Image Source: David Liitschwager/National Geographic

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MICROPLASTICS

The Tiny Particle That Could Have a Big Impact

Tina Liu

SAME Industry Day
Kansas City

October 19, 2021

Micro Minute

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How long does it take a plastic bottle to decompose?

A. 4.5 years
B. 45 years
C. 450 years
D. 4,500 years

Data Source: WWF Australia

Micro Minute

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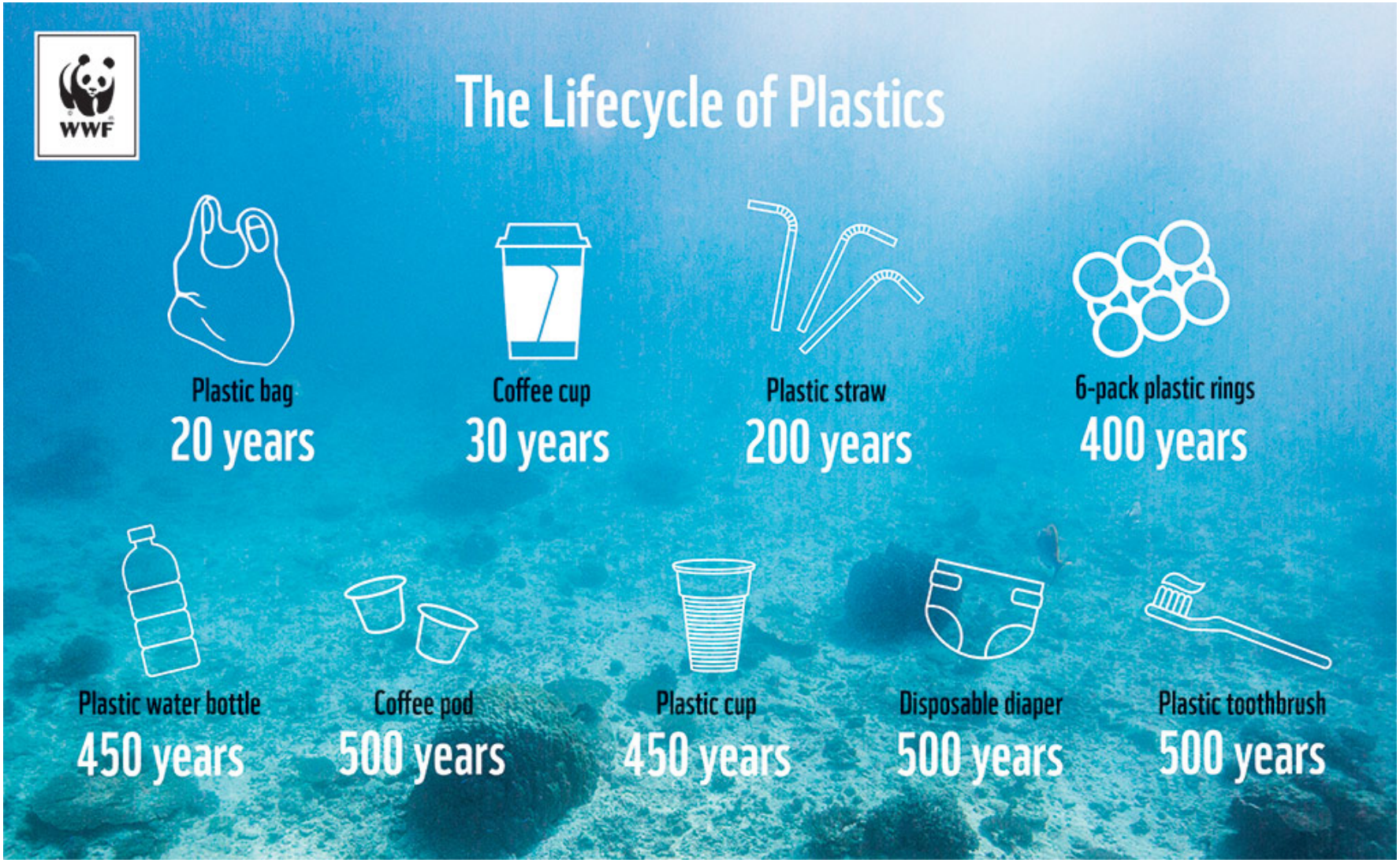

Data Source: WWF Australia

Agenda

- Microplastics 101
- State of Science
- Regulatory Drivers
- Comparison to PFAS
- Data Gaps

Image Source: Quench Water

History of Plastics/Microplastics

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- Early 20th century – first synthetic plastic produced
- 1950s – mass production of plastics
- 1960s/1970s – observations of small pieces of plastic debris in surface water, stomachs of birds and fish described in scientific papers
- 1990s – monitoring of plastic debris begins
- 2004 – term “microplastics” introduced
- 2010s – ongoing scientific research and increased attention of the impact of plastics on the environment
- 2018-2021 – 800+ peer-reviewed articles on microplastics have been published

What are Microplastics?

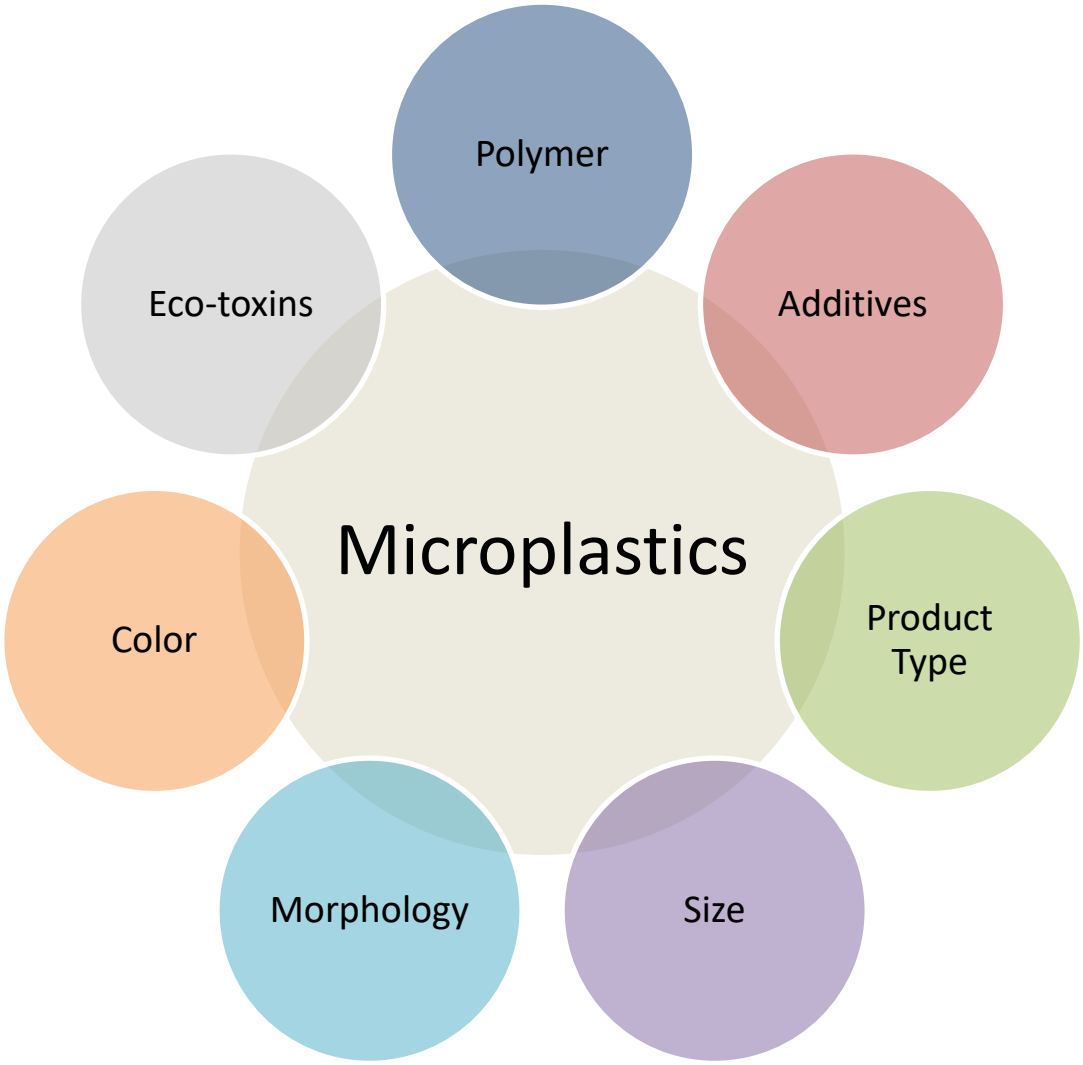
films
fibers
spheres
fragments
particles

