INTRODUCTION TO MICROPLASTICS AND HEALTH IMPLICATIONS:

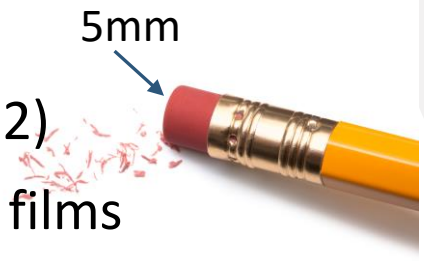
WHERE ARE WE AND WHERE ARE WE GOING?

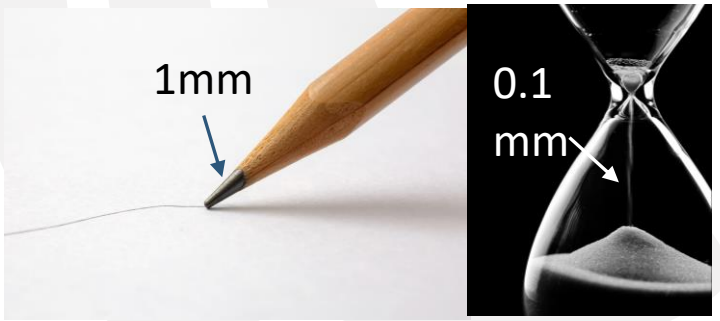
MARGARET SPRING – MONTEREY BAY AQUARIUM

ROBERT ELLIS-HUTCHINGS – DOW

DEFINING THE TERMS

WHAT ARE MICROPLASTICS?





Plastic particles < 5 mm in length (WHO, 2022)

- Shape: Irregular fragments, sphere, fibers, films
- Composition and surface characteristics

WHAT ARE PARTICLES?

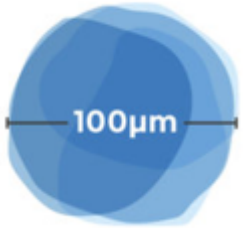


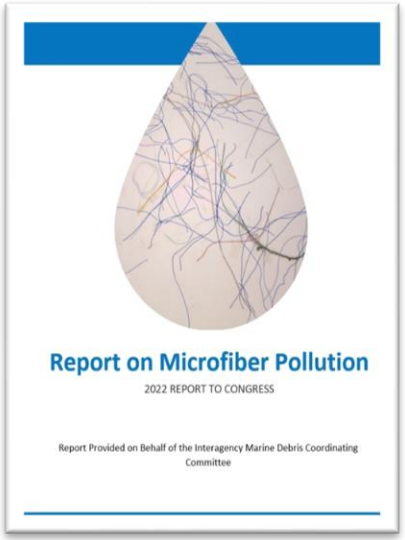
Table salt
(100 microns)

https://safesilica.eu/respirable-crystalline-silica/

A minute piece of matter with defined physical boundaries and a defined physical boundary as an interface (EU Commission, 2011)

WHAT ARE MICROFIBERS? ARE THEY MICROPLASTICS?

- Solid polymer-containing fiber particle with dimensions: length of 3 nm ≤ x ≥ 15 mm and a length to diameter ratio of > 3 (WHO, 2022)
- Considered microplastic if the size, shape and polymer compositions requirements are met.

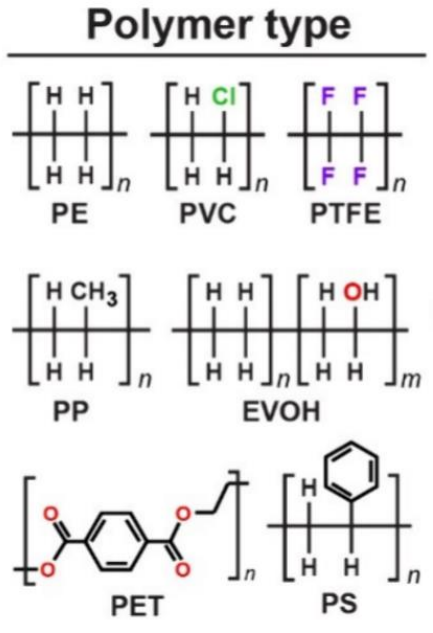


EPA and NOAA Interagency Marine Debris Coordinating Committee, 2022

DEFINING THE TERMS

WHAT ARE PLASTICS?

- High relative molecular mass polymer (20,000-200,000 Da)
- Shaped by flow at some stage in its processing into finished products (ISO 472:2013)

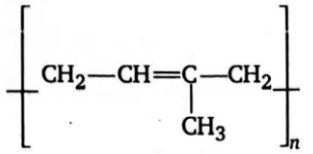


Adapted from Duncan et al., Analytical Chemistry, 2024

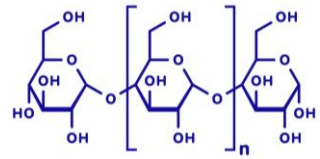
PE=Polyethylene, PVC=Polyvinylchloride, PTFE=Polytetrafluoroethylene, PP=Polypropylene, EVOH=Ethylene Vinyl Alcohol, PET=Polyethylene Terephthalate, PS=Polystyrene

WHAT ARE POLYMERS?

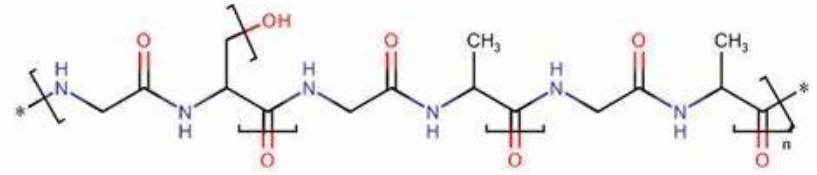
- Molecule of high relative molecular mass
- Multiple repeating units of low relative molecular mass molecules (IUPAC, 2008)



Natural rubber



Polysaccharide



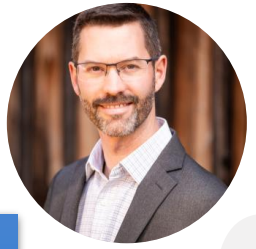
Silk

https://tardigrade.in/question/the-natural-rubber-is-the-polymer-of-zac57edh

https://www.thoughtco.com/polysaccharide-definition-and-functions-4780155

https://www.researchgate.net/publication/313988058

DEFINING THE TERMS



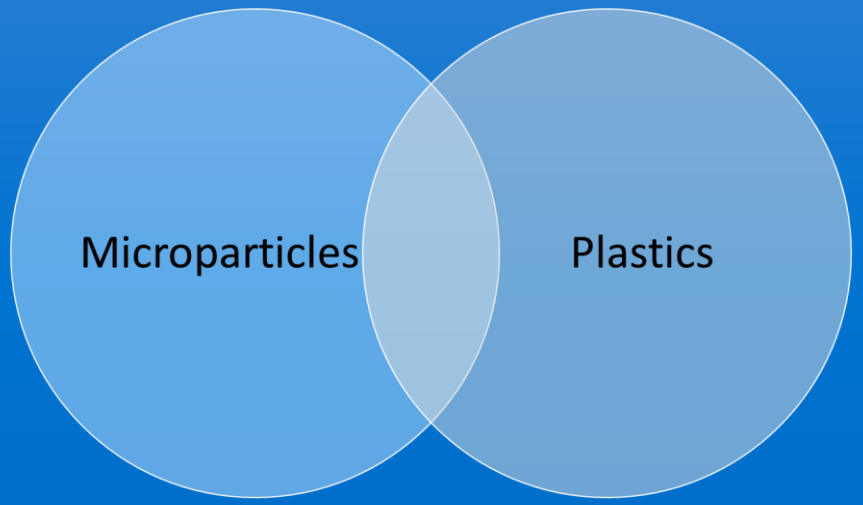
WHA

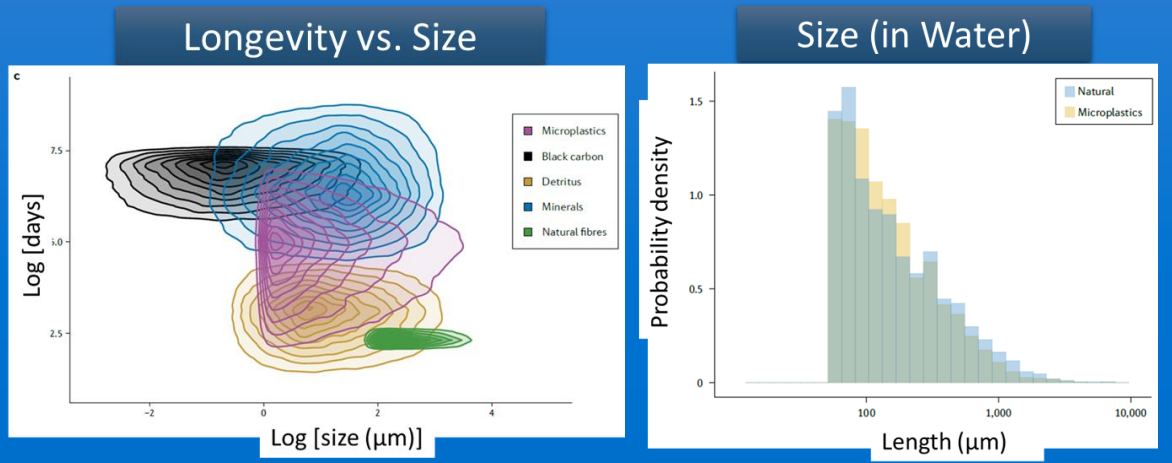
- Hi
- Sh
  pr

WHA

- Mo
- Mu
  mo

Microplastics have features both of microparticles and plastics.

