Microplastic Overview and Aspects Related to Human Health (for Consideration)

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April 4th, 2019 – Measuring Microplastics: Best Practices

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NSERC CHAIR IN DRINKING WATER RESEARCH

Drinking Water Health Concerns

Apply treatment to prevent risk of illness

Pathogen removal/inactivation primary focus

- Pathogen specific

Pathogen	Size (µm)	Filtration	UV Disinfection	Chemical Disinfection
Cryptosporidium	4 – 6	++	++	--
Giardia	5 – 15	+	++	+
Bacteria	0.5 - 10	-	+	+
Viruses	0.01 – 1	--	-	++

Plastics in Drinking Water

Microplastics present in raw and treated water

- 1,500 to 3,600 particles/L - raw water
- 340 to 630 particles/L - treated water
- 2,650 to 4,900 particles/L - bottled water

Oßmann et al., 2018, *Wat. Res.*, 141

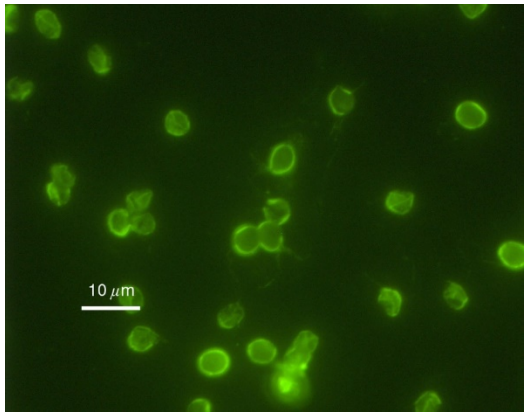
Pivokonsky et al., 2018, *Sci. Tot. Env.*, 643

Significant number of particles consumed

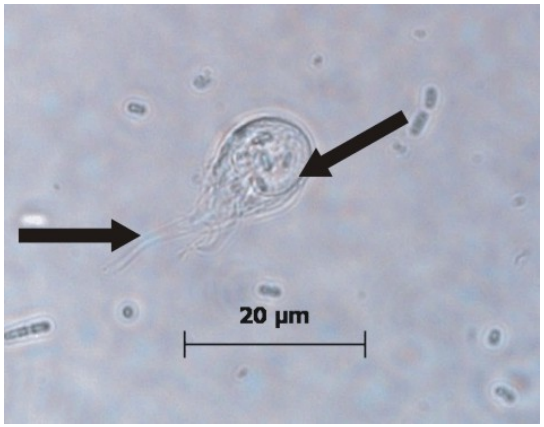
- >80% of particles <20 µm; >99% of particles <150 µm

Similar size to pathogens of concern

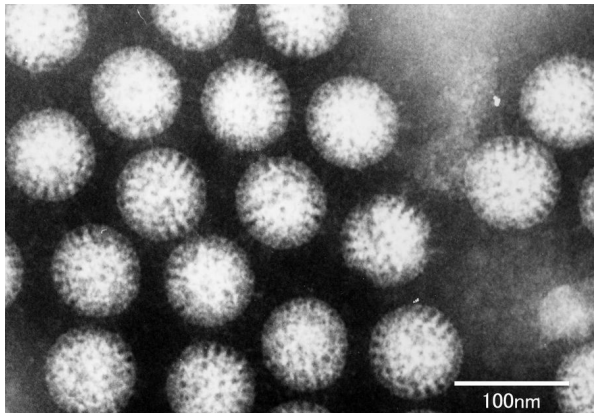
Parallels to Micro-/Nanoplastics



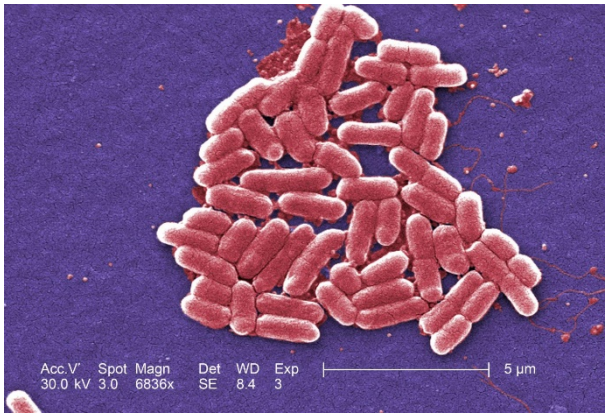
Cryptosporidium
(microsphere)



Giardia
(fragment)



Rotavirus
(nanosphere)



E. coli
(fiber)

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Potential Health Impacts

Plastics <150 µm - able to translocate across gut epithelium into lymphatic system

- Particle accumulation in mammalian liver, kidneys and gut has been observed

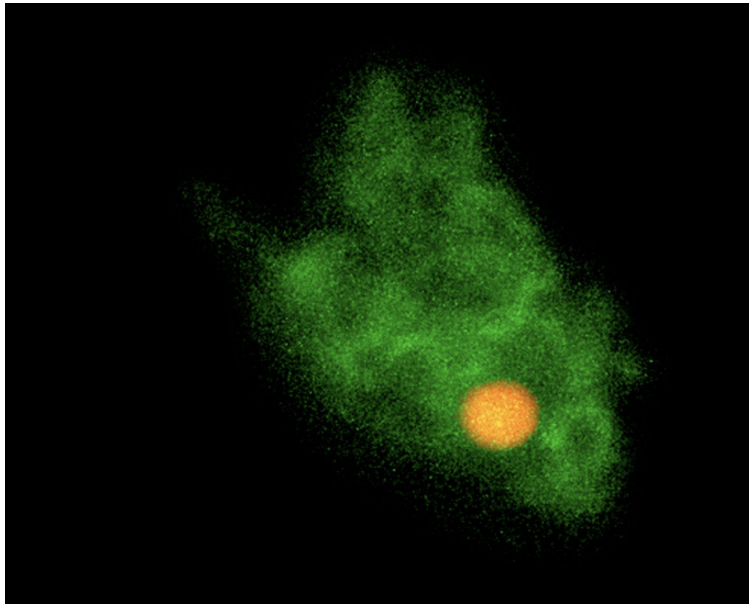
  Hussain et al., 2001, *Adv. Drug Deliv. Rev.*, 50

