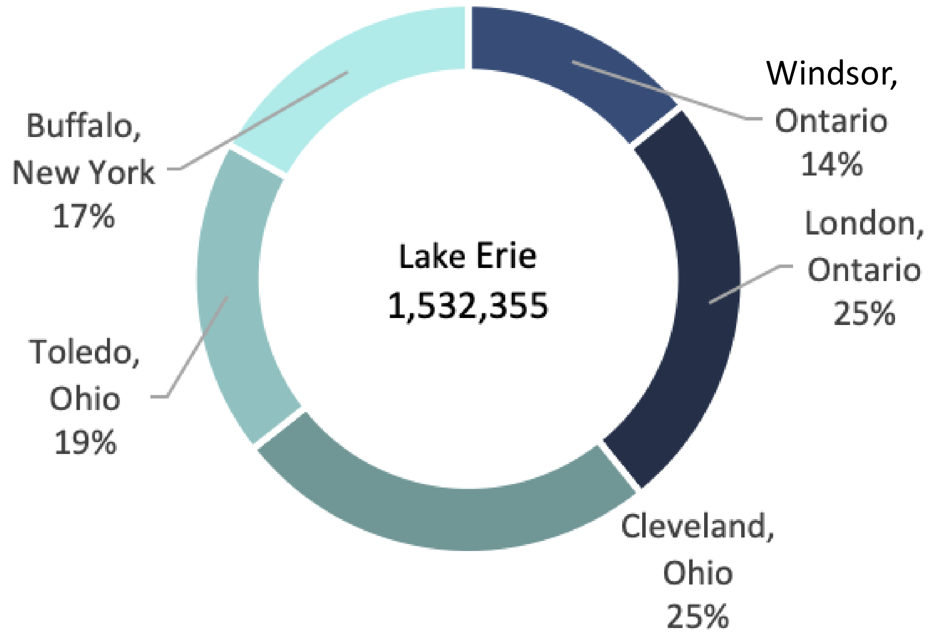
PHYSICAL DATA

- **Volume:** 484 km^3
- **Average Depth:** 19 m
- **Retention Time:** 2.6 years
- **Shoreline Length:** 1,402 km

FLOW PATTERNS

- In summer, an anticyclonic gyre is dominant with a smaller cyclonic gyre in western region of lake
- In winter, anticyclonic movement is present in the north and cyclonic flow is present in the south

