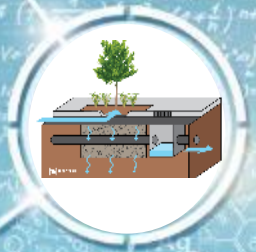


TETRA TECH

Standardization of Terminology Recommendations for Microplastic Ecological Risk Assessments in the Chesapeake Bay and its Watershed

PPAT Meeting

November 9, 2020

Jennifer Flippin and Bob Murphy, Tetra Tech

Background

Recommendation from April 2019

STAC should undertake a technical review of terminology used in microplastic research, specifically size classification and concentration units, and recommend uniform terminology for the CBP partners to utilize in monitoring and studies focused on plastic pollution in the bay and watershed.

Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals

STAC Workshop Report
April 24-25, 2019
Woodbridge, VA

STAC Publication 19-006

Purpose

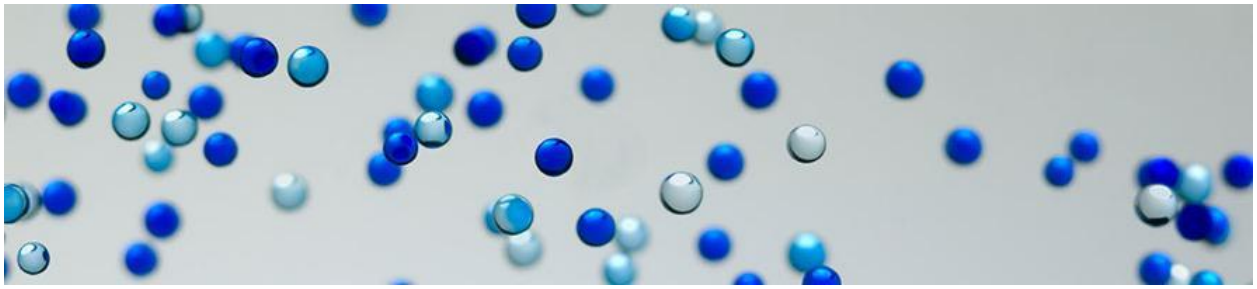
- Describe and recommend a uniform size classification and concentration unit terminology for microplastics
  - Apply terms to the parallel effort to develop an environmental risk assessment (ERA) framework
  - Eventual monitoring plan for microplastics in the tidal Potomac River

Part 1: Size Classification

Broad Categories of Microplastics

- **Primary Microplastics**
  - Deliberately manufactured as small pieces of plastic
  - Examples: Microbeads used for exfoliation in personal care products; abrasives for air blasting; pre-production plastic pellets

https://marinedebris.noaa.gov/



https://www.environment.gov.au/protection/waste-resource-recovery/plastics-and-packaging/plastic-microbeads

Broad Categories of Microplastics

- **Secondary Microplastics**
  - Larger plastic products broken into smaller pieces by environmental degradation
  - Examples: Pieces of plastic cups, bags, bottles.

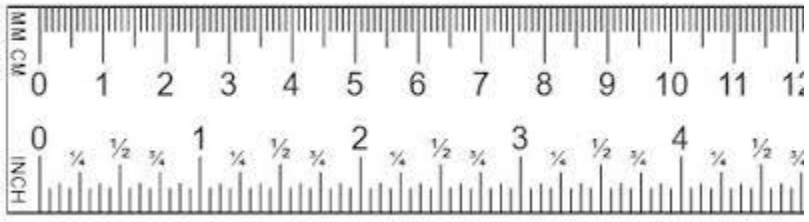
Photo: http://blogs.ifas.ufl.edu/lakeco/2017/09/17/microplastics-whats-big-deal/

