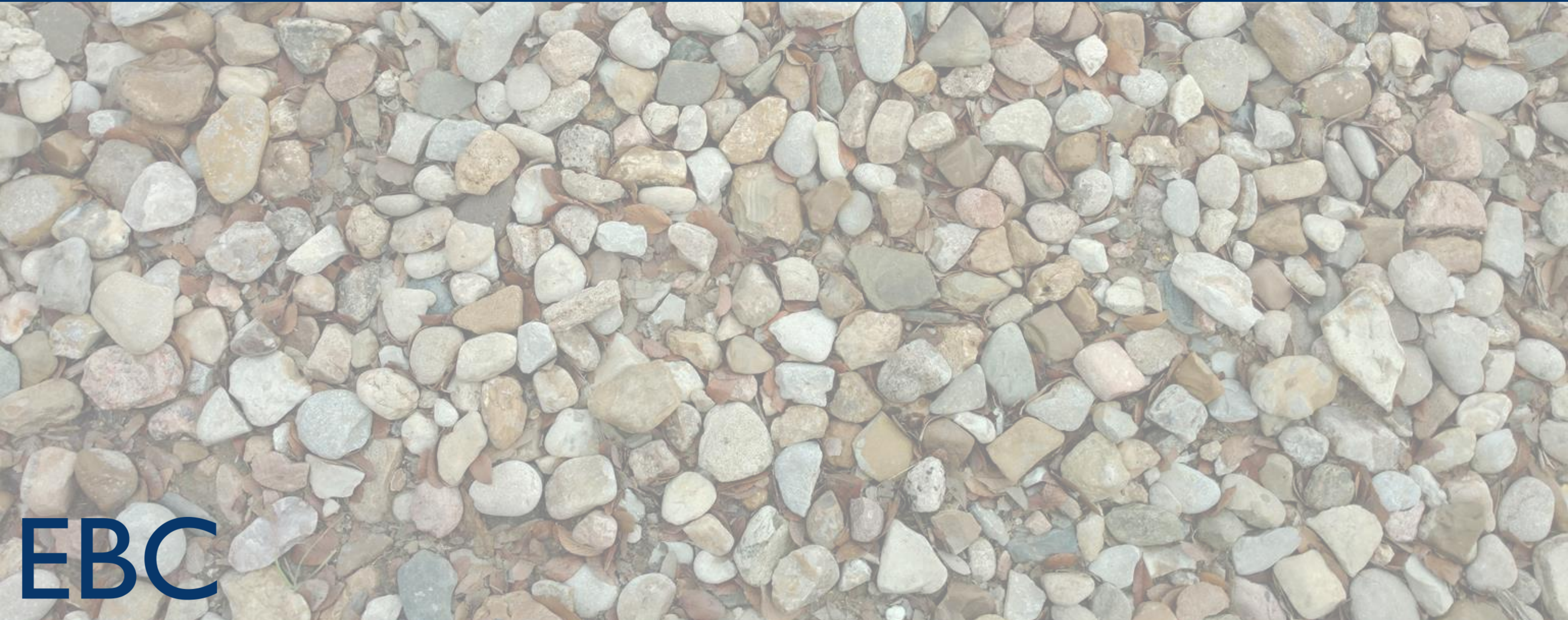
EBC Emerging Contaminants Webinar

Beyond PFAS – What Other Emerging Contaminants Should We Be Concerned With?



Welcome

Steven LaRosa

Member, Leadership Team

Emerging Contaminants Working Group

EBC TSCA and Emerging Contaminants Committee

Senior Project Manager, Weston & Sampson

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Introduction

Jaana Pietari

Program Co-Chair and Moderator

Senior Managing Consultant
Ramboll

Understanding Microplastics

Alia Enright

Project Engineer

TRC

Understanding Microplastics

- Not just microbeads
- Innumerable sources
- Exponential production trends

Environmental Impacts

Studies find microplastics in…

- Freshwater lakes, rivers, streams
- Ocean water (surface to deep; coasts to remote islands)
- Groundwater (karst)
- Arctic snow/ice
- Rainfall
- Wastewater effluent
- Stormwater
- Sediment
- Outdoor air
- Household air

- Human blood
- Human feces and urine
- Human placenta
- Earthworms
- Fish/shellfish
- Bottled Water
- Tap Water

Outline

- Definition
- Transport
- Sampling
- Risk
- Guidance & Regulations
- Management & Treatment

Source Type

- Primary
  - Cosmetics/cleaning products
  - Pellets for manufacturing

- Secondary
  - Wear and tear
  - Mismanaged wastes

Polymers

- Variety of polymers
  - Polyethyelene
  - Polyethylene terephthalate
  - Polyvinyl chloride
  - Polystyrene
  - Polypropylene
  - Others (rubber, silicone, cellulose acetate, etc.)
- Additives
  - BPA
  - Phthalates
  - Alkylphenols

Size

Macro

Micro

Nano

<5 mm

<100 nm

Shape

Bead

Fiber

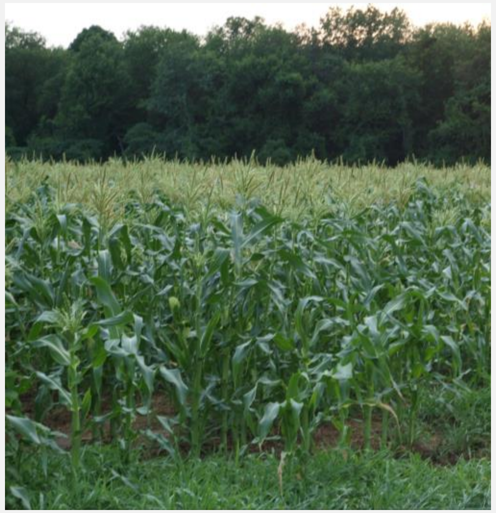
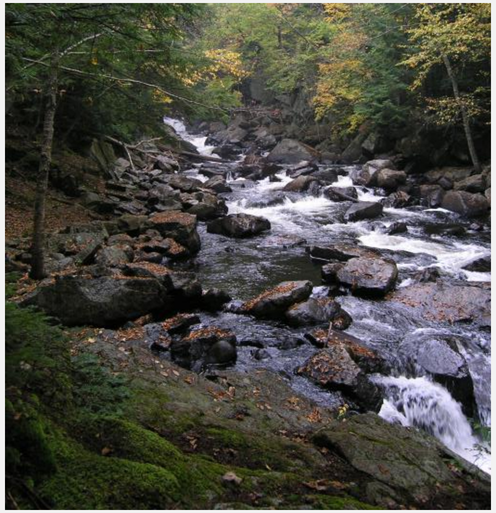
Foam

Film

Fragment

Transport

- Wind
- Precipitation
- Surface Flow
- Ocean Currents
- Settling in Sediment
- Wastewater/Stormwater
- Sludge Application (agriculture)
- Mismanaged Wastes

Sampling

TRC

- Water
  - Includes surface water, groundwater, stormwater, wastewater, drinking water
  - Typical methods:
    - Grab sample
    - Neuston/bongo net
    - Extraction pump with sieves

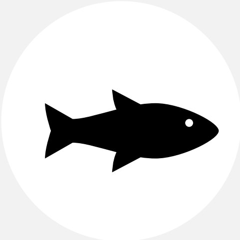
- Solids
  - Includes sediment, sand, soil, biosolids
  - Typical methods:
    - Corer/shovel
    - Grab sample

- Air
  - Includes outdoor and indoor
  - Typical methods:
    - Passive atmospheric dust sampling

- Biota
  - Includes fish, invertebrates, vertebrates, plants, biofilms, humans
  - Typical methods:
    - Large variety in methods depending on investigation intent

Ecological Risk Studies

- **Fish** (*Daphnia magna, Oryzias melastigma)*
  - Decreased growth/size
  - Oxidative stress
  - Accumulation in gill, intestine, liver
  - Affect reproduction



- **Shellfish** (*Mytilus edulis* L.)
  - Inflammatory response
  - Histological changes
- **Plankton** (*Daphnia pulex*)
  - Disrupt metabolism
  - Immune defense

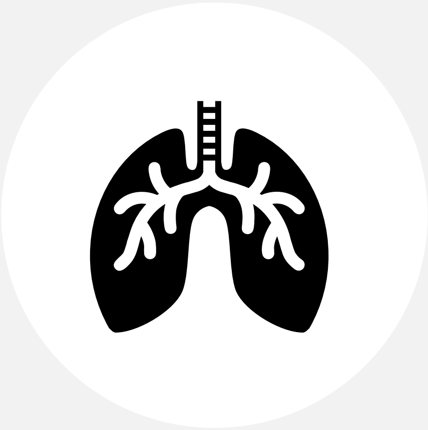
- **Coral** (*Cladocopium goreaui)*
  - Reduced population/cell size
  - Stress response

- **Earth worms** (*Aporrectodea rosea*)
  - Weight loss

- **Rice** (*Oryza sativa* L.)
  - Oxidative stress
  - Altered root growth
- **Terrestrial plants** (*Arabidopsis thaliana*)
  - Reduced biomass/height

Human Health Studies

- Main exposure routes
  - Ingestion
  - Inhalation
- 74,000 particles/year



General Risks

- Stress
  - Oxidative stress
  - Inflammation
  - Immune response
- Lung scarring
- Digestive disease
- Tumor promotion

Ecological & Human Risk

Co-Contaminants

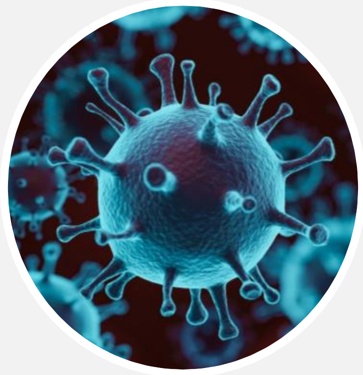
- Plastic additives
  - BPA
  - Phthalates
  - Alkylphenols
- Biological
  - Invasive species
  - Harmful algal blooms
  - Pathogens
- Sorbed Toxic Substances
  - PCBs
  - PAHs
  - Metals
  - Pesticides
  - PFAS

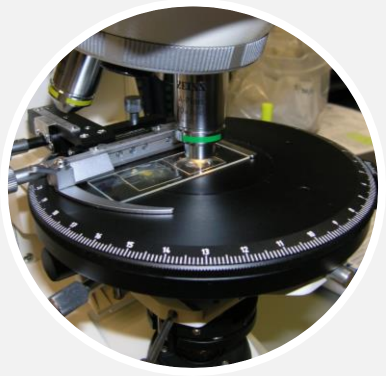
Large Particles

- Perforation of digestive tract

Nanoparticles

- Penetrate lipid membranes
- Cross blood-brain barrier





Guidance & Regulations

Guidance

- Technical
  - United States Environmental Protection Agency
  - Group of Experts on the Scientific Aspects of Marine Environmental Protection
  - Interstate Technology & Regulatory Council
  - National Oceanic and Atmospheric Administration
- Health
  - World Health Organization
  - National Institute for Occupational Safety and Health
- Business
  - World Wildlife Fund

Regulations

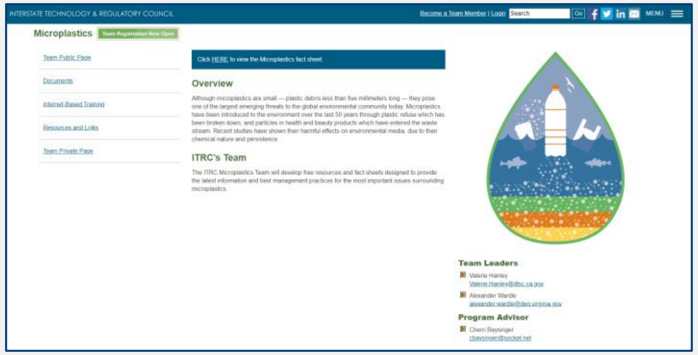
- U.S. Regulations
- European Regulations