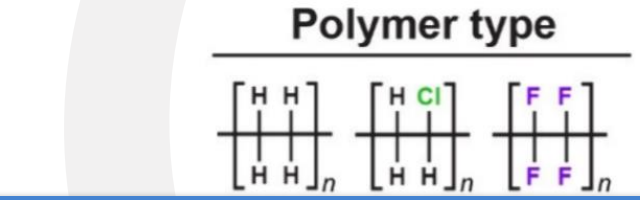




Adapted from Koelmans et al., Nature Reviews, 2022

How are they formed?

What are common sources?



l from
et al.,
al
ry, 2024

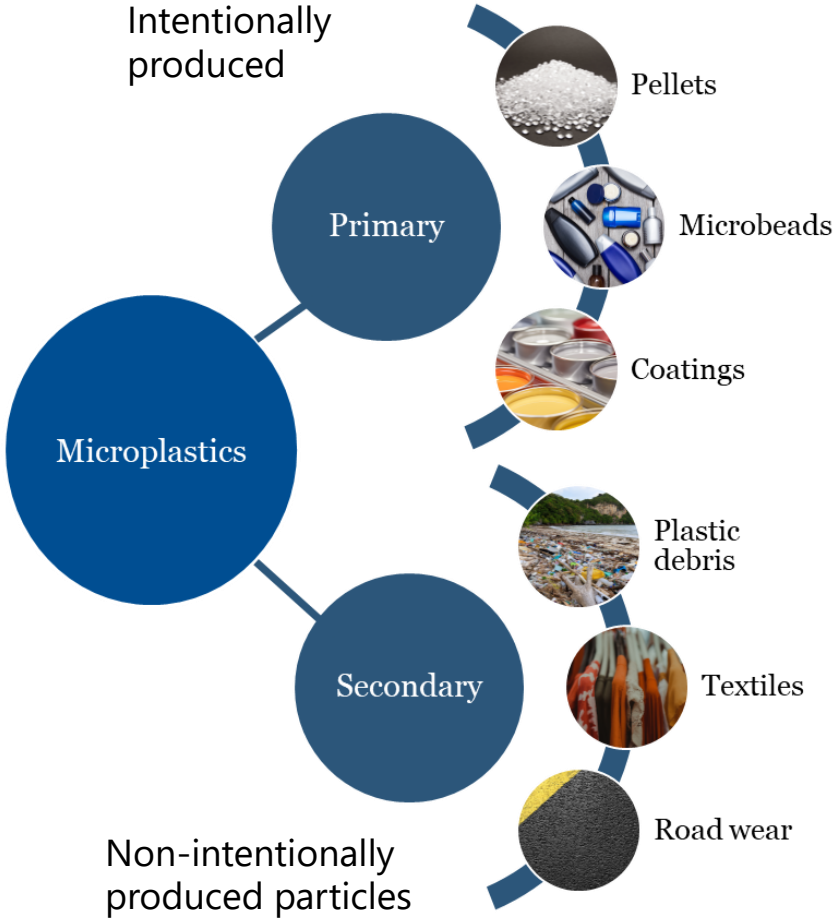
ppylene,

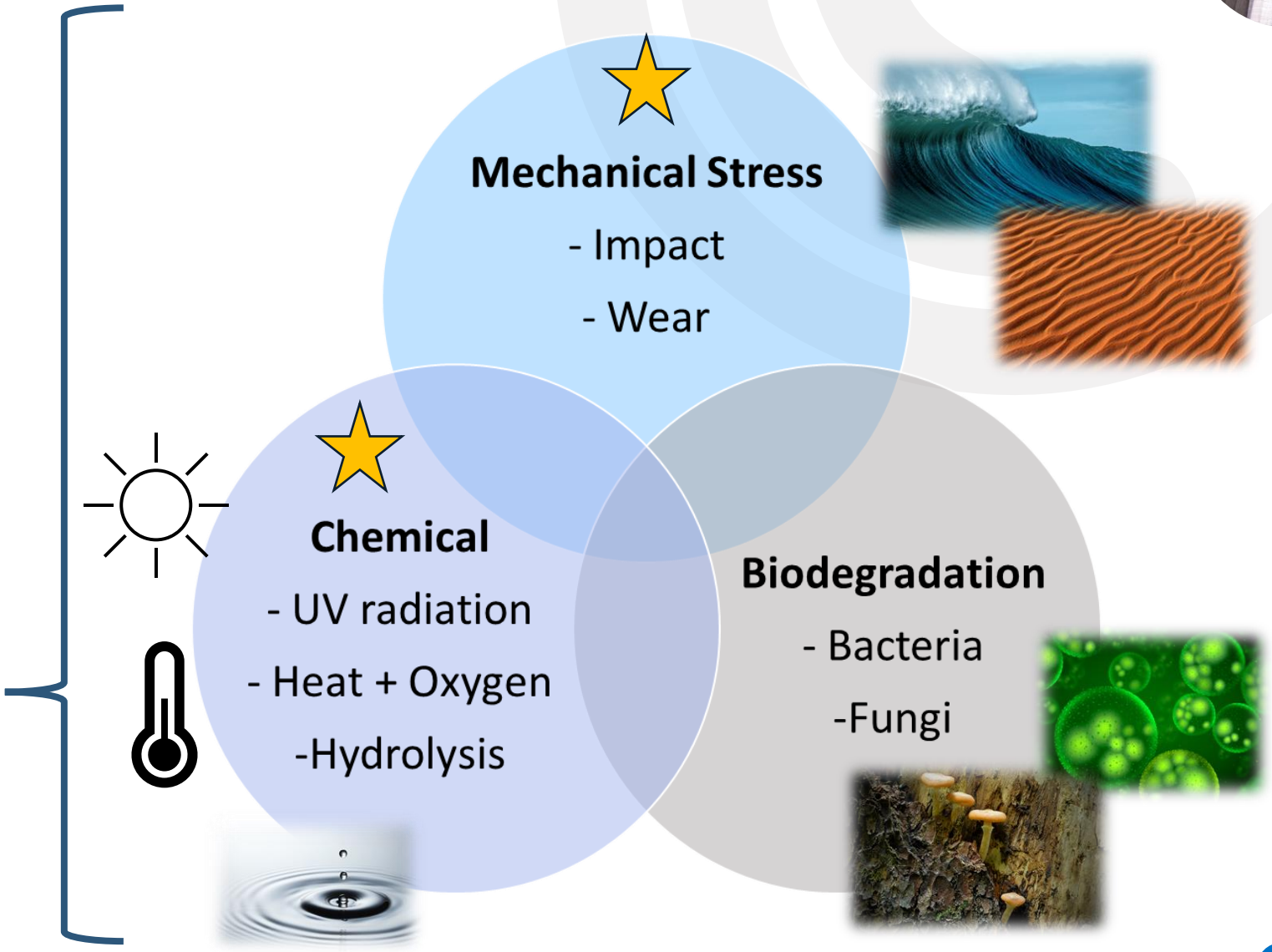
styrene

le

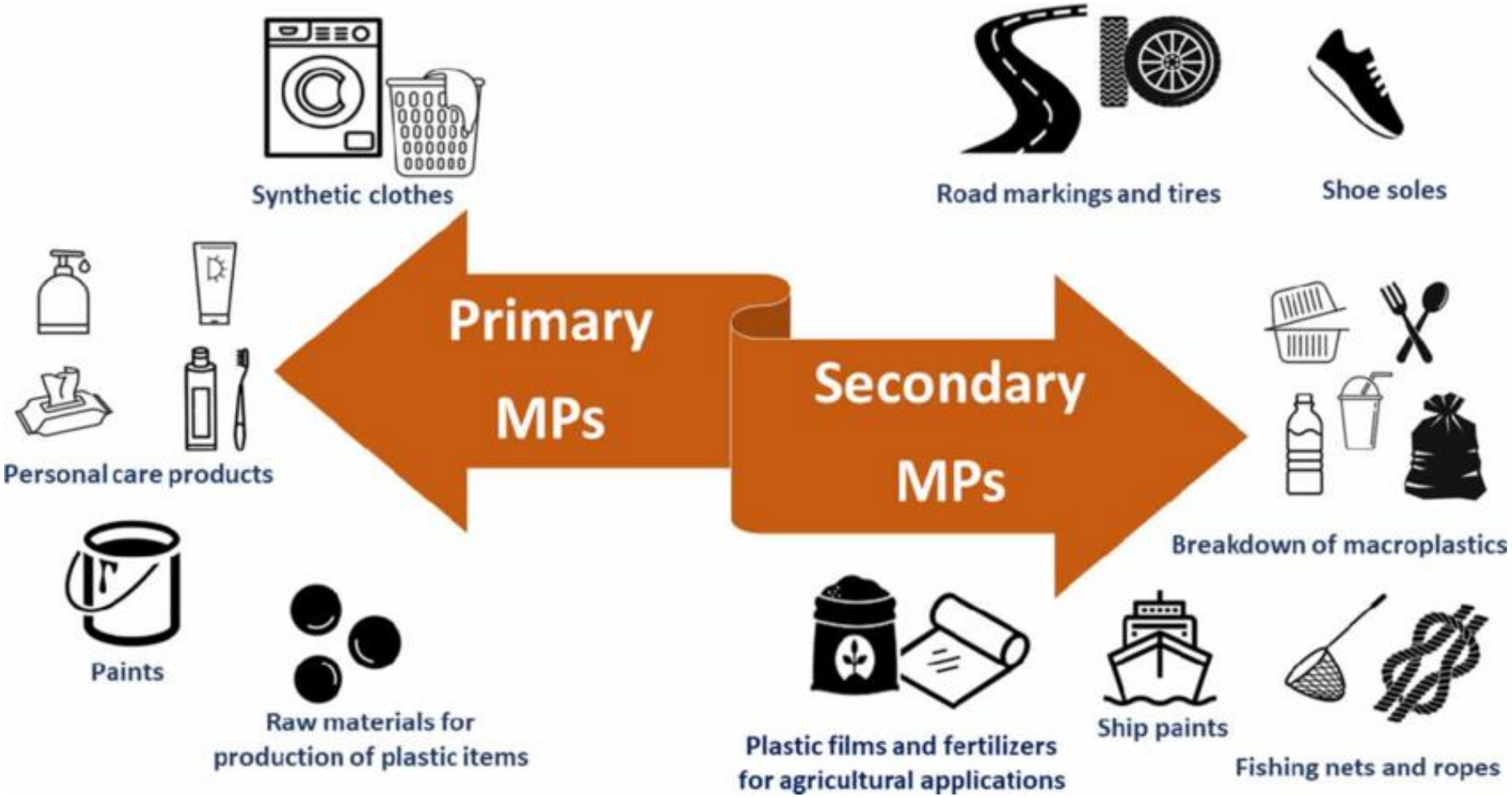
Silk

HOW ARE MICROPLASTICS FORMED?





COMMON AND MAJOR SOURCES OF MICROPLASTICS

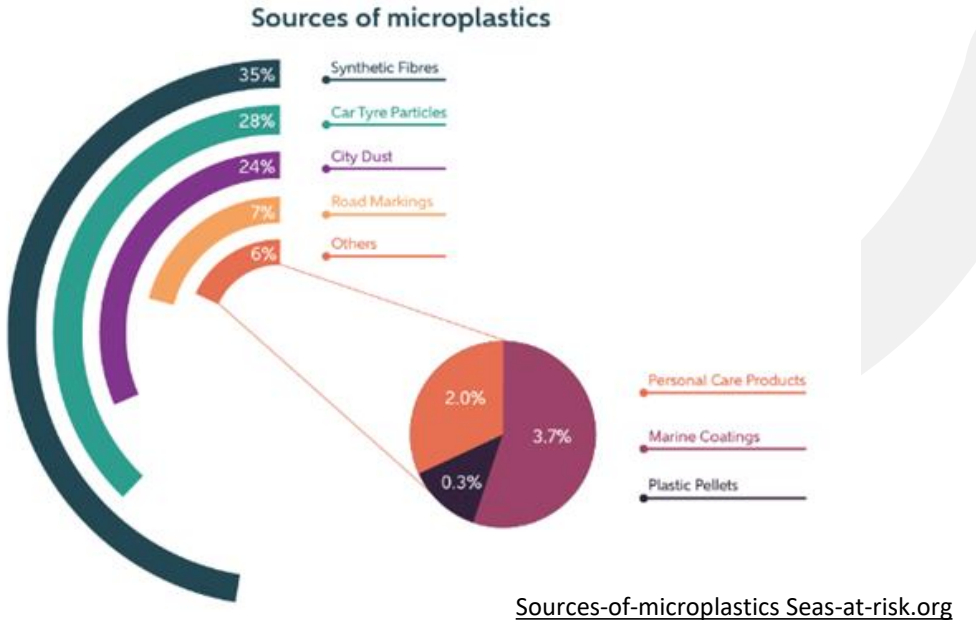


EXAMPLES: RELATIVE PROPORTIONS OF SOURCES

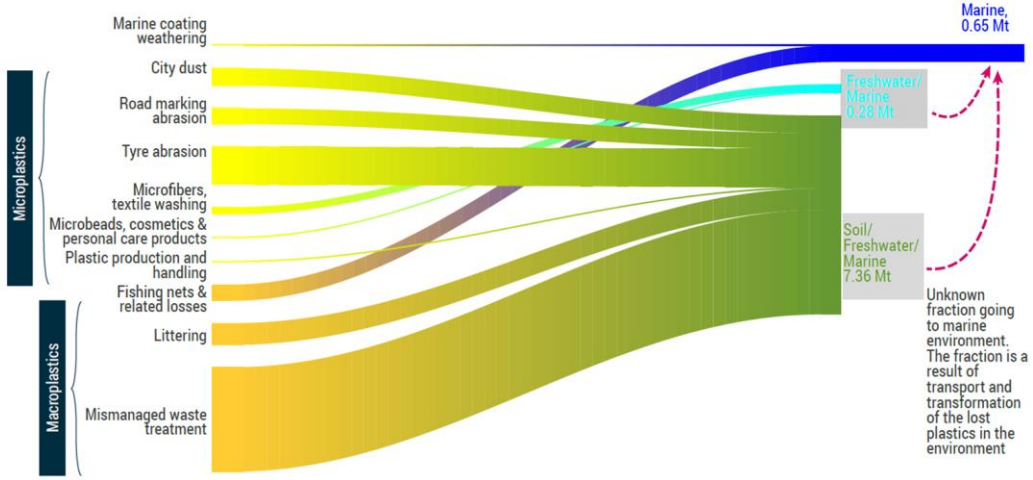
https://www.weforum.org/agenda/2022/08/where-oceans-microplastics-come-from/

Plastic type	Share of total microplastic loss [%]	Share of total macroplastic loss [%]	Share of total loss [%]
PP	4%	20%	14%
LDPE, LLDPE	3%	16%	11%
PVC	3%	3%	3%
HDPE	3%	12%	9%
PET	1%	8%	6%
PS, EPS	1%	5%	4%
PUR	1%	1%	1%
Other Thermopl.	1%	1%	1%
ABS, ASA, SAN	0.5%	2%	2%
PC	0.2%	0.2%	0.2%
PA	0.2%	0.2%	0.2%
Elastomers (other than tyres)	0.5%	0.5%	0.5%
Thermosets	2%	2%	2%
Adhesives	1%	1%	1%
Sealants	0.1%	0.1%	0.1%
Coatings	0.2%	0.2%	0.2%
Marine coatings	2%	0%	1%
Road marking coatings	20%	0%	7%
PP fibers	7%	9%	8%
PET fibers	4%	5%	5%
PA fibers	1%	13%	8%
Elastomers (tyres)	47%	0%	17%
Bioplastics	0.1%	1%	0.5%
Total	100%	100%	100%