https://marinedebris.noaa.gov/

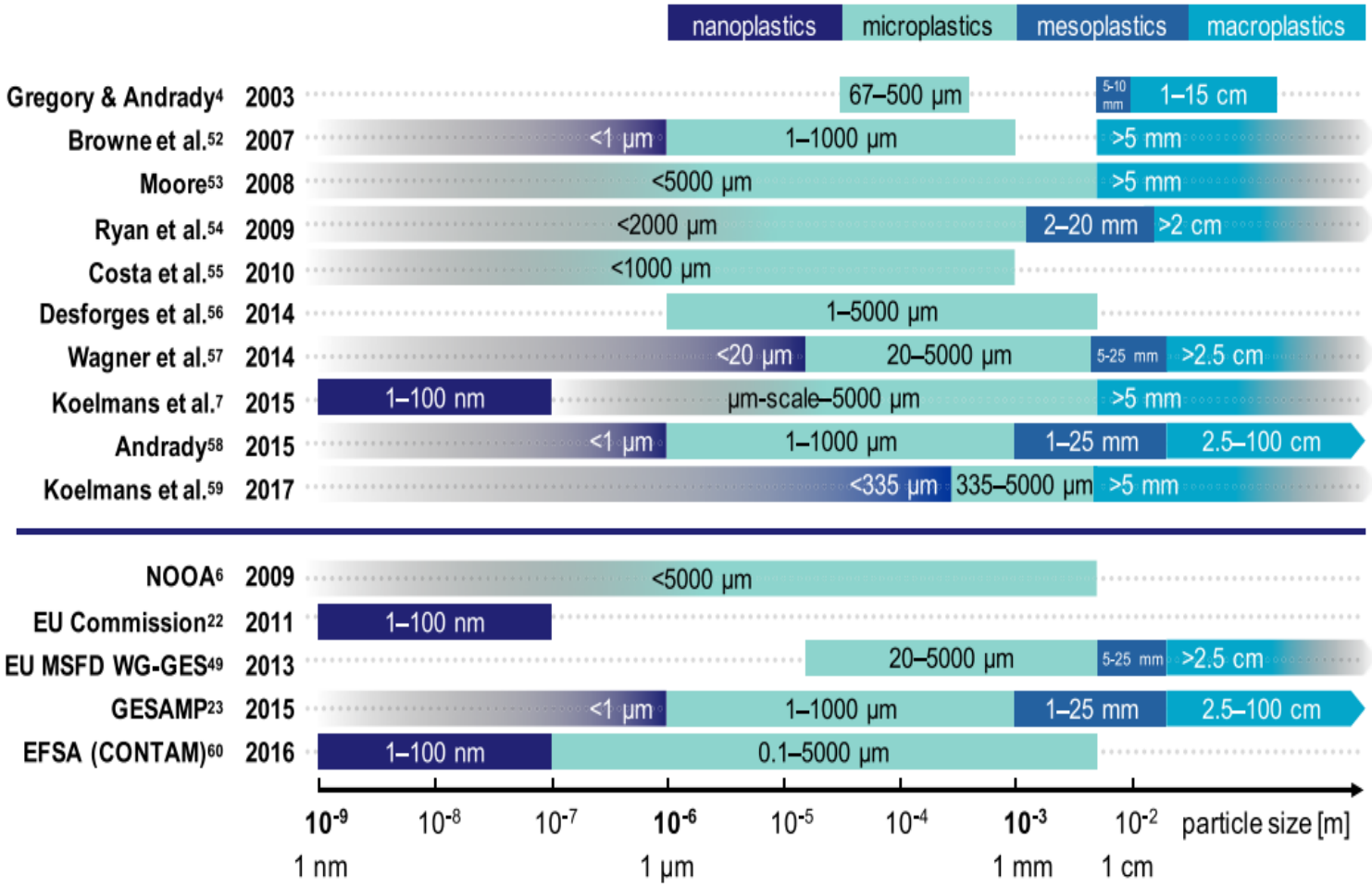
Classification of Microplastics

- Size, shape, density, composition, color, age, or a combination of several of these factors are frequent classifiers.

- Size classification is not yet consistent
  - ***Microplastics*** have been defined as 67-500 µm, 1-5000 µm, 20-5000 µm, or more broadly as <5,000 µm (the definition supported by NOAA).
  - ***Nanoplastics*** have included sizes ranging from an upper limit of <20 µm to as small as 1nm.



Classification of Microplastics



Hartmann et al 2019.

Classification of Microplastics

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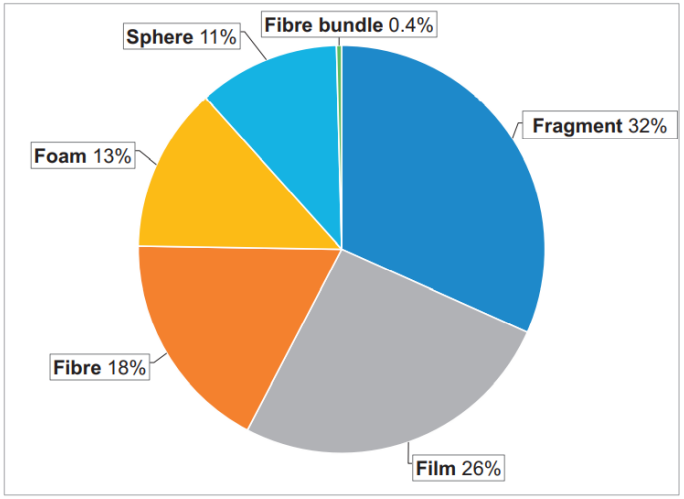