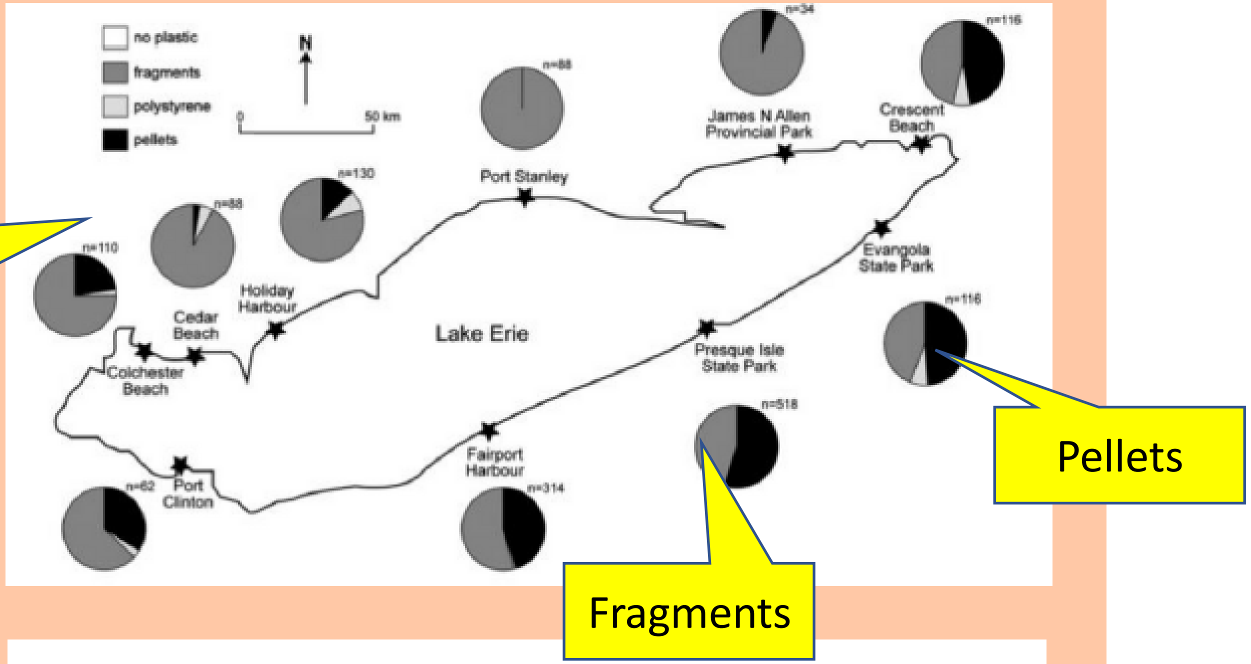
MAJOR CITIES AND POPULATED REGIONS



SUMMARY OF STUDIES: LAKE ERIE

Fragments, Pellets & Microplastics:
90% of all pelagic plastic debris
collected in study throughout Great Lakes