Ryberg et al. (2018). UNEP Report

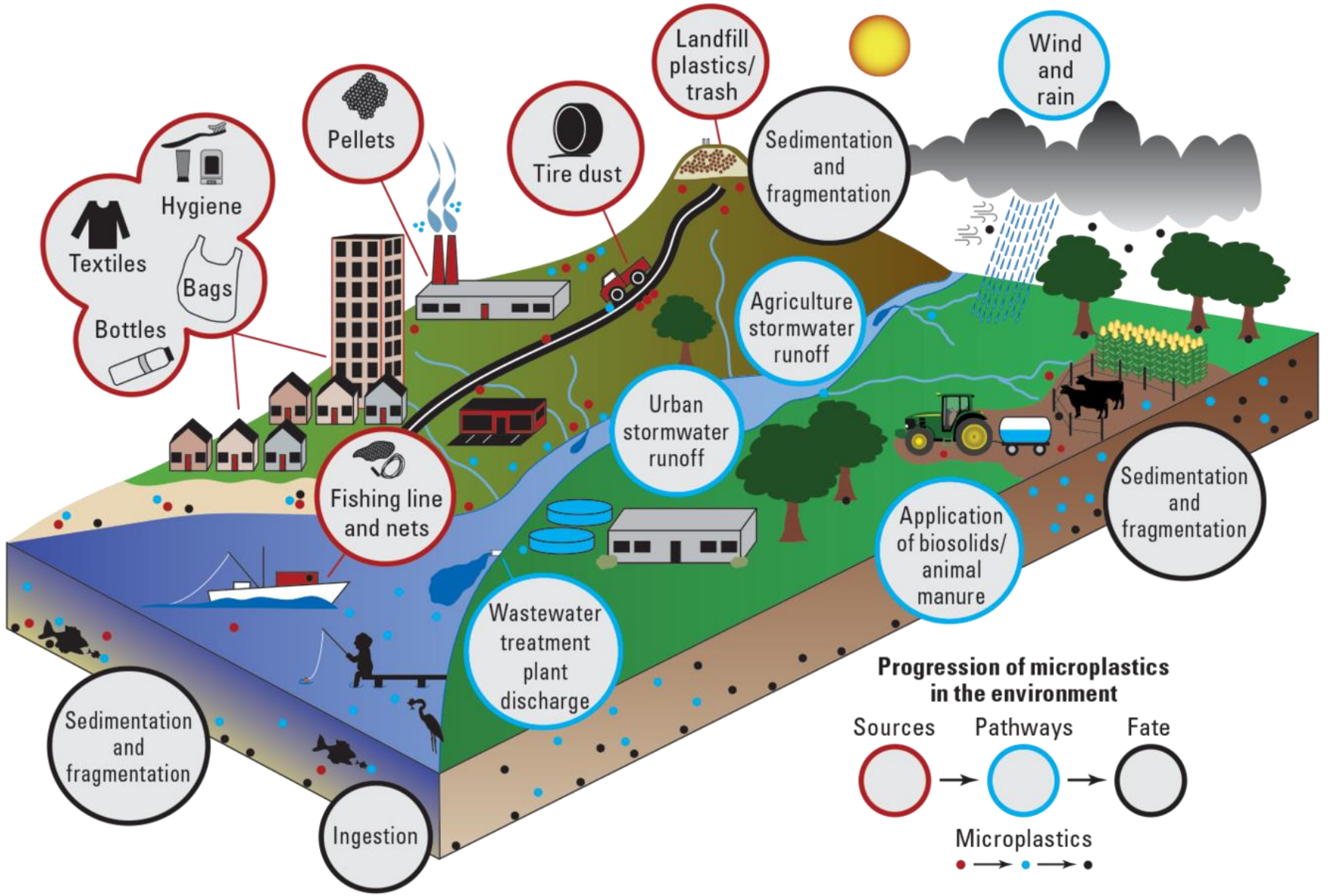


Sources-of-microplastics Seas-at-risk.org



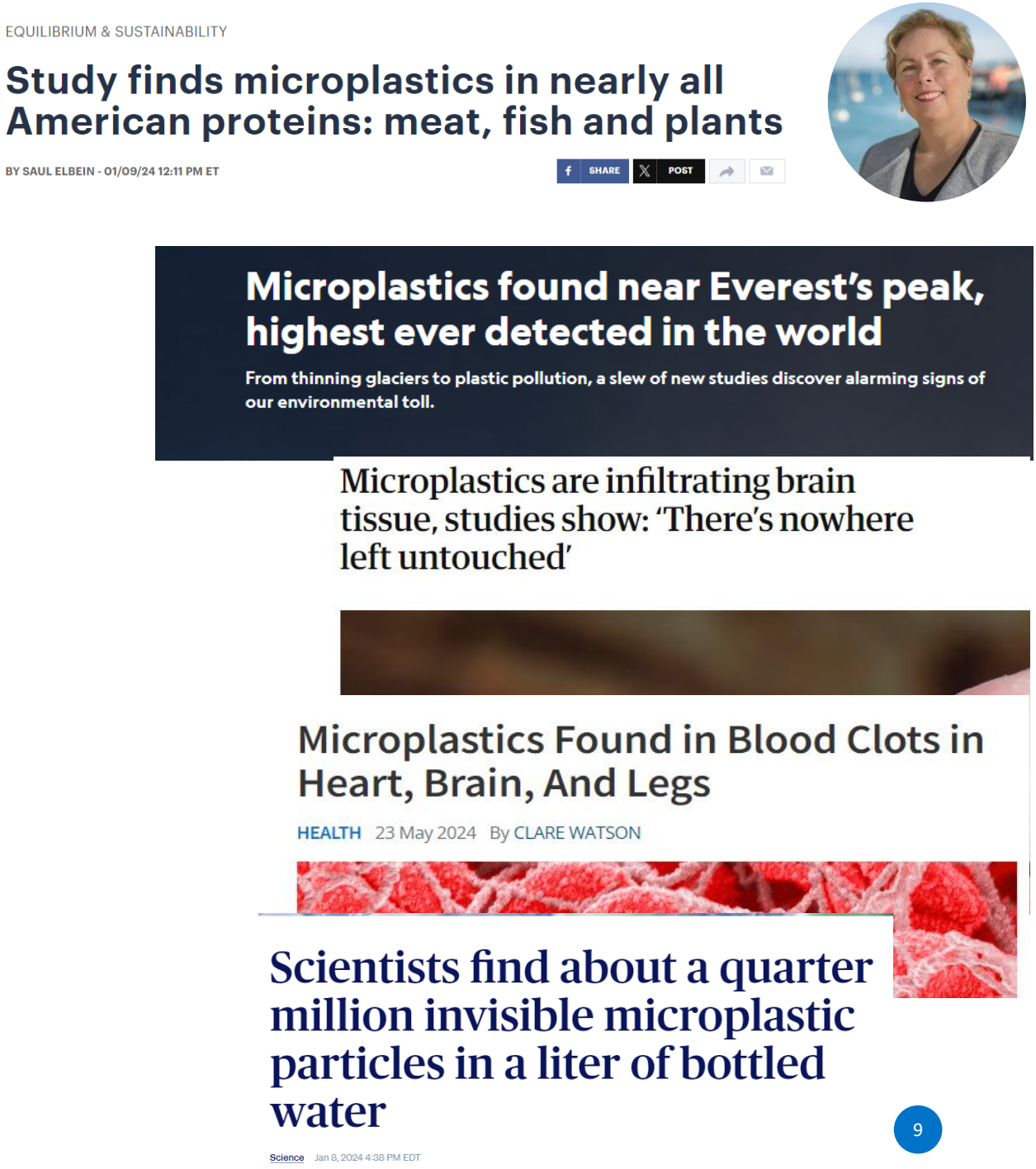
Ryberg, M., Laurent, A., & Hauschild, M. Z. (2018). Mapping of global plastic value chain and plastic losses to the environment: with a particular focus on marine environment. United Nations Environment Programme.

MICROPLASTIC PATHWAYS & FATE



CONCERNS - UBIQUITY

- Plastic pollution, including microplastics, found everywhere in the world
- Found in all environmental compartments including water, soil, biota, ice, clouds, and air
- Microplastics have been detected throughout the human body, including brain tissue, blood, reproductive organs, and placentas



EQUILIBRIUM & SUSTAINABILITY

Study finds microplastics in nearly all American proteins: meat, fish and plants

BY SAUL ELBEIN - 01/09/24 12:11 PM ET

SHARE POST

Microplastics found near Everest's peak, highest ever detected in the world

From thinning glaciers to plastic pollution, a slew of new studies discover alarming signs of our environmental toll.

Microplastics are infiltrating brain tissue, studies show: 'There's nowhere left untouched'

Microplastics Found in Blood Clots in Heart, Brain, And Legs

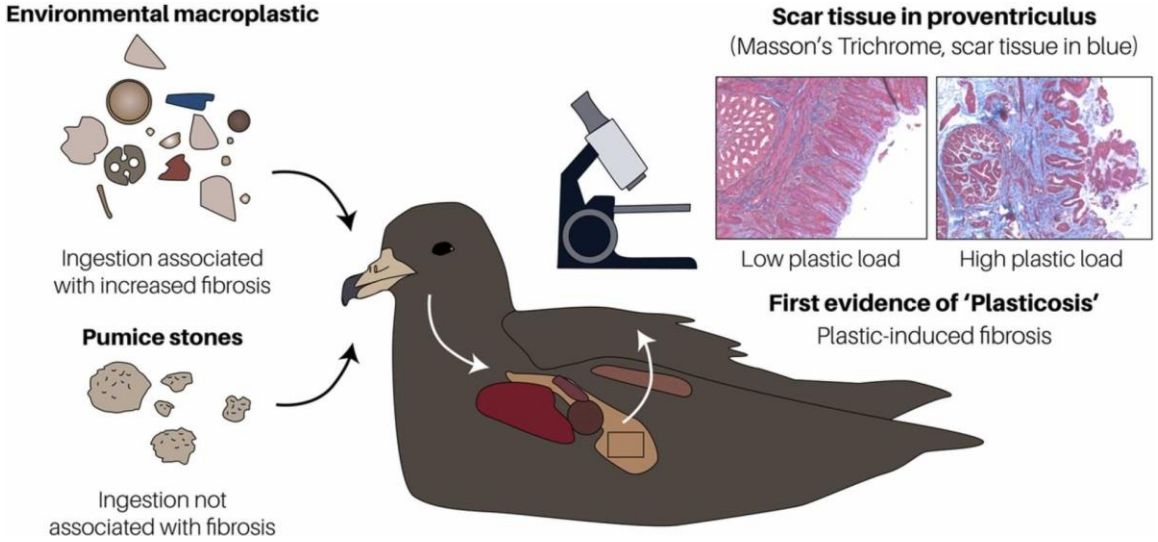
HEALTH 23 May 2024 By CLARE WATSON

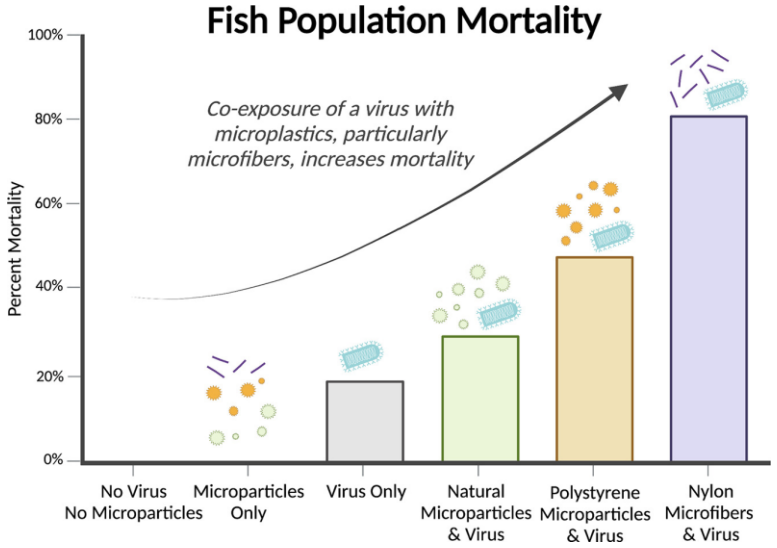
Scientists find about a quarter million invisible microplastic particles in a liter of bottled water