May act as contaminant vector and aid transport

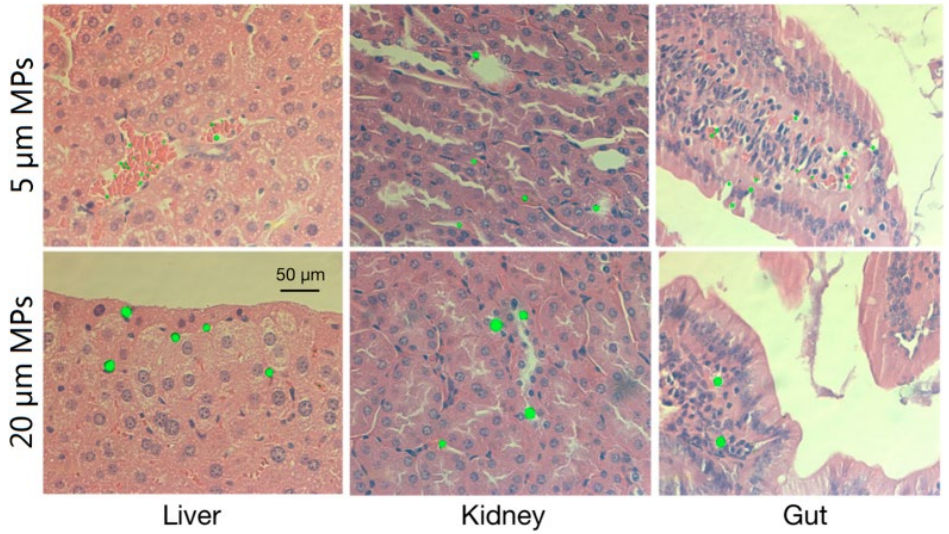
- Organic pollutants, heavy metals, pathogens, etc.
- Leaching of plastic additives and plasticizers
- Concentrations up to 6x higher than background

  Alimi et al., 2018, *Env. Sci. Tech.*, 52

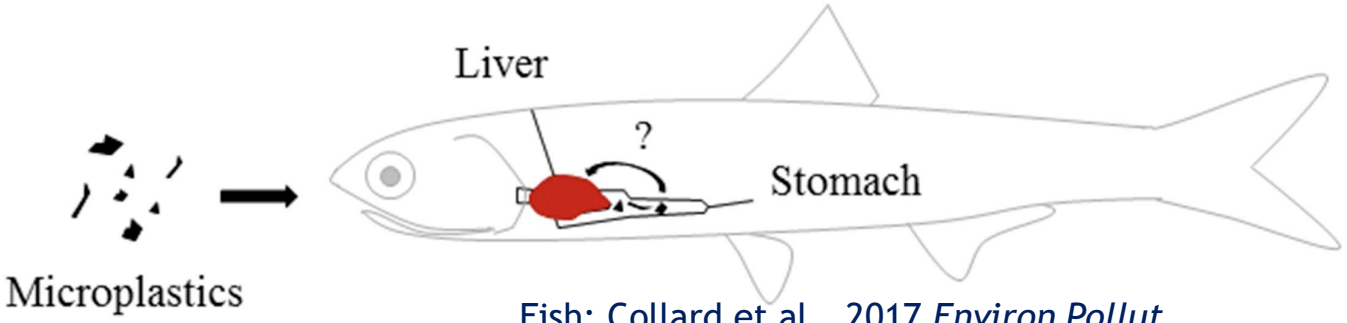
Evidence of Translocation of Microplastics



Mussels: Browne et al., 2008 *ES&T*



Mice: Deng et al., 2017 *Scientific Reports*



Fish: Collard et al., 2017 *Environ Pollut*

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What About Nanoplastics?

Nanoparticles (<1 µm) can penetrate cells

- Potential to enter blood stream

  Revel et al., 2018, *Curr. Op. Env. Sci. Health*, 1

Have shown to induce inflammation and apoptois of the liver and spleen

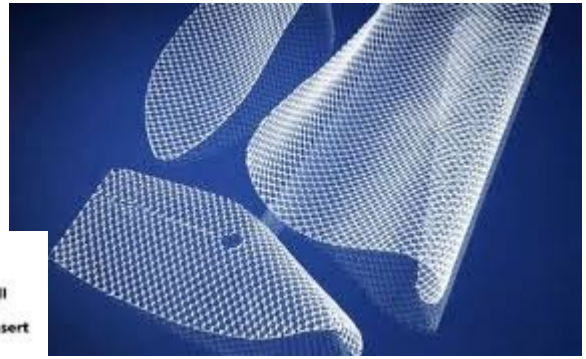
Khlebstov & Dykman, 2011, *Chem. Soc. Rev.* 40.