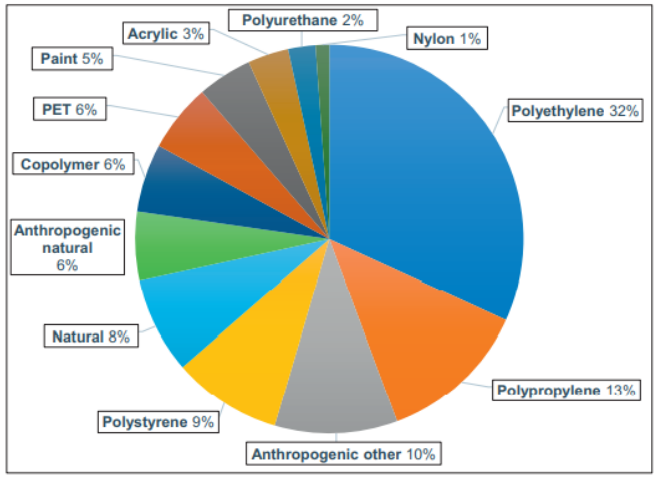

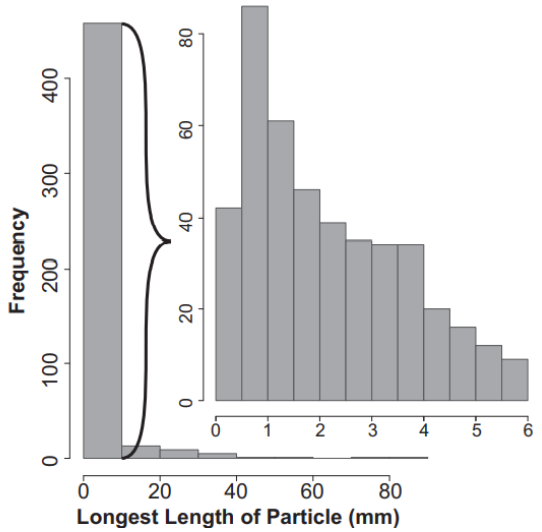

Examples of plastic classifications in the Chesapeake Bay
Bikker et al 2020

Size Classification

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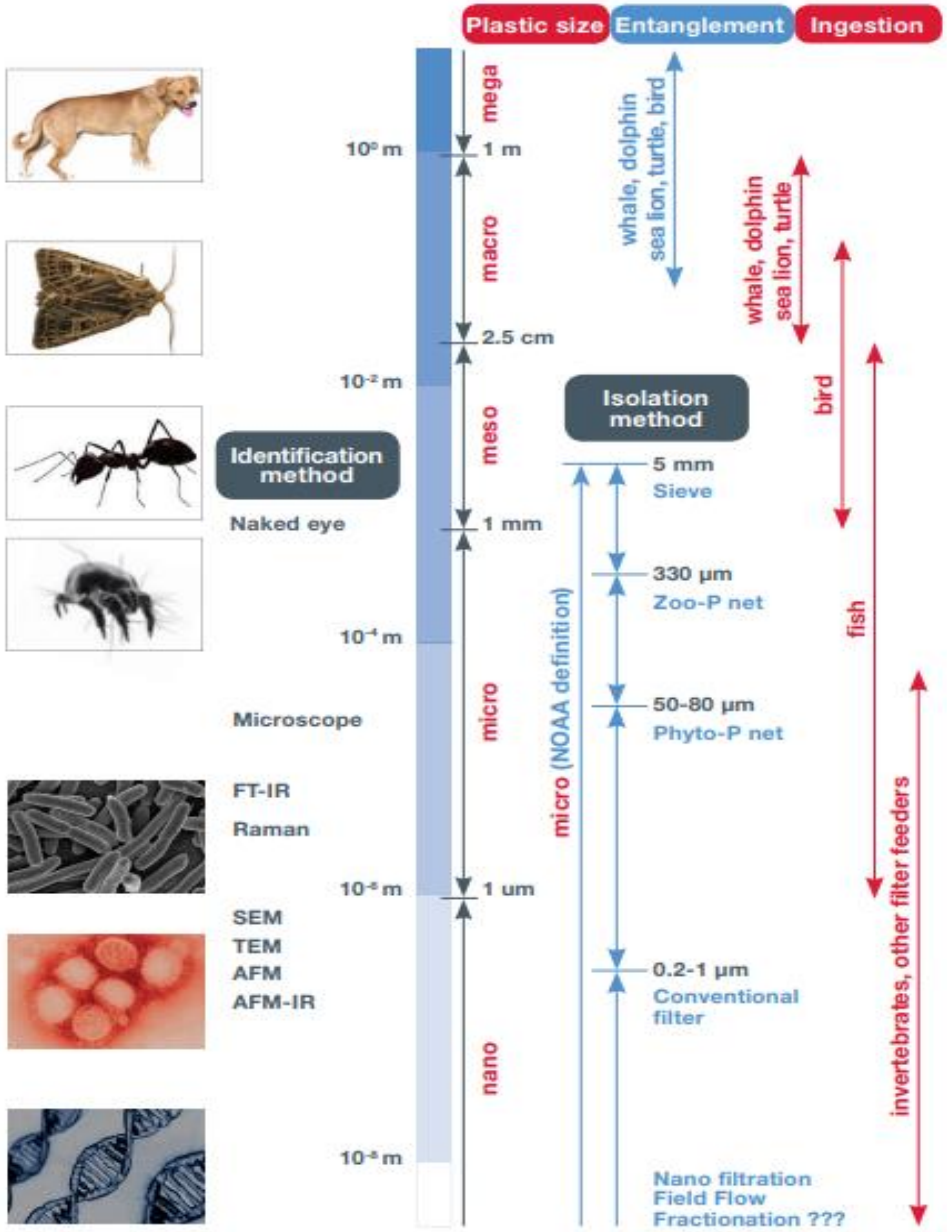
Most schemes to classify are influenced by the desire to capture