Technical Guidance

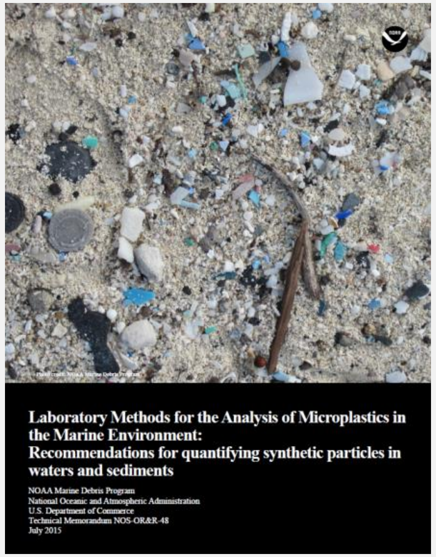
U.S. EPA

GESAMP

ITRC

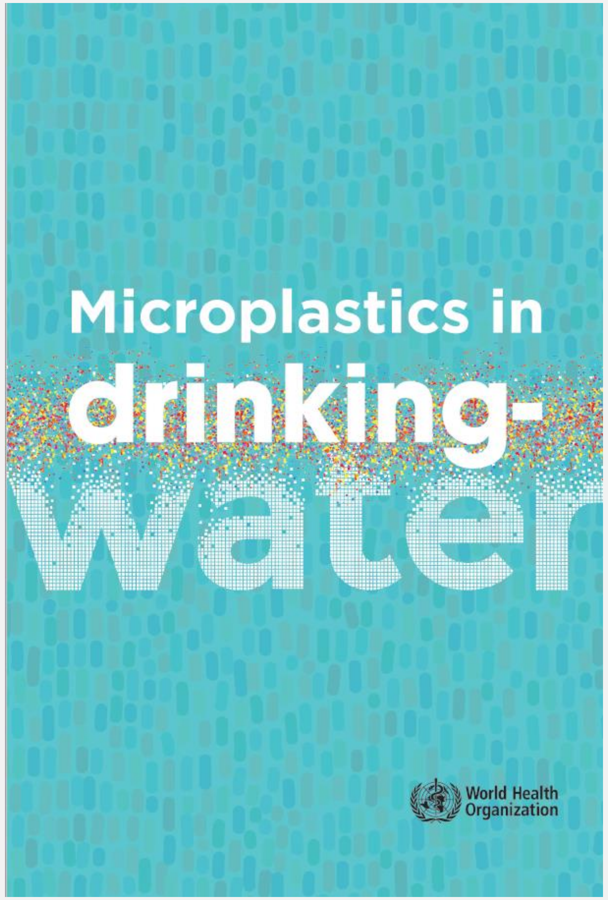


NOAA



Health Guidance

WHO



NIOSH

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

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Are There Nano- and Microplastics in the Workplace?

Posted on February 19, 2020 by Vladimir Murashov, PhD; Charles L. Geraci, Jr., PhD, CIH, FAIHA ; Paul Schulte, PhD; and John Howard, MD

Figure 1. A dense cluster composed of multiple smaller nanoscale particles collected in a workplace using multiple 3D printers with plastic filament (Courtesy of A. Knepp, NIOSH).

The growing problem of plastic pollution in the environment is receiving an increasing amount of attention (see article in Nature). Small particles of plastics are often referred to as microplastics (plastic particles smaller than 5 mm [1]) and nanoplastics (the nanoscale fraction of plastic particles). Nano- and microplastic particles (NMPPs) can be formed through environmental and mechanical degradation (the top-down mechanism). They can be also generated through condensation of molecular species, for example, during heating or burning of plastics (the bottom-up mechanism).

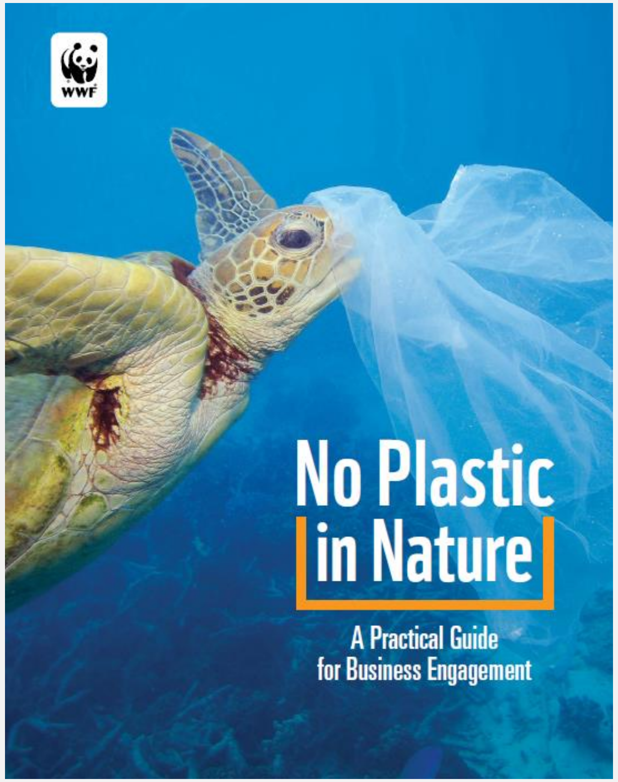
A lot of attention is focused on the presence of NMPP in the food chain. A critical issue from an occupational health perspective is how workers might be exposed to NMPPs. Do they become airborne? If NMPP are airborne, the main route of exposure in the workplace is through inhalation.

In the workplace, potential for inhalation exposure exists to nano- and microplastics generated through both the top-down and bottom-up mechanisms. In the top-down mechanism, NMPPs can be emitted during mechanical and environmental degradation of plastic goods which can lead to potential exposures to nano- and microplastics among workers in the waste management and recycling operations [6]. Degradation of carpets and other synthetic fiber products can produce airborne fibers considered NMPPs [14] with potential for exposure among office/teleworkers and custodial staff. Another example of a workplace process potentially leading to worker exposure is machining of polymer and plastic products generating dusts [7, 9]. In the bottom-up mechanism, NMPPs can be emitted during high energy or high heat processes (such as laser cutting or high-speed drilling), treatment of polymer composites, [2] and during 3D printing from melting or fusing of plastics [3, 4, 5, 8] (Figure 1). Workers in the facilities hosting plastic processers and printers could be exposed to airborne nano- and microplastic particles.

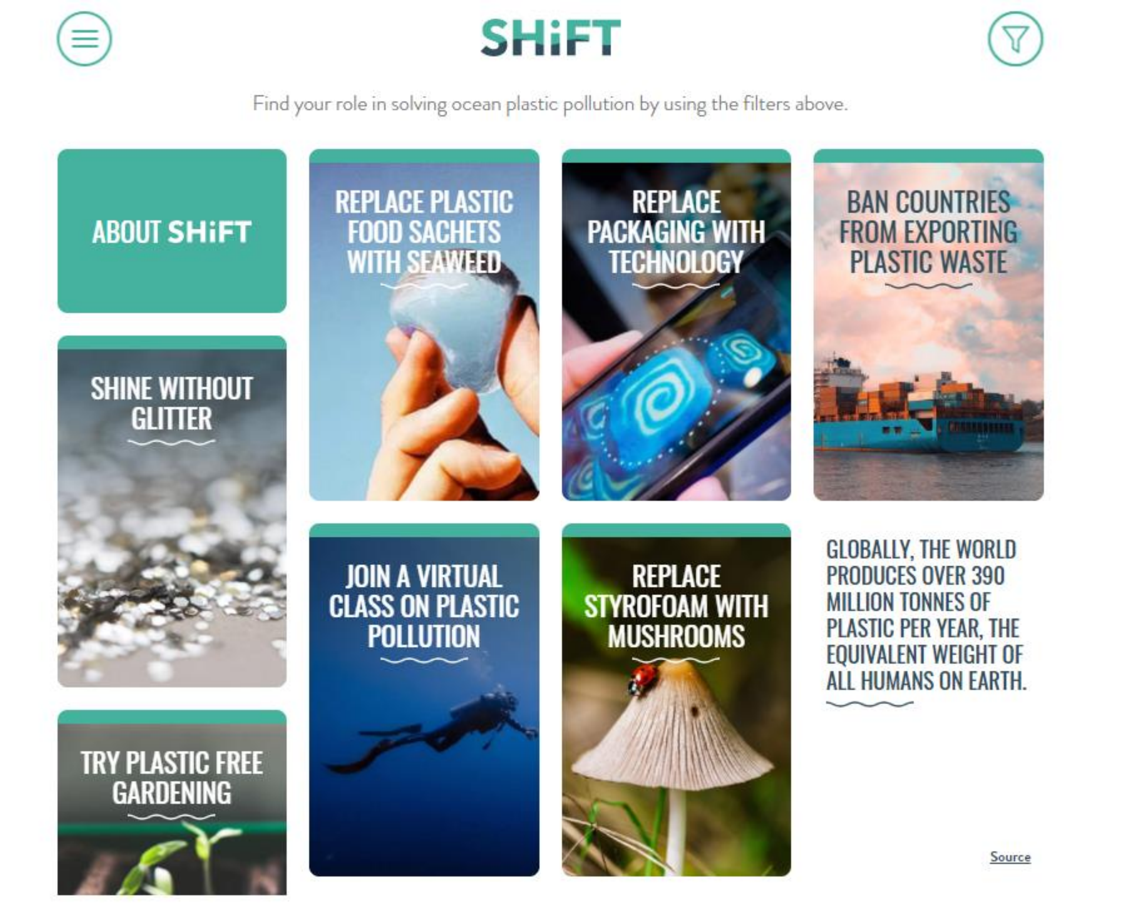
Toxicity of inhaled NMPPs is not well characterized in part due to the complexity of their chemical compositions and size and shape distributions and common association with other chemical hazards producing mixed exposures. For example, inhalation of thermal degradation products of polytetrafluoroethylene can lead to "polymer fume fever" [10] and in extreme cases to fatal acute pulmonary oedema [11]. These adverse health effects were associated with the presence of nanoscale particles

Business Guidance

WWF



SHiFT Platform

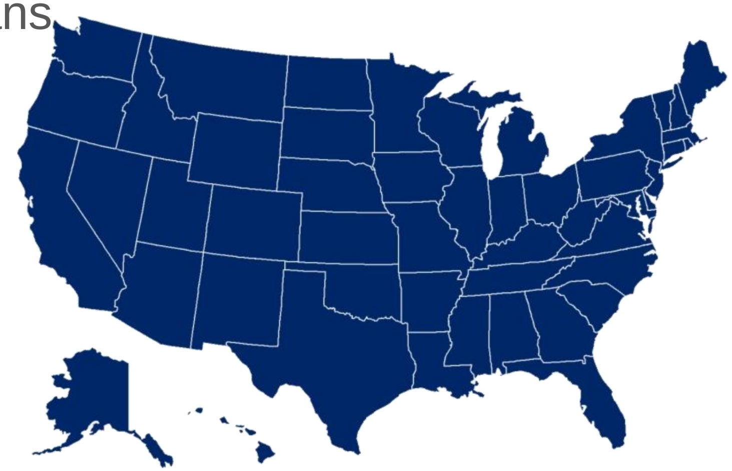


shift.how

Regulations

United States

- 2015 microbead ban
- California
  - Done - Definition
  - In Progress – Standardized sampling/analysis, monitoring, health effects
- Hawaii
  - Single use bans

