Addressing Key Questions on Microplastics in Drinking Water

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San Diego, CA
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Microplastics in the Potomac River Basin:
Drinking Water & Source Water Protection Perspectives

Tuesday, October 12, 2021
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POTOMAC River Basin Drinking Water Source Protection PARTNERSHIP

Companion Article

Mulling the Mysteries of Microplastics

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Brent Alspach, Arcadis
Allison Spinelli, OWSA

Mulling the Mysteries of Microplastics

Brent Alspach and Allison Spinelli

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Unlike other critical water quality challenges or our era, such as lead and per- and polyfluoroalkyl substances (commonly known as PFAS), microplastics remain somewhat of an enigma. Although there's broad awareness of the prevalence of microplastics in the environment, it's largely unclear across the water industry to what extent microplastics may be a concern. However, given the steady rise of mainstream media coverage, consumers will increasingly question whether their drinking water supplies—and by extension their health—may be compromised by microplastics.

Thus, it's important for water treatment professionals to be ahead of the curve on understanding this emerging contaminant. Accordingly, the AWWA Emerging Water Quality Issues Committee is committed to providing the most current information and associated resources. In its November 2019 issue, *Journal AWWA* published an article titled "Microplastics: What Drinking Water Utilities Need to Know" that offered a useful overview of microplastics, citing several valuable references. The purpose of this column is not to reiterate that content, but rather to add perspective about critical aspects of the microplastics issue being tracked by the AWWA Water Quality Technology Division and its Emerging Water Quality Issues Committee. To focus the discussion, this column is partitioned by questions of interest.

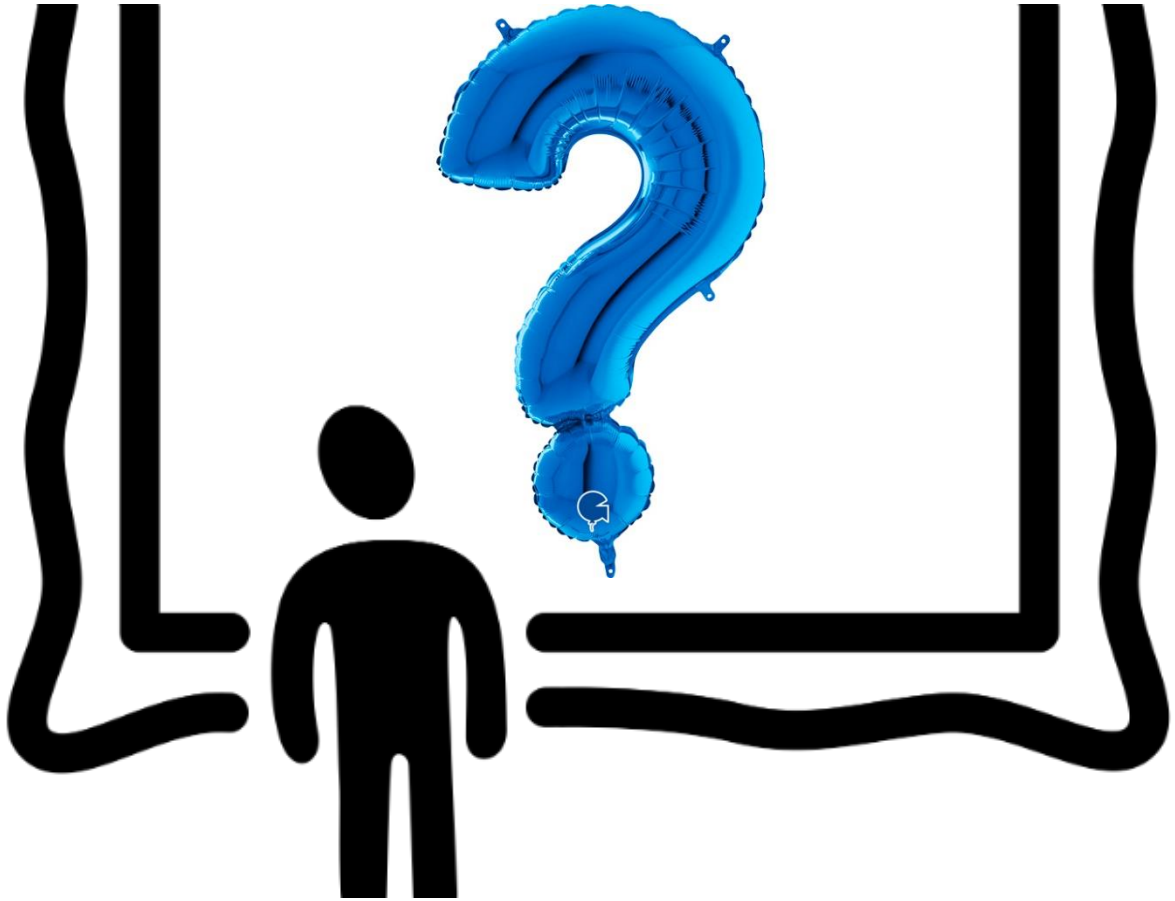
What Are the Key Issues Associated With Microplastics?

Although the occurrence of microplastics in drinking water supplies is a foundational concern (addressed by the next question), analytical methods are by far the most substantive area of microplastics research and development at present. And these two issues are fundamentally interrelated, as reliable analytical methods are essential for characterizing occurrence. This point was underscored at the technical session on microplastics at AWWA's 2019 Water Quality Technology Conference. The session consisted of presenters from Luxembourg-based Eurofins Scientific and the University of Toronto (Ont.) who are on the leading edge of developing analytical methods applicable to drinking water matrixes.

Among the most significant focus areas for analytical method development are those that pertain to the information that can be conveyed by such methods, including microplastic quantification (in terms of both enumeration and mass concentration), size characterization, and minimum thresholds for detection (size and mass). Moreover, because plastic is a category rather than a monolithic material, there's interest in identifying specific materials among the microplastics that may be present in a sample (e.g., polypropylene, polystyrene, polyethylene terephthalate, and many others). Sampling procedures are also critical, considering the challenges to detecting increasingly miniscule quantities and the ubiquitous presence of plastics posing a risk for sample contamination, including vectors from labware, clothes, and even airborne particulates. Improving the efficiency of and reducing the turnaround time for results are likewise areas of ongoing research.

Microplastics: The Big Picture

Many more important questions than answers!



Presentation Objectives

- ✓ Create awareness of critical questions
- ✓ Build institutional knowledge
- ✓ Foster discussion
- ✓ Advance the discourse

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- ✓ Create awareness of critical questions
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- ✓ Foster discussion
- ✓ Advance the discourse

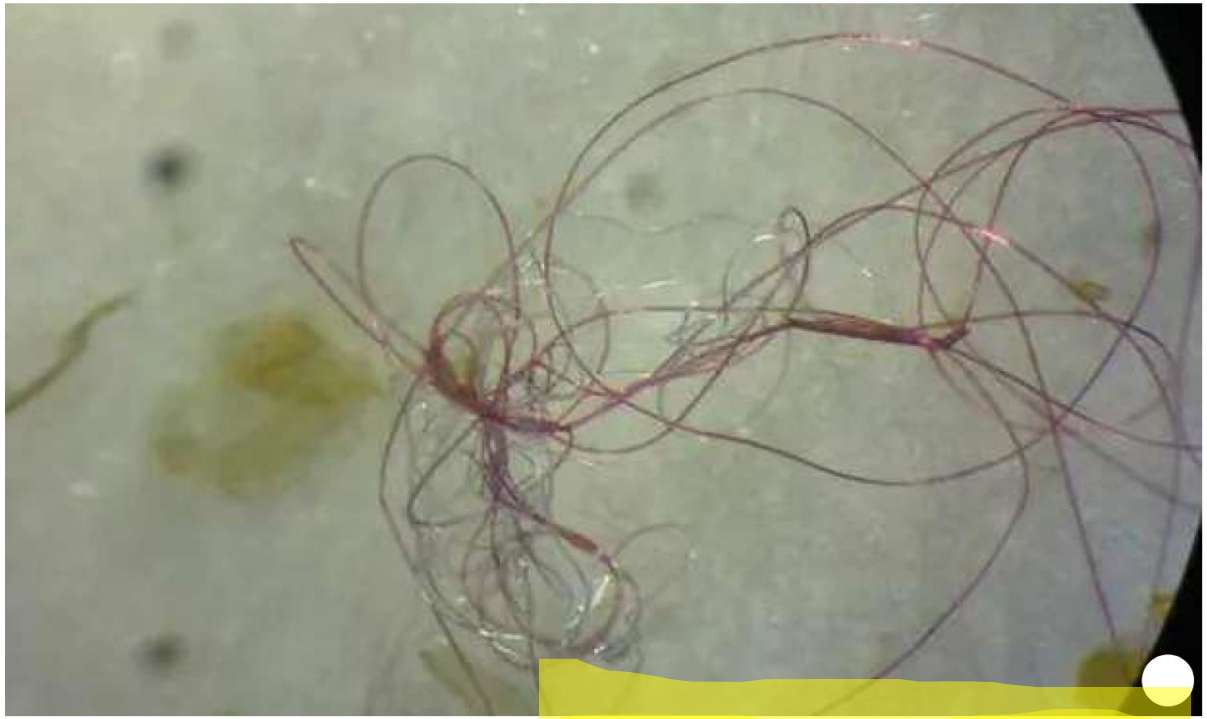
The need is imminent

Problematic Magnitude

13.3 quadrillion plastic fibers released in 2019 alone*

* UC Santa Barbara study
for The Nature Conservancy California;
not yet published or peer-reviewed

The Guardian



Groundbreaking study finds 13.3 quadrillion plastic fibers in California's environment

Exclusive: report reveals far more microfibers than there are stars in the Milky Way – and they can easily enter oceans and waterways

Microplastic Ubiquity!

Microplastics are everywhere

Microplastic Ubiquity!

Microplastics are everywhere …including water supplies.

One of the few definitive statements we can make about these contaminants

Microplastic Ubiquity!

Are these microplastics?