1) **Biological relevance of plastic pieces**
   - Ingestion
   - Passage across cell walls

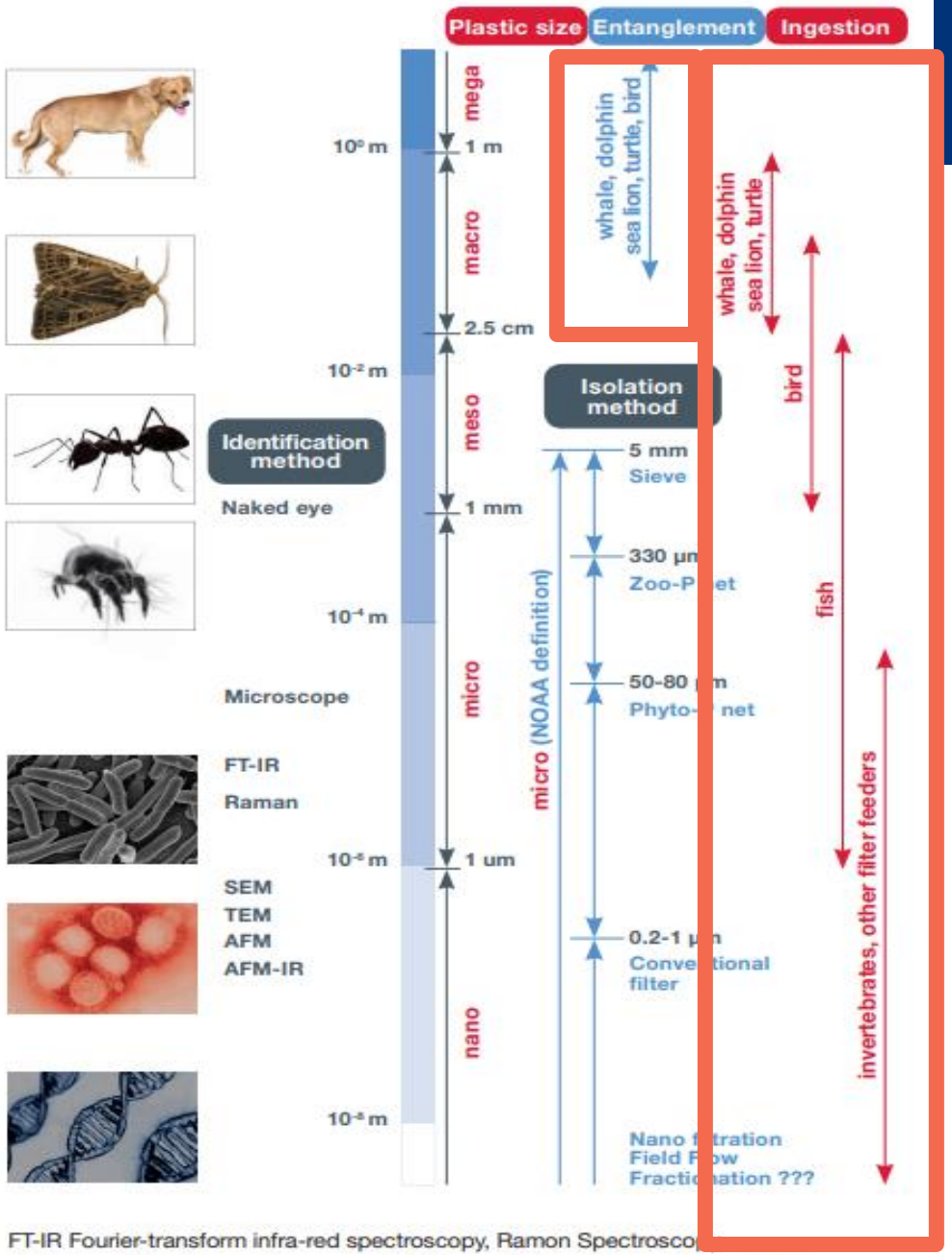
2) **Limitations to capture or detect plastics**
   - Sampling
   - Analytical

3) **A scientifically consistent naming framework**
   - Consistent with SI naming convention



FT-IR Fourier-transform infra-red spectroscopy, Ramon Spectroscopy,
SEM scanning electron microscopy, TEM transmission electron microscopy,
AFM atomic force microscopy, AFM with IR