Hoffman & Hittinger 2017



Results

Debris along Lake Erie shoreline

60% fragments

Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America

Zbyszewski et al. 2014

SUMMARY OF STUDIES: LAKE ERIE

Microplastic pollution in the surface waters of the Laurentian Great Lakes

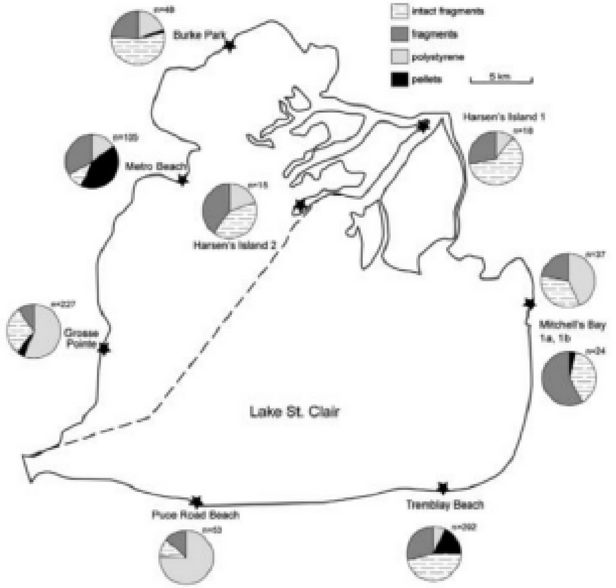
Eriksen et al. 2013

Inventory and transport of plastic debris in the Laurentian Great Lakes

Hoffman & Hittinger 2017

Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America

Zbyszewski et al. 2014



Debris along Lake St. Clair shoreline

30% Styrofoam

OVERVIEW: LAKE ONTARIO

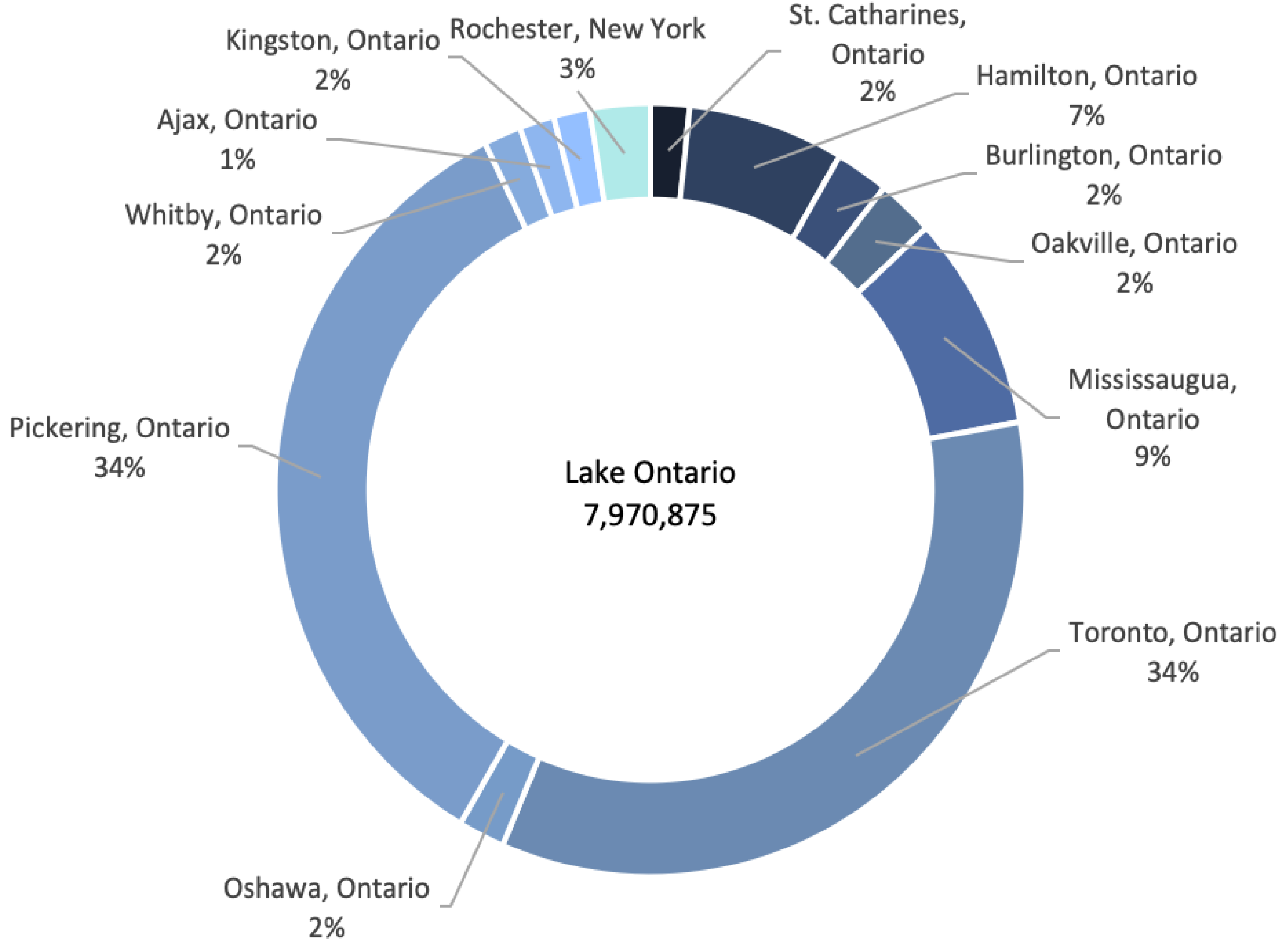
PHYSICAL DATA

- **Volume:** 1,640 km^3
- **Average Depth:** 86 m
- **Retention Time:** 6 years
- **Shoreline Length:** 1,146 km

FLOW PATTERNS

- Large cyclonic gyre and a smaller anticyclonic gyre in western portion of late
- Water travels in counter-clockwise direction around Lake Ontario due to Coriolis Effect

MAJOR CITIES AND POPULATED REGIONS



SUMMARY OF STUDIES: LAKE ONTARIO

Sources and Sinks of Microplastics in Canadian Lake Ontario Nearshore, Tributary and Beach Sediments

Ballent and Corcoran, 2016

Hidden plastics of Lake Ontario, Canada and their potential preservation in the sediment record

Corcoran et al., 2015

Results

dominant plastics <2mm at collection sites:

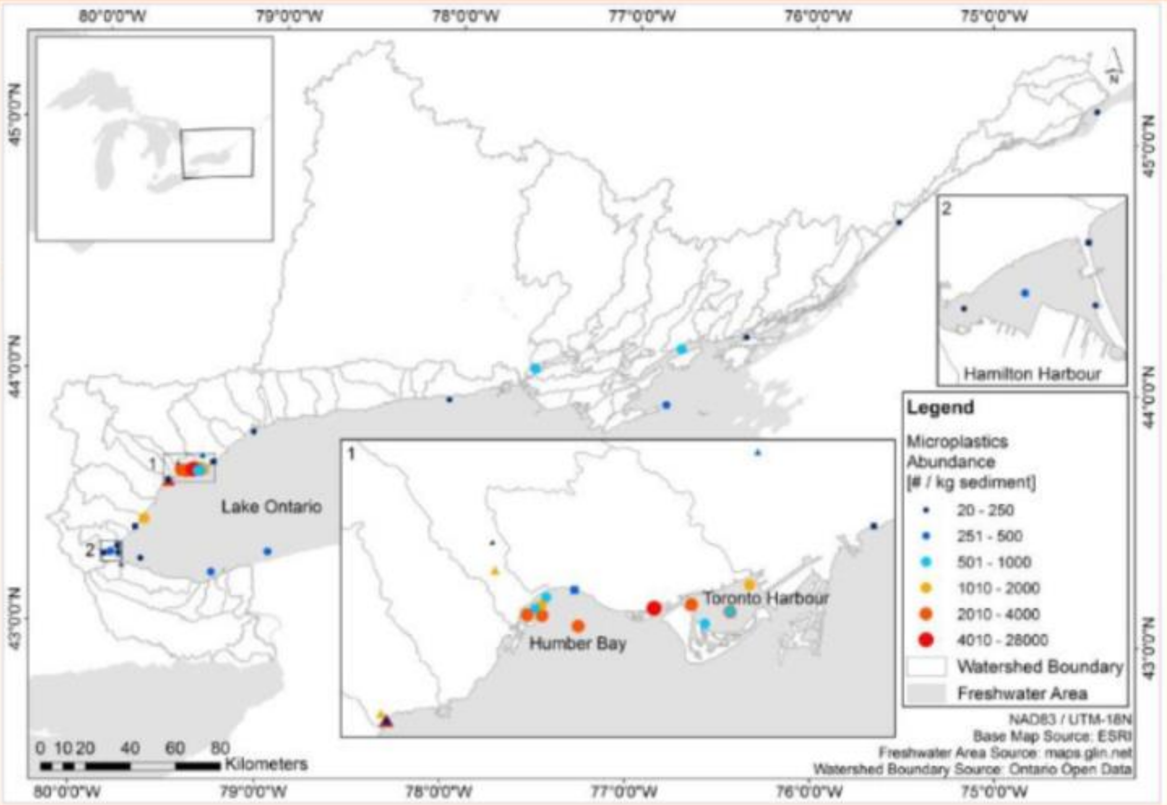
fibers & fragments

SUMMARY OF STUDIES: LAKE ONTARIO

Sources and Sinks of Microplastics in Canadian Lake Ontario Nearshore, Tributary and Beach Sediments

Ballent and Corcoran, 2016

Microplastic abundance in particles/kg of sediment across the 50 sites surveyed



Results

overall microplastic abundance:

700 particles/kg of sediment

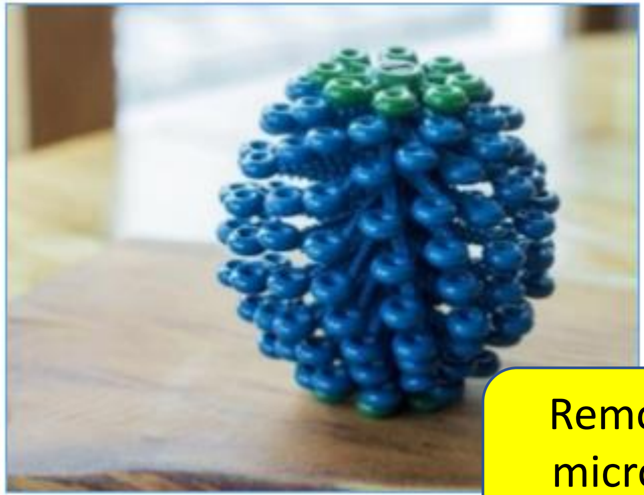
Humber Bay is a large source plastic pollution.