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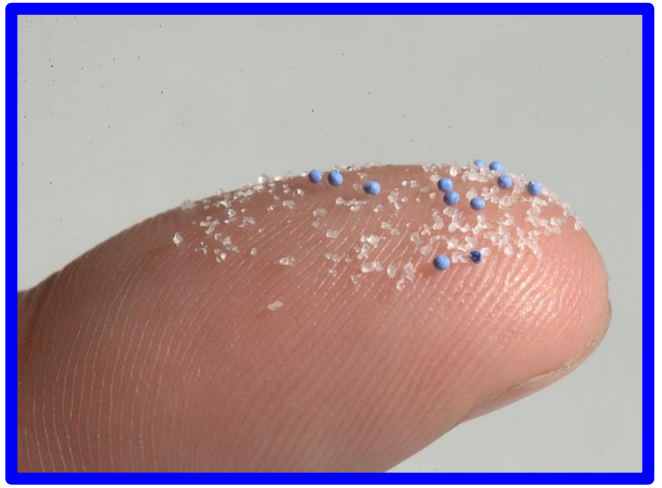
Are these microplastics?

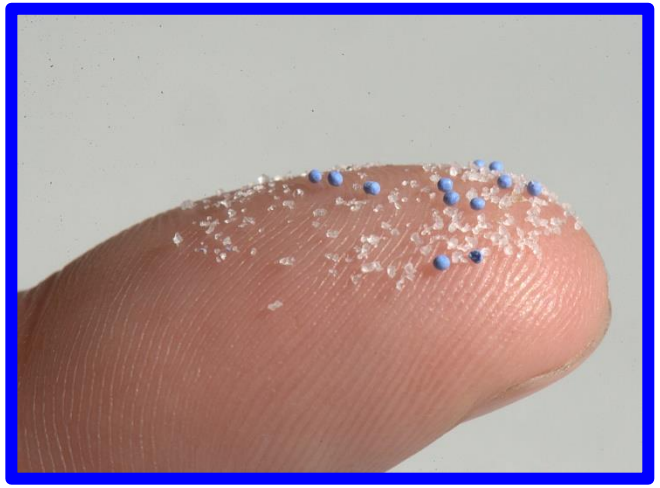


Depends on who you ask...!

What are Microplastics?

“Defining” Characteristics

- No precise scientific meaning
- **“Micro”** in the descriptive/qualitative sense…
- …not **“micro”** in terms of rigorous SI units
- Subjectively characterized and classified



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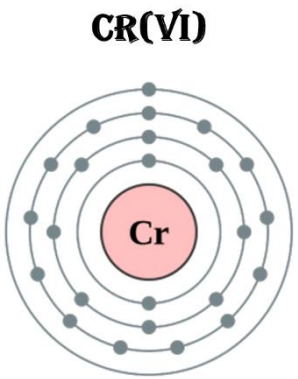
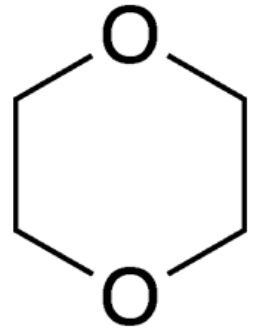
Most contaminants do not require a formal regulatory definition



Hexavalent chromium

1-4-Dioxane



Contrasting Paradigm

(examples)

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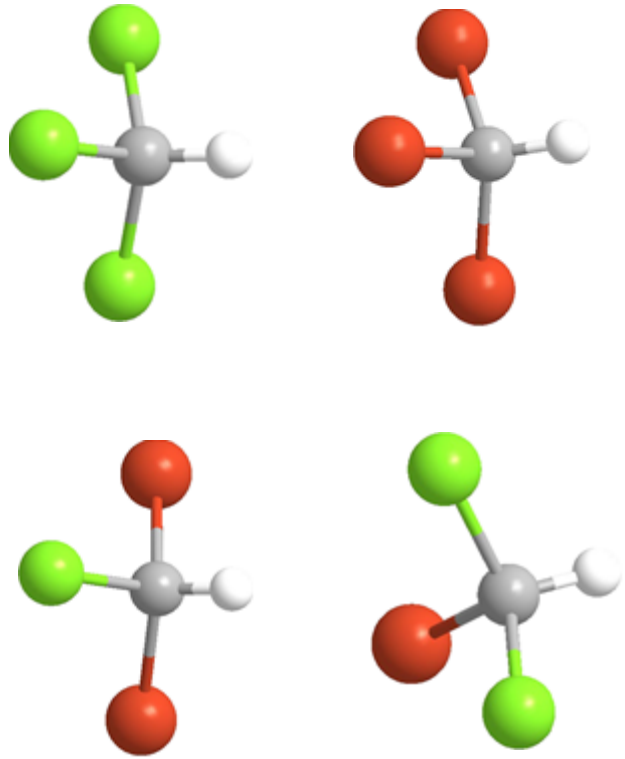

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Prescriptive
(not descriptive)

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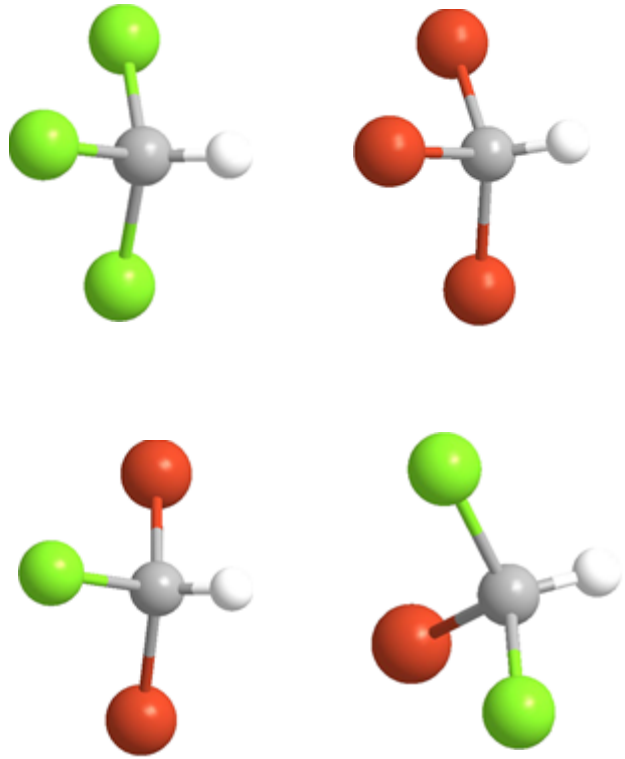

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Prescriptive? Descriptive?

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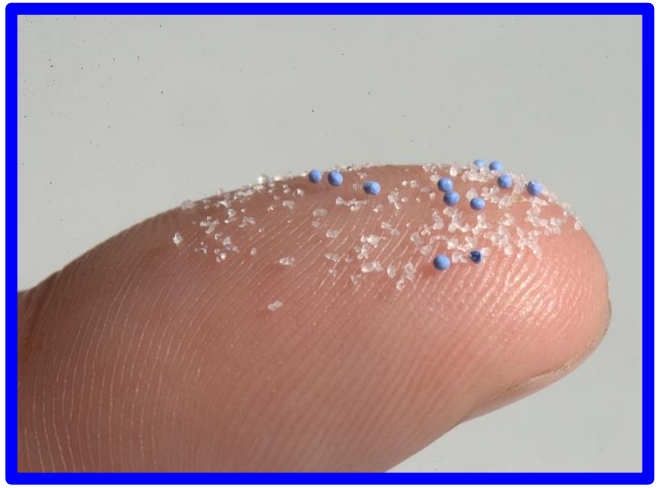

Microplastics definitions will be statutory

What are Microplastics?

"'Microplastics in Drinking Water' are defined as solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least three dimensions that are greater than 1 nanometer and less than 5,000 micrometers. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded."

Adopted June 6, 2020
California State Water Resources Control Board

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Liquid / soluble phase polymers are excluded

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Well-below accurate and reliable detection with current methods

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Readily visible with the naked eye

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Size range spans nearly seven orders of magnitude

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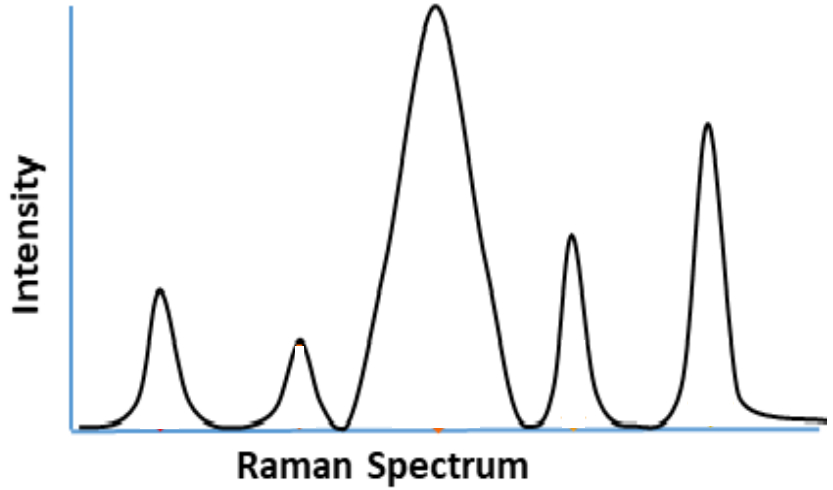

Informally: Plastic particulates you can't see

Figure source: https://tmkorter.expressions.syr.edu/plastics/

What are the Key Issues?

1. Occurrence
2. Analytical Methods

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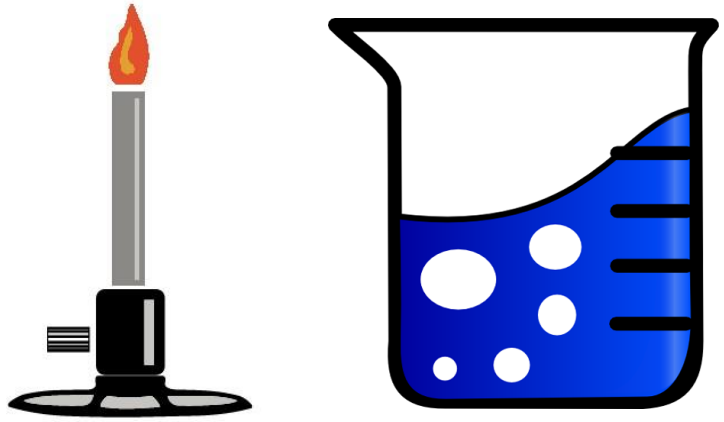
1. Occurrence
2. **Analytical Methods**



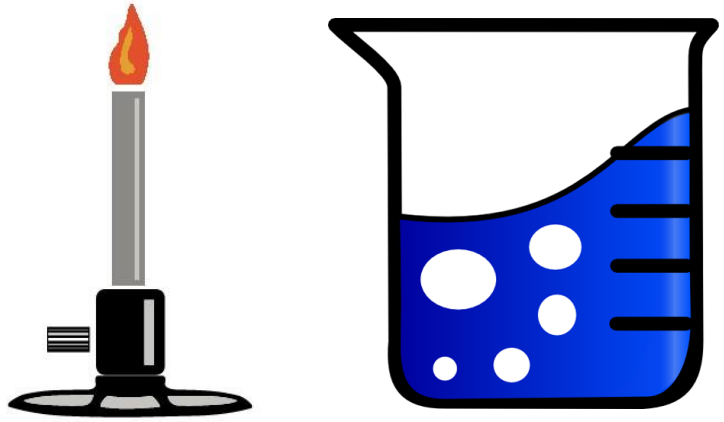
Critical considerations:

- Sample contamination
- Turnaround time
- Automation
- Resolution
- Reliability
- QA/QC

Areas of active research & development

What are the Key Issues?