Science Jan 8, 2024 4:38 PM EDT

CONCERN – IMPACTS ON ENVIRONMENT & BIODIVERSITY

- Contamination (air, water, soil)
- Chemical release & transformation
- Ingestion and inhalation
  - Toxicity
  - Physical lacerations
  - Dietary dilution
  - Decreased reproductive health
  - Increased severity of infections
- Climate Change
- Transport
  - Invasive species
  - Viruses and pathogens
- Microbial growth and community dynamics

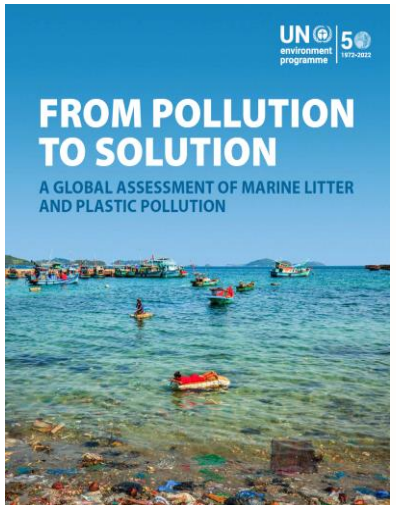


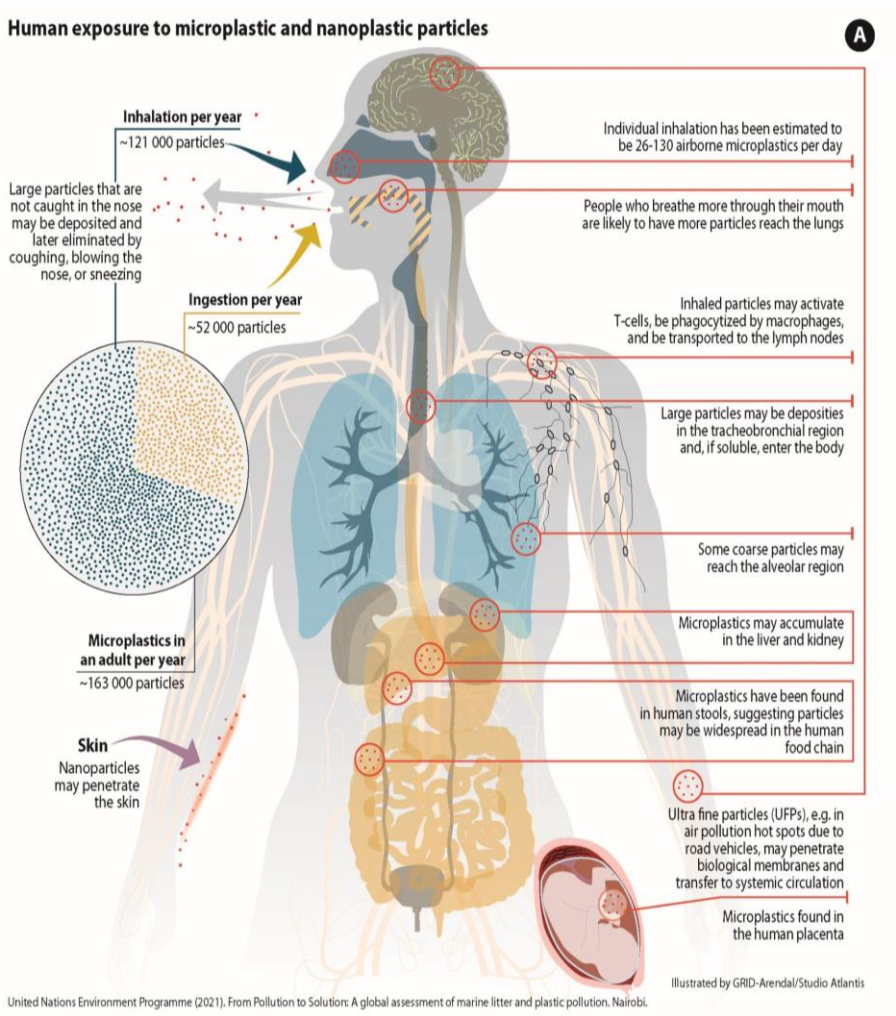


SLIDE CREDIT: IMARI WALKER-FRANKLIN

CONCERN- IMPACTS ON HUMAN HEALTH

- Microplastics found in human organs, placentas (can cross cell barriers too)
- Major exposure pathways:
  - Inhaling airborne particles
  - Ingesting contaminated food and drink
- 3 processes for health impact:
  - Physical impact to organ
  - Toxicity from infection, disruption of gut microbiota
  - Direct toxic effects from chemicals





CONCERN – IMPACTS ON VULNERABLE COMMUNITIES

- **Disproportionate exposure:** higher microplastic exposures due to proximity to pollution sources and limited access to clean water and air
- **Increased Health Risks:** Pre-existing conditions and limited healthcare access make these communities more vulnerable to adverse effects of microplastics

STATE OF THE SCIENCE & RESEARCH NEEDS - ENVIRONMENTAL

"…while ecological risks are very rare at present for nano- and microplastics (NMPs), there are at least some locations in coastal waters and sediments where ecological risks might currently exist."

"…a lot is already known about [NMPs], but some of the evidence remains uncertain and it is by its nature, complex (for instance, differences in size, shape, chemical additives, concentrations, measurements, fates, unknowns, human factors…)"

"…there is a need for improved quality and international harmonization of the methods used to assess exposure, fates and effects of NMPs on biota and humans."

SAPEA, Science Advice for Policy by European Academies, 2019

STATE OF THE SCIENCE & RESEARCH NEEDS - ENVIRONMENTAL

2022

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Applying next-generation science to aquatic ecosystems management

A PUBLIC AGENCY

RESEARCH Open Access

Risk-based management framework for microplastics in aquatic ecosystems

Alvine C. Mehinto[1*], Scott Coffin[2], Albert A. Koelmans[3], Susanne M. Brander[4], Martin Wagner[5], Leah M. Thornton Hampton[1], Allen G. Burton Jr[6], Ezra Miller[7], Todd Gouin[8], Stephen B. Weisberg[1] and Chelsea M. Rochman[9]

Derived thresholds values for two effects mechanisms:

- Food dilution & tissue translocation

<u>High confidence</u>

- Management framework & analytical approach

<u>Relatively low confidence</u>

- Derived thresholds values

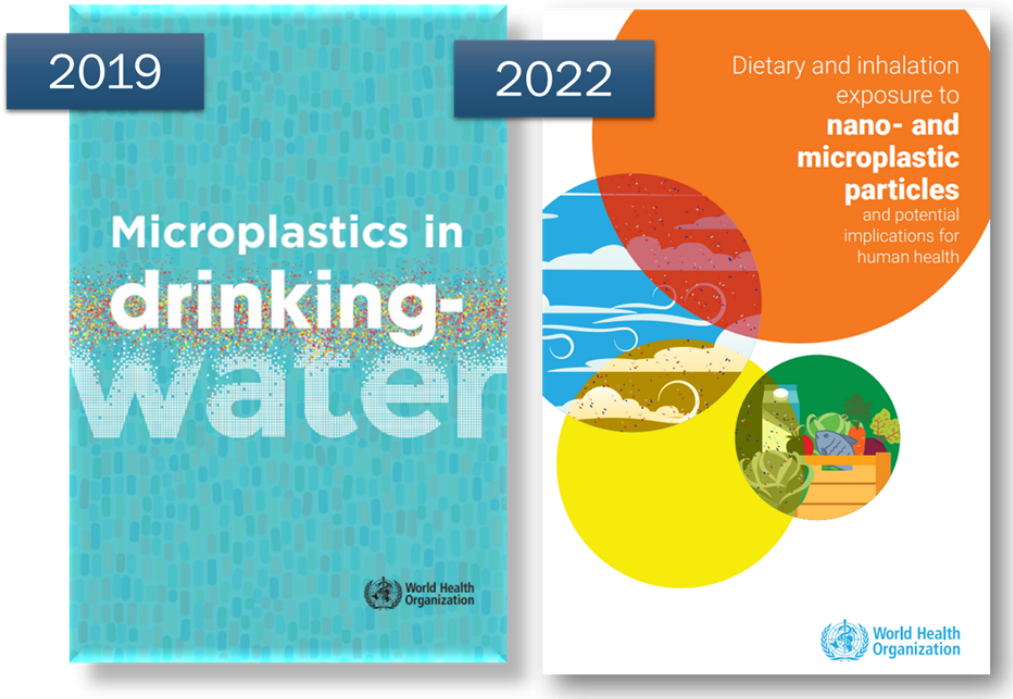
PERSPECTIVE Open Access

Research recommendations to better understand the potential health impacts of microplastics to humans and aquatic ecosystems

Leah M. Thornton Hampton[1*], Hans Bouwmeester[2], Susanne M. Brander[3], Scott Coffin[4], Matthew Cole[5], Ludovic Hermabessiere[6], Alvine C. Mehinto[1], Ezra Miller[7], Chelsea M. Rochman[6] and Stephen B. Weisberg[1]

- Particle characterization
- Particle selection for hazard ID
- High quality toxicity tests – aquatic & sediment
- Understanding of ecologically relevant adverse effects

HUMAN HEALTH - STATE OF THE SCIENCE



World Health Organization

"The weight of the scientific evidence provided by current data on adverse effects of NMP on human health is low, because of substantial limitations of the available information."