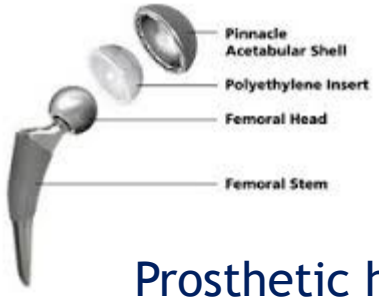
Affects barrier properties of gut epithelium

- May pose a synergistic risk when combined with unknown contaminants of concern

What does the medical literature tell us?

Hernia mesh





Prosthetic hip

TABLE 6.2

Medical literature on impact of microplastics and nanoplastics originating from inhalation and surgical materials at various levels of biological organization

Level of biological organization	Particle type and size	Effect	Reference
Macromolecules	PE 100 nm–30 μm PS 50 nm–4.7 μm PMMA 1 μm–2 μm PC 1 μm–55 μm	DNA damage, changes in gene and protein expression	Gelb *et al.*, 1994; Brown *et al.*, 2001; DeHeer *et al.*, 2001; Gretzer *et al.*, 2002; Petit *et al.*, 2002; Ingram *et al.*, 2004; Clohisy *et al.*, 2006; Kaufman *et al.*, 2008; Markel *et al.*, 2009; Huang *et al.*, 2010; Hallab *et al.*, 2012; McGuinness *et al.*, 2011; Samuelsen *et al.*, 2009; Smith and Hallab 2010; Pearl *et al.*, 2011
Organelles*	PMMA 10 μm	more micronuclei	Zhang *et al.*, 2008
Cells	PS 20 nm–4.7 μm PE 300 nm–10 μm PMMA 2 μm–35 μm PS 20 nm–200 nm PS 60 nm–200 nm	cell clotting, necrosis, apoptosis, proliferation and loss of cell viability Oxidative stress Increased Ca ions	Gelb *et al.*, 1994; Brown *et al.*, 2001; Gretzer *et al.*, 2002; Bernard *et al.*, 2007; Fröhlich *et al.*, 2009; Samuelsen *et al.*, 2009; Hallab *et al.*, 2012; McGuinness *et al.*, 2011
Tissues	PE 600 nm–21 μ, PMMA 1 μm–35 μm	inflammation and bone osteolysis	Gelb *et al.*, 1994; Clohisy *et al.*, 2006; Markel *et al.*, 2009; Pearl *et al.*, 2011
Organs	PMMA 1 μm–10 μm	lesions	Zhang *et al.*, 2008; Pearl *et al.*, 2011

*An organelle is a specialized subunit within a cell (e.g. mitochondria) with a specific function.
PE (Polyethylene), PS (Polystyrene), PMMA (Poly(methyl methacrylate)), PC (Polycarbonate).

FAO Report 2017; Data from Rochman et al., 2016 *Ecology*

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Why the Concern?

Ubiquitous in surface waters

Recently reported in treated drinking water samples

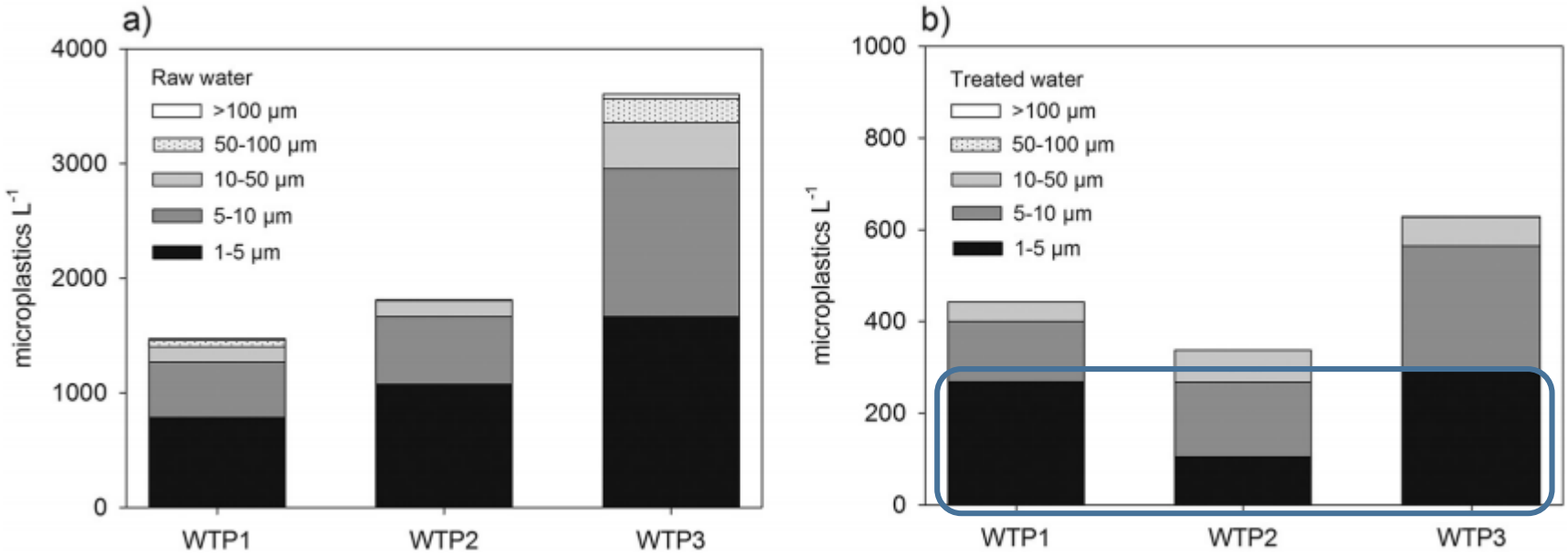
Removal during drinking water treatment

- Impact of unit processes?
- Potential for optimization?