1. Occurrence
2. **Analytical Methods**



Critical considerations:

- Sample contamination
- Turnaround time
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- Resolution
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Underpins almost every other significant question

What are the Key Issues?

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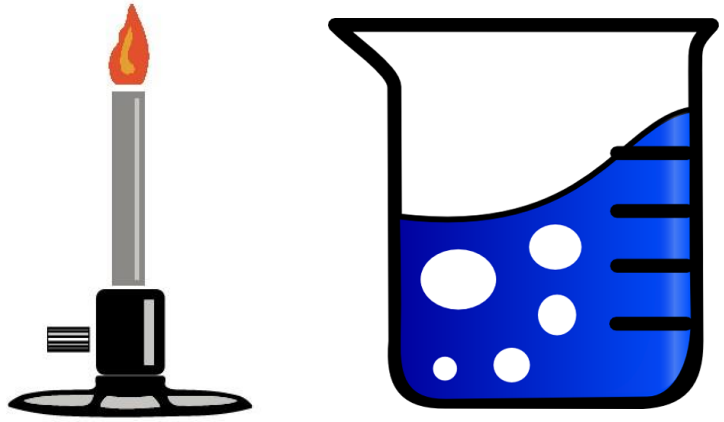
2. **Analytical Methods**



Critical considerations:

- **Sample contamination**
- Turnaround time
- Automation
- Resolution
- Reliability
- QA/QC

Many inherent questions with this consideration

What are the Key Issues?

1. Occurrence
2. **Analytical Methods**

What do we need / want to know?

Quantification

Enumeration?

Mass?

Morphology

Size characterization

Polymer type

What are the Key Issues?

1. Occurrence
2. **Analytical Methods**

What do we need / want to know?

Quantification

How many?
How much?

Morphology

Size characterization

Polymer type

What are the Key Issues?

1. Occurrence

2. **Analytical Methods**

◄ **Interests** ►

Origin?

Mechanism of formation?

What do we need / want to know?

Quantification

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Polymer type

What are the Key Issues?

1. Occurrence

What do we need / want to know?

2. Analytical Methods

Morphology

◄ Interests ►

Origin?

Mechanism of formation?

Litter

Industry / Manufacturing

Textiles

What are the Key Issues?

1. Occurrence

What do we need / want to know?

2. Analytical Methods

◄ **Interests** ►

Origin?

Mechanism of formation?

Breakdown Breakdown

- **Mechanical**
- **Chemical**
- **Biological**
- **UV**

Quantification

Enumeration?

Mass?

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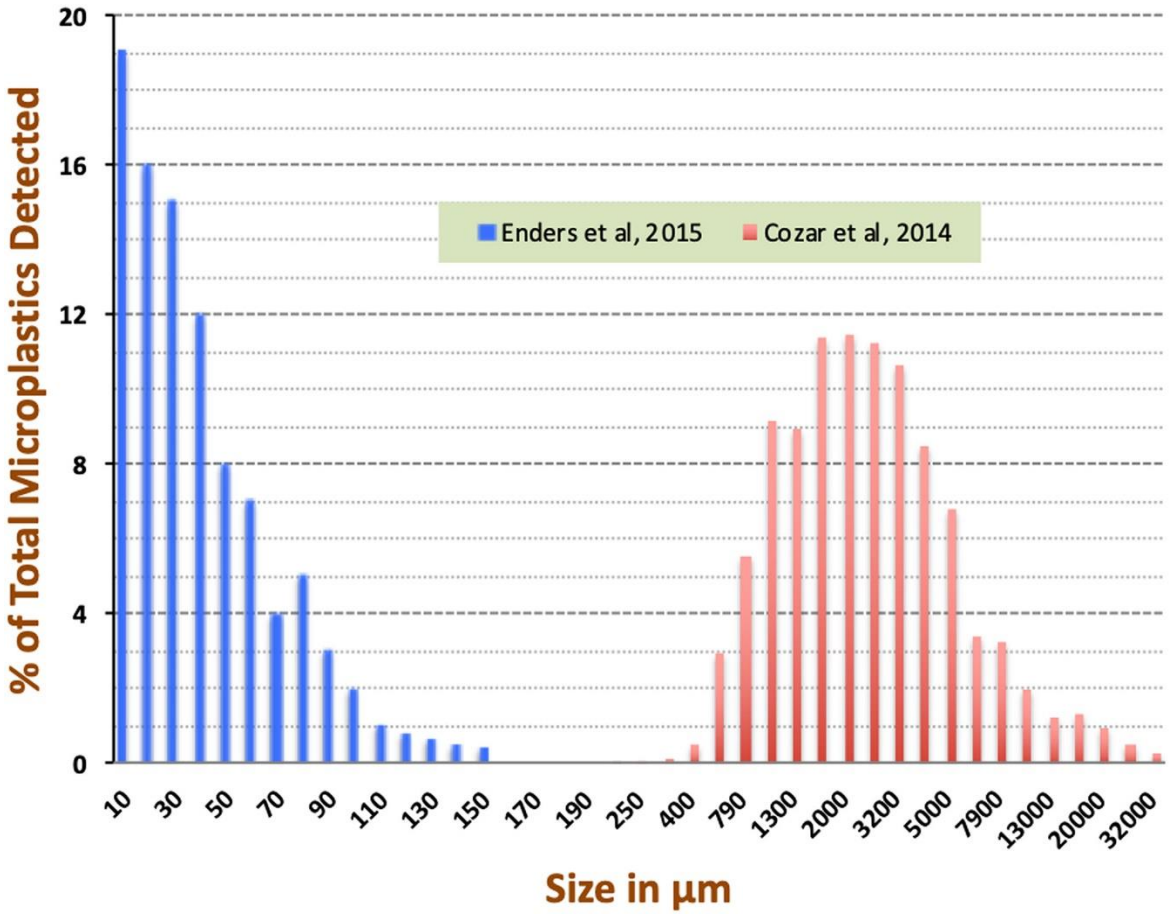
What are the Key Issues?



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Source: Hale et al. 2020. A Global Perspective on Microplastics. *Reviews of Geophysics*.

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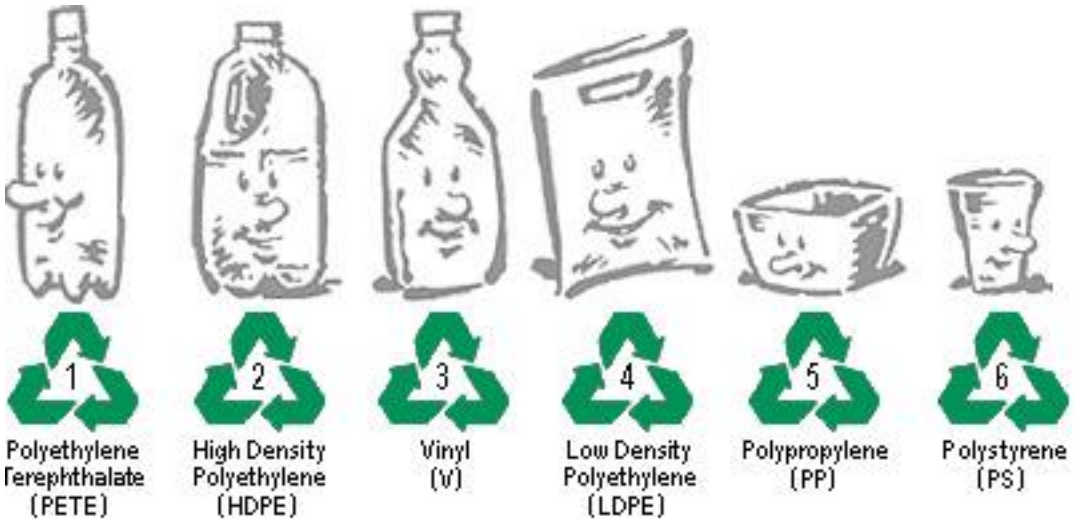

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Figure source: https://flowvella.com/s/x2c/presentation-end

What are the Key Issues?

1. Occurrence
2. **Analytical Methods**

How can we be confident that our data are good?

What do we need / want to know?

Quantification

Enumeration?

Mass?

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Polymer type

What are the Key Issues?

1. Occurrence
2. **Analytical Methods**

How can we be confident that our data are good?

Are Microplastics in Drinking Water?

Not that simple

Are Microplastics in Drinking Water?

Example Treated Water Supplies			
Attribute	**Supply 1**	**Supply 2**	**Supply 3**
Particles (#/L)	**0**	**10**	**1,000**

Equitable Comparison…?

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Mass			
Water Quality			
Method			
Treatment			

Very important qualifying information

Are Microplastics in Drinking Water?

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Attribute	**Supply 1**	**Supply 2**	**Supply 3**
Particles (#/L)	0	10	1,000
Mass			
Water Quality			
Method	**Many important questions!**		
Treatment			

Sizes…?
Detection limits…?

Sampling protocol…?
QA/QC…?

Are Microplastics in Drinking Water?

Example Treated Water Supplies			
Attribute	**Supply 1**	**Supply 2**	**Supply 3**
Particles (#/L)	0	10	1,000
Mass			
Water Quality			
Method			
Treatment	**What treatment processes were used?**		

Can WTPs Remove Microplastics?

Our treatment processes are very effective for removing conventional particulates.

How comparable are microplastics?