nanoplastics
microplastics

Small pieces of plastic that are less than 5 mm

PET
LDPE
HDPE
PS
PVC
PP

A Diverse Contaminant Suite



Data Source: Rochman et al, 2019

Plastic Type & Purpose

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Polymer

Product Type

1 PET	2 HDPE	3 PVC	4 LDPE	5 PP	6 PS	7 OTHER
POLYETHYLENE TEREPHTHALATE	HIGH-DENSITY POLYETHYLENE	POLYVINYL CHLORIDE	LOW-DENSITY POLYETHYLENE	POLYPROPYLENE	POLYSTYRENE	OTHER
WATER BOTTLES; JARS; CAPS	SHAMPOO BOTTLES; GROCEY BAGS	CLEANING PRODUCTS; SHEETINGS	BREAD BAGS; PLASTIC FILMS	YOGURT CUPS; STRAWS; HANGERS	TAKE-AWAY AND HARD PACKAGING; TOYS	BABY BOTTLES; NYLON; CDS
						

Image Source: Plastics For Change

Micro Minute

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What percent of plastics are recycled in the U.S.?

A. 9%

B. 19%

C. 29%

D. 39%

Data Source: EPA 2018

Micro Minute

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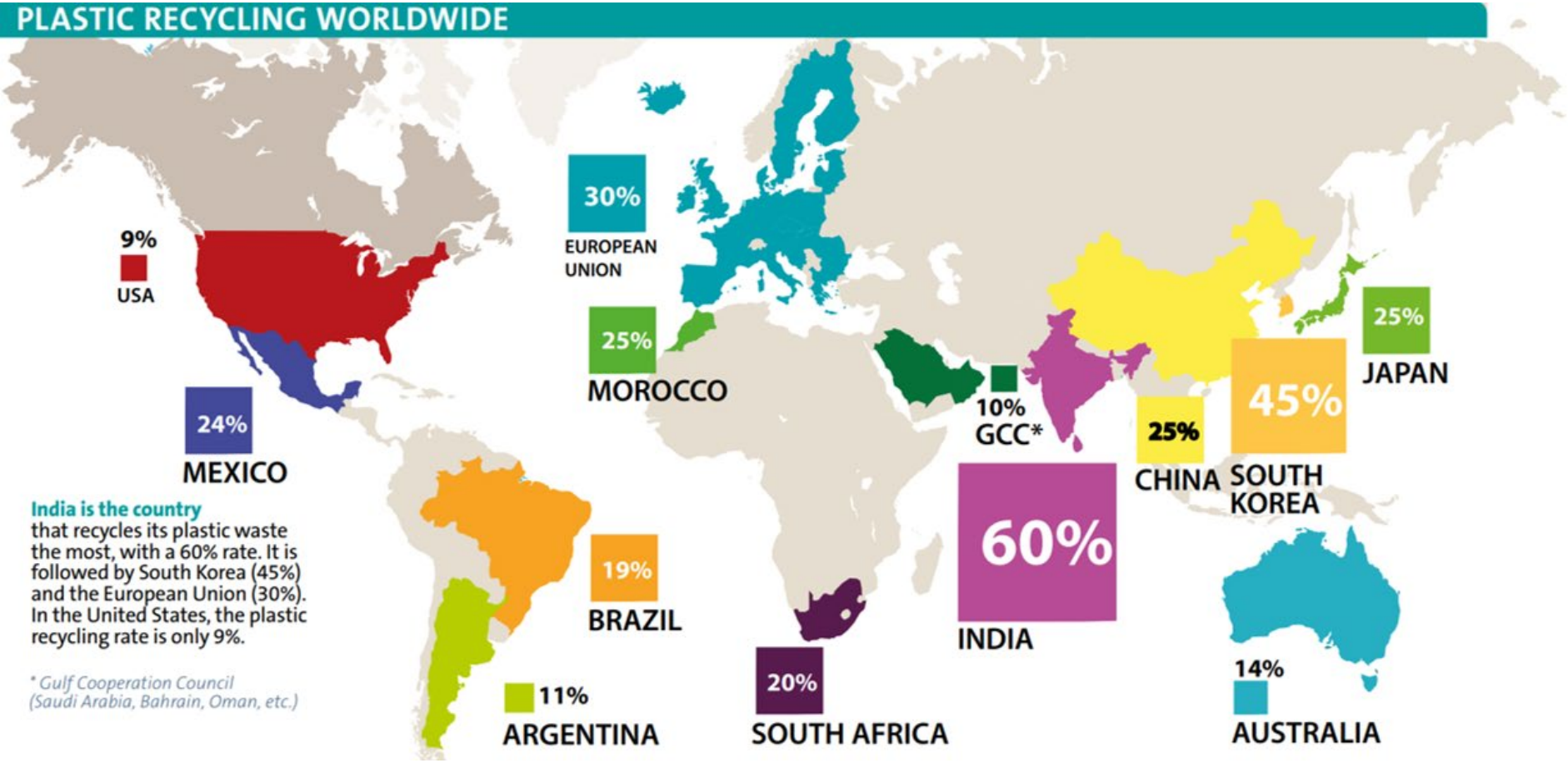

