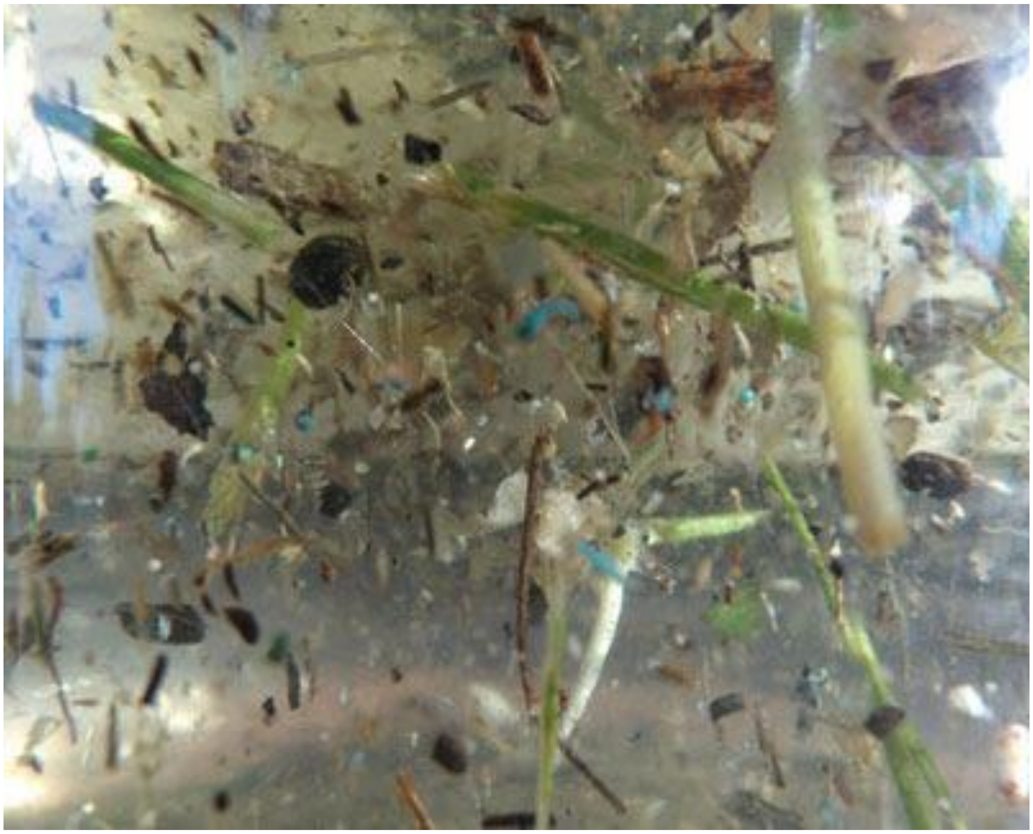
STAC Technical Review of PPAT Product: Microplastics Terminology Document



STAC Review Report
November-December 2020

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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

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Background

In November 2019, EPA's Chesapeake Bay Program Management Board approved the formation of a Plastics Pollution Action Team (PPAT) to address the emerging and growing concerns of microplastics in the watershed. More specifically, the PPAT was asked to assist in implementing the following recommendations resulting from the April 2019 workshop, *Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals*:

- The Scientific, Technical Assessment and Reporting Team should incorporate development of Ecological Risk Assessments (ERAs) of microplastics into the CBP strategic science and research framework, and the Plastic Pollution Action Team should oversee the development of the ERAs focused on assessment of microplastic pollution on multiple living resource endpoints.
- 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.

In support of these recommendations, the PPAT is currently overseeing the preparation of an Ecological Risk Assessment of microplastics in the Potomac River and creation of a Terminology document currently being performed by a third party. The contractor, Tetra Tech, is currently under contract with US EPA Region III to develop a uniform size classification and concentration unit terminology for microplastics and a Preliminary Ecological Risk Assessment. The Chesapeake Bay Scientific and Technical Advisory Committee (STAC) has been formally requested by both US EPA Region III and the Chesapeake Bay Program Management Board to provide a Technical Review of the report (Standardization of Terminology Recommendations for Microplastic Ecological Risk Assessments in the Chesapeake Bay and its Watershed, hereafter referred to as the Terminology Document).

The purpose of the Terminology Document, as stated in the introduction, is to, “describe and recommend a uniform size classification and concentration unit terminology for microplastics, with the intended use of application to the parallel effort to develop an ecological risk assessment (ERA) framework and eventual monitoring plan for microplastics in the tidal Potomac River”. In satisfying this intent, as well as addressing the workshop recommendations stated above, it is understood that this effort should inform current and future work in assessing the risks posed by microplastics in the Chesapeake Bay and its watershed. However, it is not intended to serve as an exhaustive resource for microplastic classification based on multiple factors. Rather, its focus is to provide context for size and concentration unit terminology used in the ERA framework, which will identify data gaps and serve as a basis for conducting the aforementioned research on microplastics in the Chesapeake Bay and watershed.