DOMESTIC SOLUTIONS

The domestic solutions assessed aim to remove microplastics from residential washing machine effluent streams.

CORA BALL

The Cora Ball is a laundry ball that is added to a load of laundry. The ball is designed with hoops intended to catch and collect microfibres which can later be removed by hand.



GUPPYFRIEND

The Guppyfriend is a bag where the consumer adds their laundry and adds to the machine. Following the wash the consumer can remove the microfibres collected inside of the bag.

Removes 90% of microfibers > 50 micrometers

LINT LUV-R

Lint LUV-R is external filter system mounted above a washing machine. The filter connects to the effluent line and the water is run through the basket which collects the fibres.

DOMESTIC SOLUTIONS

For best performance combine:

- Cora Ball
- Guppyfriend
- And a Fixed filter (Filtrol 160, Lint LUV-R, PlanetCare)

To reduce microplastics from laundry:

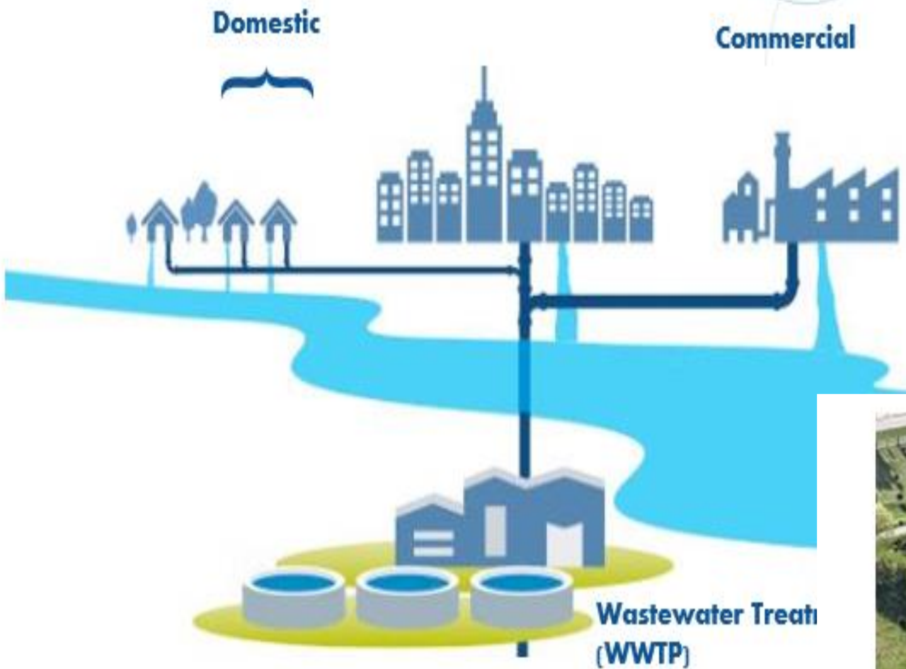
- Use fabric softener
- Lower washing machine rpm
- Reduce amount of synthetic clothing worn

DOMESTIC SOLUTION EVALUATION

Classification	Weight	Cora Ball	Filtrol 160	Lint LUV-R	Guppy Friend	Planet Care
Efficiency/ Effectiveness	15	1	1	3	5	5
Simplicity of Operation	20	3	3	3	3	3
Environmental Impact	20	3	3	3	3	5
Technology Readiness Level	15	5	5	5	5	5
Product Availability	10	3	4	3	5	3
Cost	20	4	2	3	5	1
TOTAL	100	300	260	330	**420**	360

IMPORTANCE OF INDUSTRIAL SCALE SOLUTIONS

- Ability to treat large volumes of effluent
- Subject to regulations and oversight
- Funded by federal, provincial and municipal levels of government