Currently unknown health risk

- Especially when considering particles <100um (or smaller)

Existing Research



Pivokonsky et al., 2018

What We Have Learned – (*So far*)

Water treatment plants can remove microplastics

Majority of particles either fibers or fragments

Small particles (<20 µm) dominant

95% - Pivokonsky et al., 2018

80% - Schymanski et al., 2018

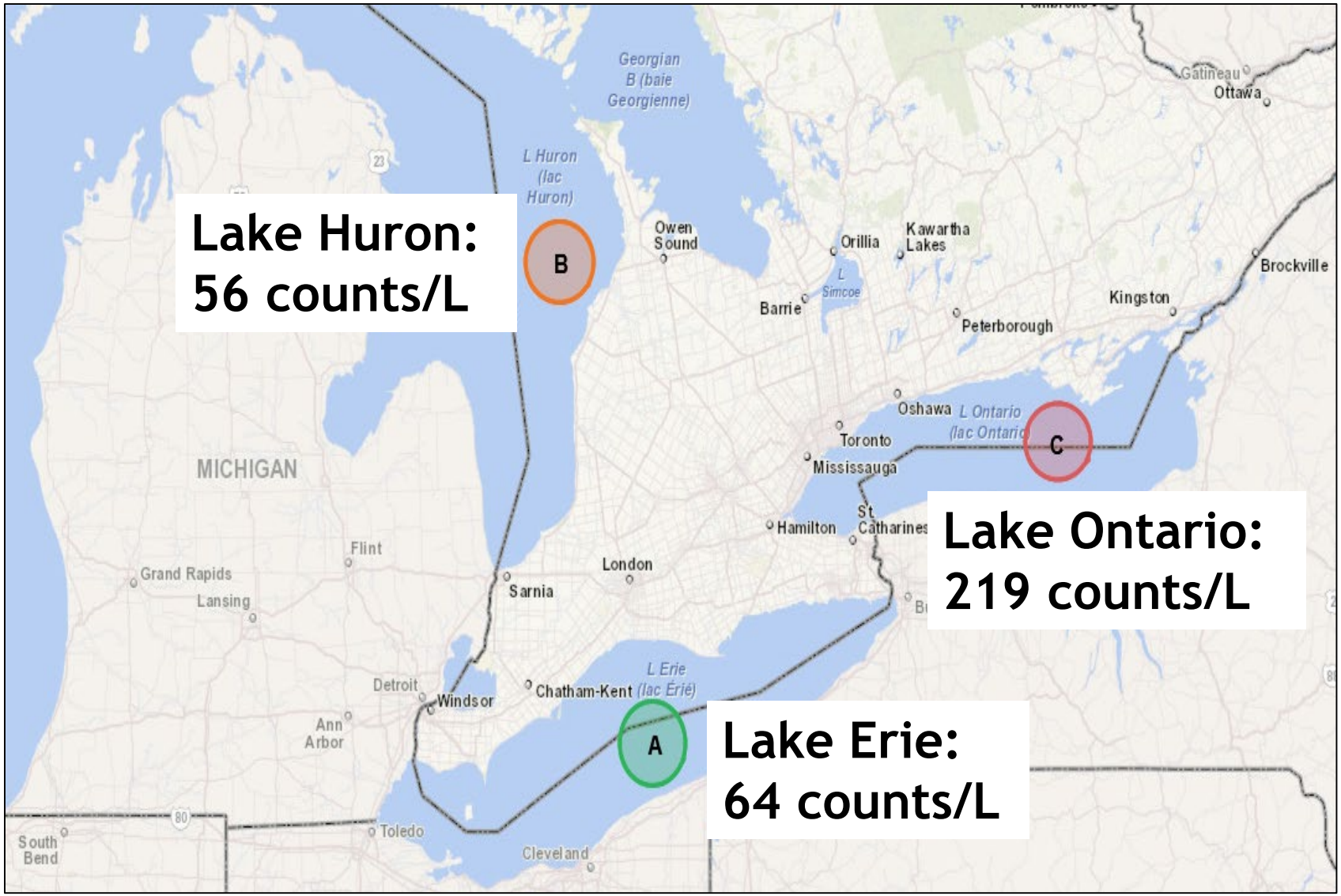
Large particles (>50 µm) preferentially removed

Recent Work (2018-2019)

1) Determine microplastic concentrations in drinking water originating from the Great Lakes
   - ~4,000 water supply systems
   - 40,000,000+ people (IJC State of the Great Lakes Report – 2017)

2) Quantify presence, size and types of microplastics from source water to tap

3) Evaluate treatment efficiency - conventional processes



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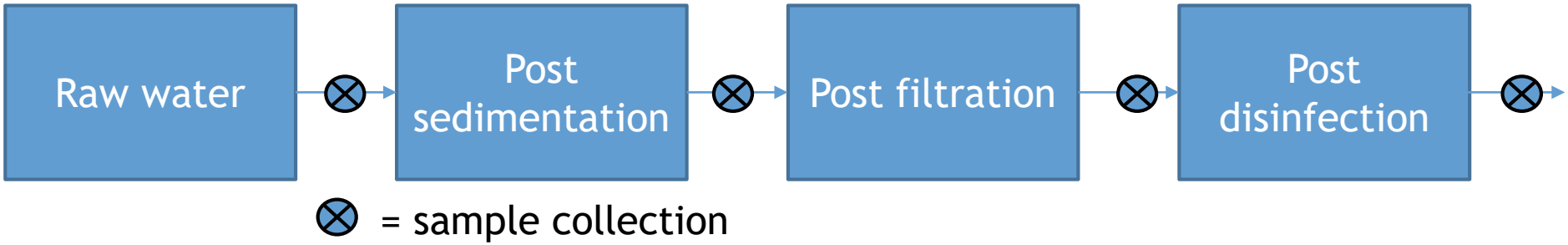
Treatment Plant Sampling