Image Source: Veolia

Physical Characteristics

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- Morphology
- Size
- Color

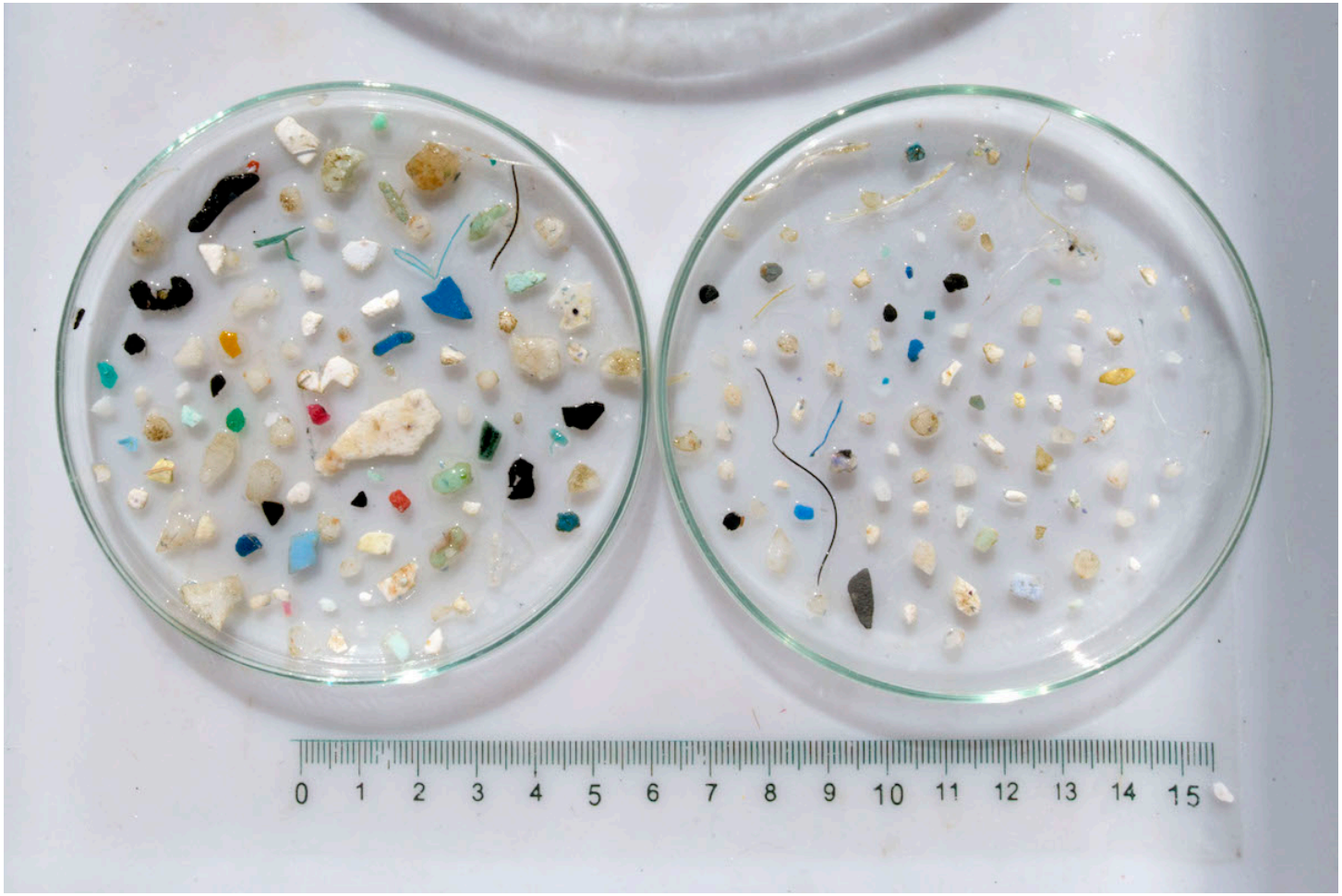

Image Source: Samuel Bollendorff/Fondation Tara Océan

Macroplastics, Microplastics, Nanoplastics

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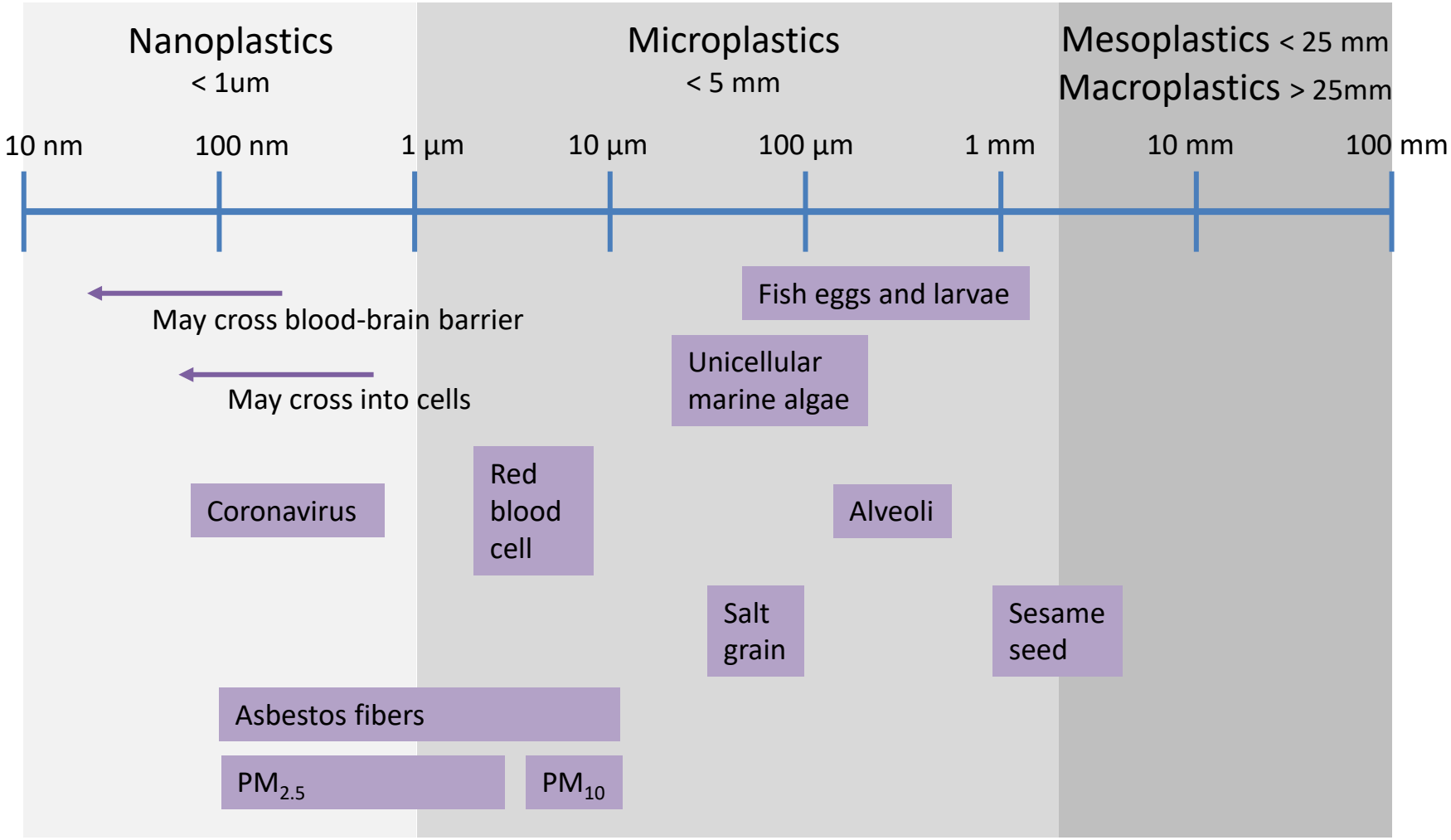
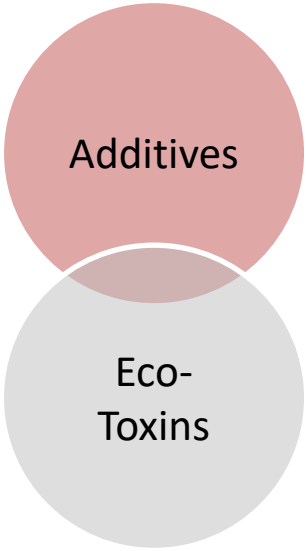


Adapted from: Lim 2021

Additional Characteristics



Colorants

PCBs

Stabilizers

PBDEs

PAHs

Reinforcements

DDT

Fillers

Flame retardants

Heavy metals

Plasticizers

Data Source: Rochman et al, 2019

Microplastics in Drinking Water

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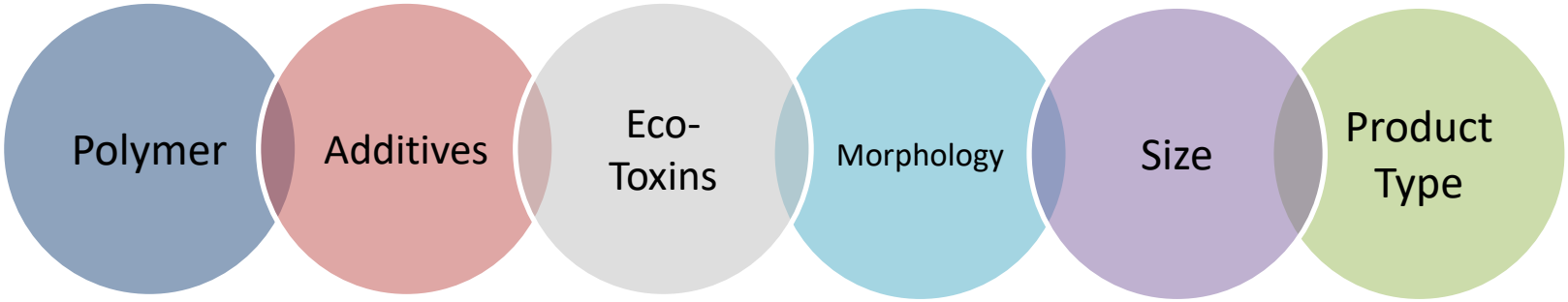
As defined by California State Water Resource Control Board:

> *"…**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 nm and less than 5,000 µm**. **Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded**."*