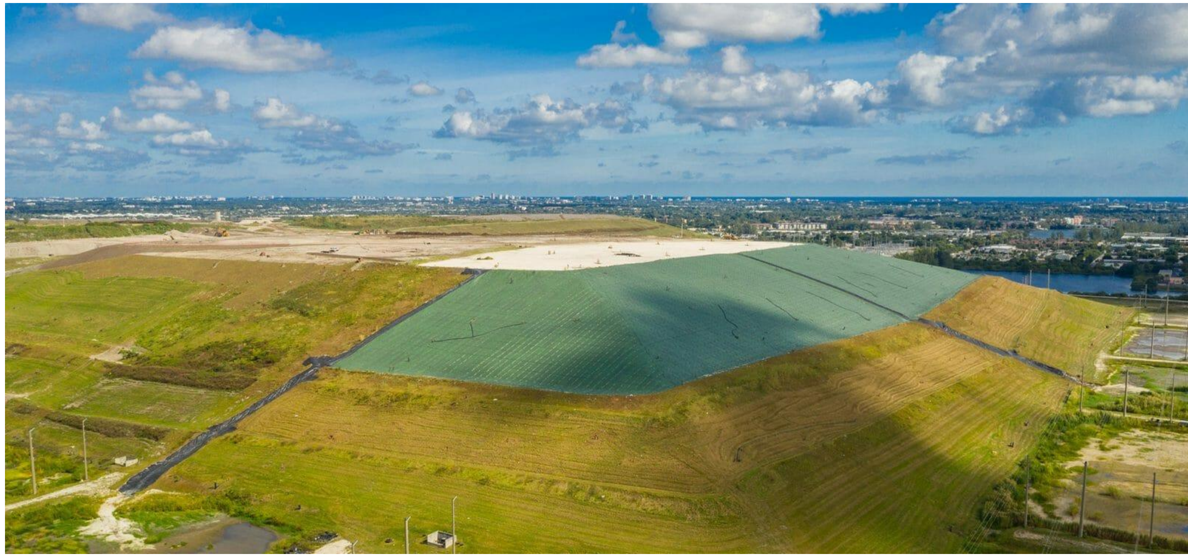


Europe

- Restrictions
- Bans
- Labeling
- Recycling accountability

Management & Treatment

- Prevention is best
- Upstream actions for large sources
  - Solid waste management
  - Wastewater treatment removal
- Removal options for high impacts



Solid Waste Management

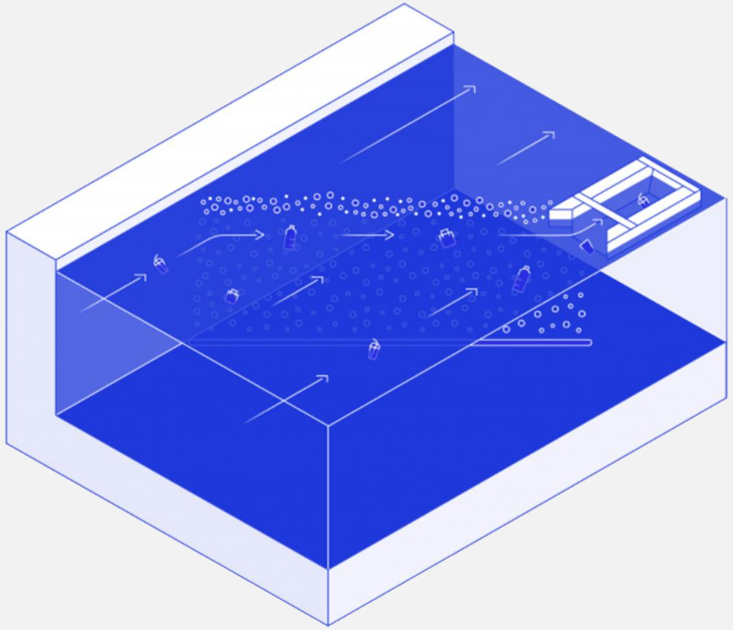
- Volume
- Litter
- Transport
- Recycling
  - <10% recycled

Wastewater Treatment

- Existing wastewater treatment facilities
  - >90% removal
  - Tertiary steps:
    - Drum/disc filter
    - Rapid sand filter
    - Membrane filter
- Sludge management
  - Incineration/landfill

River Removal Technologies

Bubble Barrier

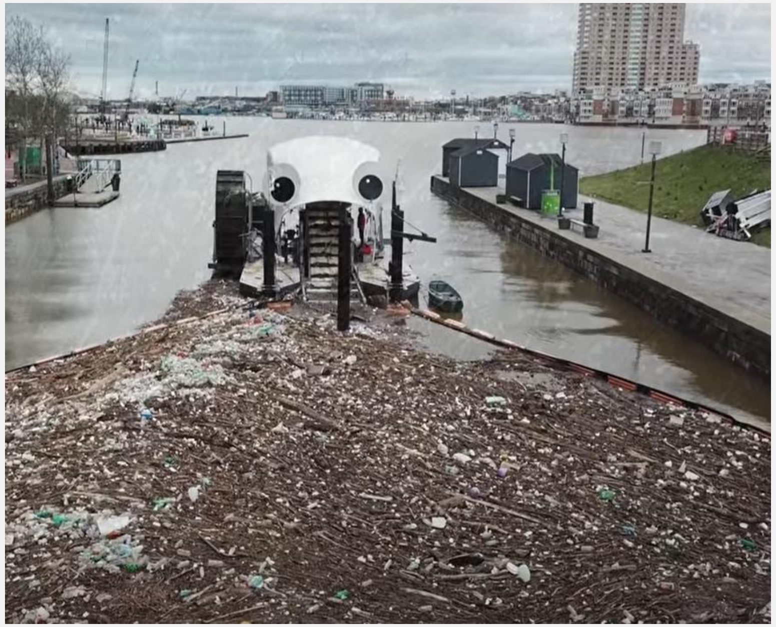


thegreatbubblebarrier.com

Drain Socks

www.youtube.com/watch?v=3kISpelek_4

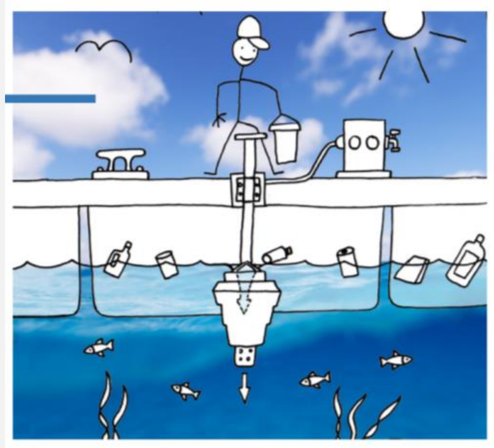
Trash Wheel



mrtrashwheel.com

Surface Water Removal Technologies

Seabin

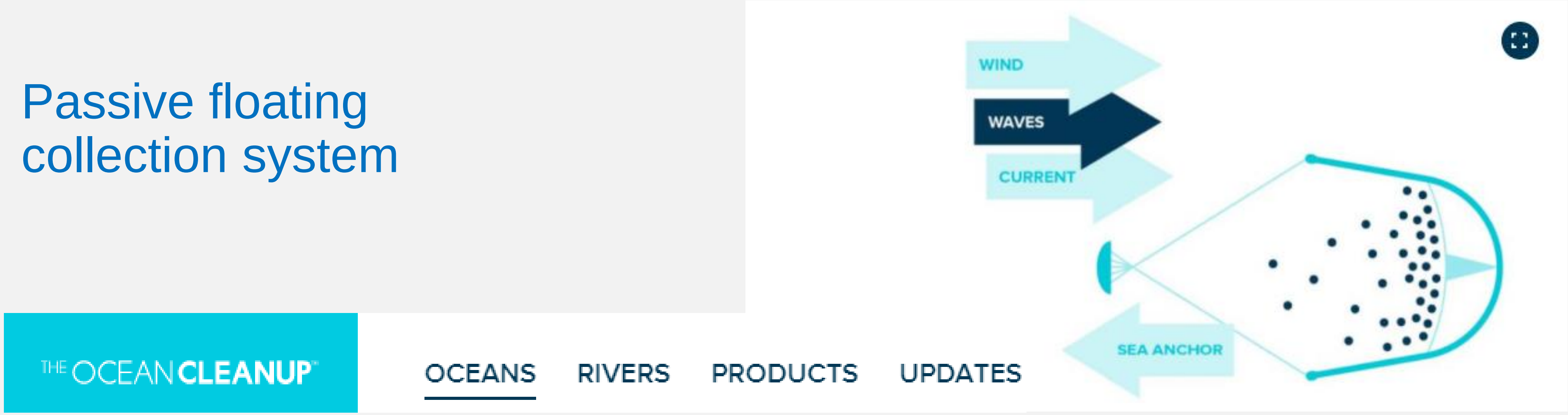


seabinproject.com

Drones

dronesolutionservices.com/wasteshark

Passive floating collection system



theoceancleanup.com

Sand/Solids Removal Technologies

Beach sand "vacuum"

hoolaone.com

Summary

- Innumerable sources
- Ubiquitous in environment
- Risks present, but no standards yet
- Prevention/source reduction is key
- No silver bullet

Thank you

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Rapid Detection of Microplastic Particles in Water by Fluorescent Tagging

Pamela Hizar

Microscopy Technical Manager

ALS Environmental

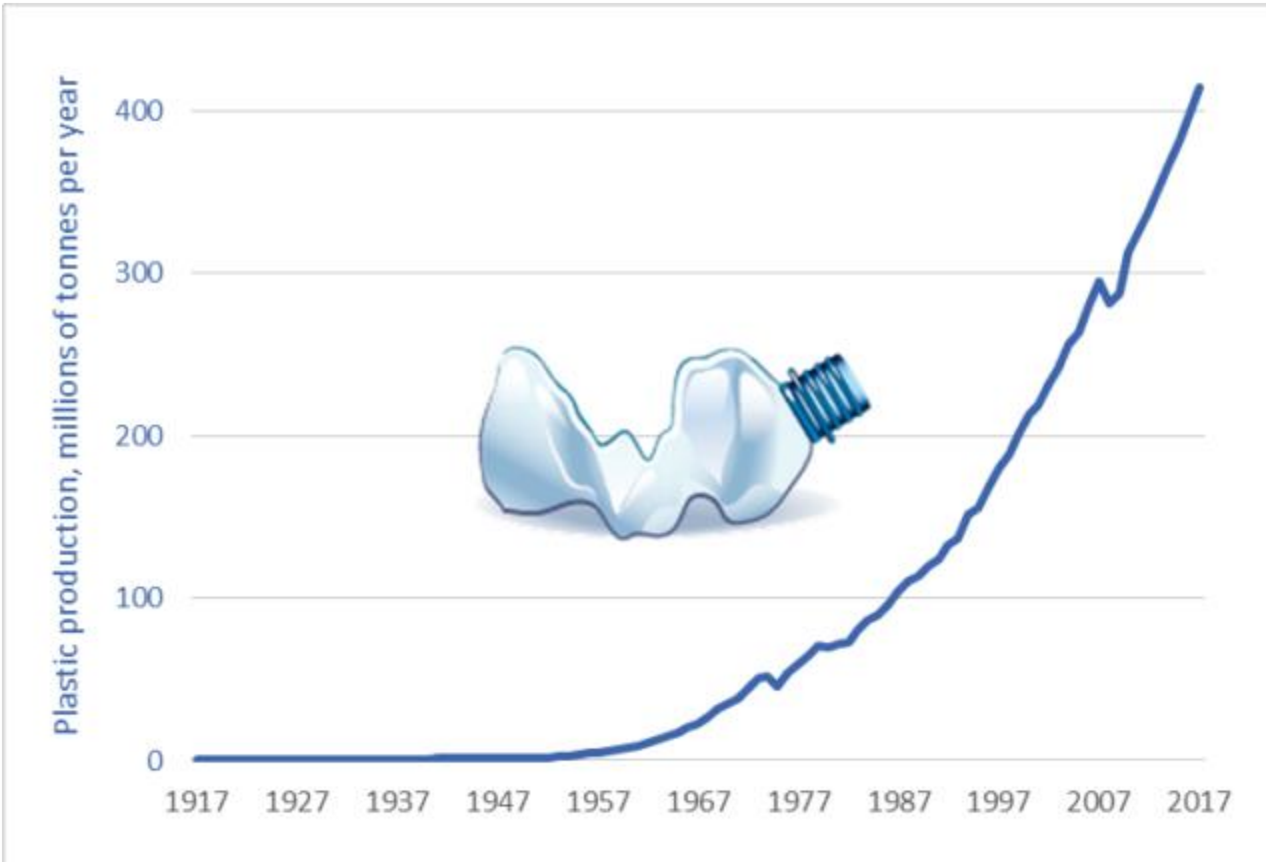
Rapid Detection of Micro Plastic Particles in Water by Fluorescent Tagging