First evaluated three “conventional” treatment

- Coagulation/flocculation/sedimentation
- Filtration
- Disinfection

Provide insight into majority of treatment plants (in North America)



Methods - Sample Collection and Prep

20 L samples collected

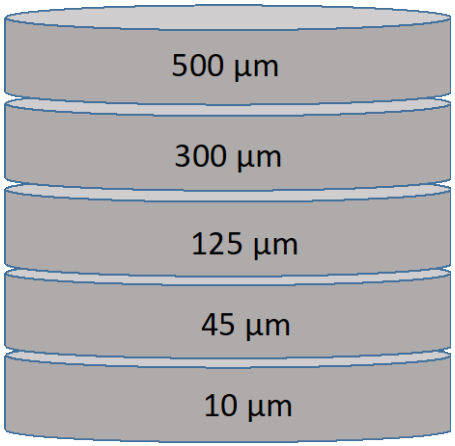
Filtered through Sieves and 10 µm polycarbonate filters

- Stainless steel filtration apparatus

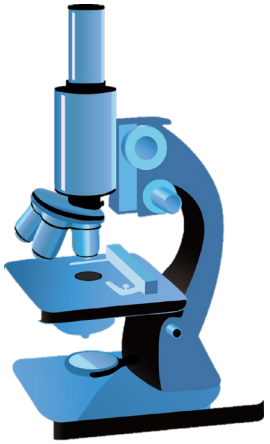
QA/QC is critical

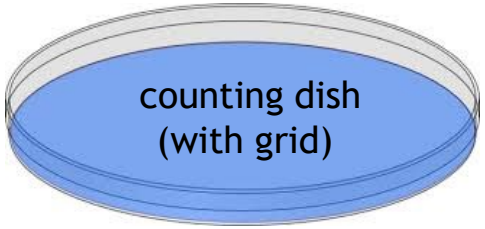
- Plastic-free sample containers
- Conducted inside a clean cabinet
- HEPA filter – lab air
- Minimum one lab blank per plant
- Blank subtraction (colour/category)

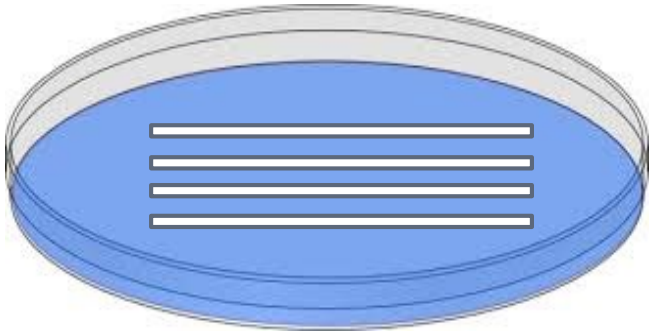
Sample Prep and Analysis

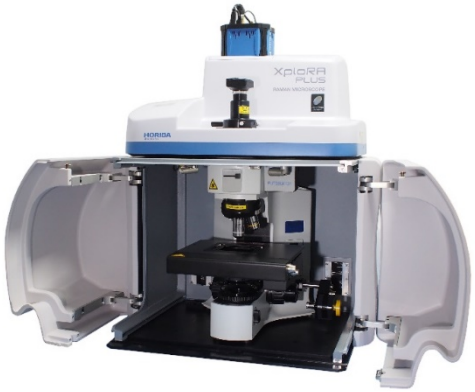


(10-500 um)