Size? **Morphology?**

Density? **Surface Charge?**

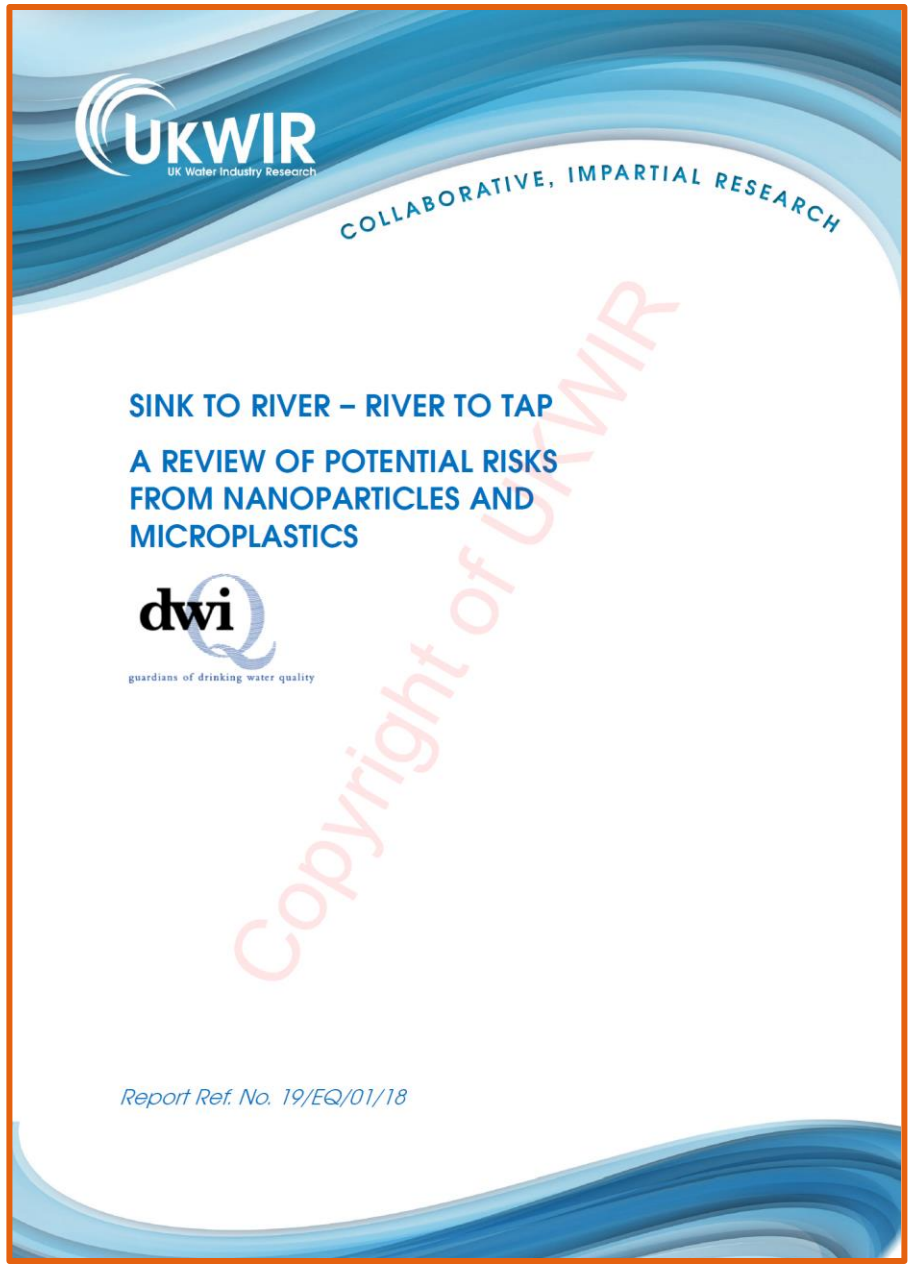
These attributes affect treatment efficacy for coagulation, flocculation, settling, and filtration.

Can WTPs Remove Microplastics?

UK Study

Highlights:

- Concentrations of microplastics in potable water supplies are very low
- Water treatment removal efficiency characterized as >99.99% (4-log reduction)
- Size distribution suggests greater numbers of smaller microplastic particulates



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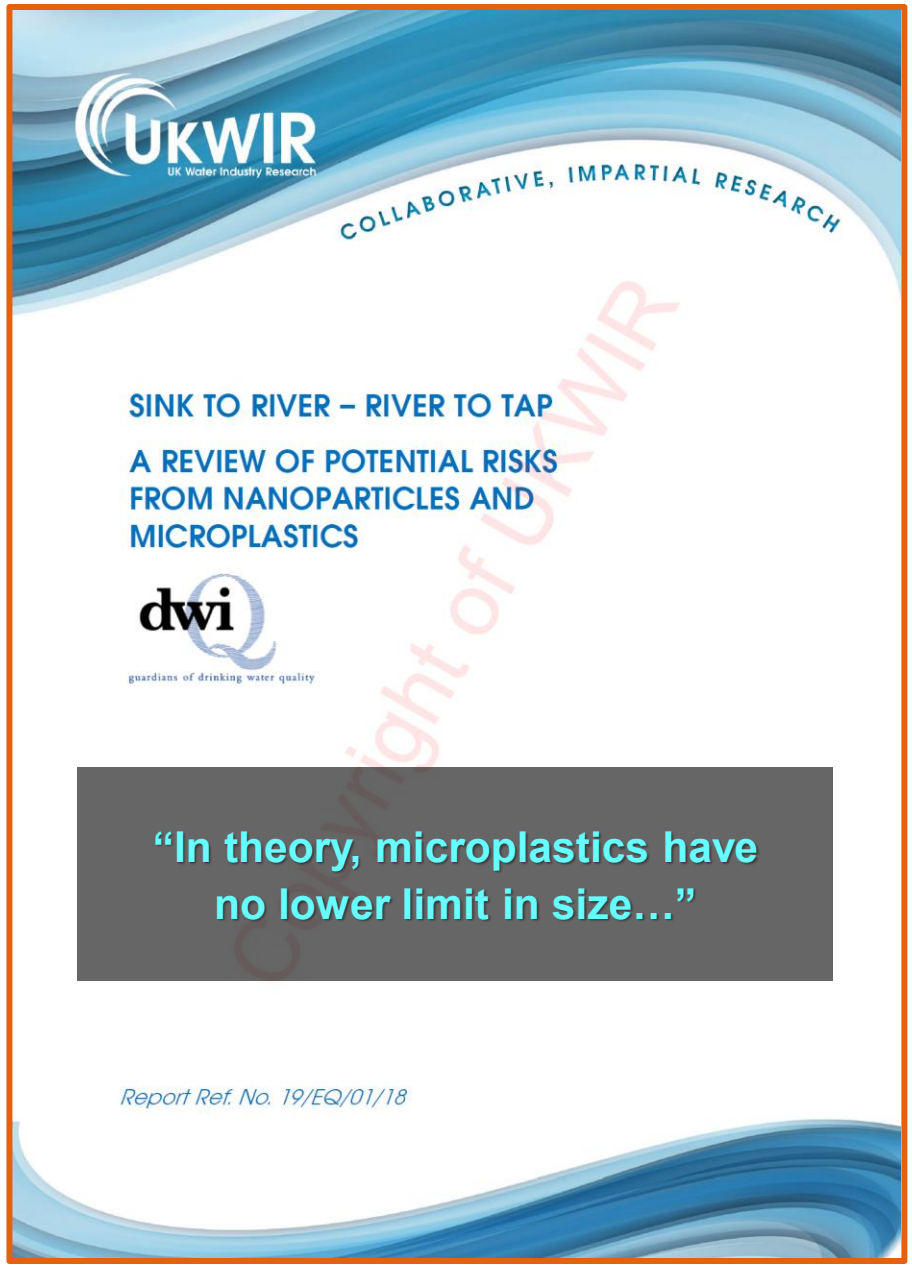

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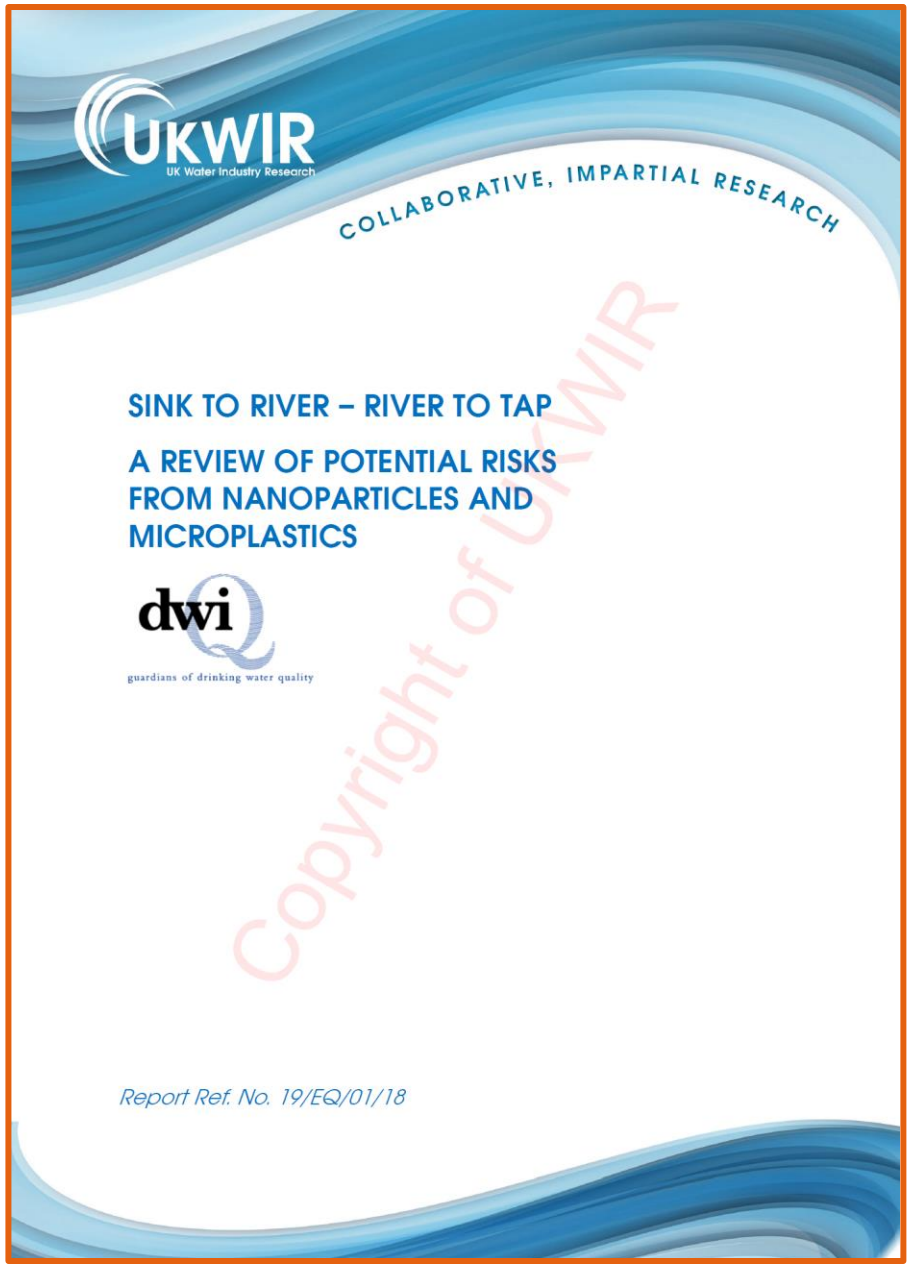
Limitations:

- Method resolution of >25 µm
- Number of smaller microplastics is likely underestimated
- Better methods and protocols are needed



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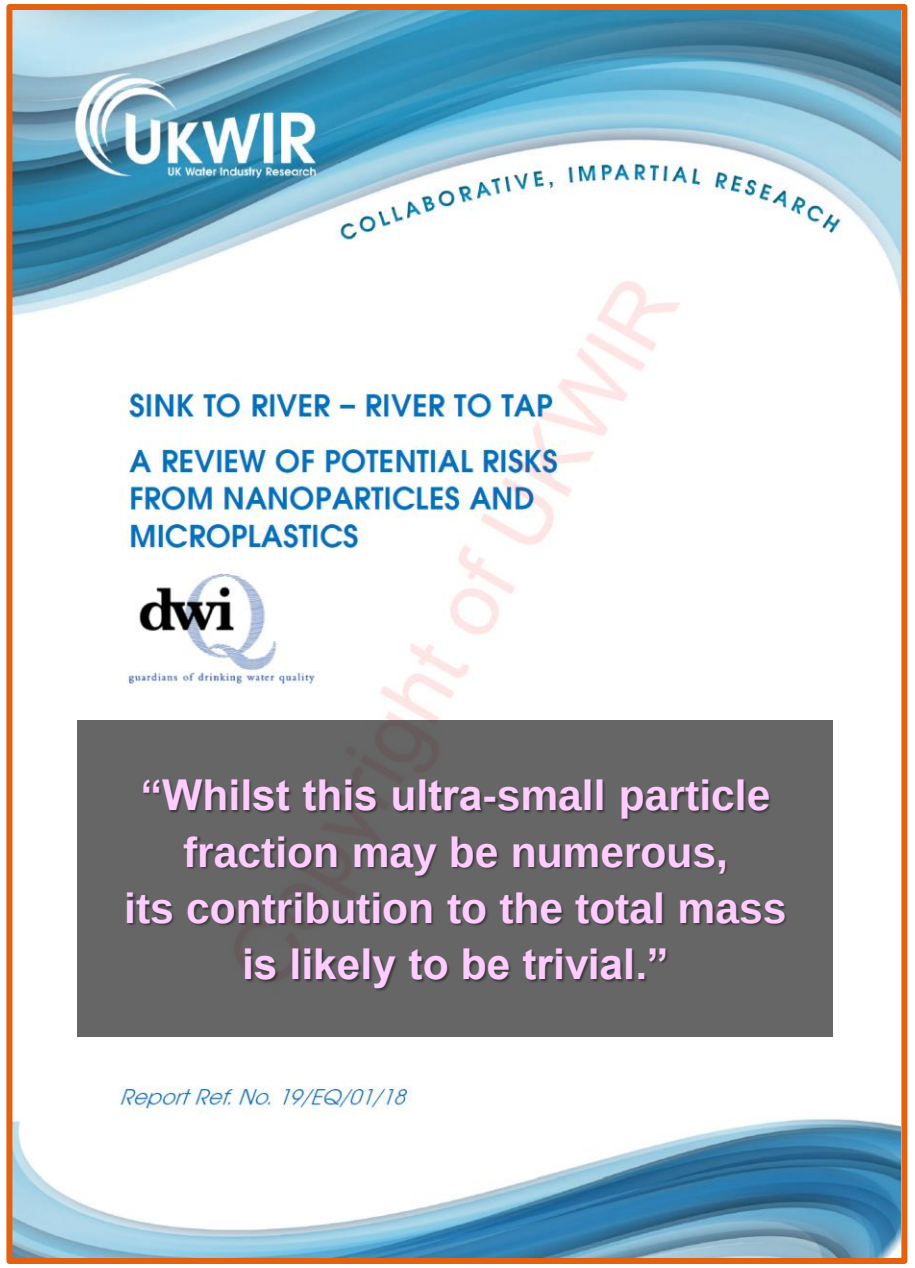

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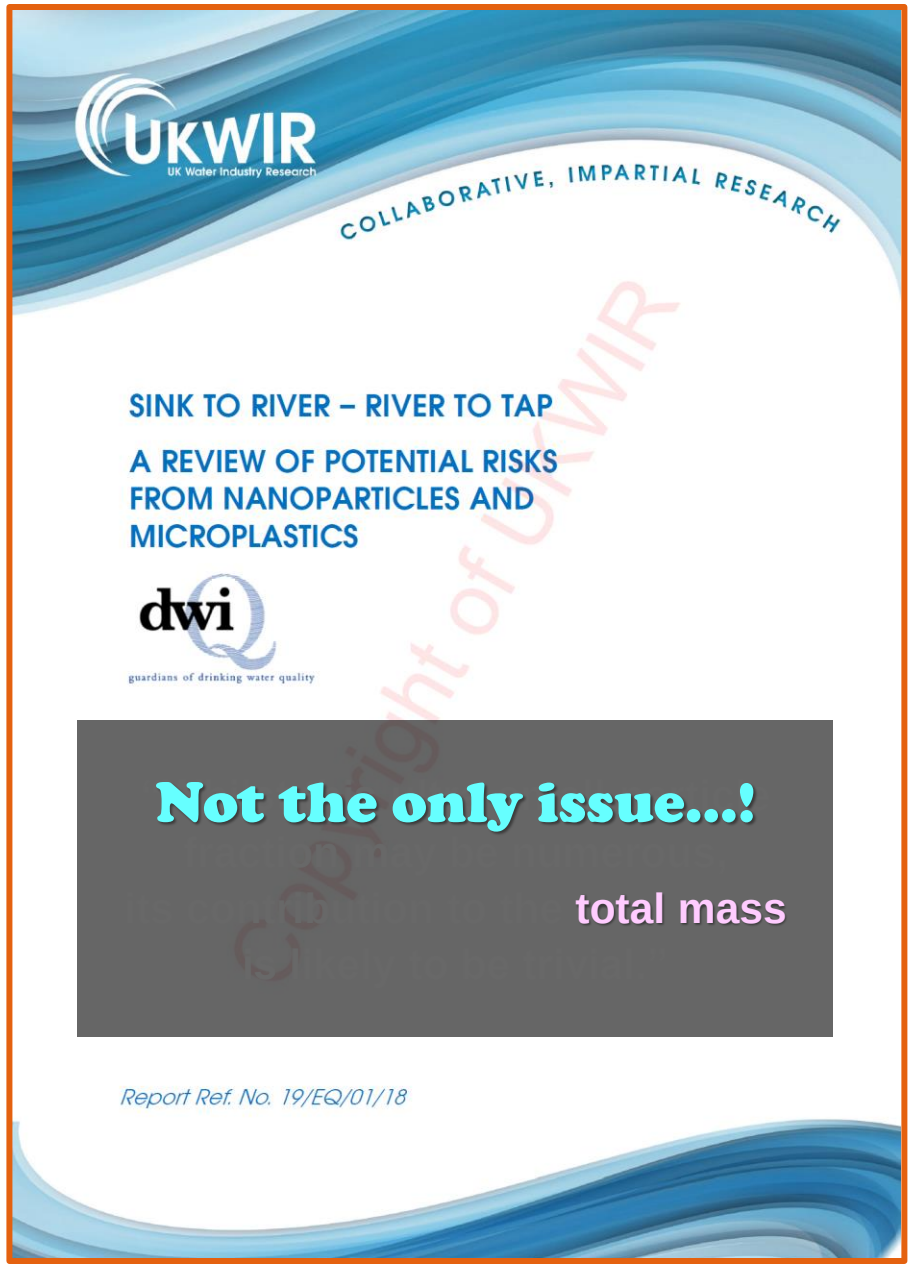
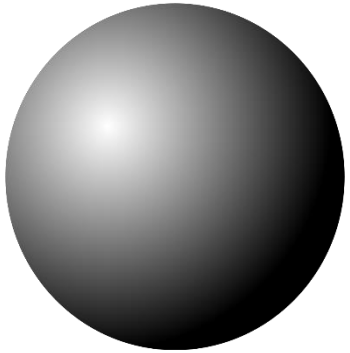


Size Matters

Particulate Size Influences:

- Residence time in the human body
- Intrinsic particulate toxicology
- Secondary contaminant toxicology
- Treatment efficacy



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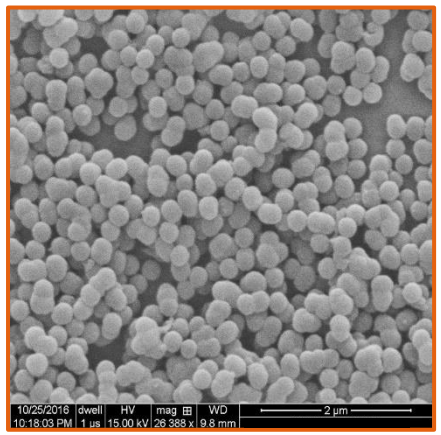

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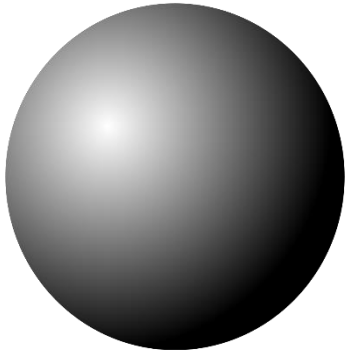

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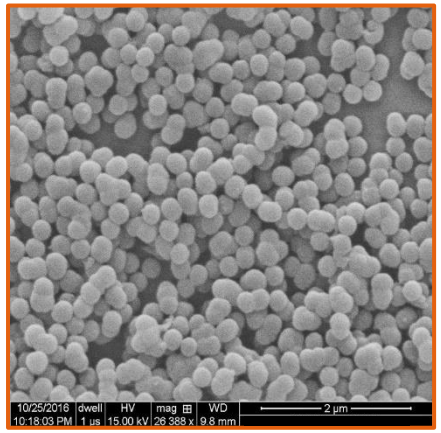