(ALS Cincinnati Test Code: MICRO_FLUOR_001)

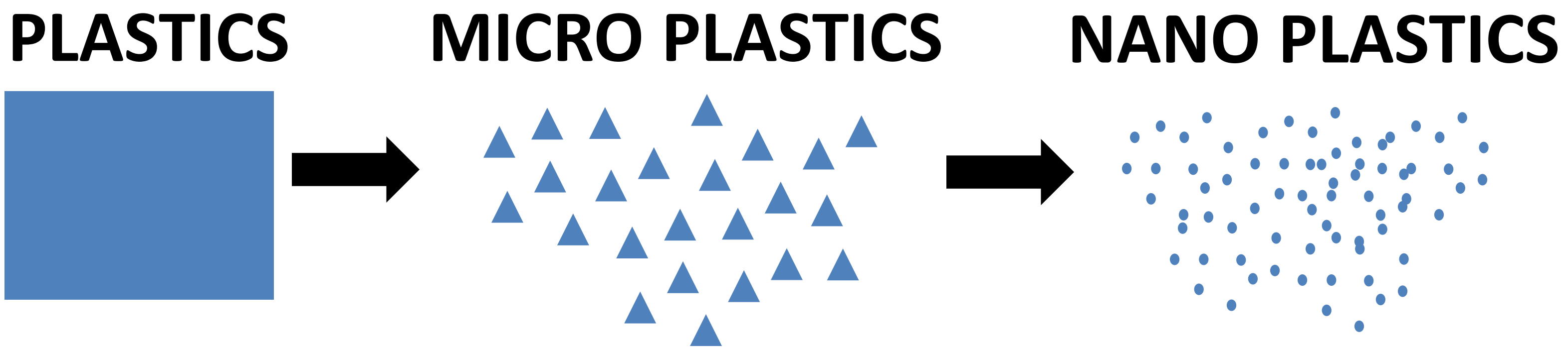
Pamela M. Hizar
Microscopy Technical Manager
ALS Environmental
Cincinnati, Ohio

NEED FOR MICRO PLASTICS TESTING

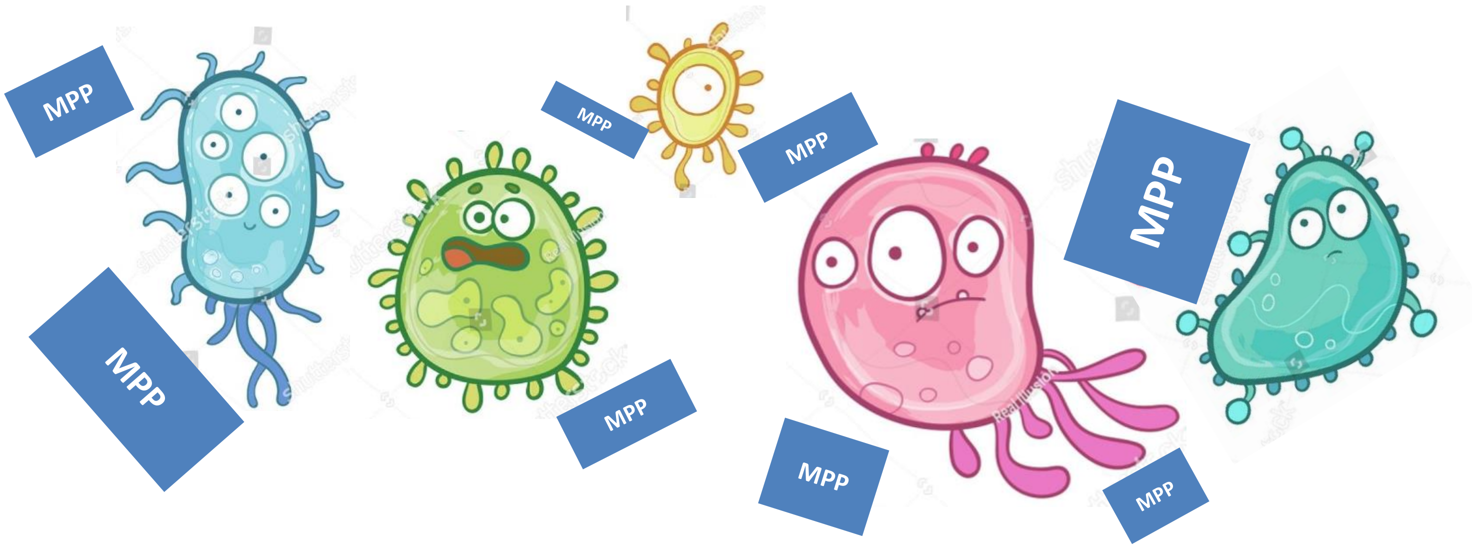
Exponential growth in plastic production;
1945 = 1M tons, 2014 = 300M tons, 2017 = >400M tons!



The hydrocarbon chains in plastics are inherently stable. Plastics break down via photo-oxidation but their molecular structure doesn't change much…



Plastics are synthetic and have only been in our environment since ~1907 when humans began mass producing them.
Most microorganisms haven't yet evolved to utilize them as a food source.
So the degraded bits of 100+ years of plastics are largely still out there…



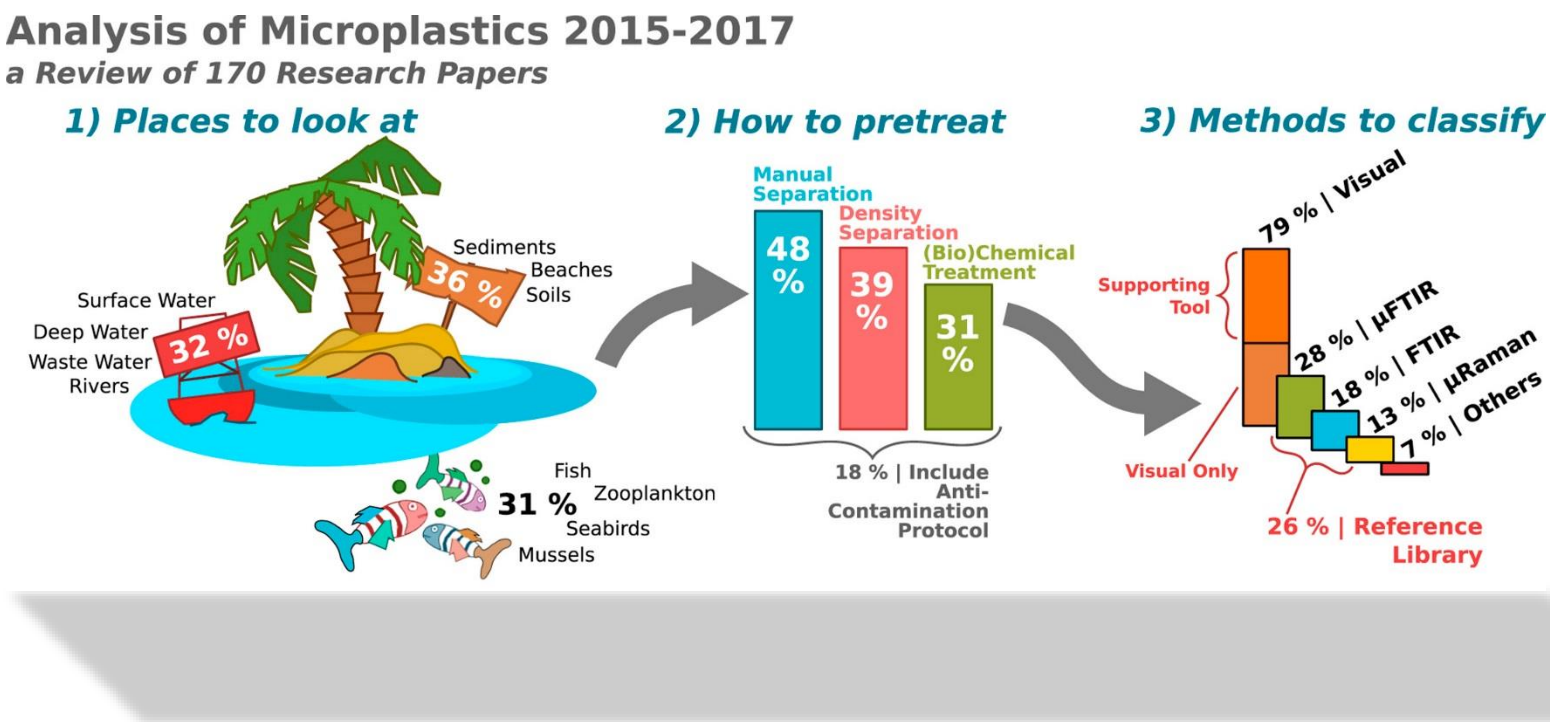
Explosive rise in plastics manufacturing
+ Lack of effective means of biodegradation
= Plastic contaminating entire planet!

WATERS; oceans, lakes, inland seas, rivers, wetlands, and tap waters.

ORGANISMS; from tiny plankton to huge whales & nearly every species in between!

CONSUMABLES; fish, mussels, beer, sea salt, tea bags, and bottled water.

Since ~2004 when micro plastics first appear in literature, thousands of researchers have focused on the topic but to date there is a lack of standardization. Methodologies vary widely depending on the types of samples being analyzed, the complex ways they must be separated, treated and prepared, and the different instruments used for analysis.



In 2018 ALS Cincinnati developed a version of the "rapid screening" test based on the SUNY study, "Synthetic Polymer Contamination in Bottled Water."

SUNY Study Synopsis

- Department of Chemistry,
  State University of New York (SUNY) at Fredonia
  Fredonia, NY, USA
- "Synthetic Polymer Contamination in Bottled Water"
- Sherri A. Mason, Victoria Welch, Joseph Neratko
- T716.673.3292
- Edited by:
  Teresa A.P. Rocha-Santos, University of Aveiro, Portugal
- Reviewed by:
  Gerrit Renner, Hochschule Niederrhein, Germany;
  Monica F. Costa, Universidade Federal de Pernambuco, Brazil

- Tested 259 individual bottles from 27 different lots across 11 brands from 19 locations in 9 countries
- **93% of all bottled water tested showed MPP contamination**
- 5% of MPP >100µm averaging ~10 MPP/L (*confirmed by FTIR*)
- 95% MPP >6.5≤100µm averaging 315 MPP/L (*using NR alone*)
- **Total average of 325 MPP/L**
- NR alone proven sufficient for the **rapid detection** of polymerics including;
  - polyethylene,
  - polypropylene,
  - polystyrene, and
  - nylon 6

(5 Most common=PET,HDPE,PVC,LDPE,PP)

ALS Method Synopsis

Preparation/Analysis

- NR injected to 10µg/mL^{-1}
- Minimum 30min incubation
- Vacuum filtered through 1µm GFF
- Optical microscope with integrated 3 MP camera
- Blue crime lite to elicit fluorescence
- 4 quadrants imaged at ~8x through orange filter
- Calibrated static image analysis software counts fluorescing particles and sizes them by area in square microns

Reporting Results

- 1 pixel = 6.39μm^2
  Therefore, smallest reliably detected particle at this mag is set at 6.5um^2
- AS based on 1 MPP detected in the total area analyzed
- Sample volume filtered, effective filter area, magnification/image area and number of images analyzed all effect the final calculated AS
- Concentration (MPP/L) = AS * #MPP
- Reported in size categories;