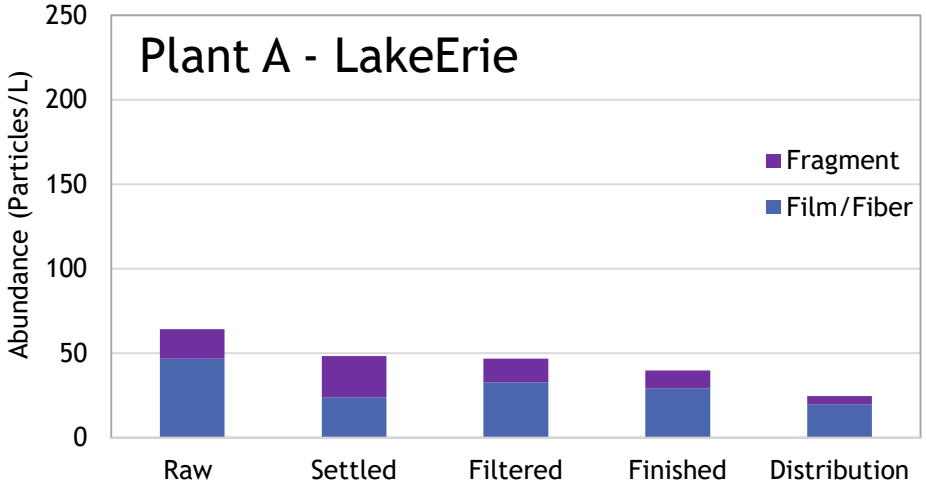
HORIBA Xplora Plus

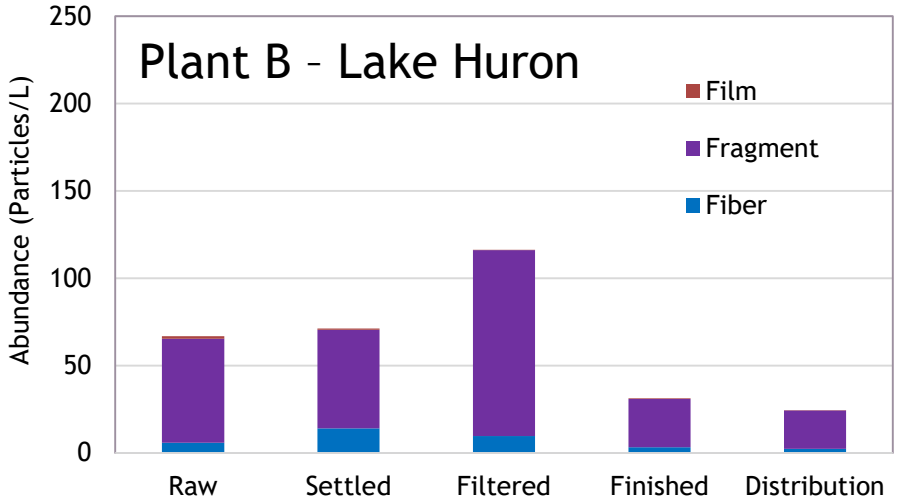
Filter samples through different size sieves for size fractionation

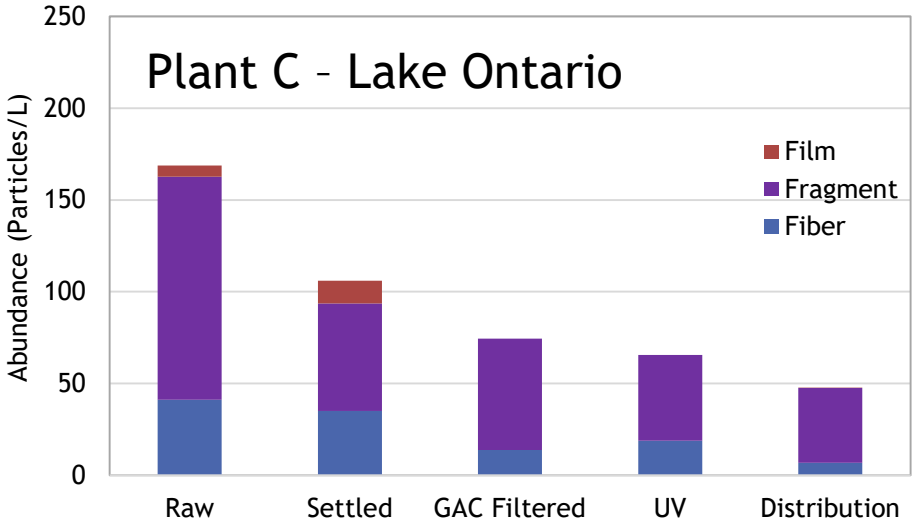
Tally all particles by colour and shape category (fiber, film, fragment) for each individual size fraction

Approx 10% of particles from each colour/category combination are selected at random for Raman spectroscopy (for each size fraction)

Microparticle Abundance







Note: Overall particle abundance decreases when comparing raw to finished water

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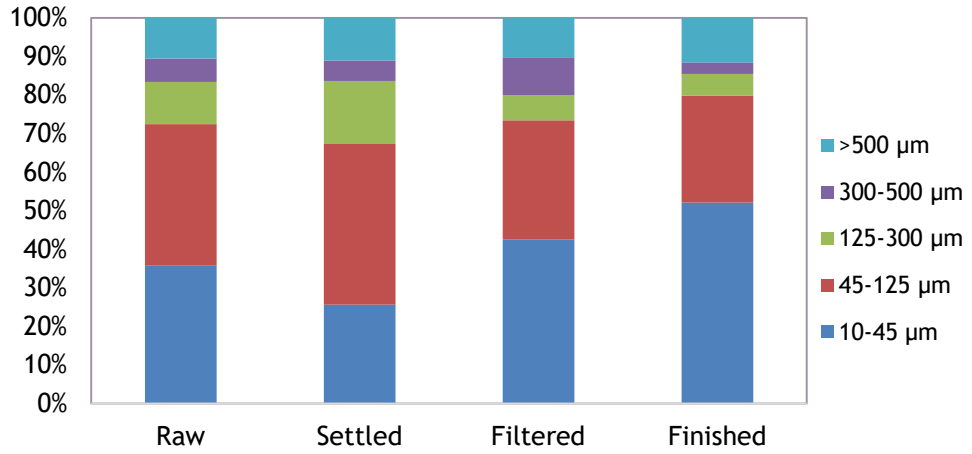
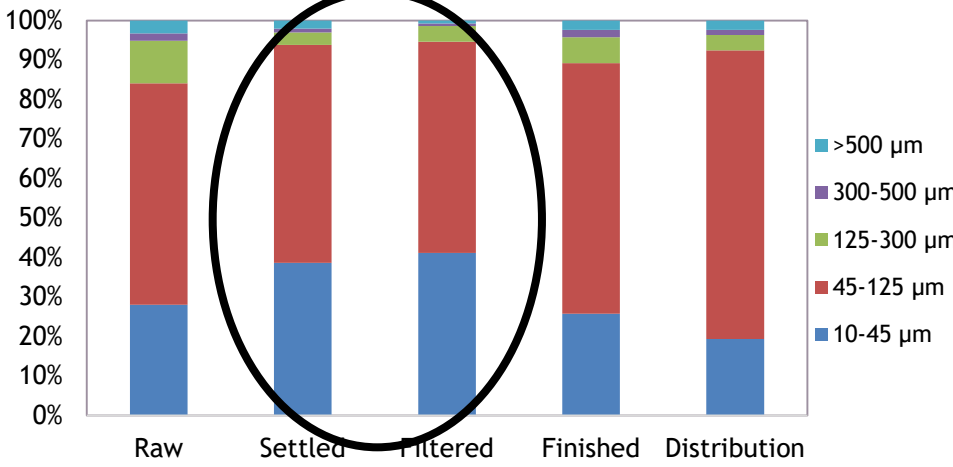
Particle Size Distribution