INDUSTRIAL SCALE EXISTING SOLUTIONS

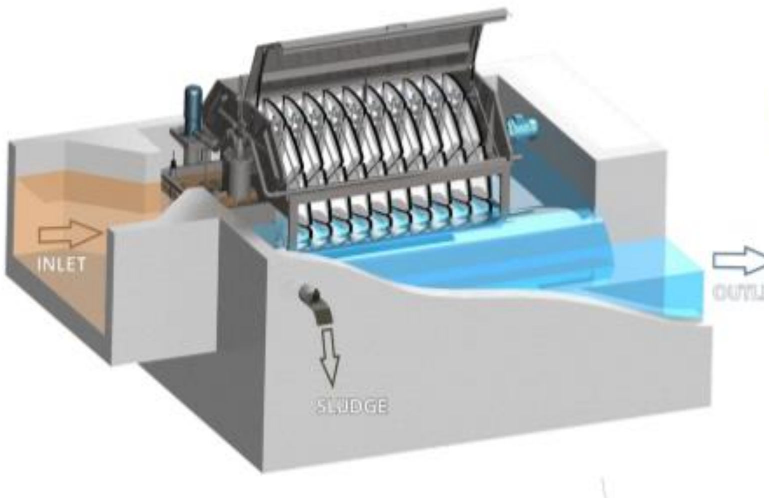
All remove > 90% of particles > 20 micrometers

The industrial solutions assessed are methods which may be implemented in local Wastewater Treatment Plants (WWTPs)

DISC FILTER

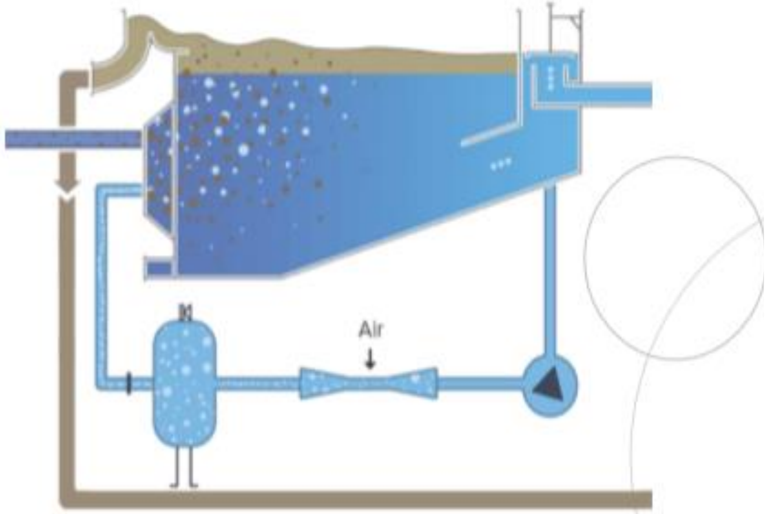
Consists of a series of round meshed panels in an enclosed tank.

Trapped particles cleared using backwash or centripetal forces.



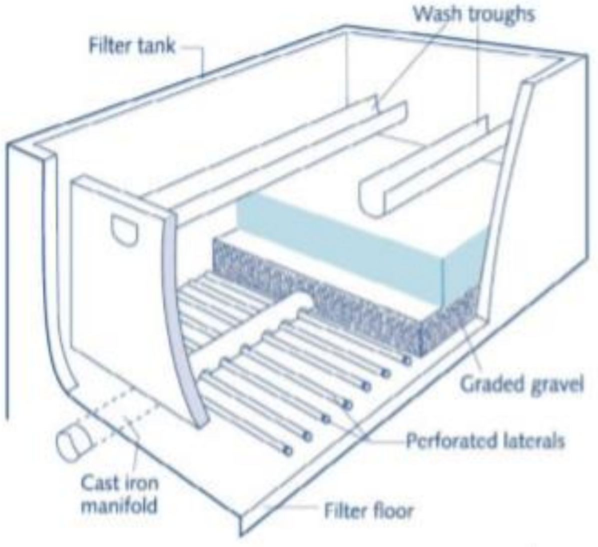
DISSOLVED AIR FLOTATION

Through the addition of a coagulant and fine bubbles, particles either coagulate and sink or adhere to bubble and rise to surface.