Pathways to the Environment

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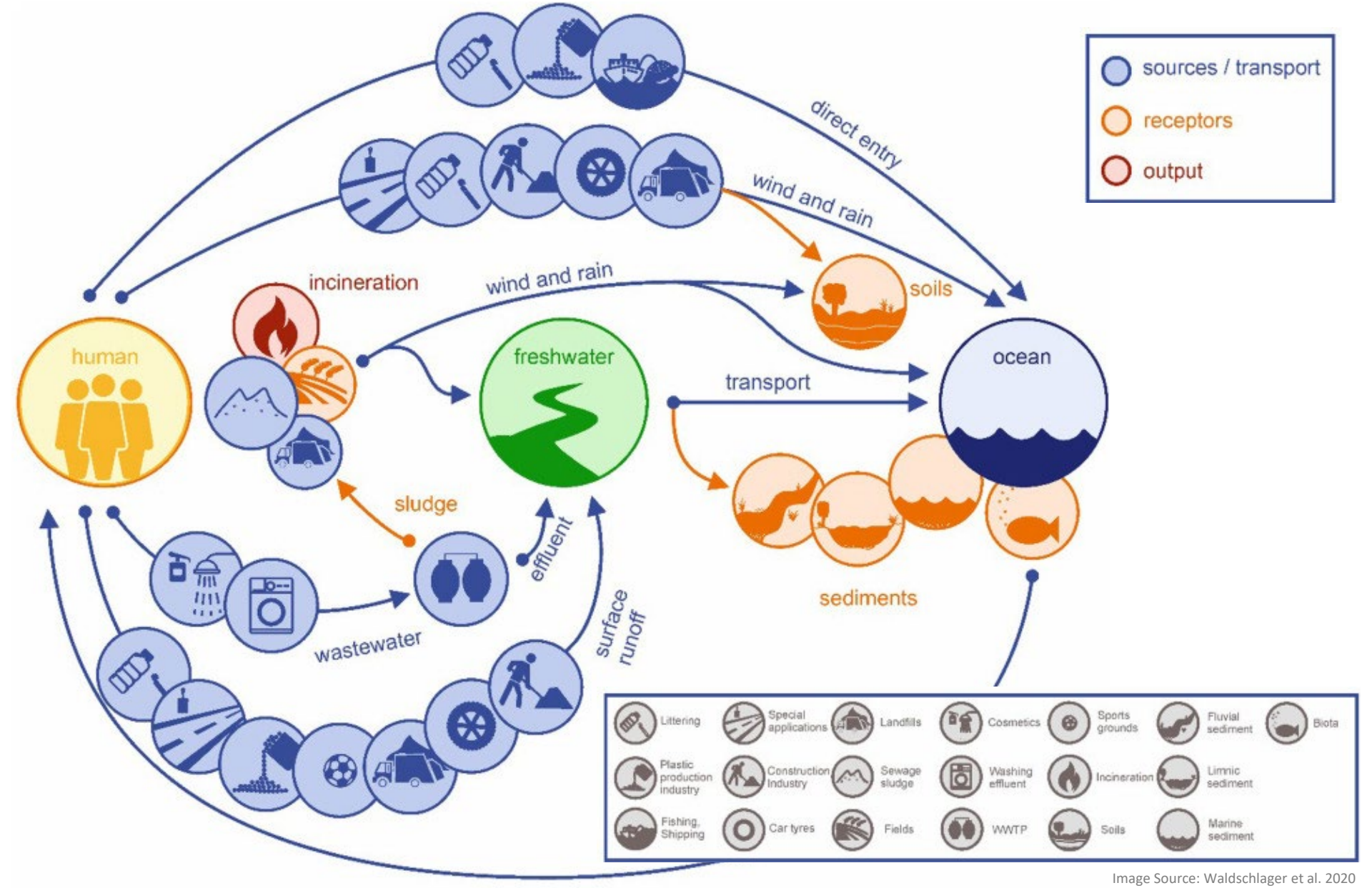

Image Source: Waldschlager et al. 2020

Sources

Primary Microplastics

Small pieces of plastics that are purposely created by manufacturers to be smaller than 5 mm and enter the environment as such

Secondary Microplastics

Plastic fragments derived from the breakdown of larger plastic debris due natural degradation processes

Information Source: Cole et al. 2011

Entry Points for Microplastics

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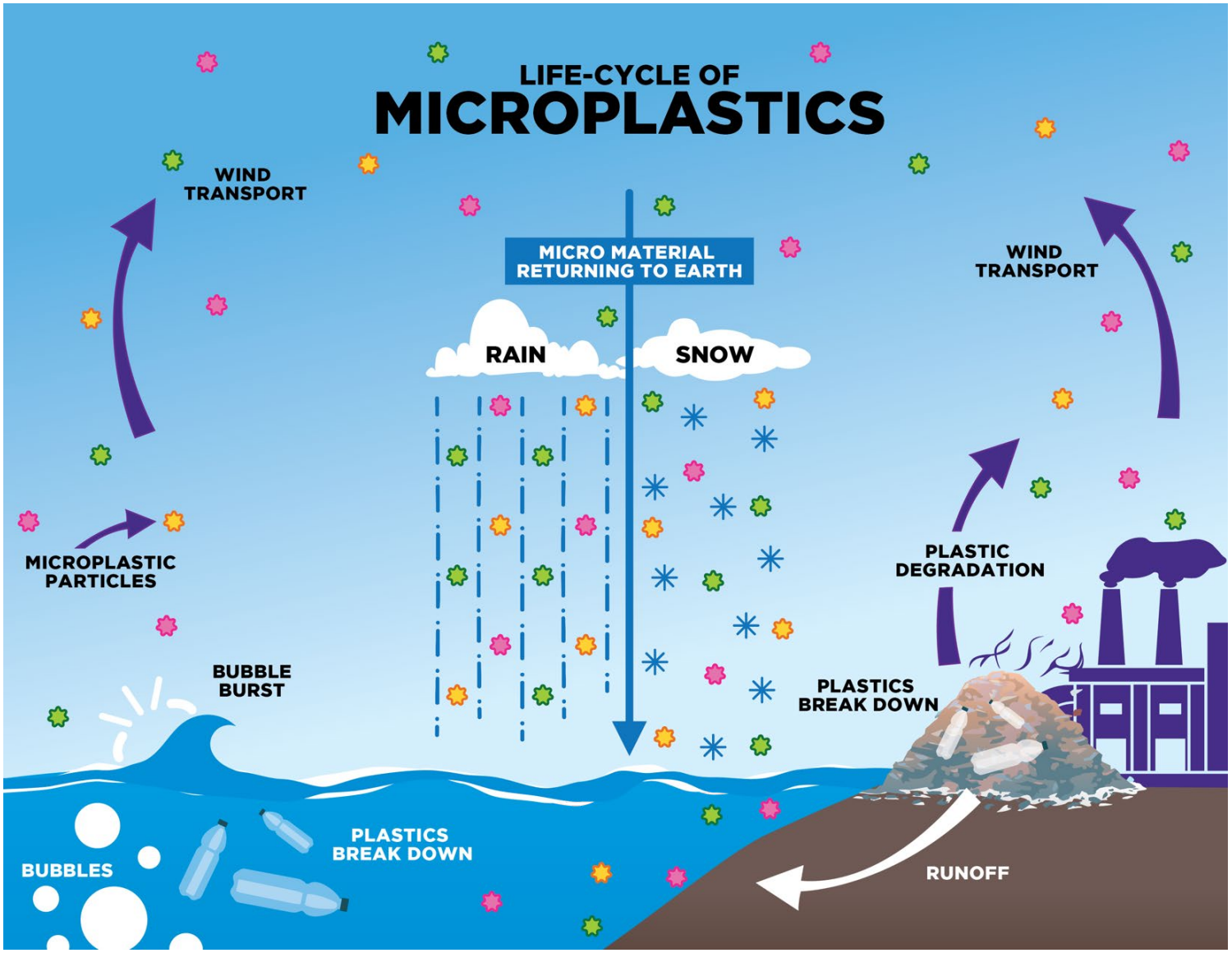

Atmospheric Fallout or Precipitation

Direct Release

Stormwater

Landfill Leachate

Wastewater & Biosolids

Image Source: Andrea Steffen

Wastewater & Biosolids

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- Preliminary studies indicate that WWTPs are efficient at removing microplastics; however:
  - For many WWTPs, during heavy rainfall, a CSO allows influent to bypass treatment and be discharged
  - Only 20% of the world's wastewater is treated before discharge
- Fibers are the most common microplastic debris found in wastewater effluent
- WWTPs concentrate microplastics in the biosolids/sludge
  - Application onto agricultural fields as fertilizer
  - Landfill leachate

Information Source: Waldschlager et al. 2020

Micro Minute

How many fibers can be released in an average sized load of laundry?