HUMAN HEALTH - STATE OF THE SCIENCE

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Applying next-generation science to aquatic ecosystems management

A PUBLIC AGENCY

2022

Microplastics and Nanoplastics

RESEARCH Open Access

Development and application of a health-based framework for informing regulatory action in relation to exposure of microplastic particles in California drinking water

Scott Coffin[1*], Hans Bouwmeester[2], Susanne Brander[3], Pauliina Damdimopoulou[4], Todd Gouin[5], Ludovic Hermabessiere[6], Elaine Khan[7], Albert A. Koelmans[8], Christine L. Lemieux[9], Katja Teerds[10], Martin Wagner[11], Stephen B. Weisberg[12] and Stephanie Wright[13]

"…it was not possible to extrapolate a human–health-based threshold value for microplastics, which is largely due to concerns regarding the relative quality and reliability of current data, but also due to the inability to extrapolate data from studies using monodisperse plastic particles, such as polystyrene spheres to an environmentally relevant exposure of microplastics."

HUMAN HEALTH - STATE OF THE SCIENCE

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Applying next-generation science to aquatic ecosystems management

A PUBLIC AGENCY

2022

Microplastics and Nanoplastics

RESEARCH Open Access

Developr
of a healt
regulator
of microp
water

Scott Coffin[1*], Hans B
Ludovic Hermabessi
Martin Wagner[11], Ste

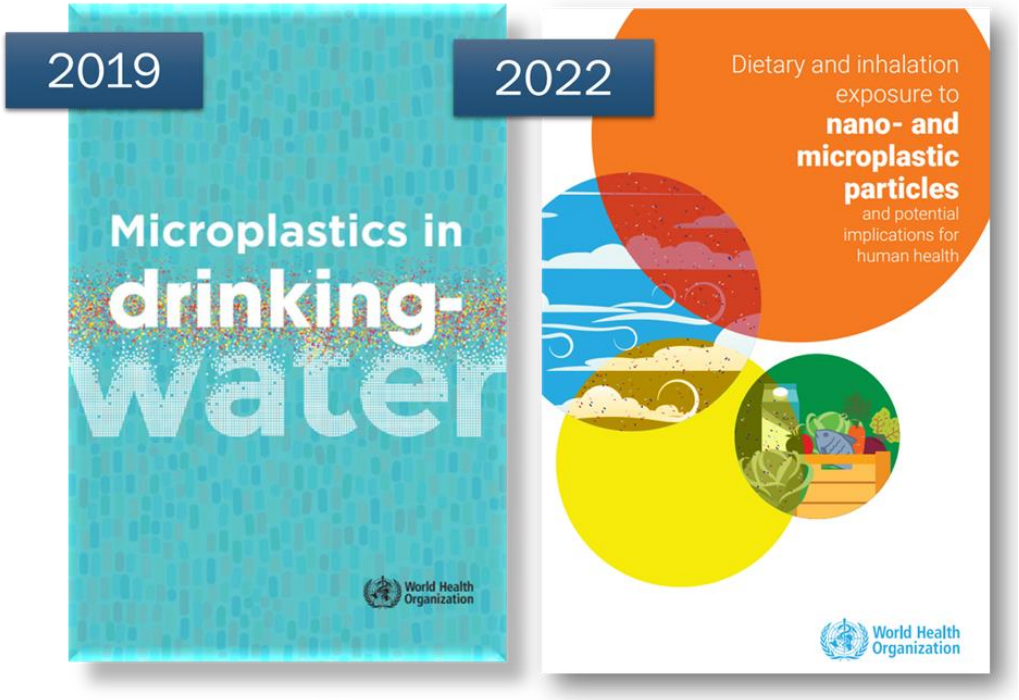
"...it was not possible to extrapolate a human–health-based threshold value for microplastics, which is largely due to concerns regarding liability of to the ta from se plastic ene tally relevant exposure of microplastics."

2024

"Current scientific evidence does not demonstrate that levels of microplastics or nanoplastics detected in foods pose a risk to human health."

FDA, 2024. Microplastics and Nanoplastics in food. https://www.fda.gov/food/environmental-contaminants-food/microplastics-and-nanoplastics-foods

HUMAN HEALTH - RESEARCH NEEDS



World Health Organization

- Particle characterization: toxicology studies, monitoring studies, reference standards
- Uptake and fate: inhaled and ingested MPs
- Toxicology studies
  - Quality-assured and suitable for risk assessment
  - Exposures characterized
- Sampling & analysis standard methods: air, water, food, & beverages

HUMAN HEALTH - RESEARCH NEEDS

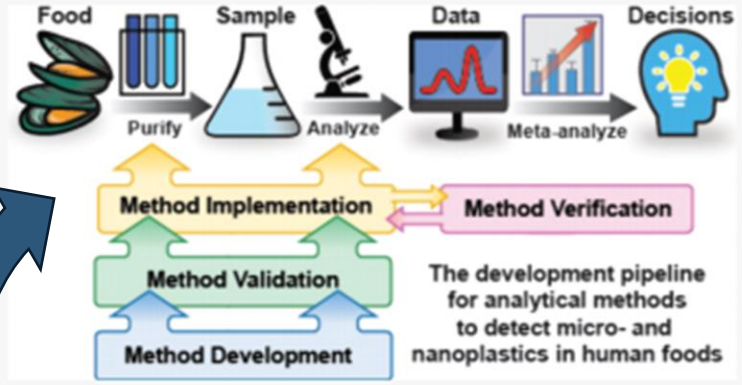
Regulatory Science Perspective on the Analysis of Microplastics and Nanoplastics in Human Food

Timothy V. Duncan,* Sadia Afrin Khan, Anil K. Patri, and Stacey Wiggins*

Cite This: *Anal. Chem.* 2024, 96, 4343–4358 Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: Microplastics are increasingly reported, not only in the environment but also in a wide range of food commodities. While studies on microplastics in food abound, the current state of science is limited in its application to regulatory risk assessment by a continued lack of standardized definitions, reference materials, sample collection and preparation procedures, fit-for purpose analytical methods for real-world and environmentally relevant plastic mixtures, and appropriate quality controls. This is particularly the case for nanoplastics. Thes methodological challenges hinder robust, quantitative exposure asses ments of microplastic and nanoplastic mixtures from food consumptio



terization: toxicology
oring studies, reference

te: inhaled and ingested

dies

ured and suitable for
ment

characterized

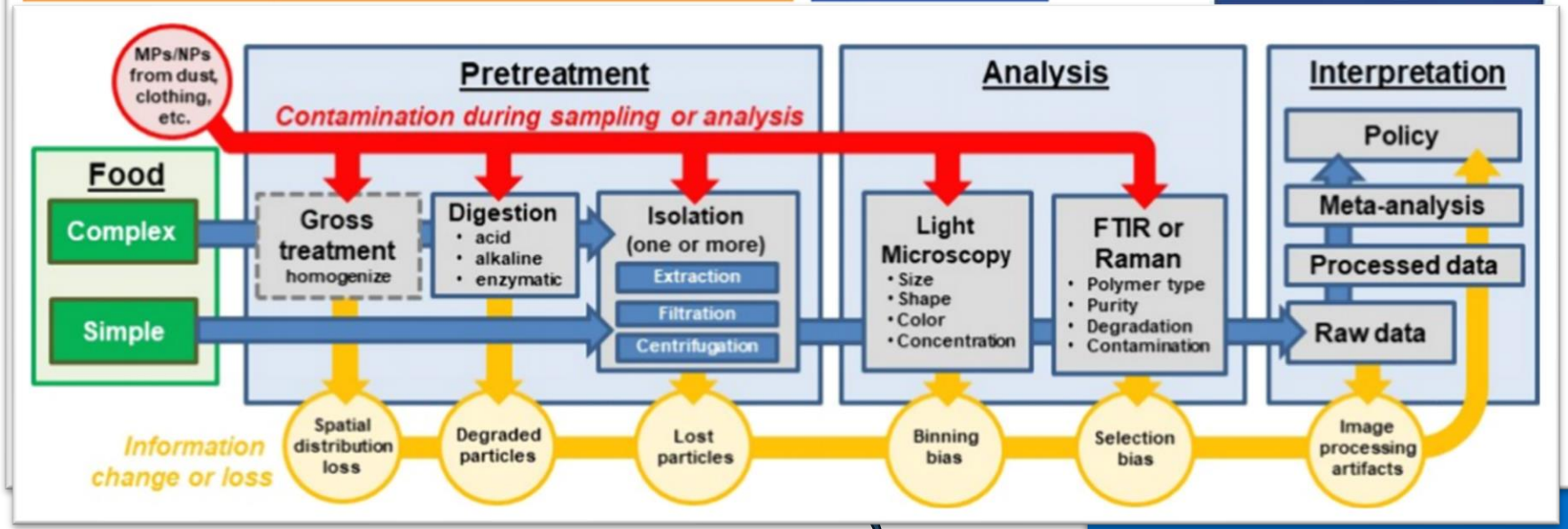
- Sampling & analysis standard methods: air, water, food, & beverages

HUMAN HEALTH - RESEARCH NEEDS

Regulatory Science Perspective on the Analysis of Microplastics and Nanoplastics in Human Food