GESAMP



FT-IR Fourier-transform infra-red spectroscopy, Ramon Spectrosco
SEM scanning electron microscopy, TEM transmission electron microscopy,
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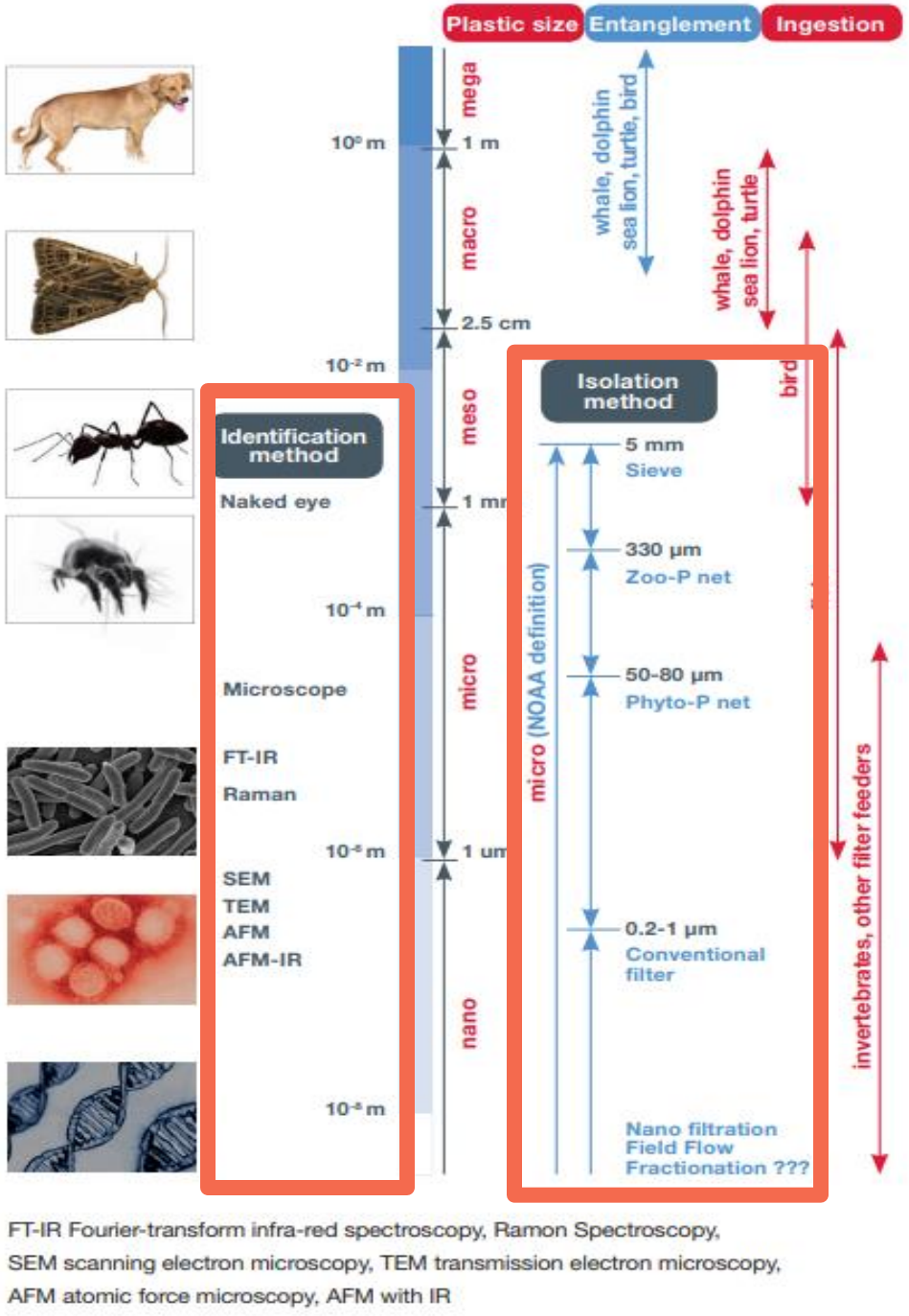
Biological Relevance of Plastics by Size

GESAMP



FT-IR Fourier-transform infra-red spectroscopy, Ramon Spectroscopy, SEM scanning electron microscopy, TEM transmission electron microscopy, AFM atomic force microscopy, AFM with IR

Sampling and Analytical Considerations Size

GESAMP

Classification of Microplastics

- NOAA
  - <5mm in length
  - Most likely ingested by animals and potential for adverse biological effects beyond physical GI blockage
  - Lower boundary not defined
    - 333 µm is a practical lower boundary due to sampling equipment limitations (zooplankton nets)

Classification of Microplastics

- Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

Terminology	Size Classification
Megaplastics	>1 m
Macroplastics	25-1000 mm
Mesoplastics	5-25 mm
Microplastics	<5 mm
Nanoplastics	<1 µm

Recommended inclusion of <5mm because lower cutoff might exclude data from pertinent published studies