Influence of Particle Size on Surface Area

Volume (μm^3)	# of Particles	Particle Diameter (μm)	Total Surface Area (μm^2)	Surf. Area Magn. Factor
523,598,333	1	1,000	3,141,590	1
523,598,333	10	464	6,768,350	2.2
523,598,333	100	215	14,581,969	4.6
523,598,333	1,000	100	31,415,900	10.0
523,598,333	10,000	46	67,683,505	21.5
523,598,333	100,000	22	145,819,691	46.4
523,598,333	1 billion	1	3,141,590,000	1,000
523,598,333	1 quintillion	0.001	3,141,590,000,000	1,000,000

Size Matters

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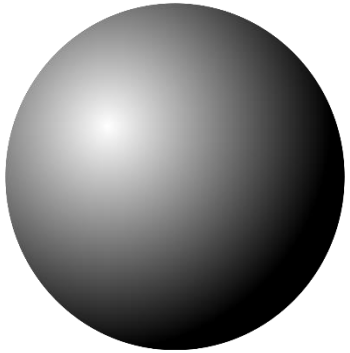

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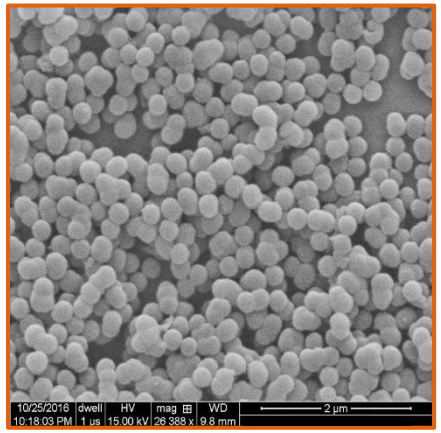

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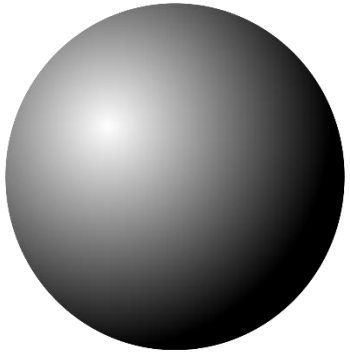
Available sorption surface area increases significantly with decreasing particle size

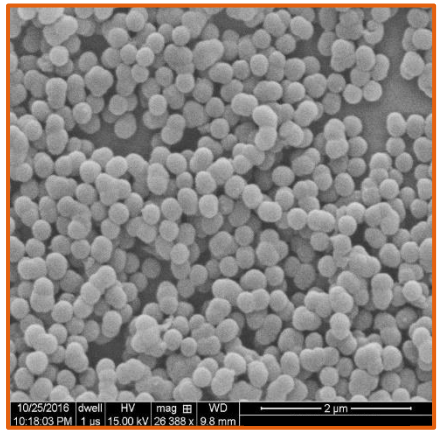
Size Matters

Particulate Size Influences:

- Residence time in the human body
- Intrinsic particulate toxicology
- Secondary contaminant toxicology
- **Treatment efficacy**



VS.



Influence of Particle Size on Surface Area

Volume (μm^3)	# of Particles	Particle Diameter (μm)	Total Surface Area (μm^2)	Surf. Area Magn. Factor
523,598,333	1	1,000	3,141,590	1
523,598,333	10	464	6,768,350	2.2
523,598,333	100	215	14,581,969	4.6
523,598,333	1,000	100	31,415,900	10.0
523,598,333	10,000	46	67,683,505	21.5
523,598,333	100,000	22	145,819,691	46.4
523,598,333	1 billion	1	3,141,590,000	1,000
523,598,333	1 quintillion	0.001	3,141,590,000,000	1,000,000

Available sorption surface area increases significantly with decreasing particle size

The Intersection of Key Questions

Environmental Science & Technology

Article

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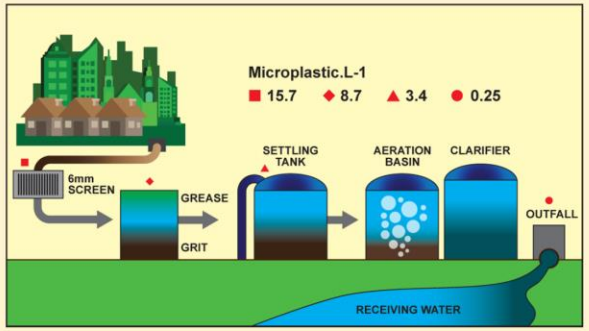

Treatment Efficacy

Occurrence

Analytical Methods

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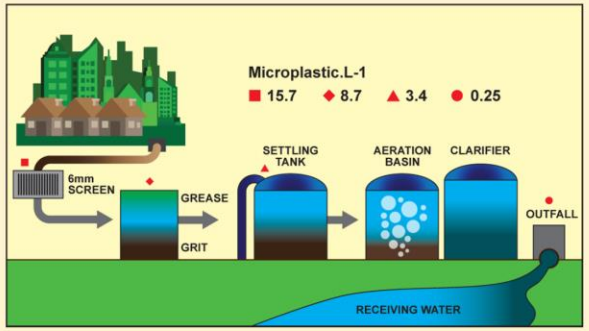

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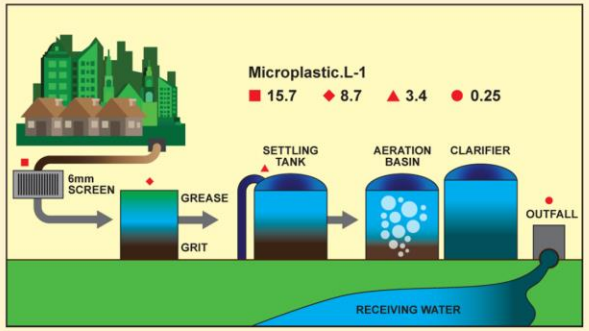

1. Can treatment processes remove microplastics?

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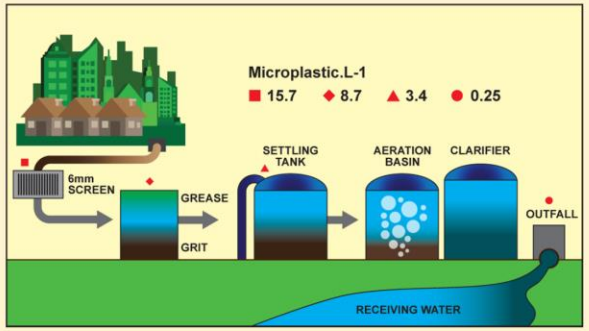

- ✓ Can treatment processes remove microplastics?

2. What is the *potential* contribution of microplastics in treated wastewater to drinking water sources?

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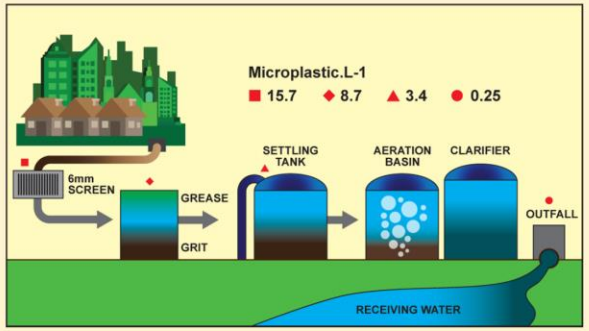

- ✓ Can treatment processes remove microplastics?
- ✓ What is the *potential* contribution of microplastics in treated wastewater to drinking water sources?
3. What is the analytical method resolution for particulate size?

The Intersection of Key Questions

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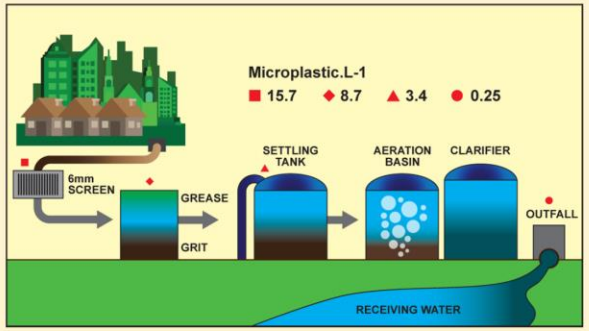

? Can treatment processes remove microplastics?

? What is the *potential* contribution of microplastics in treated wastewater to drinking water sources?

3. What is the analytical method resolution for particulate size?

Lack of information undermines study results.

Can WTPs Remove Microplastics?

Can WTPs Contribute Microplastics?

Conventional Treatment

Filter underdrains

Tube / plate settlers

Polymer

Can WTPs Contribute Microplastics?

Conventional Treatment

Filter underdrains

Tube / plate settlers

Polymer

We actively add plastics in the treatment process

Can WTPs Contribute Microplastics?

Conventional Treatment

Filter underdrains

Tube / plate settlers

Polymer

Advanced Treatment

IX and GAC vessels

MF/UF (polymeric)

NF/RO

Membrane materials
Elements
Pressure vessels

Other Common Components

Piping
(e.g., PVC)

Coatings
(e.g., epoxy)

Chemical systems

Storage tanks
Tubing
Feed pump parts

Can WTPs Contribute Microplastics?

All materials (even "certified") can exhibit leaching or particle shedding in water.

Two critical questions:

1) **How much?**
2) **How fast?**

Can WTPs Contribute Microplastics?

All materials (even "certified") can exhibit leaching or particle shedding in water.

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2) **Kinetics**

Can WTPs Contribute Microplastics?

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2) **Kinetics**

Extent depends on materials and water quality

The Alternatives…?

The Alternatives…?

All contain significant plastic materials.

Is Toxicity a Concern?