Timothy V. Duncan,* Sadia Afrin Khan, Anil K. Patri, and Stacey Wiggins*

Cite This: *Anal. Chem.* 2024, 96, 4343–4358 Read Online



terization: toxicology
oring studies, reference

te: inhaled and ingested

dies

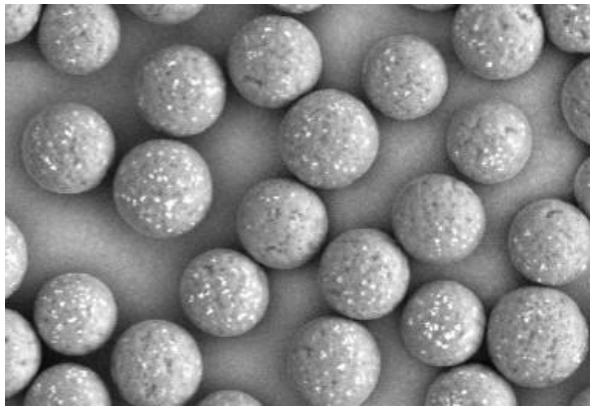
ured and suitable for
ment

characterized

- Sampling & analysis standard methods: air, water, food, & beverages

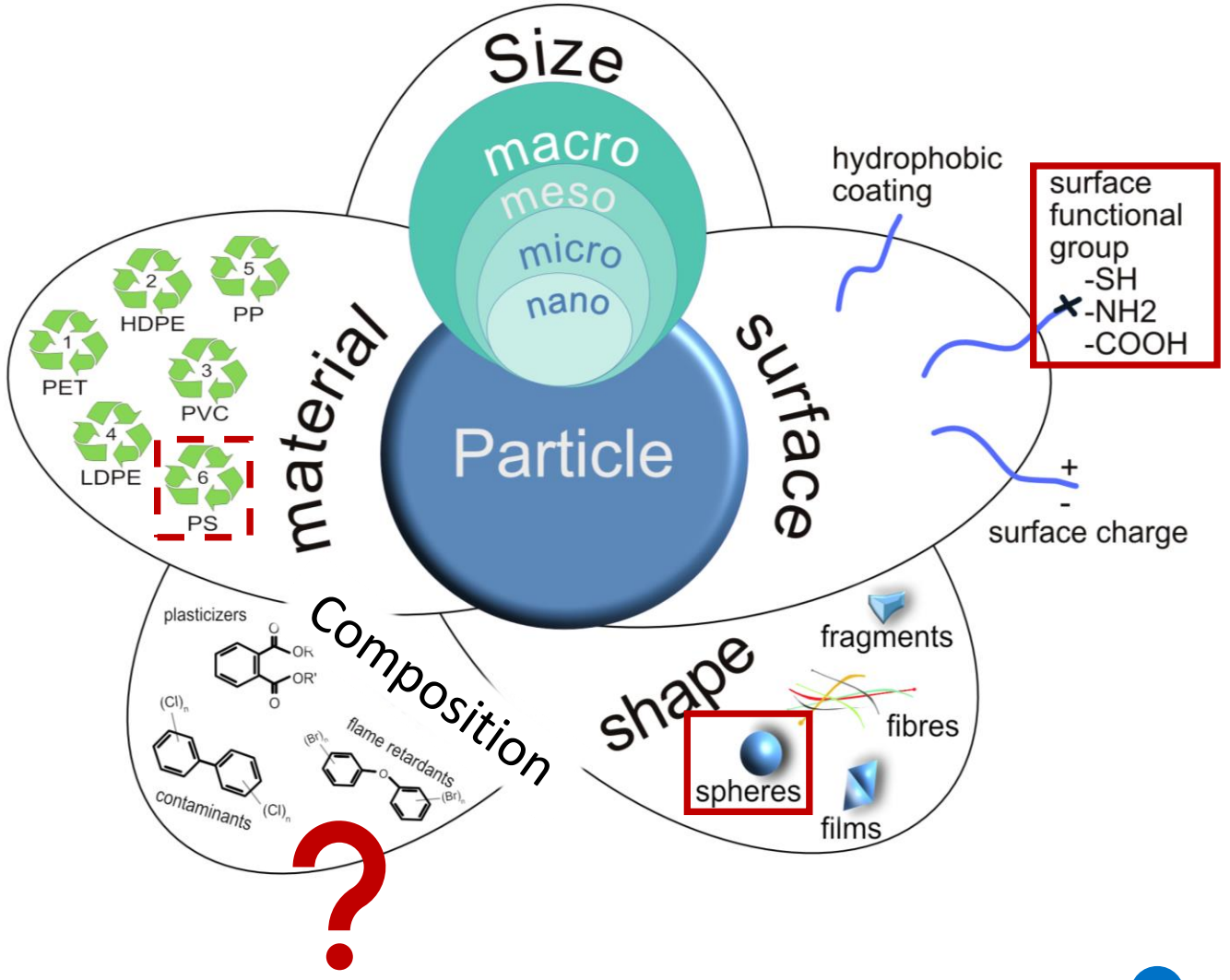
CURRENT MICROPLASTIC TEST MATERIALS ARE INSUFFICIENTLY REPRESENTATIVE

MOST COMMON MICROPLASTIC IN TOXICOLOGY STUDIES



Pre-formed purchased Polystyrene

≠



Adapted from WHO, 2022

CURRENT MICROPLASTIC TEST MATERIALS ARE INSUFFICIENTLY REPRESENTATIVE

MO
MICR
TOXICO

Pre-fo
P

Representative test materials needed to answer questions of health effects and risk of exposure with relevant data.

obic

surface functional group
-SH
-NH2
-COOH

+
-
surface charge

022

WHAT IS BEING DONE TO CLOSE SCIENTIFIC GAPS

CUSP
POLYRISK
PlasticsFatE
IMP TOX
AURORA
plasticheal

source: EU Horizon 2020

PAPILLONS HORIZON 2020

source: EU Horizon 2020

MOMENTUM Microplastics and Human Health Consortium

source: ZonMw

cornet microplastic@food
Method development for the qualitative and quantitative detection of microplastics in foods, causation and preventive measures
ofi IVLV eco plus UNIVERSITÄT BAYREUTH ipf

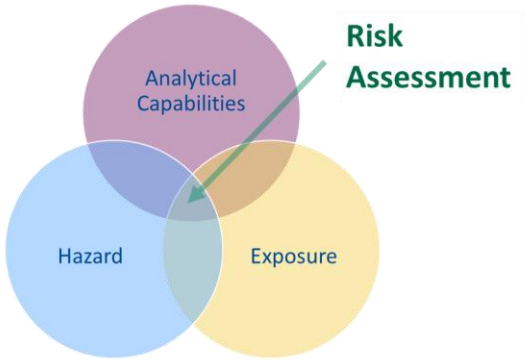
source: ecoplus

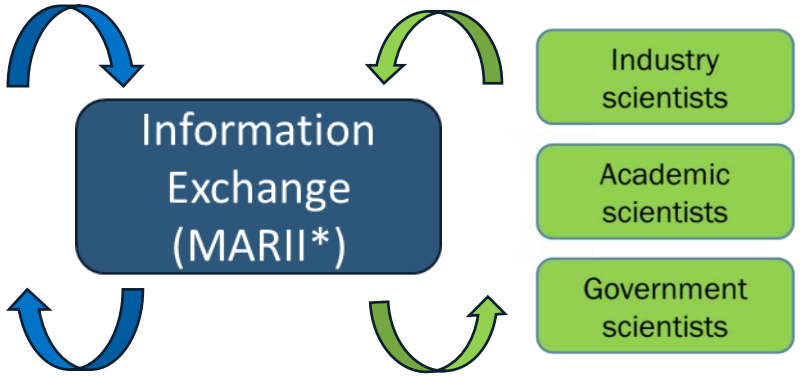
ETC.

INDUSTRY EFFORTS

International Council of Chemical Associations (ICCA)

American Chemistry Council
cefic
PLASTICS EUROPE Enabling a sustainable future
JCIA





http://plasticscircularity.org/microplastics/

https://plasticscircularity.org/additives/#subsequent

*Microplastics Advanced Research and Innovation Initiative (MARII)

WHAT IS BEING DONE TO CLOSE SCIENTIFIC GAPS

CUSP
POLYRISK
PlasticsFatE
IMP TOX
AURORA
plasticheal

source: EU Horizon 2020

MOMENTUM Microplastics and Human Health Consortium

source: ZonMw

PAPILLONS HORIZON 2020

source: EU Horizon 2020

cornet
microplastic@food
Method development for the qualitative and quantitative detection of microplastics in foods, causation and preventive measures
ofi IVLV eco plus UNIVERSITÄT BAYREUTH ipf

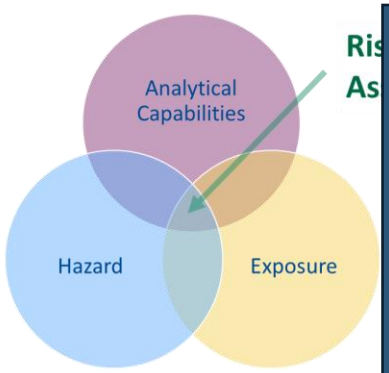
source: ecoplus

ETC.