A. 7,000
B. 70,000
C. 700,000
D. 7,000,000

Data Source: Napper et al. 2016

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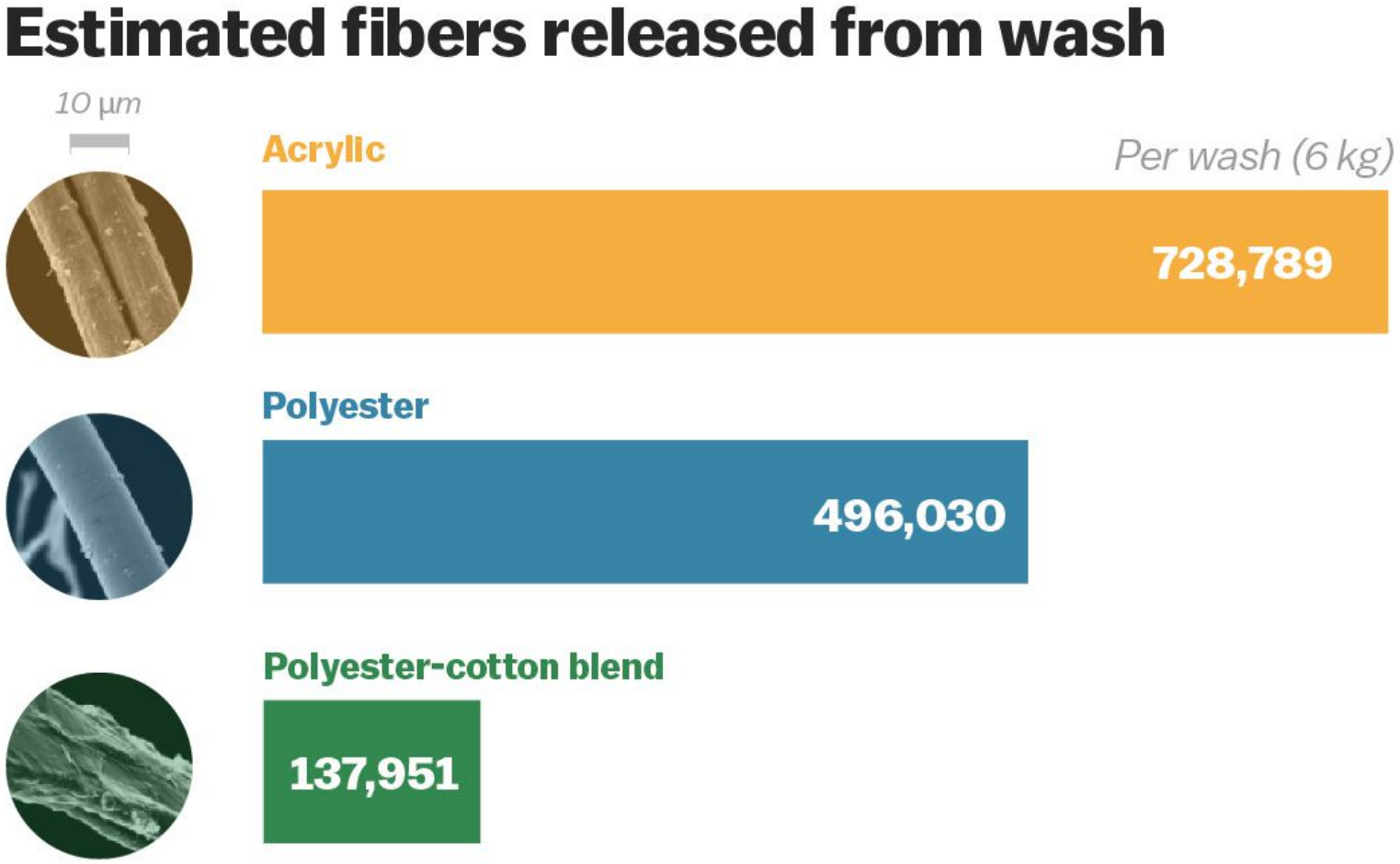

Microplastics in Freshwater Environments

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- Particle properties
  - Lower density microplastics may float towards oceans or are retained by physical barriers
  - Higher density microplastics may sink into riverbed
  - Different shapes behave differently
- Flow conditions can resuspend/deposit microplastics
- Microplastics settle in areas where flow is reduced

Information Source: Waldschlager et al. 2020

Microplastics in Marine Environment

- Ocean currents
  - Accumulation in the five ocean gyres
- Wind/waves
  - Deposit on beaches or transported back to the ocean