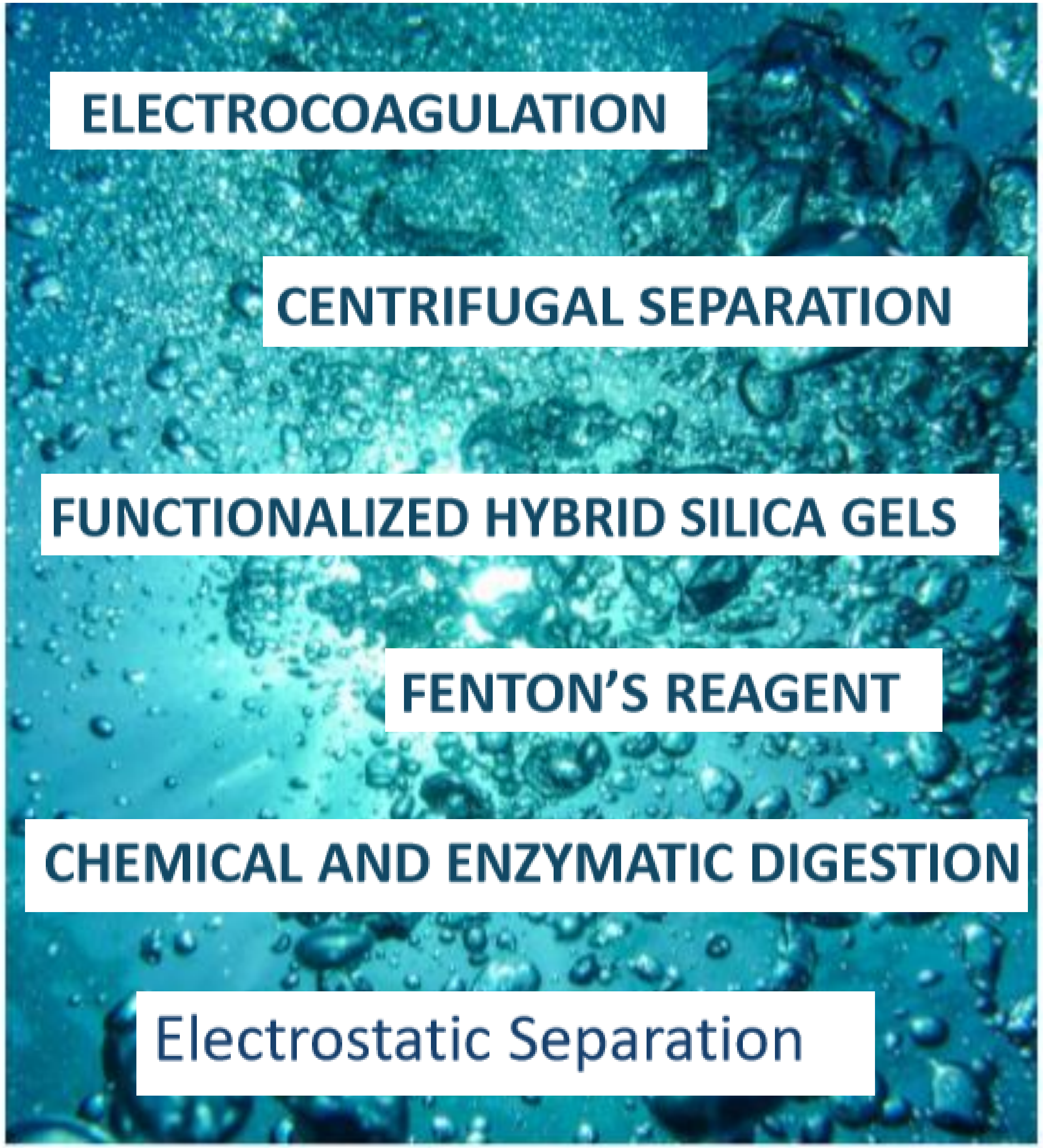
RAPID SAND FILTER

System uses layers of sand and gravel to filter effluent using mechanical straining and physical adsorption.