  $>6.5\leq10\mu m^2$

  $>10\leq100\mu m^2$

  $>100\leq500\mu m^2$

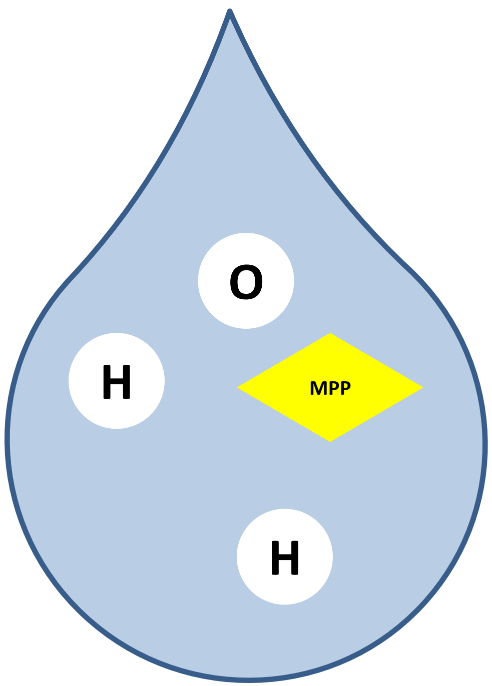
  $>500\mu m^2\leq1mm^2$

  $>1\leq5mm^2$

Potable vs Non-potable

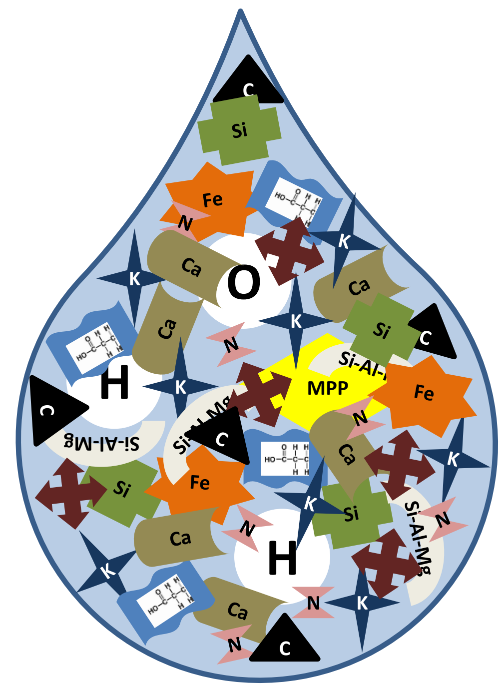
Drinking Water

- Method was developed for bottled drinking waters containing few impurities to interfere with MPP detection



Other "Waters"

- Tap, ground, waste, effluent, river, and other waters contain **MANY** impurities that can interfere with MPP detection



2 Types of Interferences

OPAQUE PARTICLES

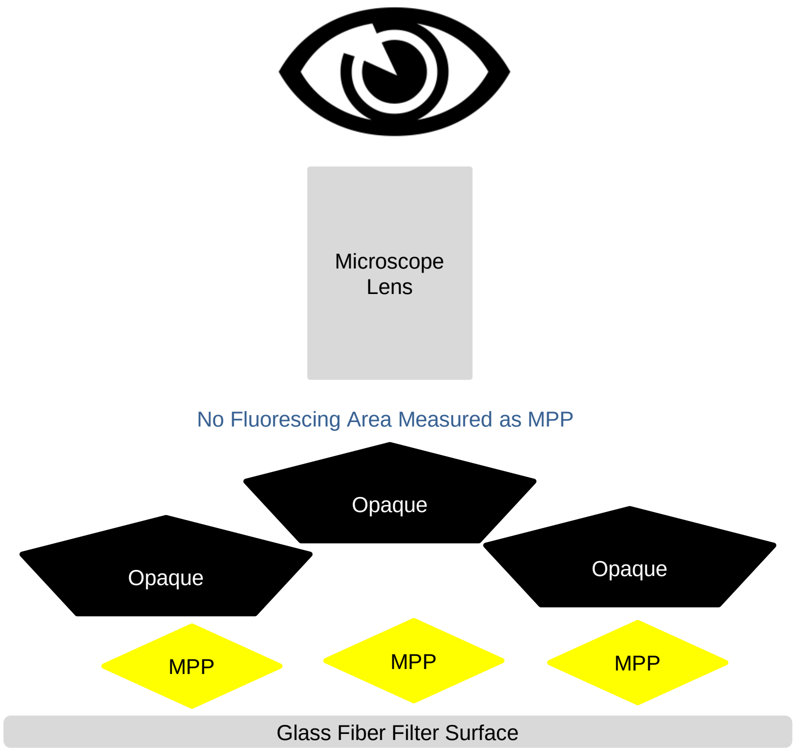
- Samples with high suspended solid opaque particles such as sediment, iron or other inorganics may obscure the view of fluorescing MPP by covering all or part of them
- E*ntirely* covered MPP results in a **negative bias** by prohibiting detection of MPP underneath
- P*artially* covered MPP results in a **sizing bias** by making the fluorescing area appear smaller as part of them is hidden behind the opaques

HIGH LIPID CONTENT

- Samples with high lipid content particles such as fats, oils and proteins may obscure the view of fluorescing MPP by masking all or part of them with the extreme fluorescence that lipids emit when stained with NR
- Intense fluorescence from lipids may *entirely* overwhelm the fluorescing MPP resulting in a **negative bias** by prohibiting their detection
- Intense fluorescence from lipids may *partially* overlap fluorescing MPP resulting in a **sizing bias** by making the fluorescing area appear larger

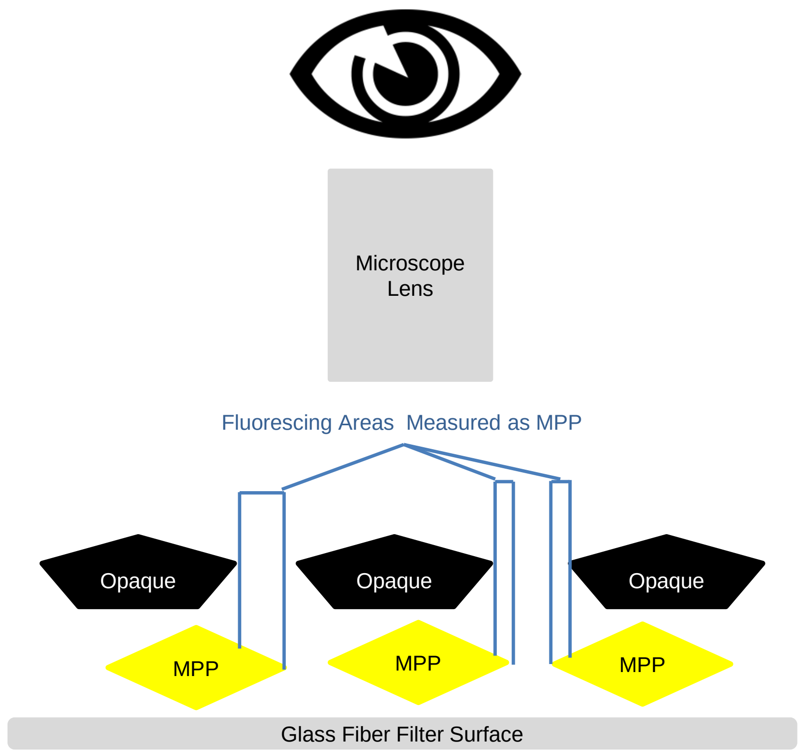
OPAQUE PARTICLES

Completely covering MPP = Negative Bias



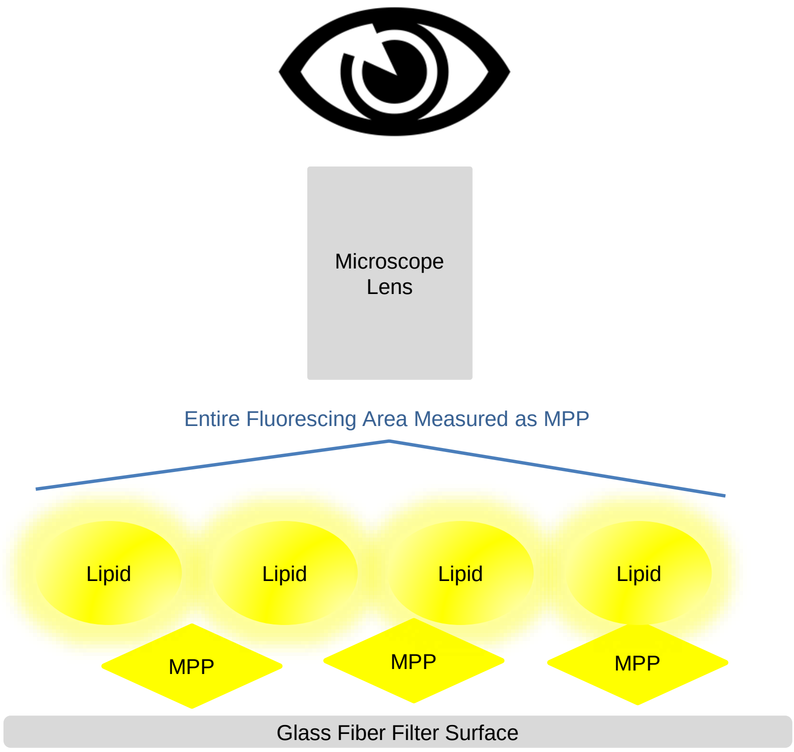
OPAQUE PARTICLES

Partially covering MPP = Sizing Bias



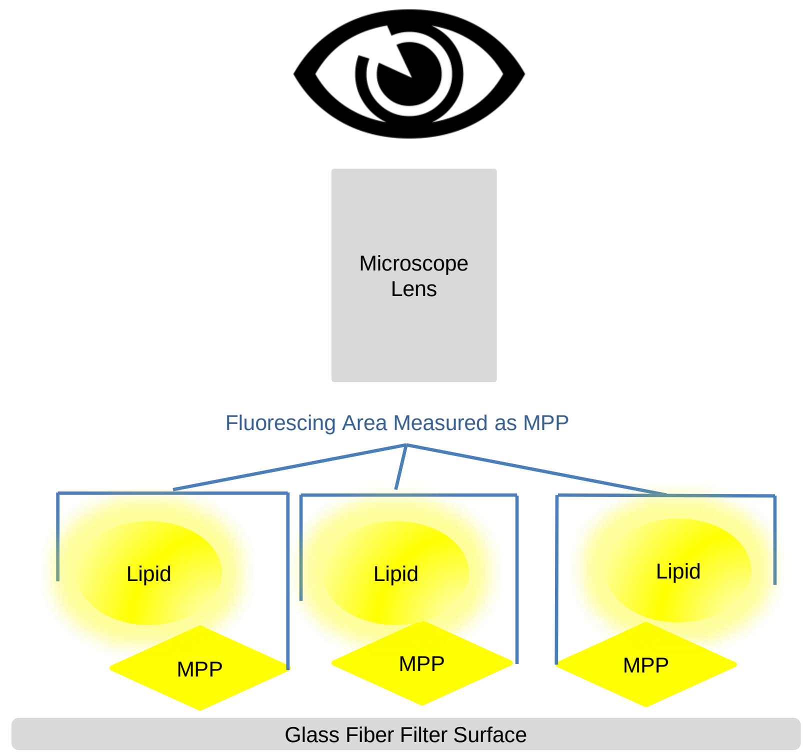
HIGH LIPID PARTICLES

Completely obscuring MPP = Negative Bias



HIGH LIPID PARTICLES

Partially obscuring MPP = Sizing Bias



Resolving Interferences

- All particles must be dispersed across the filter surface to minimize overlapping
- Therefore, samples containing high concentrations of suspended solids or other interfering materials may require dilution and filtration of very low volumes resulting in extremely high AS

Harmful Algal Blooms: Management and Control

Matt Ladewig

Senior Water Resources Manager
ESS Group, Inc.