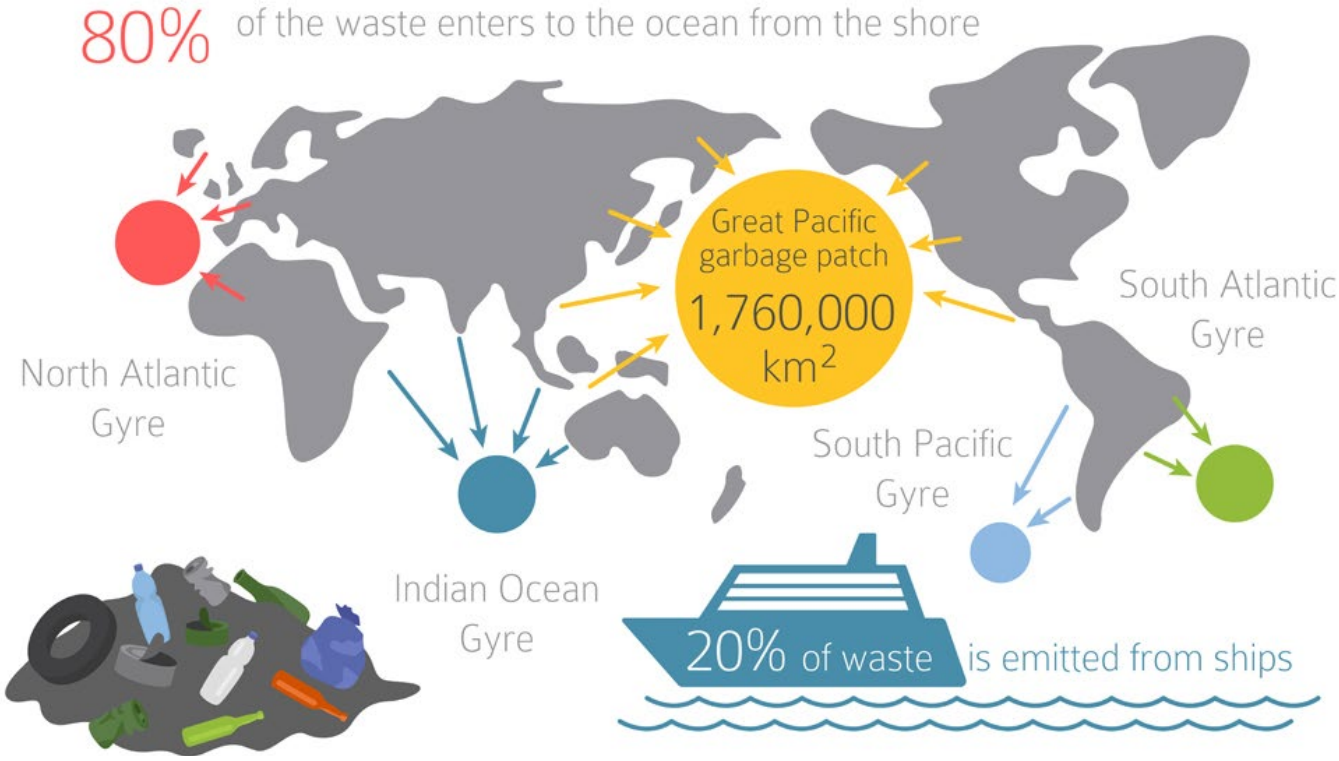

Image Source: Science ABC
Information Source: Waldschlager et al. 2020

Microplastics in Soil

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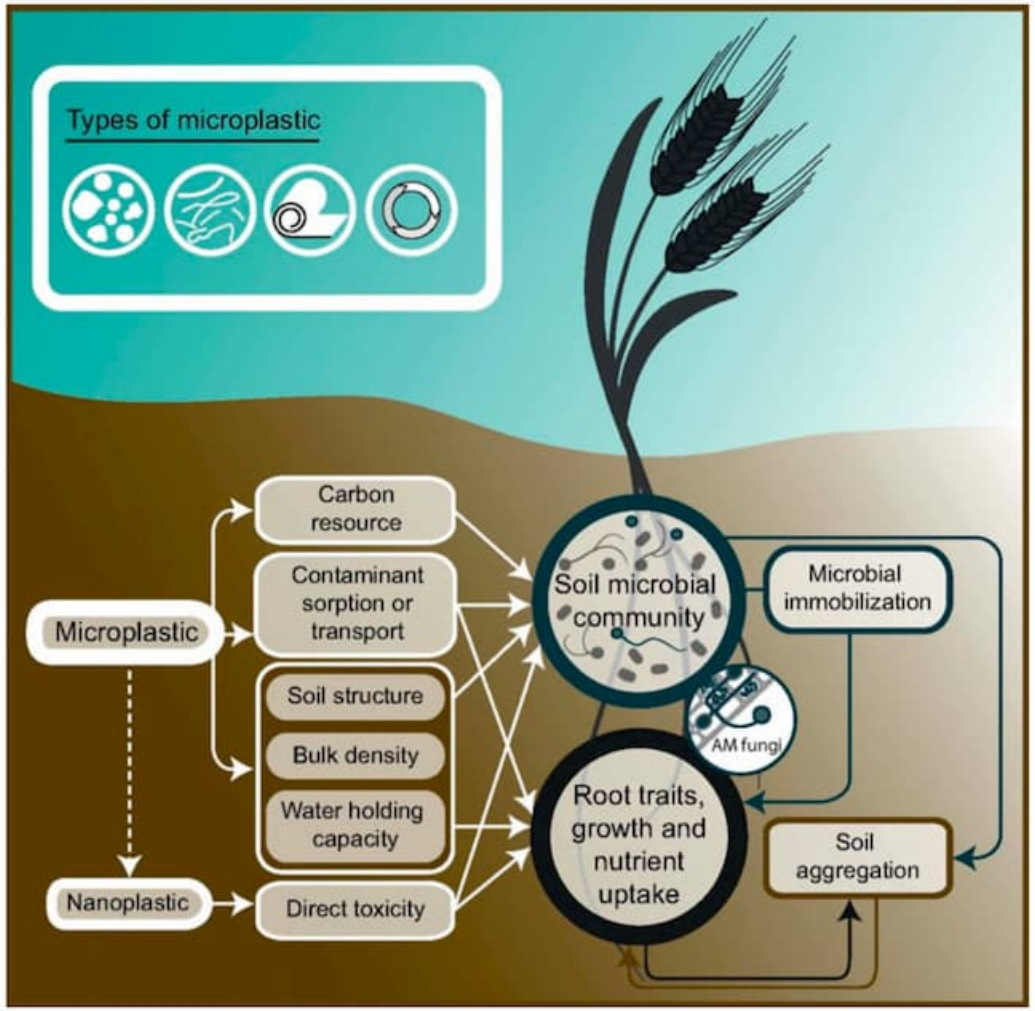
- Limited studies
- Particle properties
  - Size/shape
  - Hydrophobia
- Soil aggregation
  - Ploughing of fields
  - Drainage flows
  - Transport by earthworms and other biota



Information Source: Waldschlager et al. 2020
Image Source: Rillig et al. 2019

Microplastics in Groundwater and Air

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- Limited studies
- Recent studies have documented microplastics in groundwater aquifer potentially due to infiltration through soils
  - Long residence time of groundwater and slow degradation of plastics result in microplastics build-up
- Fibers are the most common microplastic detected in groundwater and air

Information Source: Waldschlager et al. 2020

Ecological Health

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Microplastic particles per liter:

10^4
- Fish: embryo toxicity
- Invertebrates: embryo toxicity

10^5
- Fish: slowed growth
- Invertebrates: slowed growth, decreased molting

10^6
- Fish: inhibited reproduction
- Invertebrates: inhibited reproduction, larval death

10^7
- Fish: halted growth, inflammation
- Invertebrates: halted growth, inflammation

10^8
- Fish: death
- Invertebrates: adult death

Data Source: Burns et al. 2018

Image Sources: Clip Art Best, Baldor Food, Epicurious, Supreme Lobster, TGR ED

Human Health

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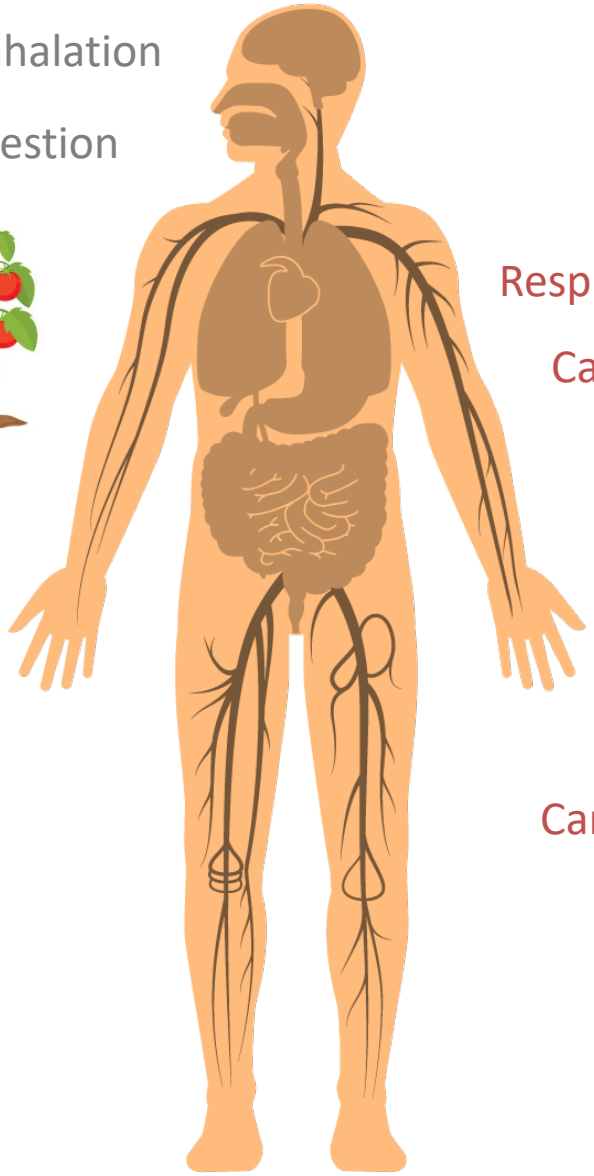
Inhalation

Ingestion

Dermal contact



Respiratory problems

Cardiovascular disease

Digestive problems

Reproductive effects

Skin irritation

Cancer

Data Source: Campanale et al. 2020

Image Sources: Washington Post; iStock

Micro Minute

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Approximately, how many microplastic particles does an adult consume per day?

A. 8
B. 80
C. 800
D. 8,000

Data Source: Nor et al. 2021

Micro Minutes

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Image Sources: A Spicy Perspective, BBC Good Food, The Spruce, Daily Alternative, iStock, Getty Images, Medical News Today

Sampling for Microplastics

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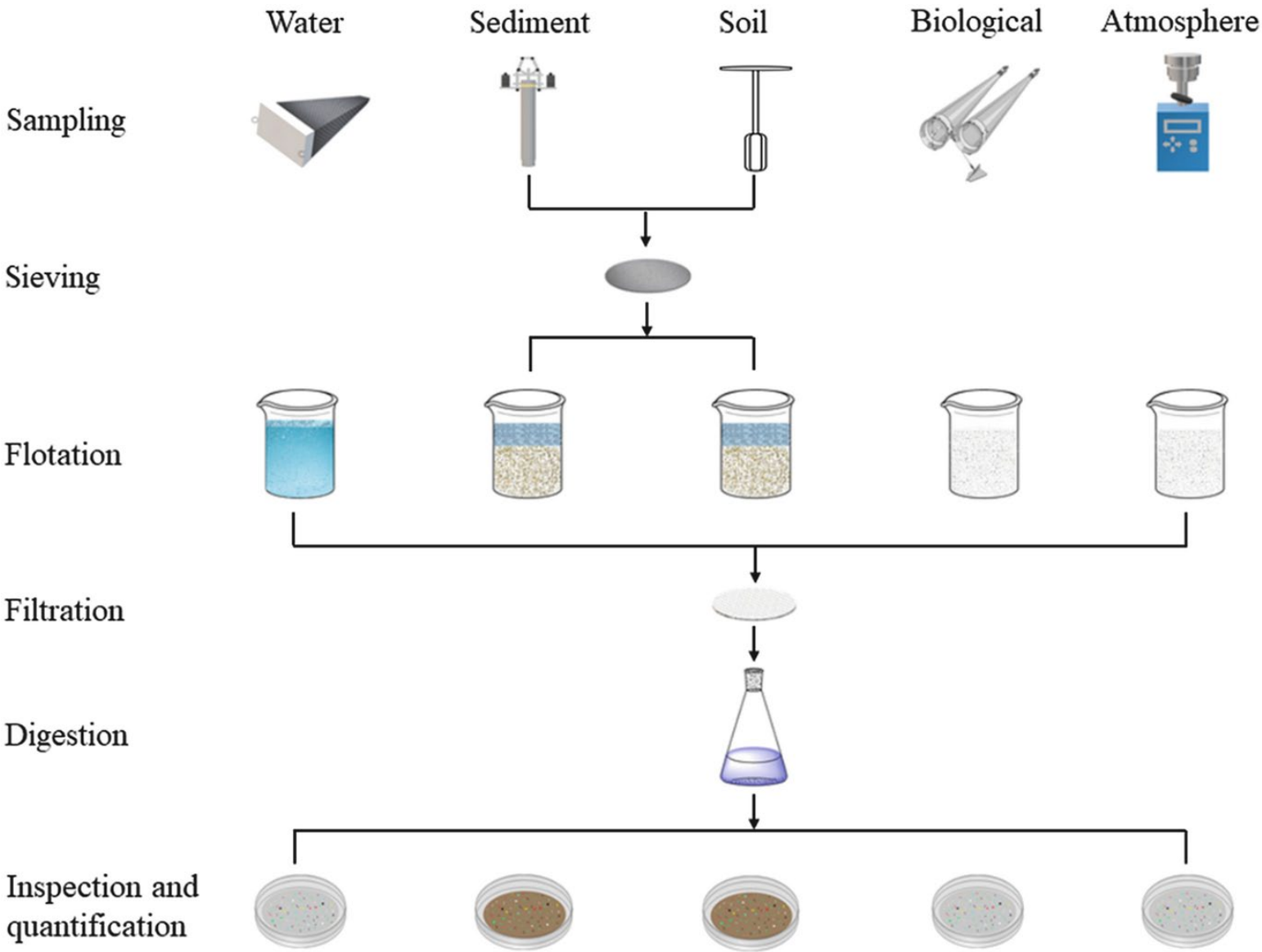