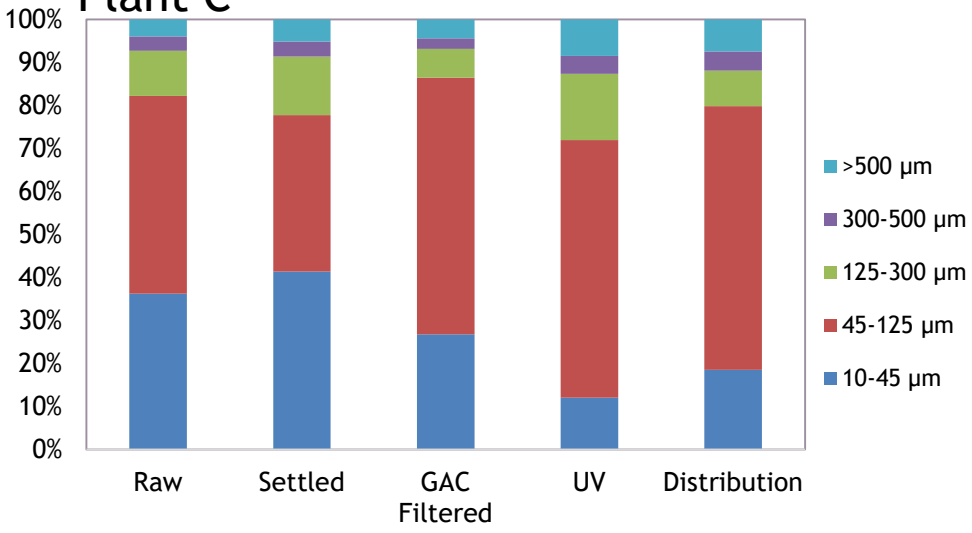
Plant A



Plant B



Plant C



Note: Fraction of a given particle size may decrease (or increase), but recall that overall particle abundance decreases through treatment.

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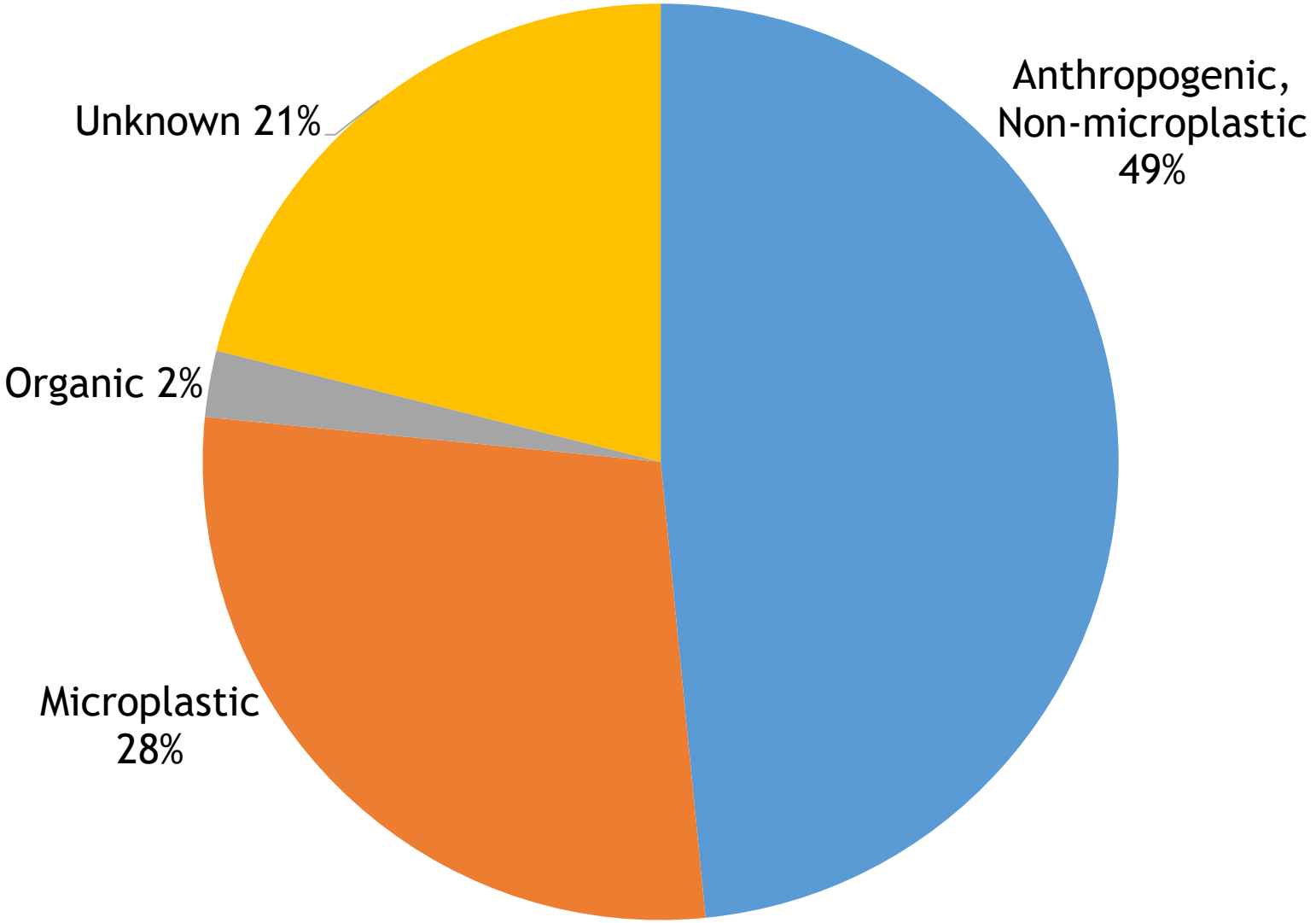
Filtered Water Particle Composition – Plant A