Harmful Algal Blooms: Management and Control

EBC Virtual Webinar

"Beyond PFAS – What Other Emerging Contaminants Should We Be Concerned With"?

ESS Group, Inc.

Matt Ladewig, CLM

May 18, 2021

Overview

- What are Harmful Algal Blooms (HABs)?
- What causes HABs?
- How are HABs monitored?
- How can HABs be managed?
  - Time-tested management approaches
  - Case study
  - Other approaches

What Are Harmful Algal Blooms?...

- In freshwater, HABs typically = cyanobacteria (ITRC calls them HCBs)
  - Not strictly “algae”
  - Widely adapted – found almost everywhere
  - Can be highly visible (e.g., scums, spilled paint, or pea soup) but not always
  - Many able to control buoyancy and some able to fix atmospheric nitrogen

How Are Blooms Harmful?

- Potentially toxigenic but not always toxic – not entirely certain why
  - Microcystin – hepatotoxin
  - Cylindrospermopsin – hepatotoxin
  - Anatoxin-a – neurotoxin
  - Saxitoxin – neurotoxin
  - Others
- May also produce taste and odor compounds (e.g., MIB, geosmin)
- Drinking water or recreational health advisories

How Can We Assess HABs?

- Visual monitoring
- Grab sampling
  - Taxonomic analysis and cell counts
  - Field screen or lab testing of toxins
- SPATT – unattended samplers
- Continuous data buoys/logger arrays
  - Pigments
  - Dissolved oxygen
  - Turbidity, pH, etc.
- Remote sensing

What About Prevention?

- HAB prevention is difficult
- Unlike invasive mussels and plants, keeping cyanobacteria out is not a viable option
- Ambient phosphorus increasing at a continental scale and even some "pristine" water bodies experience cyanobacteria blooms
- Climate change favoring cyanobacteria – longer, warmer growing seasons & more extreme precip
- Prevention requires active measures

Time-tested Management Methods

- Algaecides
- Nutrient Inactivation - Alum

Algaecides

- Many copper-based formulations (copper sulfate, chelated copper) but also hydrogen peroxide (e.g., PAK 27)
- Chemically kills algae/cyanobacteria
- Relatively low cost per dose

Advantages	Limitations
Fastest control, especially over large areas	Rapid lysing of cells may release cyanotoxins (if present) and deplete dissolved oxygen
Some selectivity possible with different formulations	May impact some non-target organisms
	Does not address cause/no lasting water quality benefits

Nutrient Inactivation - Alum Part I

- Aluminum sulfate
  - Forms flocculent that sinks to the bottom
  - Al binds P even where dissolved oxygen is absent
- Different application strategies
  - Stripping
  - Maintenance
  - Sediment dosing
  - Dosing stations
- Requires careful planning, application, and monitoring to get dose right and avoid impacts to aquatic organisms

Nutrient Inactivation - Alum Part II

- Often buffered with sodium aluminate in softwater lakes
- Polyaluminum chloride (PAC) also used, particularly for dosing stations
- Cost per unit P removed is very low (but varies with commodity prices)

Advantages	Limitations
Addresses typical cause of cyano dominance (excess phosphorus)	More logistically difficult than algaecide treatments
Works quickly and can be effective for extended periods of time (decades, in some cases)	If not well-designed/applied or monitored, can result in non-target species impacts (typically at higher doses)
Long track record of implementation with substantial body of peer-reviewed literature	In-lake treatments may not address external loading. Dosing stations may not address internal loading.

Case Study – In-Reservoir Alum Treatment

Other Management Methods

- Aeration/Circulation
- Biological Controls
- Dyes
- External Source Controls
- Sonication
- More...

Aeration/Circulation

- Mixing and/or introduction of air/oxygen
- Controls cyanobacteria through one or more mechanisms (light limitation, enhanced P binding, etc.)
- Proper design and sizing critical to success
- Costs vary substantially by volume, technology, and design requirements

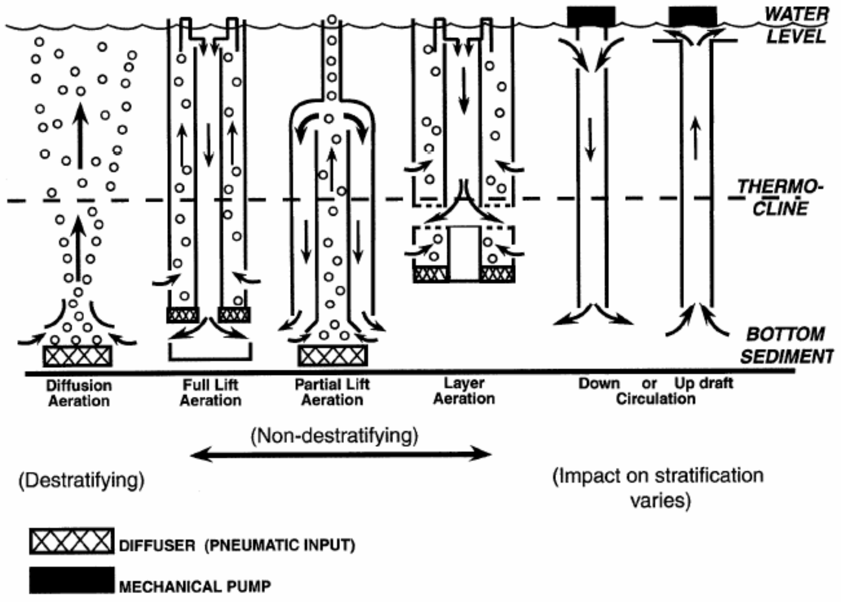


Figure 3-1 Methods of artificial circulation and aeration (from Wagner, 2001)

Advantages	Limitations
Improves dissolved oxygen levels – benefit to aquatic life	O & M costs high (some solar-powered options but these are often underpowered for natural lakes)
Enhances P removal – helps control a driver of HABs	Few large-scale projects achieve desired goals and some produce unintended consequences

Biological Controls

- Wide range of “natural” controls
  - Barley Straw – bales in the water
  - Bioaugmentation – adding microbes to compete with algae and/or enhance biogeochemical processes
  - Biomanipulation – usually fish stocking to enhance zooplankton grazing
- Costs typically low

Advantages	Limitations
Biomanipulation can be effective where fishery has become dominated by planktivorous species	Lack of sufficient peer-reviewed literature to support use of most
Does not come with stigma of mechanical or chemical approaches	Predictability of outcome is low
	Risk of impact to non-target species

Dyes

- Addition of concentrated dyes to reduce light
- Must be reapplied over growing season to maintain control
- Cost per volume treated is fairly high

Advantages	Limitations
Dyes are non-toxic	Often simply masks the problem
Can be used to manage both plant and algae growth	May actually select for certain cyanos
	Not useful in well-flushed ponds
	Possible impact on non-target species

External Source Controls

- Mainly watershed stormwater controls targeting nutrients
- Wide variety of controls, including structural and non-structural
- Cost varies but often among most expensive per unit P removed

Advantages	Limitations
Addresses cause of the problem, where external pollutant loading is a primary source	May take years to assess, fund, implement, and see improvements in water quality
May provide opportunity to incorporate other community amenities and benefits	Operations and maintenance requirements may be extensive
Often removes other pollutants, too	Hard to achieve substantial improvements in bigger and more urbanized watersheds

Sonication

- Ultrasonic disruption of cyanobacteria
- Ruptures internal cell structures (gas vesicles) without lysing cells
- Cost varies by number of units needed, power to operate, and optional features (e.g., sensors)

Advantages	Limitations
Potential for selectivity	May take days or weeks of operation to see results
Can be placed at critical locations	Operations and maintenance costs can be high over the life of the units
	Does not address cause of blooms
	Proprietary nature of units makes it difficult to assess effectiveness of approach as a whole

A Few More

- Dilution – introduction of clean, nutrient-poor water
- Dredging – removal of internal loading source (sediments)
- Hypolimnetic Withdrawal – removal of oxygen poor/nutrient rich water
- Non-alum Nutrient Inactivation – addition of other P binders such as calcium, iron, or lanthanum/bentonite clay (Phoslock)
- Nutrient Harvesting – targeted capture and removal of biomass or P released from sediments
- Sediment Inversion – inversion of clean sediments over P-rich ones
- Shading – extreme light limitation
- This list is not exhaustive

How To Succeed at HAB Management

- Clearly identify water body uses and goals
- Diagnose the key drivers of HABs in your system
- Assess how climate change, development pressure, and other environmental shifts may impact your system in the future
- Develop a long-term management plan that is holistic, realistic, and adaptive
- Act, implement, do

Thank You.

Questions?

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Pharmaceuticals in our Water: What are the Concerns?

Jaana Pietari

Senior Managing Consultant

Ramboll

PHARMACEUTICALS IN OUR WATER:

WHAT ARE THE CONCERNS?

EBC Emerging Contaminants Webinar

Beyond PFAS – What Other Emerging Contaminants Should We Be Concerned With?

Jaana Pietari, PhD, MBA, PE

May 18, 2021

RAMBOLL Bright ideas. Sustainable change.

AGENDA

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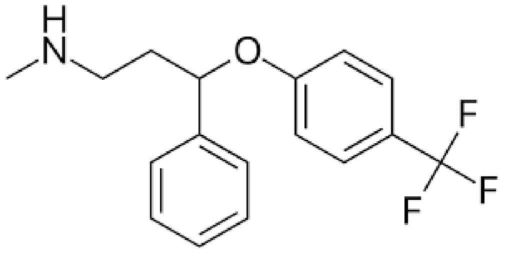
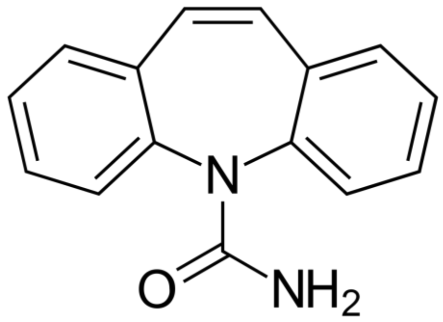
PHARMACEUTICALS AS ENVIRONMENTAL CONTAMINANTS?