Image Source: Liu et al. 2020

Laboratory Analysis & Quantification

- Spectroscopy – Particle
  - Fourier transform infrared (FTIR) spectroscopy
  - Raman spectroscopy
  - Laser Direct Infrared (LDIR)
- Spectrometry – Chemical
  - Pyrolysis-gas chromatography mass spectrometry (GC/MS)
  - X-ray fluorescence spectrometry

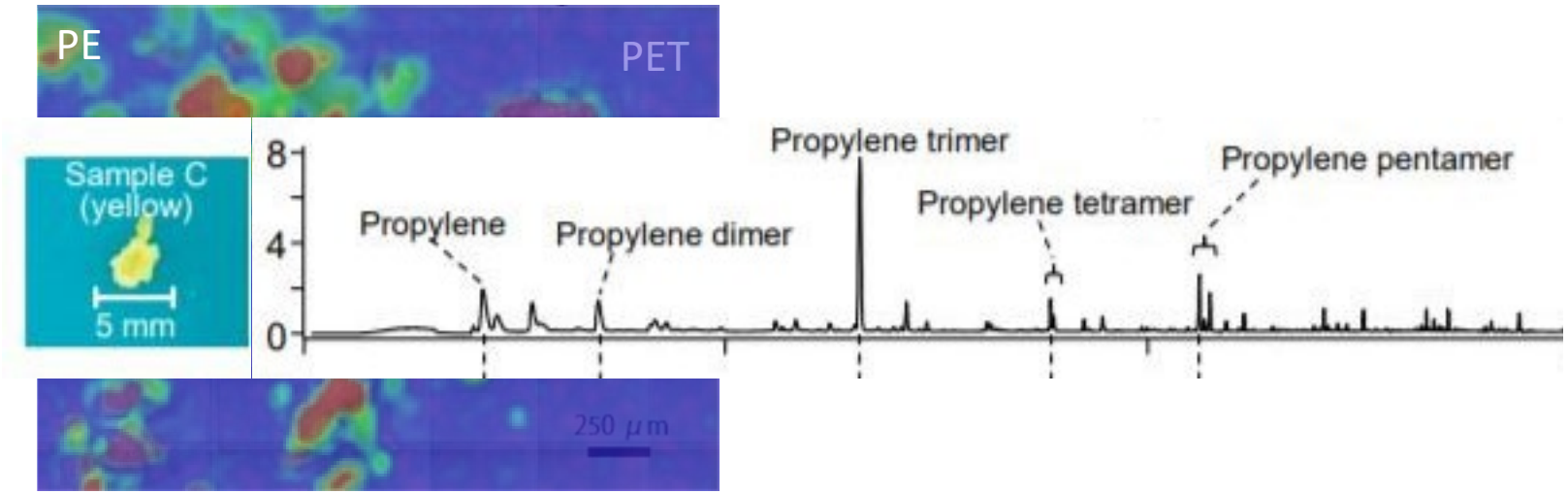

Image Sources: Shimadzu, Quantum Analytics

Available Tools & Technology

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- Databases
  - National Centers for Environmental Information (NCEI)
  - Toxicity of Microplastics Explorer (ToMEX)
- Temporal tracking – NASA CYGNSS

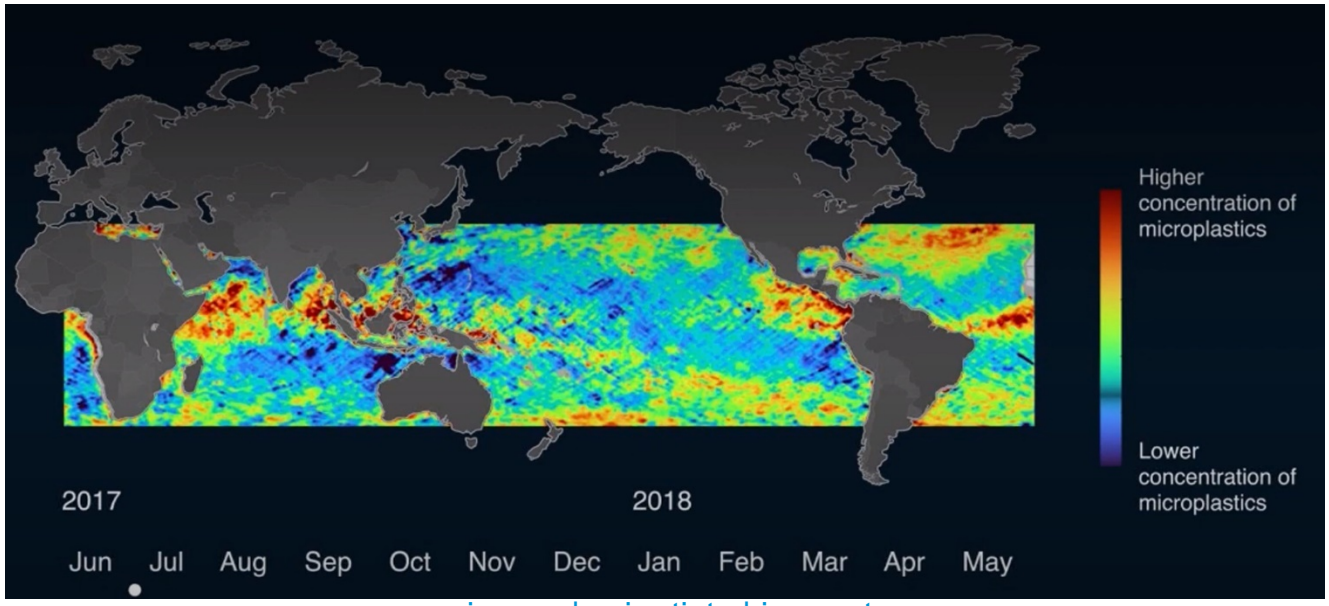

Image Source: University of Michigan Engineering

Possible Treatment/Mitigation

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A 'Bubble Barrier' is trapping plastic waste before it can get into the sea

Maheshpreet Kaur Narula, CNN

Smithsonian MAGAZINE

INNOVATION

This 12-Year-Old Girl Built a Robot That Can Find Microplastics In the Ocean

Massachusetts seventh grader Anna Du has developed an ROV that moves through water and detects microplastics on the seafloor

Microplastic Removal and Degradation by Mussel-Inspired Adhesive Magnetic/Enzymatic Microrobots

Huaijuan Zhou, Carmen C. Mayorga-Martinez, Martin Pumera

Engineering a microbial 'trap and release' mechanism for microplastics removal

Sylvia Yang Liu [a], Matthew Ming-Lok Leung [a], James Kar-Hei Fang [a, b], Song Lin Chua [a, c]

Micro Minute

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What is the estimated amount of microplastics on the ocean floor?