INDUSTRY EFFORTS

ICCA International Council of Chemical Associations

American Chemistry Council
cefic
PLASTICS EUROPE Enabling a sustainable future
JCIA



Preventing pellet loss

Operation Clean Sweep

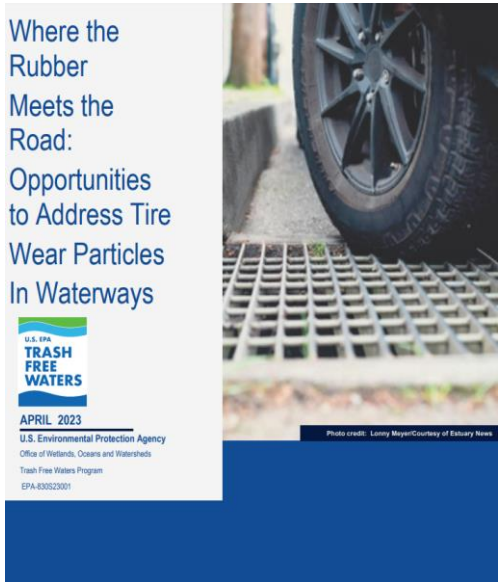
http://plasticscircularity.org/microplastics/

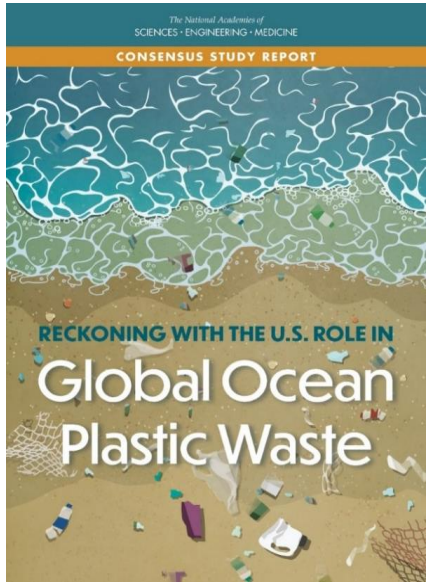
https://plasticscircularity.org/additives/#subsequent

*Microplastics Advanced Research and Innovation Initiative (MARII)

HOW ARE U.S., OTHER GOVERNMENTS ADDRESSING THE ISSUE?

GOVERNMENT REPORTS PROVIDE INSIGHTS, DIRECTION





HOW ARE U.S., OTHER GOVERNMENTS ADDRESSING THE ISSUE?

- **Europe** and **California** have enacted the majority of laws: initial focus on banning microbeads in cosmetics
- U.S. **Microbead-Free Waters Act** prohibits the manufacturing, packaging, and distribution of rinse-off cosmetics containing plastic microbeads
- Ongoing government action (local to national) focuses on research, measurement, and prevention/mitigation (e.g. filtration devices on washing machines)

HOW ARE U.S., OTHER GOVERNMENTS ADDRESSING THE ISSUE?

IN THE U.S.: CALIFORNIA LEADING THE WAY

- First-ever comprehensive microplastics strategy in the nation
- Identifies early actions and research priorities to reduce microplastic pollution

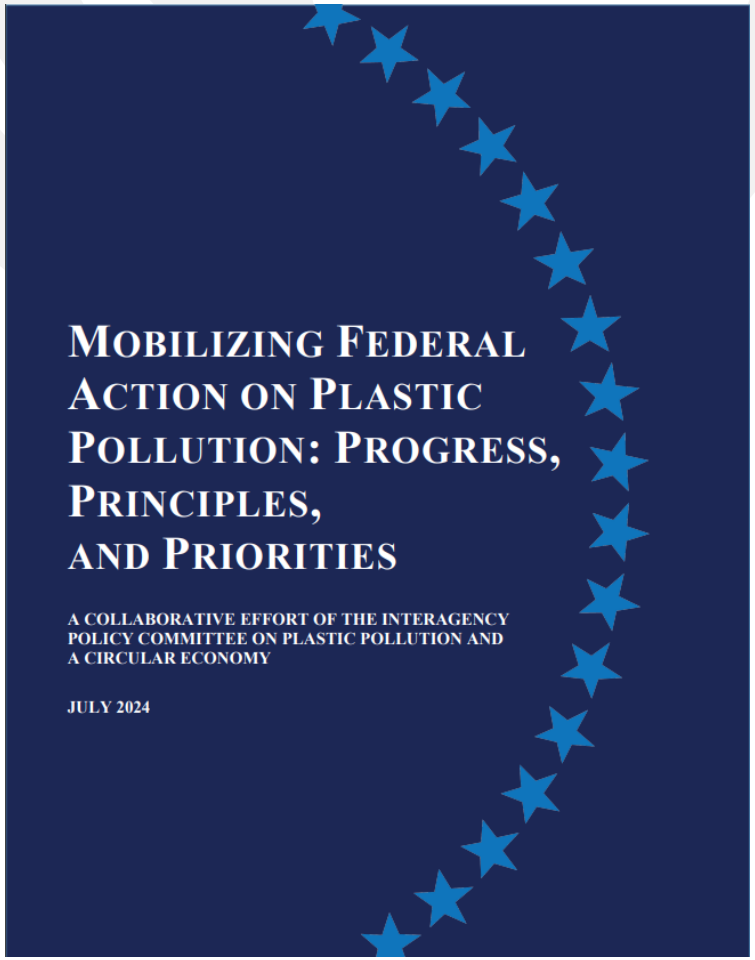
- Provides guidance for addressing microplastic pollution in California's marine environments and assessing the risk to marine ecosystems, marine animals and humans

- World's first requirements for testing microplastics in drinking water sources
- Up to 30 of the CA's largest water providers are ordered to start quartely testing for two years

HOW IS THE U.S. ADDRESSING THE ISSUE?

JULY 2024: FIRST U.S. FEDERAL PLASTIC STRATEGY

- Responds to top recommendation of NASEM *Reckoning with the U.S. Role in Global Ocean Plastic Waste* report
- Identifies current federal action and *potential actions* at every stage of plastic lifecycle
- **Microplastic focus: research, monitoring; *exploring reducing harmful emissions from plastic production***
- Administration also sets new goal to phase out federal procurement of single-use plastics
  - From food service operations, events, and packaging by **2027**
  - From all federal operations by **2035**



U.S. FEDERAL AGENCIES' WORK ON MICROPLASTICS

MICROPLASTICS & HEALTH

CDC

FDA

NIH NIEHS

MICROPLASTIC MATERIALS, TECHNOLOGIES, AND MEASUREMENT

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES · OFFICE OF SCIENCE AND TECHNOLOGY POLICY

NIST

NSF

NOAA

MICROPLASTICS PREVENTION & CLEAN-UP

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NOAA

MOVING FORWARD: A GLOBAL PLASTIC TREATY

- **Last negotiating meeting is November 25-December 1 in Busan, Republic of Korea**
- Intersessional work now is focusing on chemicals and products of concern.
- Member states are concerned about health impacts of plastics and microplastics.
- A key focus is reducing production of certain harmful plastics and chemical additives.
- Microplastics are currently included in the treaty but scope and measures not yet clear.

[3 *bis alt.* Micro- and [nanoplastics]] (proposed placement: move to Provision 8)

[Option 0

***No provision.*]**

[Option 1]

[[1. Each party [is encouraged] [or Parties] [shall] [take effective measures] [shall endeavour] to promote research [, within its capacities and considering national circumstances] on [scale and scope] of [leakage of [intentionally added] micro and [nanoplastics]] [micro plastic pollution] across the [entire] lifecycle of [plastics] [plastic products] and their impacts on all ecosystems, [biodiversity, food chains] and human health.]

[2. Each party [shall take measures] [shall endeavour] [to promote transparency] and reduce [[emissions] of both intentionally added microplastic ingredients [and all forms of] [and unintentional] releases] of microplastics] [microplastic pollution]].

[*OP2 bis.* Each party shall take necessary measures to minimize current and future health and environmental impacts of micro- and nanoplastics guided by science.]

[3. Parties [shall] [are encouraged to based on national circumstances [to promote national organizational arrangements for establishment of national centres] and capabilities] establish [regional centres] [national centres] of excellence to monitor and report on leakage [and dispersal] of microplastics in land, water, air and in [living organisms] [biota].]

[4. The dedicated fund established under this treaty shall provide resources to establish infrastructure[,] to promote research on [micro and [nanoplastics]] [microplastic pollution].] (proposed placement: to be moved to Part III)

CONCLUSIONS


- Microplastics, as a subset of microparticles, are a global challenge due to their ubiquitous environmental presence and resistance to degradation.
- Increasingly there are questions if microplastics cause human health-relevant effects.
- Additional science is needed to help us better understand sources in the environment and potential for exposure and health effects.
- Development and adoption of standardized methods and relevant materials to ensure quality data from research projects can be compared, replicated and fully utilized.
- Filling scientific gaps with data of sufficient quality for environmental and human health risk assessments is needed, especially for policy makers.
- Regulatory criteria for action may differ based on legislative or administrative authorities.

PATH FORWARD


- Prevent plastic environmental pollution using existing and innovative sustainable approaches
  - Sector- and compartment-specific solutions may be needed
  - Avoid regrettable substitutions or regrettable approaches

- Collaboration is key
  - **Between subject matter experts:**
    - Analytical (all possible exposure types), Polymer chemistry, Particle science, Toxicologists, Environmental fate, Environmental health, Biomonitoring, Medical
  - **Between stakeholder groups:**
    - Academics, Government, Industry (full value chain), NGOs, Consumers, Etc.

- Prioritize and fund this needed science (as we have seen other countries do)

THANK YOU

Margaret Spring: mspring@mbayaq.org

Robert Ellis-Hutchings: rellis-hutchings@dow.com