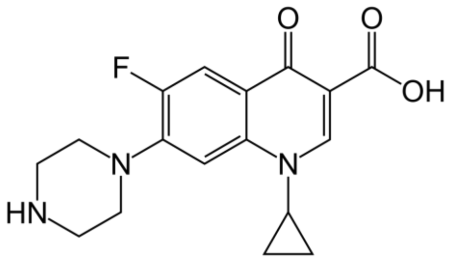
- **Pharmaceuticals** include drugs for human and animal use, including
  - Prescription drugs, over-the-counter drugs
  - Homeopathic drugs, compounded drugs
  - Investigational new drugs
  - Dietary supplements
- Numerous compounds in several **therapeutic classes**
  - 1000+ to 4,000+ compounds
  - Antibiotics, antihistamines, antidepressants, antivirals, etc.
- Range of physical properties
  - Designed to be stable & taken up by organisms



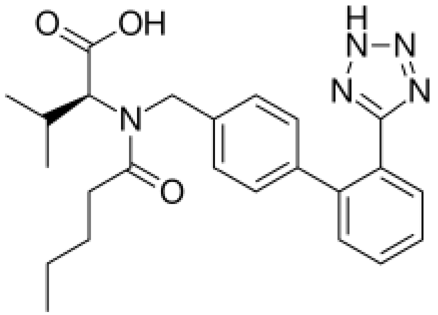
Fluoxetine



Carbamazepine

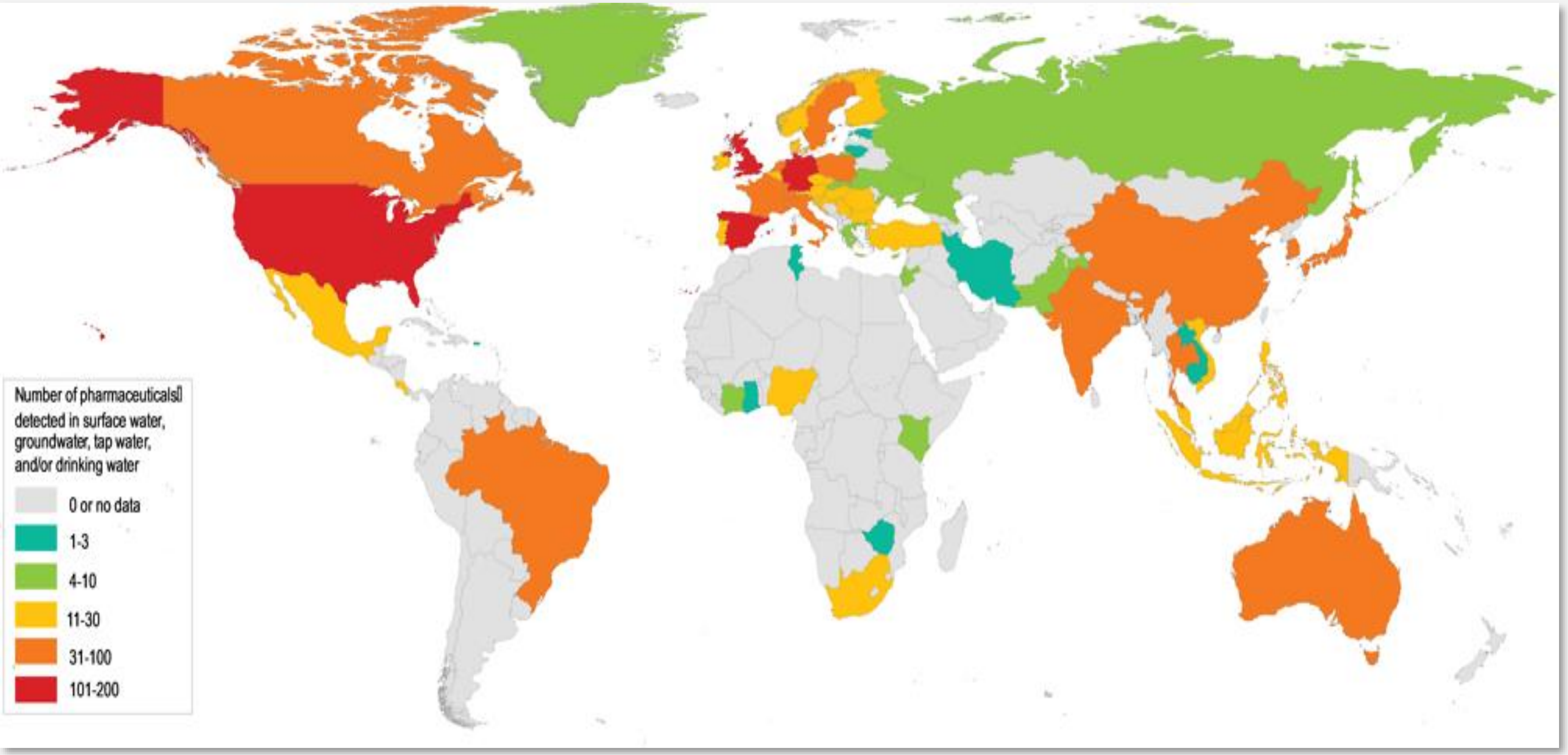


Ciprofloxacin



Valsartan

PHARMACEUTICALS ARE UBIQUITOUS IN THE ENVIRONMENT



- Pharmaceuticals Detected in
  - Surface waters
  - Wastewater effluents
  - Biosolids/Sewage sludge
  - Drinking water
  - Groundwater

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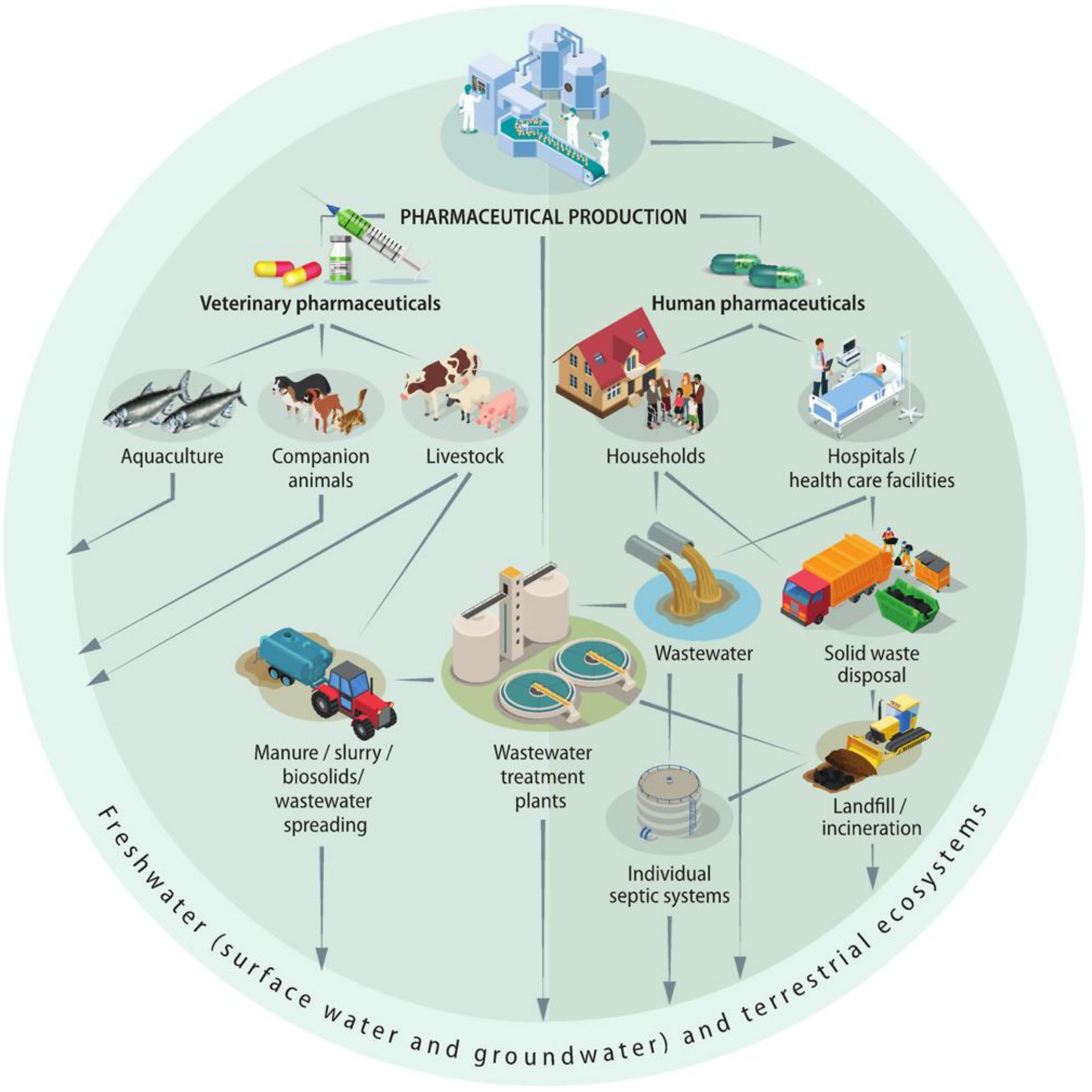
Source: aus der Beek, T. et al. 2016. *Environ. Toxicol. Chem.* 35: 823-835

THE GROWING PHARMACEUTICAL MARKET

MARKET	MARKET DRIVERS	DRUGS
• 2020: $1.23 trillion • 2025: $1.70 trillion • U.S has 48.7% share	• Increasing population • Aging population • Increasing food production • Climate change?	• More than 1,400 drugs approved by FDA • Average of 43 drugs approved per year • Number of approved drugs increasing • 20,000+ prescription drug products approved for marketing

MULTIPLE PATHWAYS TO THE ENVIRONMENT

- Human use: **wastewater** from households
- Veterinary use: **land application** of manure/slurry
- Manufacturing plants may be “hotspots”



Source: OECD. 2019. Pharmaceutical Residues in Freshwater. Hazards and Policy Responses. November 19.

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PHARMACEUTICALS IN THE ENVIRONMENT

WWTP EFFLUENTS

Kostitch et al. 2014:

- 63 prioritized pharmaceuticals and metabolites from 50 large WWTPs
- 43 detected at least once in effluents
- Antihypertensives detected most frequently and at highest concentrations
  - Hydrochlorothiazide detected in all samples
  - Valsartan at 5,300 ng/L

DRINKING WATER

Furlong et al. 2017:

- 118 pharmaceuticals in drinking water samples from 25 U.S. treatment plants
- Concentrations substantially reduced by treatment
- Some may persist through treatment (e.g. lithium, carbamazepine)

GROUNDWATER

Bexfield et al. 2019:

- 1000+ sites in Principal Aquifers evaluated for 21 hormones and 103 pharmaceuticals
- At least one compound detected in 5.9% of public and in 11.3% private wells
- Vulnerability of groundwater to contamination by pharmaceuticals compounds low

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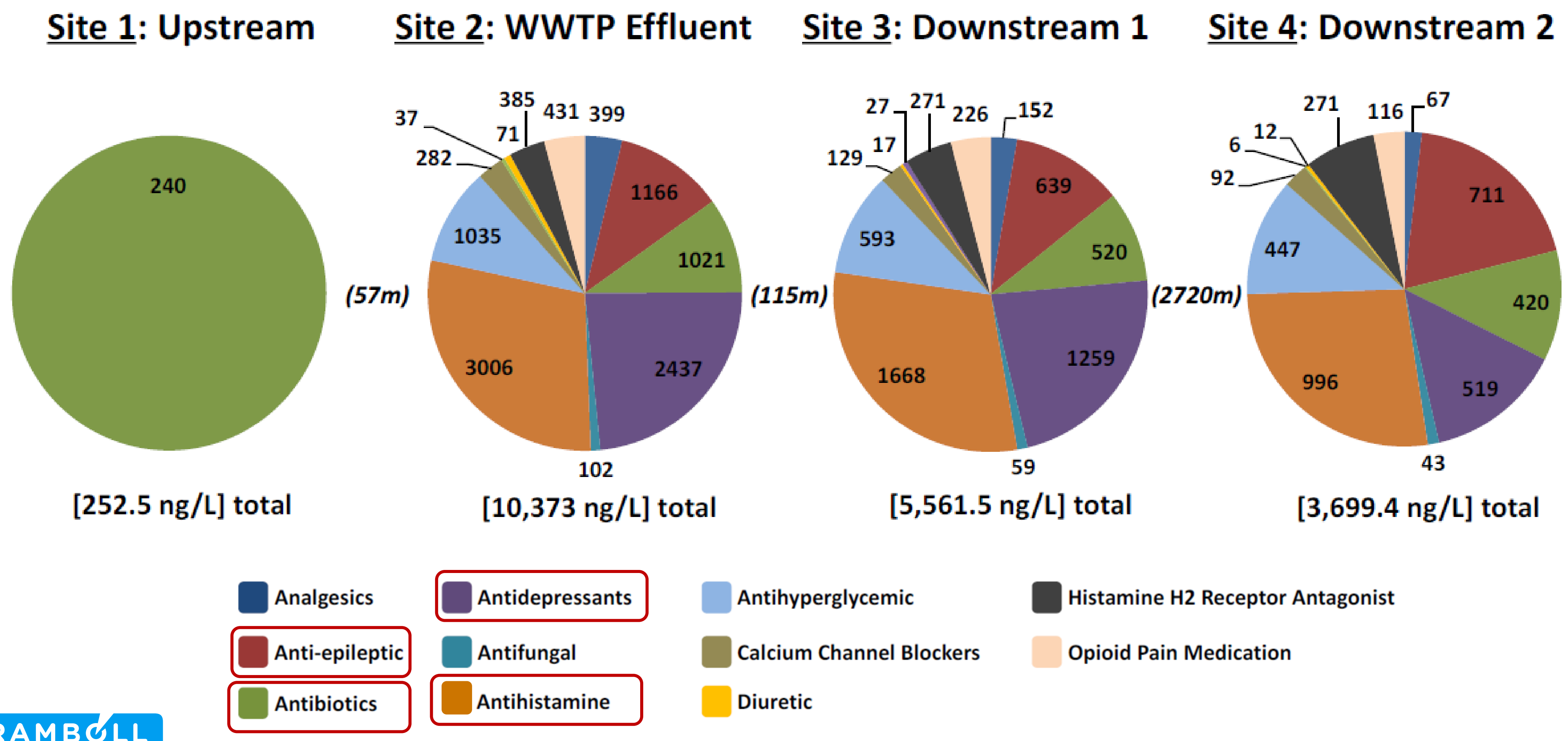
Sources:
Kostitch et al. 2010. *Environ. Poll.* 184:354-359
Furlong et al. 2017. *Sci. Tot. Environ.* 579:1629-1642
Bexfield et al. 2019. *Environ. Sci. Technol.* 53: 2950-2960