A. 4 million metric tons

B. 14 million metric tons or 15.4 million tons

C. 40 million metric tons

D. 140 million metric tons

Data Source: Barrett et al. 2020

Micro Minute

Geosyntec consultants

How heavy is 15.4 million tons?

70 Willis Towers (222,500 tons)

360 Gateway Arches (43,300 tons)

700,000 Golden Drillers (22 tons)

5.1 million Nelson-Atkins Museum Shuttlecocks (3 tons)

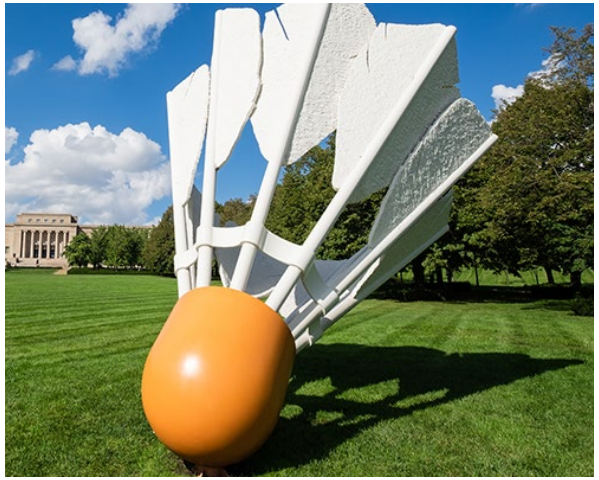

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Image Source: Chicago Tribune, NPS, Visit KC, Travel OK
Data Source: The Skydeck, Gateway Arch, Weird Missouri, Travel OK

Federal Regulatory Update

- Microbead-Free Waters Act (2015)
  - Prohibits addition of plastic microbeads in certain personal care products
- Break Free from Plastic Pollution Act (2021)
  - Proposing amendments to the Solid Waste Disposal Act including reducing the production/use of certain single-use plastic products
  - Proposing a microplastics pilot program
- Plastic Pellet Free Waters Act (2021)
  - Proposing that the EPA set limitations to pre-production pellet pollution

State Regulatory Update

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- California Safe Drinking Water Act: Microplastics (2018)
  - Adopt first definition for microplastics in drinking water in 2020
  - Adopt standardized methods for testing microplastics in drinking water in 2021
- California Ocean Protection Council: Statewide Microplastics Strategy (2018)
  - Develop, adopt, and implement strategy to understand risk of microplastics in marine environments
- Microbead, plastic resin pellet, and single-use plastic regulations in numerous states/territories

International Regulatory Update

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- 2018 – Similar microbead bans in Canada, EU (Belgium, France, Ireland, Italy, Sweden), and UK
- 2018 – 127 countries have adopted some form of legislation to regulate plastic bags
- 2019 – Basel Convention is modified to include plastic waste
- 2019 – At the UN Environmental Assembly in Nairobi, 170 countries pledged to reduce use of plastics by 2030
- 2021 – Canadian EPA adds plastic manufactured items added to the List of Toxic Substances

Micro Minute

Geosyntec consultants

What is the estimated number of face masks used globally per month during the COVID-19 pandemic?

A. 12.9 thousand masks
B. 129 thousand masks
C. 129 million masks
D. 129 billion masks

Data Source: Prata et al. 2020

Micro Minute

Geosyntec consultants

COVID-19 & Microplastics

- Increased use of PPE, plastic barriers, etc.
- Increased use of single-use plastic
  - Take-out containers and utensils
  - Shopping bags

Image Source: CNN

Other Drivers

- Litigation
  - 2019 Formosa Plastics case with $50 million settlement for illegal discharge of plastics pellets
- Increased focus on corporate responsibility and sustainable practices
- Public awareness of the environmental impacts of consumer products
- Development and perception of other high profile emerging contaminants such as PFAS and 1,4-dioxane

The Next PFAS?

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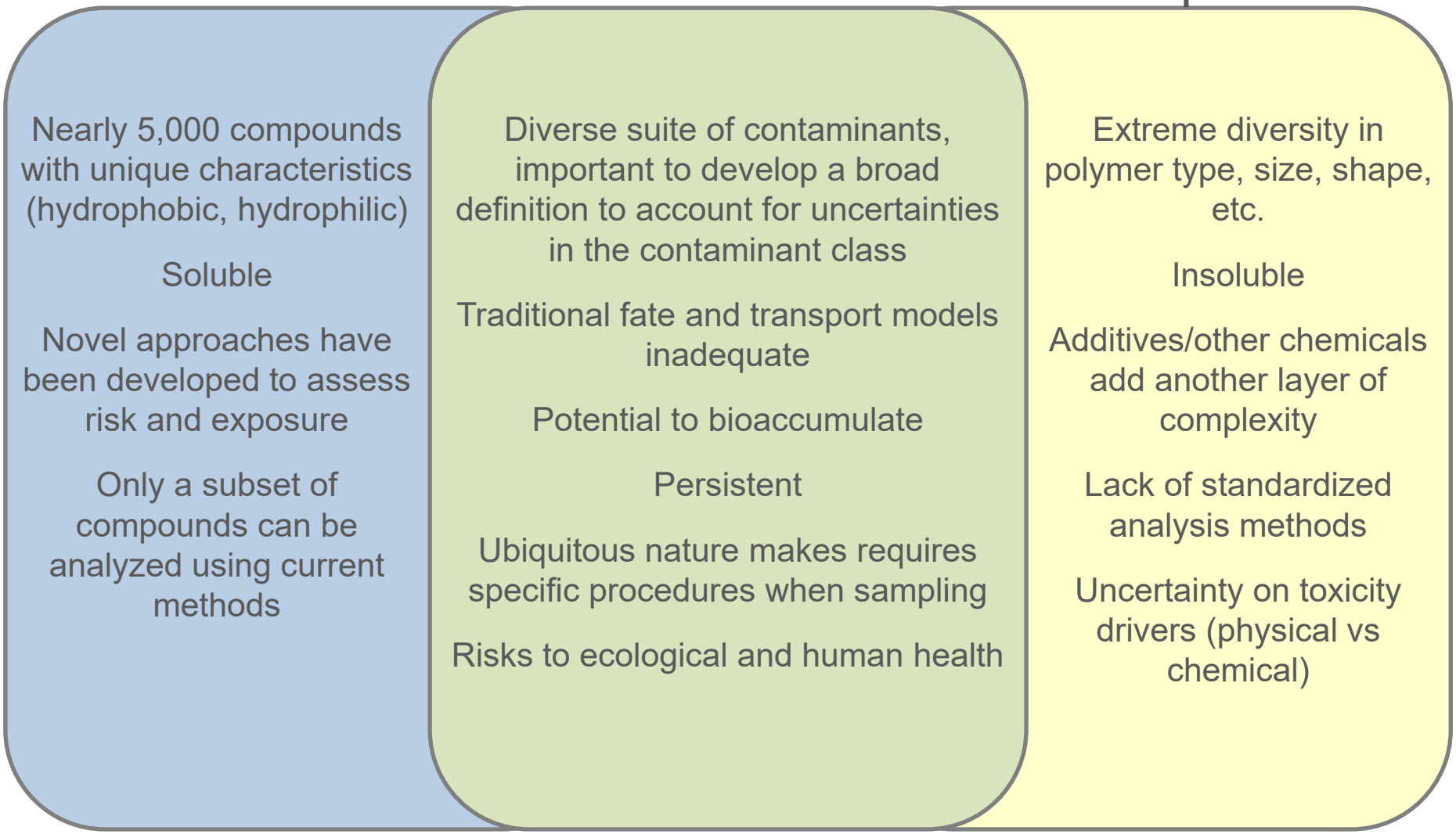

Information Source: Coffin et al. 2021

Data Gaps

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- Fate and transport studies – especially in terrestrial environments
- Toxicity studies – what drives toxicity?
  - Physical: Size, shape
  - Chemical: Additives, polymer
  - Many studies are bias towards PE and PS spheres and fragments
- Standardized methods for sampling, quantifying, and characterization
- Understanding data quality
- Risk assessment framework

Questions?

Geosyntec consultants

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"I'm part human, part fish, and about ten per cent microplastics."

Image Source: New Yorker/Matilda Borgstrom