EVALUATION MATRIX OF EXISTING SOLUTIONS

Classification	Weight	Disc Filter	Dissolved Air Flotation	Diatomaceous Earth Filters	Rapid Sand Filter	Membrane Bioreactor
Technology Readiness Level TRL	30	3	3	1	5	3
Efficiency/ Effectiveness	25	3	5	1	5	5
Compatibility with Current Process	20	3	3	3	3	1
Simplicity of Operation	15	5	3	3	5	1
Environment and Safety	10	5	3	3	5	3
TOTAL	500	350	350	190	**460**	280



EMERGING SOLUTIONS

Solutions which are not currently used in water treatment or other industrial processes for filtration

- Reverse Osmosis
  - Expensive to operate
- Cartridge Filtration
  - Expensive to operate/maintain
- Granular Activated Carbon
  - Requires very high-quality water to effectively remove microplastic particles
- Purifics Treatment
  - Private company that offers ceramic membrane filtration and dewatering

[2]

RECOMMENDATIONS

Stakeholder Framework

- Consumers
- Business & Industry
- Educators
- Researchers
- Governments
- International Actors

SOCIAL & CORPORATE RESPONSES

SINGLE-USE VS. MULTI-USE

- Menstrual products
- Reusable tote bags

REPURPOSING

- Clothing and shoe companies
- Household decor

REDUCTION

- Strawless lids
- Plant-based products

BUSINESS & INDUSTRY RECOMMENDATIONS

FILTRATION FOR WASHING MACHINES

Washing one piece of synthetic clothing releases up to 700,000 fibers

NEW RECYCLING BIN DESIGN

Unintentional litter can be caused by wind blowing debris from industrial areas

DIRECT TRANSFER OF PELLETS

Transportation points are potential spillage risks

RESEARCHER RECOMMENDATIONS

1. IMPACT OF MICROPLASTICS
2. LINGERING THREAT OF MACROPLASTICS
3. SOURCES AND COMPOSITION
4. UNIFORM SAMPLING METHODOLOGY

RECOMMENDATIONS FOR GOVERNMENTAL ACTORS

CLARIFY THE FISHERIES ACT

BAN STYROFOAM AND SINGLE-USE PLASTICS

STRENGTHEN LABELLING AND PACKAGING

CULTIVATE INNOVATION

BILL C-68

POTENTIAL INCOMING CHANGES TO THE FEDERAL *FISHERIES ACT*

By the end of July 2019, the Liberal government hopes to make changes to the *Fisheries Act*, empowering the Minister of Environment to make regulations for the conservation of fish habitats

RECOMMENDATIONS

LEGISLATION

Implement cleanup periods focusing on beach and freshwater cleanup

Reduce the number of different plastics manufactured in synthetic materials

Tax plastic production to ensure recycling remains economically viable

Increase incentives for plastic alternatives to decrease demand for plastics

EDUCATION

Increase education and awareness of the environmental implications of plastics

Encourage consumers to reduce use of plastics, and to use renewable options

INNOVATION

Determine feasible way to implement bioremediation within Great Lakes system

RESEARCH

Increase funding for studies on the impact of microplastics on bioaccumulation within organisms

Study potential organisms for bioremediation in the Great Lakes system

NEXT STEPS

Conduct more research into:

- Sampling and testing methods
- Toxicity of microplastics
- Disposal of microplastics and microfibres
- WWTP microplastic removal efficiency
- Microplastics in sludge

Incineration vs land-fill vs Land-farmed?

If sleudges are land-farmed may blow back into watercourses.

THANK YOU

BlueGreen Innovations Group

Royal Bank

RBC

Queen's University

TEAM

[2]