Classification of Microplastics

Feature

Cite This: *Environ. Sci. Technol.* 2019, 53, 1039−1047

pubs.acs.org/est

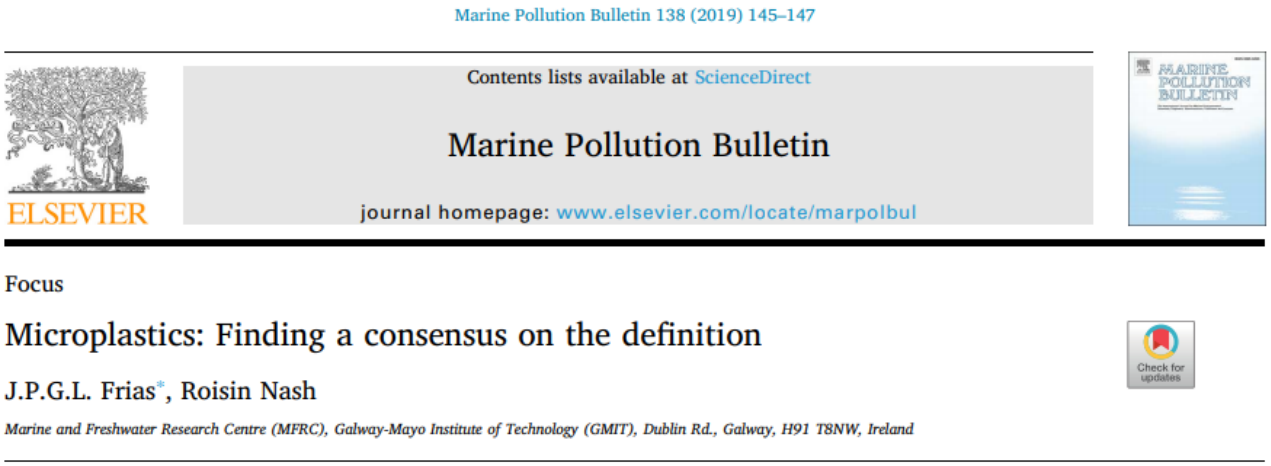
Are We Speaking the Same Language? Recommendations for a Definition and Categorization Framework for Plastic Debris

Nanna B. Hartmann,[*,†] Thorsten Hüffer,[*,‡] Richard C. Thompson,[§] Martin Hassellöv,[∥] Anja Verschoor,[⊥] Anders E. Daugaard,[#] Sinja Rist,[†] Therese Karlsson,[∥] Nicole Brennholt,[¶] Matthew Cole,[▽] Maria P. Herrling,[○] Maren C. Hess,[◆] Natalia P. Ivleva,[◇] Amy L. Lusher,[▲] and Martin Wagner[*,▽]

- Hartmann et al. (2019)

Terminology	Size Classification
Macroplastics	1 cm and larger
Mesoplastics	1 to 10 mm
Microplastics	1 to <1000 µm
Nanoplastics	1 to <1000 nm

Classification of Microplastics



Marine Pollution Bulletin 138 (2019) 145–147

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journal homepage: www.elsevier.com/locate/marpolbul

Focus

Microplastics: Finding a consensus on the definition

J.P.G.L. Frias*, Roisin Nash

Marine and Freshwater Research Centre (MFRC), Galway-Mayo Institute of Technology (GMIT), Dublin Rd., Galway, H91 T8NW, Ireland

- Frias and Nash 2019
  - Synthetic solid particle of polymeric matrix, with regular or irregular shape and with size ranging from 1 µm to 5 mm of either primary or secondary manufacturing origin, which are insoluble in water

Nanoplastics Classification

- <1000 nm (Browne 2007, Andrady 2011, Cole et al. 2011)
  - Consistent with SI prefix “nano”
- <100 nm (Koelmans et al. 2015)
  - non-polymer nanomaterials in the field of engineered nanoparticles

Other Considerations for Future Classification or Assessment

TETRA TECH

1) **Chemical composition**

   Ex. PET - Polyethylene terephthalate, PP – Polypropylene, AC – Acrylic, etc.

2) **Shape or Structure**

   Ex. Fibers and lines, foam, beads/spheres, etc.