MUDDY CREEK: 31 PHARMACEUTICALS DETECTED IN WWTP EFFLUENTS AND DOWNSTREAM



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Source: Wilkinson et al. 2019. *Appl. Sci. 9*: 1368

PHARMACEUTICALS MEASURED IN EFFLUENTS AND SURFACE WATER

Therapeutic Class	Pharmaceutical	WWTP Effluent (ng/L)	Surface Water (ng/L)
Antibiotics	trimethoprim	<0.5 – 7,900	2 – 212
	ciprofloxacin	110 – 1,100	-
	sulfamethoxazole	5 – 2,800	7 – 211
Analgesics and anti-inflammatories	naproxen	<1 – 5,100	0 – 135
	ibuprofen	220 – 3,600	0 – 34
Anticonvulsants	carbamazepine	111 – 187	2.7 – 114
Beta-blockers	atenolol	879	-
Blood lipid modifying agents	clofibrate acid	ND – 33	3.2 – 27
	gemfibrozil	9 – 300	5.4 – 16
Hormones	Estriol	–	12
	Estrone	<1 – 54	0 – 38
	Progesterone	–	14 – 27

Source: Pal et al. 2010. *Sci. Tot. Environ.* 408:6062-6069

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EFFECTS OF PHARMACEUTICALS: LITTLE EVIDENCE OF DIRECT RISK TO HUMAN HEALTH

- More toxicological information available for pharmaceuticals than for other contaminants
- Concentrations well below therapeutic doses
- Data gaps and uncertainties:
  - Mixture effects
  - Sensitive populations
  - Analytical methods and limitations
  - Prioritization
  - Data to support risk assessments

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EFFECTS OF PHARMACEUTICALS: ECOLOGICAL EFFECTS ARE A CONCERN

- Adverse effects on ecosystems, include mortality, and changes to physiology, behavior, reproduction
  - Antifungals affect fish growth
  - Antidepressants alter fish behavior
  - Endocrine disruptors affect fish reproduction
- Of greatest concern are hormones, antibiotics, analgesics, antidepressants, antiparasitics and anticancer pharmaceuticals

EFFECTS OF PHARMACEUTICALS: ECOLOGICAL EFFECTS ARE A CONCERN

- Antidepressants, psychiatric drugs, and antihistamines can affect fish behavior at levels close to those found in natural systems

Trait	Direct	Indirect
Activity	Cooperation	Community structure
Aggression	Dispersal/Migration	Cross-boundary effects
Boldness	Feeding rate	Ecosystem function
Exploration	Mating success	Feedbacks
Sociality	Parental care Predator avoidance	Population dynamics Trophic cascades

Source: Brodin et al. 2014. *Phil. Trans. R. Soc B* 369:20130580

ANTIMICROBIAL RESISTANCE – A GROWING HEALTH THREAT

- Antimicrobial resistance (AMR) occurs when microorganisms become resistant to antibiotics, antifungals or antivirals
  - Mutation of existing DNA or direct exchange from other bacteria
  - Misuse and overuse of antibiotics
- Wastewater, agriculture and aquaculture sources of antibiotic resistant bacteria and genes
- Role of environment still unclear
  - Route, reservoir & arena for resistance evolution
  - Exposures to antibiotic resistant bacteria

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REGULATIONS

- Pharmaceuticals are not regulated in drinking water or wastewater effluents
- Recent 2019 regulations ban disposal of hazardous waste pharmaceuticals in sewer at healthcare facilities and reverse distributors
- Environmental effects may be evaluated as part of new drug approvals
- Contaminant Candidate Lists
  - Hormones & antibiotic (CCL3)
  - Hormones (CCL4)
  - Lithium (proposed CCL5)
- Industry voluntary actions (AMR, Pharmaceuticals in the Environment in Europe)

KEY TAKEAWAYS

- Pharmaceuticals are a large and diverse group of chemicals
- Pharmaceuticals are found in wastewater effluents, surface waters and other environmental media
  - On-going research
- Human health impacts appear to be low, but ecological impacts may be of concern
  - Challenges and data gaps remain
- Pharmaceuticals are currently not regulated, but industry initiatives address pharmaceuticals (particularly, AMR)

RAMBOLL

Emerging Contaminants: MassDEP Framework

C. Mark Smith

Director, Office of Research & Standards

Massachusetts Department of Environmental Protection

MassDEP: An Update on Emerging Contaminants

C. Mark Smith, Ph.D., M.S.

Director, Office of Research and Standards, Boston, MA

Massachusetts Department of Environmental Protection

May 18, 2021

MassDEP

Presentation Overview

- What are emerging contaminants (ECs)?
- MassDEP's approach to ECs
- A few current ECs
- Conclusions

What the Heck Are ECs? and What Makes Them "Emerging"?

- Typical "Emergent" Characteristics
  - No regulatory standard or out-of-date
  - Some important attribute "recently discovered" or updated
    - Toxicity
    - Occurrence

Perfluorooctanoic acid (PFOA)

- ECs may not be new chemicals
- Future regulation?

MassDEP

"The EC Challenge" by the Numbers

- CAS REGISTRY[SM] > 100 million unique organic and inorganic chemical substances
- New substances every day: thousands

Vs.

- 650+ chemicals in EPA's TRI list (EPA, 2015)
- 1,232 "CAS #s" listed in MOHML (MCP, Subpart P)

So, what do we focus on?

Evolution of MassDEP EC Efforts

- **Pre-2007:** *ad hoc* process
  - Mercury 1997
    - Multimedia Agency wide effort
  - Perchlorate (Bourne)
    - Drinking Water/Waste Site Cleanup/ORS workgroup: 2002
    - 2006: MA drinking water standard and waste site cleanup standards adopted
- **2007:**
  - Emerging Contaminants Workgroup formed

MassDEP's EC Workgroup
Mission and Goals

- Mission: "to centralize MassDEP's focus on EC, foster information exchange and bring together a broad range of cross-program expertise"
- Goals include:
  - Increasing readiness by identifying new potential public health and environmental problems early on
  - Information sharing/coordination across programs/media
  - EC screening
  - Assist on EC-specific strategies to protect human health
- ORS/WES -- Lead; senior managers; BSWC; BAW; BWR; Regional Offices; DPH

MassDEP

MassDEP EC Definition

- Very broad definition
- Hazardous chemicals, biological agents, or radiological substances:
  - Threat to human health, public safety or the environment
  - Lack national health standards
  - Evolving risk information
    - Toxicology
    - Exposures
  - Significant new source, pathway or detection limit information
- May include naturally occurring or manmade chemicals
- Categorization issues: PFAS/PPCPs --- 1,000s

MassDEP EC Screening Process

PRELIMINARY LIST

↓

INITIAL SCREENING PROCESS

↓

WATCH LIST

↓

STEP 2: PRIORITIZATION

↓

TOP PRIORITIES

↓

ONGOING REVIEW/UPDATES

Subject matter and program experts
"Living" list

MassDEP jurisdiction
MassDEP program priorities
Not adequately addressed

Ranked on key attributes
Possible tangible outcomes
Cross-media issues
External drivers (e.g. legislative)

MassDEP EC Prioritization Criteria

– Chemical characteristics of heightened concern:
  - PBT: Persistence, bioaccumulative, toxic
  - High P, B or T can be sufficient
  - Qualitative rankings for each

– Risks to children

– High exposure potential
  - Drinking water; Hazardous waste sites; Air exposures; Food-chain

– Tractable

– Significant Ecorisk
  - Especially impacts to species of concern

MassDEP Initial Priority EC List

2015 Top Priority 10 ECs:

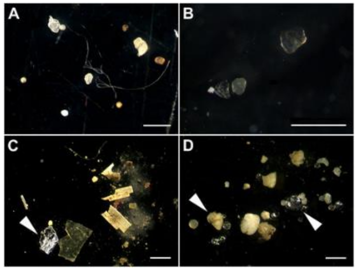
- **Perchlorate[1]**
- **1,4-Dioxane (UCMR-3)[1]**
- **Tetrachloroethylene (PCE)[1]**
- **Trichloroethylene (TCE)[1]**
- **RDX[1]**
- **Tungsten[1]**
- **PPCP[2]**
- **Cyanotoxins[2]**
- **Nanoparticles[2]**
- **Polybrominated diphenyl ethers (PBDEs)**

[1] MCP or MCL Standard(s) derived/revised since inclusion on EC list.

[2] Outreach, education, BMPs, guidance

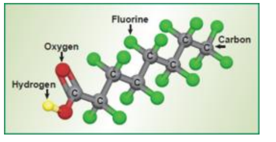
Additions

- **Watch List**
  - **Per- and polyfluoro alkyl substances (PFAS)**
  - **Microplastics**
  - **By-product PCBs**
  - **Flame retardants**
- **Priority List**
  - **Longer-chain PFAS subgroup**
  - **Flame retardants (Legislative)**



PFAS Remain a Predominant Emerging Contaminant Group

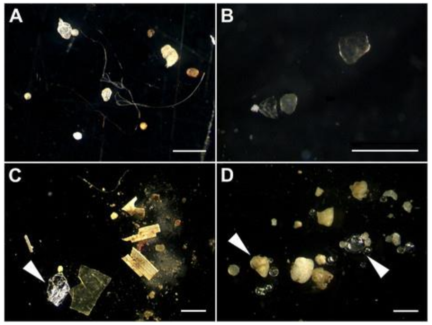
- Thousands of compounds: how to categorize?
- PFAS6 subgroup addressed
  - PFOS; PFOA; PFNA; PFHxS; PFHpA; PFDA
  - Updated toxicity values
  - MCP standards/MCL



- Many remaining: Individual or additional subgroups?

Plastics

- Persistent
- Large and increasing amounts
- Microplastics
  - Direct - microbeads
  - Indirect – microfibers -- weathering
- Effects?
  - Direct
  - Carrier
  - Monitoring challenges



Wagner et al., Environmental Sciences Europe. 26, 2014

MassDEP

Related Emerging Sources and Exposure Pathways

- PFAS Examples
  - Fluorinated containers as a possible source and exposure pathway
- Air-water interface
  - Potential for unique exposure situations

Conclusions

- Identifying and prioritizing ECs important and challenging
  - Public and environmental health challenges
  - PBT remain a focus
  - Regulatory Agencies/Regulated community
  - Program planning/resource needs + allocations/legal
- Science and regulations evolving
- Agency-wide internal workgroup
- PFAS an ongoing EC challenge

Questions?

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MassDEP

Moderated Discussion

Jeffrey Hershberger

Program Co-Chair & Panel Moderator

Senior Scientist
ESS Group, Inc.