Poorly understood

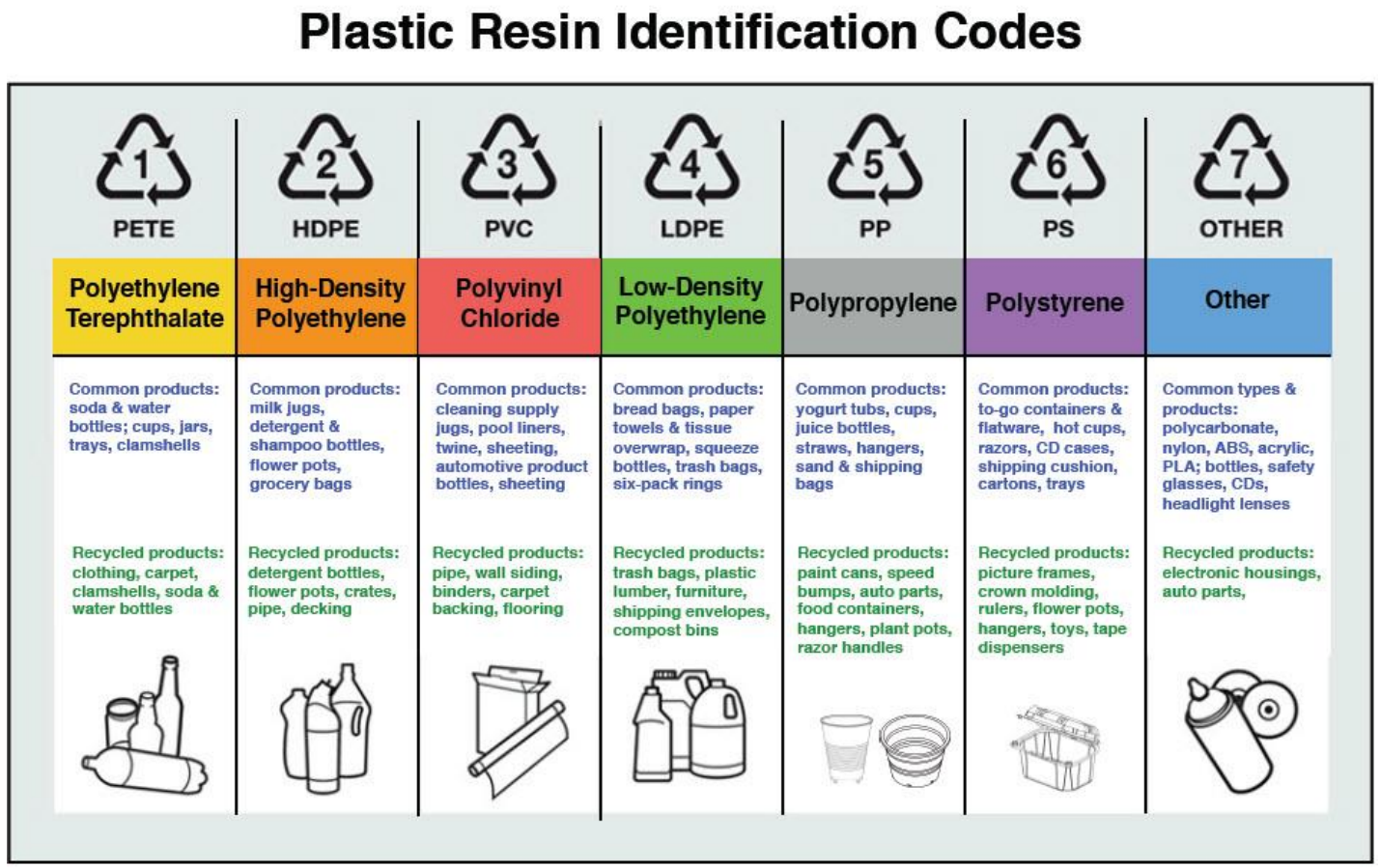
Is Toxicity a Concern?

Poorly understood …and potentially complicated.

<u>Potential variability</u>:

- Size
- Polymer material
- Residence time in the human body
- Sorption of secondary contaminants

Is Toxicity a Concern?



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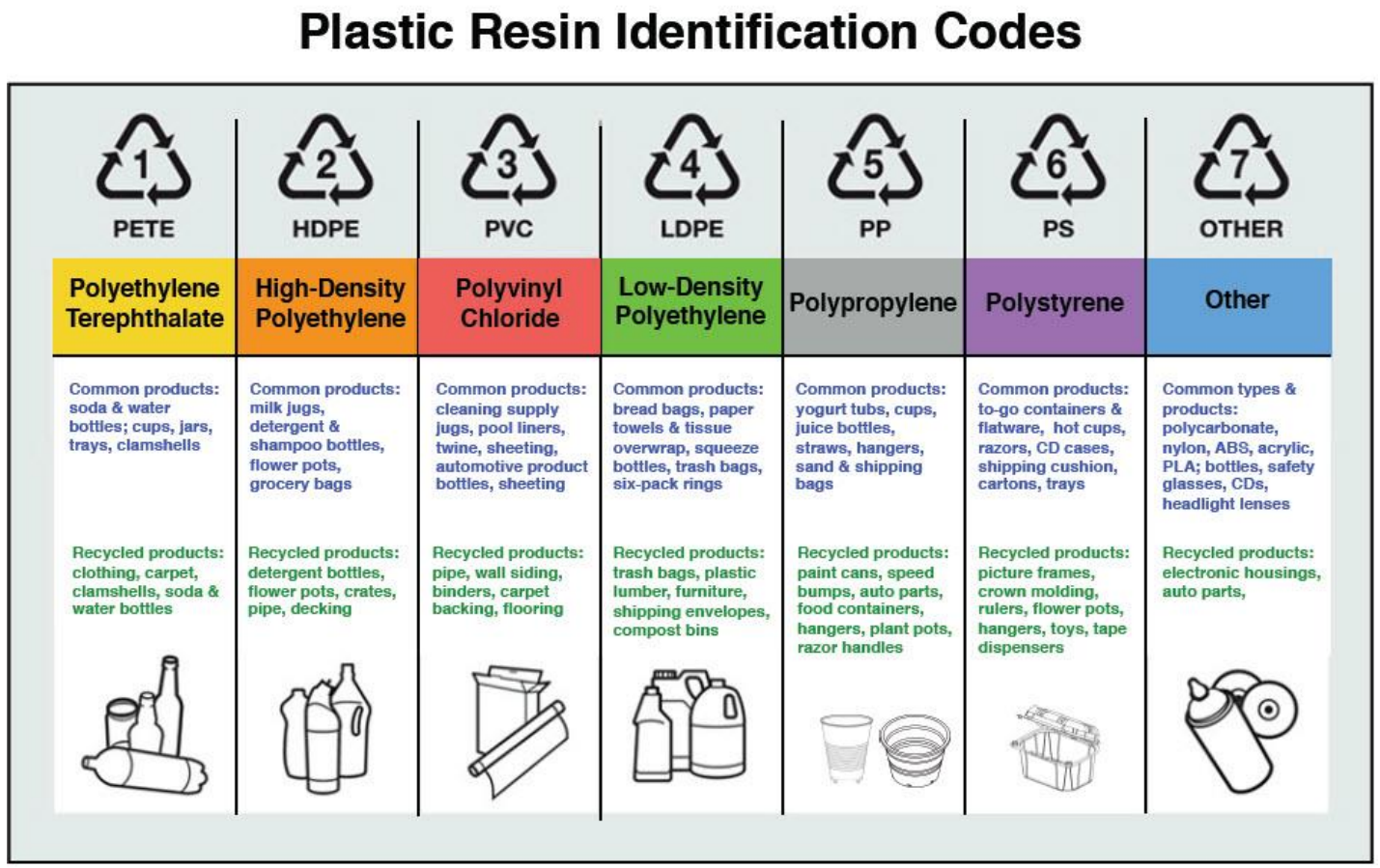

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Sorption potential varies with polymer type

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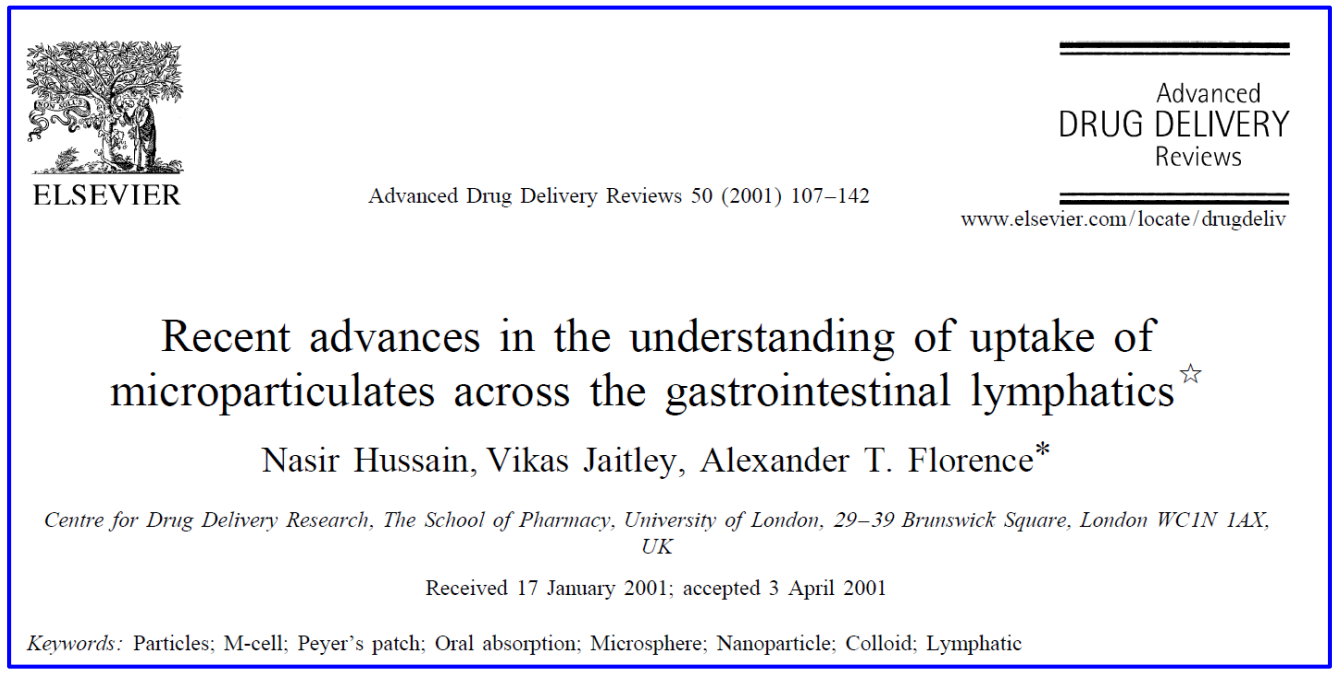

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Recent advances in the understanding of uptake of microparticulates across the gastrointestinal lymphatics☆

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Received 17 January 2001; accepted 3 April 2001

Keywords: Particles; M-cell; Peyer's patch; Oral absorption; Microsphere; Nanoparticle; Colloid; Lymphatic