3) **Color**

   Ex. Clear, translucent, and all colors

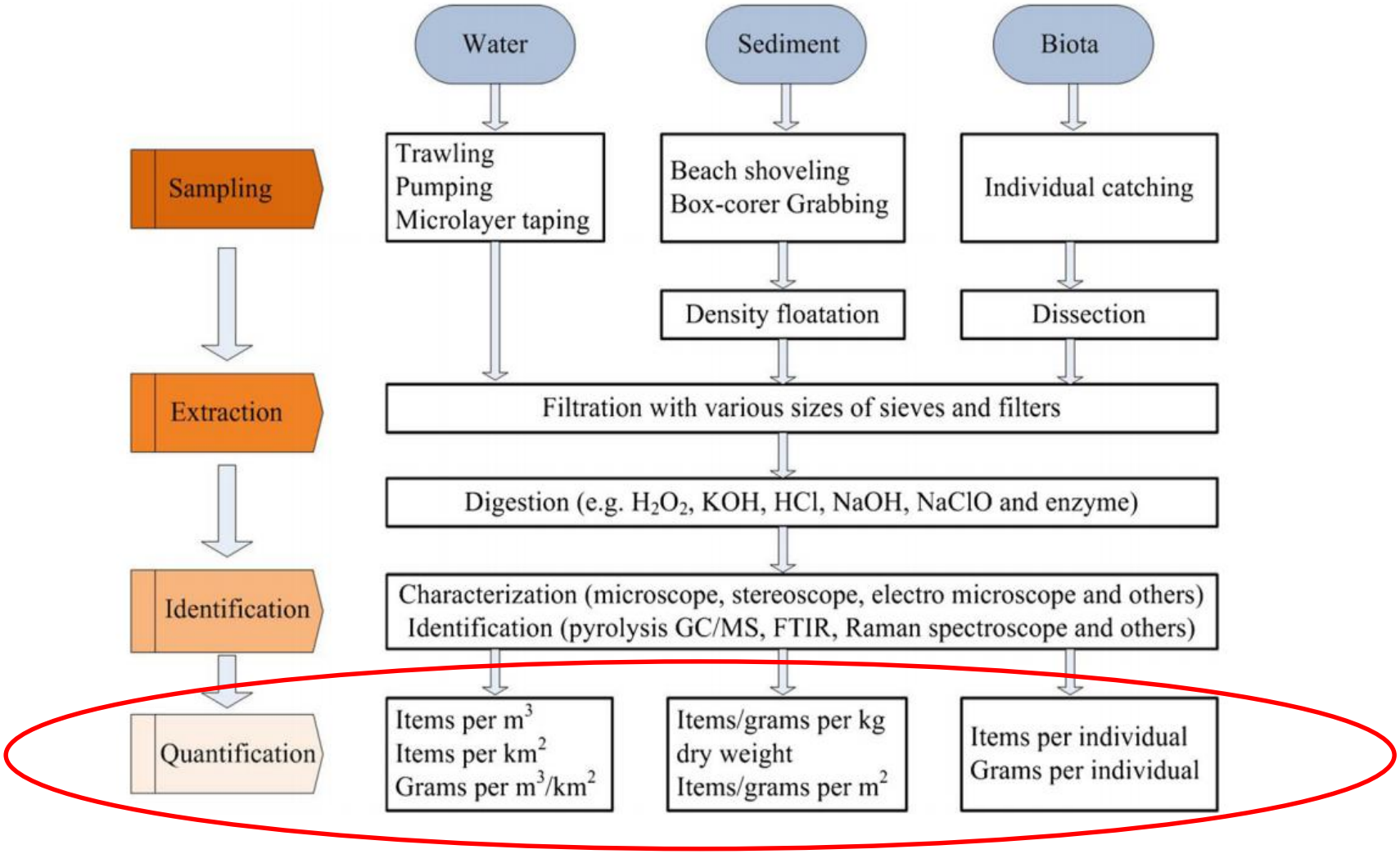
Chemical and physical properties associated with different materials influence the fate, transport, exposure, and biological relevance or toxicity of fragments.

Part 2: Units of Concentration

Concentration Units

- Measurement and reported units tend to vary by
  - **Media Type**
    - Water, sediment, fish, invertebrates, phytoplankton, and plants
  - **Study Design or Objective**
    - Volume, mass, surface area

Concentration Units (continued)



Mai et al., 2018

Water

- **Number of particles per volume of water**
  - *Number of particles m^{-3} ; Number of particles l^{-1}*
  - Quantifies number of plastic particles in water by volume
  - This unit of measurement potentially accounts for particles throughout the water column.
- **Number of particles per area of water**
  - *Number of particles m^{-2}*
  - Quantifies number of plastic particles on the surface area of water.
  - Since water, is more than area (I.e. not two-dimensional), this metric is less informative for understanding the overall amount of microplastics and may exclude particles that are lower density and not at the surface of the water column.

Sediment

- **Number (or mass) of particles per volume of sediment**
  - *Number (or mass) of particles kg^{-1} dry (or wet) weight*
  - Quantifies number of plastic particles in sediment samples and based on dry (or wet) weight of sediment.

- **Number (or mass) of particles per area of sediment**
  - *Number (or mass) of particles m^{-2} sediment surface*
  - Quantifies number of plastic particles on the surface of a quadrate area of sediment.

Organisms

- **Number (or mass) of particles per individual**
  - *Number of particles/individual*
  - Quantifies abundance of plastic particles within a whole individual.

- **Number of stomachs or GI tracts with particles**
  - *Number of organisms within a study in which plastics were found in stomachs or GI tracts*
  - Quantifies abundance of individual stomachs in which plastic particles were observed. An ecological metric that serves as an indicator of selectivity of fish

Organisms

- **Mass (or number) of plastics per stomach or gastrointestinal tract**
  - *Mass of plastics in stomach*
  - Quantifies abundance of plastic particles within stomach contents.
  - *Mass of plastics in GI tract*
  - Quantifies mass of plastic particles within the entire gastrointestinal tract

Organisms (continued)

- **Number (or Mass) of particles per wet (or dry) tissue weight**
  - *Number/Mass of particles g^{-1} wet (or dry) weight*
  - Quantifies number of plastic particles in tissue samples and based on weight of tissue.