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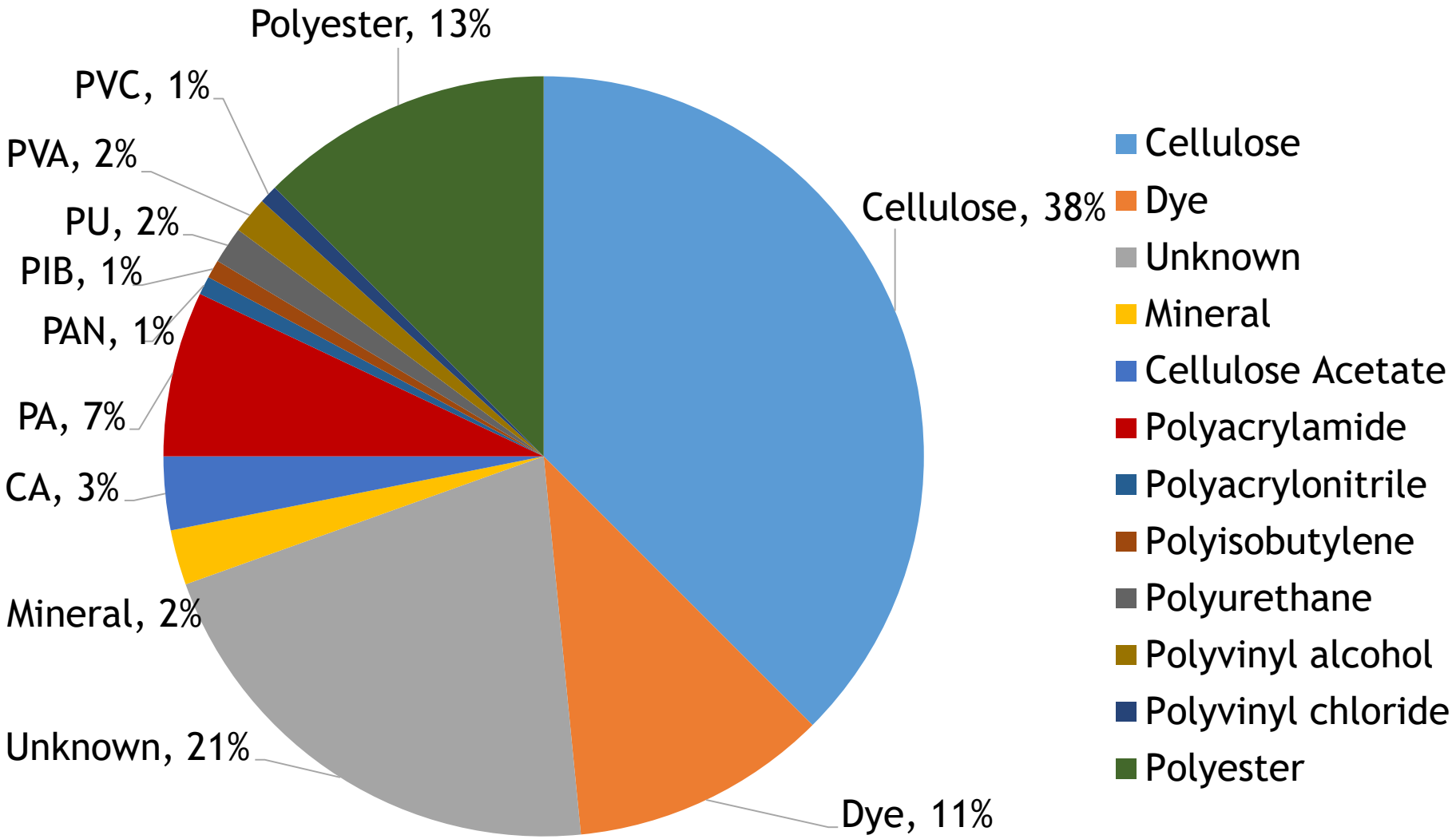

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What's Needed As We Move Forward?

Analysis automation
- Must reduce analysis time

Examine removal during drinking water treatment
- Conventional facilities (range of operating conditions)
- Membrane (ultrafiltration), conventional vs biological filtration, etc

Standardize methods
- Strong emphasis on QA/QC

Information regarding human health impacts