► Inert particulates <150 μm can pass into the mammalian gut

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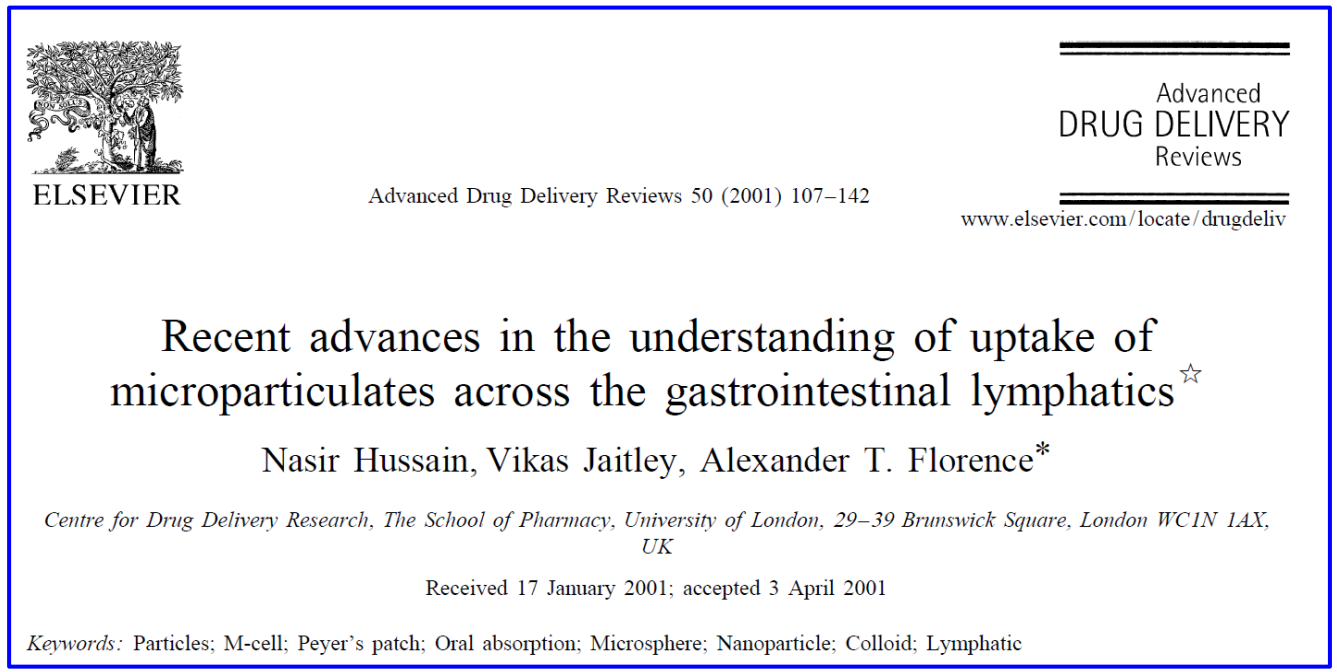

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California definition:
> 1 nm

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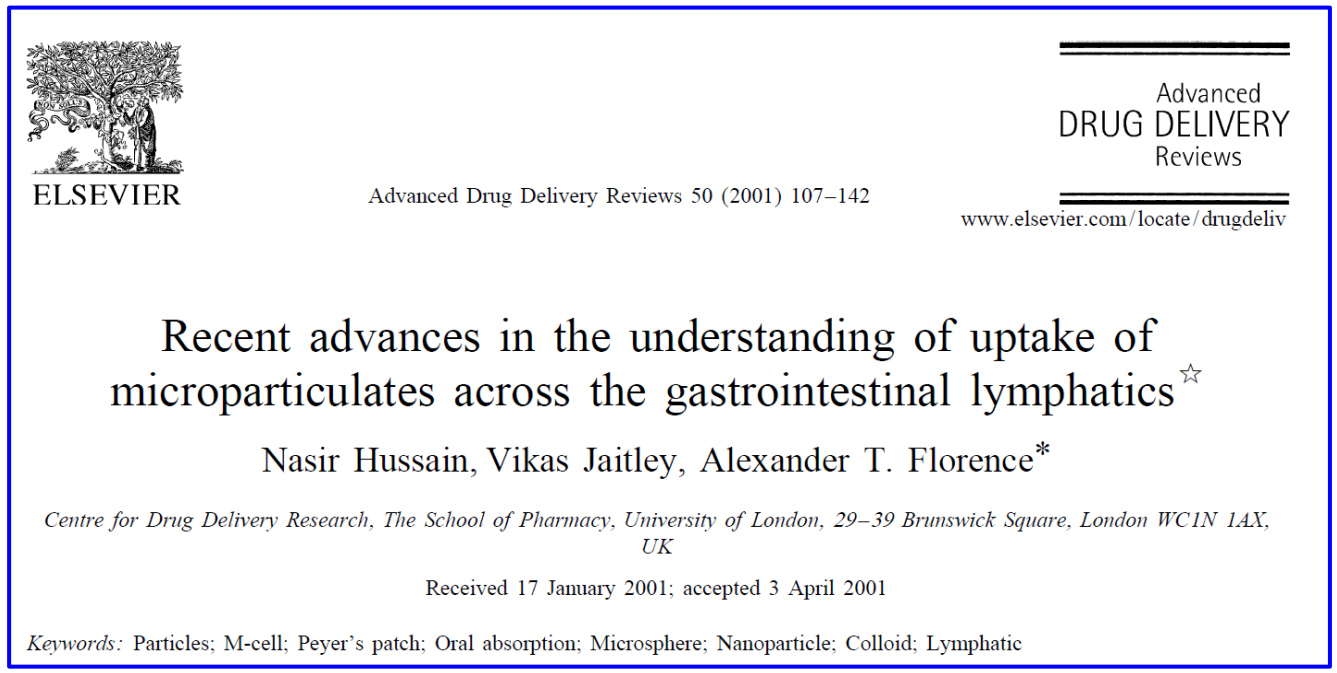

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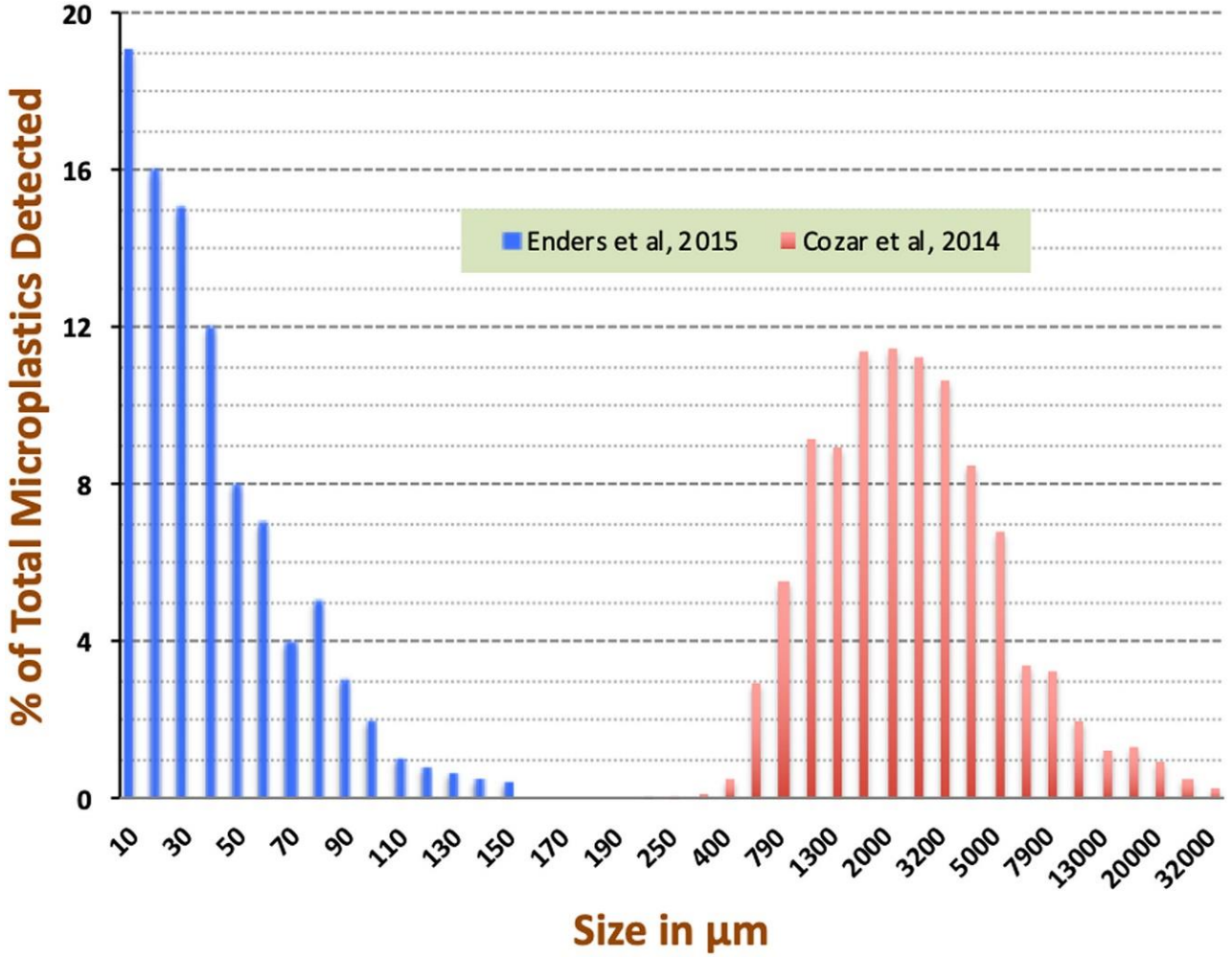

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The frontier of the frontier: **Nanoplastics**

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What's on the Horizon?

California State Mandate:

- Definition adopted in 2020
- Standard analytical methods issued on September 29, 2021
- Four years of sampling at drinking water treatment plants (window of timing TBD)

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- **Four years of sampling at drinking water treatment plants (window of timing TBD)**

Yield extensive database of broadly comparable apples-to-apples case studies

Ongoing Research Needs

Topic Area

1. Occurrence
2. Analytical methods
3. Treatment efficacy
4. Particle shedding
5. Toxicology

Foundational

Ongoing Research Needs

Topic Area

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Needs are not just topical

Ongoing Research Needs

Topic Area

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Execution

- ✓ Connection
- ✓ Conversation
- ✓ Coordination
- ✓ Collaboration

Thanks for your attention!

Brent Alspach, PE, BCEE
Director of Applied Research

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