The measurement of the number or mass of microplastic relative to body mass of an organism is intrinsically useful as it provides a standardized assessment per individual. Additionally, it allows for comparisons between studies.

Organisms (continued)

- **Number of particles on gill surfaces**
  - *Number of particles/gill surface*
  - Quantifies the number of plastic particles on or in the gill surfaces of an animal.
  - This methodology can potentially serve as a proxy for area of gill surface covered (and may be easier to measure than particle area)

- **Mass of particles on gill surfaces**
  - *Mass of plastics/ gill surface*
  - Quantifies the mass of plastic particles on or in the gill surfaces of an animal.
  - This is biologically informative measurement as gill surface area is critical for sufficient respiration (Avio et al. 2015)

Submerged Aquatic Vegetation

TETRA TECH

- **Number of Particles per Area of Blade/volume of plant canopy**
  - *Number of particles cm^{-2} of plant surface area*
  - Quantifies the number of particles attached to plant surface.
  - Can be used to assess impacts directly to plant health or as pathway for organisms feeding on plant tissue or surface
  - *Number of particles l^{-1} of samples SAV canopy*
  - If comparing the canopy filtration of particles, then a volumetric approach is more robust as one would be comparing # particles per volume of canopy sampled vs nearby similar volume of unvegetated water column

Summary and Recommendations

Summary

- Microplastic classification remains complex and a unified classification/ descriptive system is still young.
- It is not possible to exhaustively consider all chemical and physical properties in the current effort.
- The upper cutoff for microplastics in most contemporary literature or recommendations is either 5mm or 1mm.
  - 5mm has been acknowledged for its biological relevance in terms of potential uptake and is also the upper limit reported by two Chesapeake Bay studies.
  - 1mm (1000 µm) is convention driven and consistent with SI prefix “units tend to vary by type of micro” but not necessarily consistent with results of current research.
- Concentration media investigated but are most generally reported (ex. water, sediment, tissue, etc) as mass/unit volume or particles/unit.

Recommendations– Size

- For the purposes of the ERA we recommend defining a microplastic as <5mm, as consistent with the recommendations of NOAA, GESAMP, Frias and Nash (2019) to ensure that data from pertinent published studies are included.

- Two microplastic monitoring studies in the Chesapeake Bay and tributaries were consistent in reporting results with 5 mm as the upper cutoff (Bikker et al. 2020, Yonkos et al., 2014).

- 1 mm is a more clear-cut representation of the SI prefix “micro,” and arguably more appropriate in the sense of a standard naming convention, but the difference between considering 1mm and 5mm is expected to be minimal.

Recommendations– Size

- Lower practical sampling/monitoring limit for Potomac and Chesapeake Bay may be limited to existing equipment (333 µm mesh nets)

- Lower limit of ERA discussion of microplastics is recommended as 1000 nm (1µm), consistent with the SI naming and recommendations of GESAMP, Hartmann et al (2019)

Recommendations– Size

Classification	Size	Rationale
Microplastic	5 mm - 1000 nm (1µm)	--NOAA and GESAMP precedence --Upper size limit is consistent with previous monitoring studies in Chesapeake Bay and tributaries --Use of 333 µm as a lower bound potentially excludes the laboratory or monitoring studies that include data below that value. --May result in data gap/unknown for relevance of particles 1-333 µm in Chesapeake Bay -- The lower size limit is consistent with the SI naming convention.
Nanoplastic	1 nm - <1000 nm (1µm)	--The upper limit is consistent with the SI naming convention. --Limit is inclusive of particles <100 nm as defined for non-polymer nanomaterials in the field of engineered nanoparticles -- The lower size limit is consistent with the SI naming convention.

Recommendations– Concentration

- Water
  - *Number of particles m^{-3}*
  - Quantifies number of plastic particles in water by volume is recommended for standardized monitoring strategies in the Chesapeake Bay and watershed.
  - Accounts for particles throughout the water column, including those at the surface.

Recommendations– Concentration

- Sediment
  - *Number of particles m^{-3}*
  - Organisms exist in a three-dimensional environment within the sediment.
  - The exception to this would be to assess abundances of microplastics on the sediment surface as this region is exploited by a variety of errant polychaetes, crustaceans, and benthic fish.

Recommendations– Concentration

- Organism
  - *Mass of particles per individual*
  - Does not discriminate between organ or tissue as site of accumulation and accounts for an organism's total exposure to microplastics.
  - Advantageous for assessing a total dose or risk associated with microplastics

Recommendations– Concentration

- Submerged Aquatic Vegetation
  - *Dependent upon research objectives*
  - # of particles per blades provides insight into loading
  - Area covered by microplastics may be more biologically relevant as particles may block sun light from surface or consumed by grazers.
  - SAV bed metrics (like canopy capture of microplastics) might involve measuring # of particles per unit volume

Questions?