In responding to the formal request for a Technical Review of the Terminology Document, STAC virtually convened an independent panel on November 9, 2020 to address two specific questions: 1) Are the suggested units of concentration and size classification scheme appropriate to adopt as standard terminology for research in the Chesapeake region; and 2) Does the terminology allow for development of an ongoing water quality monitoring program looking at concentrations of microplastics in tidal and non-tidal waters.

The Technical Review is presented in two sections: a summary and a presentation of individual comments.

Technical Review Summary

In general, the Review Team thought the document was carefully researched and the recommendations were logical and were appreciative of the effort to ensure appropriate consistencies with other definitions (which are discussed in detail in the document). The review team was asked to assess “appropriateness” of the recommended units of size and concentration in terms of utility (is the terminology useful for studies focused on assessing the impacts of microplastics on the Bay) and commonality (is the terminology being proposed the same terminology that is being used for studies being conducted elsewhere). Utilizing these terms, the recommendations on the suggested classification and concentration units are presented as follows.

Size Classification

The Review Team generally agrees with the subdivision of “microplastics”, defined as particles less than 5 mm in size, into size-based subclasses. In particular, the Review Team generally agreed with two subclasses of 5mm – 1000 nm and 1 nm - <1000 nm. However, there were three significant points of comment, discussed separately as follows.

The first was the utilization of the term “microplastics” for one of the subclasses, and two distinct and alternative opinions were expressed by reviewers. One view was concerned that placing a lower limit on the definition of microplastics (as is recommended in the Terminology Document as particles between 1 micron and 5 mm) would present a number of potential issues going forward. As one reviewer pointed out, a single microplastic particle can give rise to hundreds or thousands of nanoplastics (as defined in the document); once analytical tools improve, it is easy to imagine a given sample containing, for example, hundreds of microplastics and thousands (or tens of thousands) of nanoplastics (again, as defined in the document). This will introduce a lack of commonality with studies conducted elsewhere, since those studies often rely on a different definition of microplastics which lacks a lower limit (e.g., NOAA’s definition), and thus they would categorize the same sample as containing thousands (rather than hundreds) of microplastics. Secondly, there is reason to suspect that in the future, there will be conclusive evidence that plastics less than 1 micron are problematic for the health of a number of organisms (e.g., humans, aquatic organisms) or ecosystems. Using the definitions described herein, this might lead to people saying “Nanoplastics are the real problem, not Microplastics”, which would confuse audiences contemplating a broader definition of microplastics. Two primary alternative classifications were proposed. In the first, “Microplastics” would be defined as plastic particles less than 5 mm, and broken up into two or more subsets. One of those two subsets could be Nanoplastics as defined in the document (i.e., between 1 nm and 1,000 nm). The second subset (referred to as “Microplastics” in the document), could retain the same definition as in the document (i.e., 1 micron to 5 mm), but would be named differently (e.g., “Demiplastic”, or anything other than “Microplastics”). The second alternative involves breaking Microplastics into three subsets would allow for subsets that are more naturally correlated to the metric system. For example, the three subsets could be: Nanoplastics (1-1,000 nm), Mikronoplastics (1 micron to 1,000 microns), and Milliplastics (1-5 mm). This would ensure potential harmony with other studies using a less restrictive definition of “microplastic”, while still providing classification via subsets that are likely to become more important and relevant going forward. The alternative view of this issue strongly advocated that the literature now commonly recognizes a lower limit at 1um for Microplastics and that Nanoplastics are anything below, and that the creation of new definitions is not useful for being consistent across the global strategies. Thus, there was no consensus within the Review Team regarding the utilization of the term “Microplastics” for one of the proposed subclasses.

A second point involves the number of proposed subclasses. Without a finer delineation of the smaller size particles, the terminology document appears to have large organisms (e.g. striped bass and SAV for the Potomac River risk assessment) in mind. It is possible that smaller organisms at the base of the food chain may be in more intimate contact with MPs and more affected than finfish; the potential toxic effects of plastics <100 µm or even 10 µm in size (Jiang et al, 2020) have been indicated along with the possibility of ecosystem alterations. In addition, the ultimate fate of these smaller size particles may differ from larger particles due to enhanced surface areas. An alternative suggests a finer scaling of classes, with a classification based on a natural logarithmic type scale (as per Hartmann’s 2019 one), where 10-fold increases separate nano from micro etc. That is a lot like other size classifications in aquatic ecology like zooplankton size classifications.

The third issue involves the elimination of any discussion concerning plastics larger than 5 mm. One reviewer pointed out the need for a classification across the size spectrum of all plastics to describe study results for a number of reasons. Firstly, fate and ecosystem effects of debris >5 mm should not be overlooked in research or environmental monitoring, and large debris is the source of secondary MPs, which exceed primary MPs in both number of particles and mass. Secondly, studies of fully visible large ocean plastic trash are as likely to continue as are work on mixtures of the smallest size classes, and plastic debris >5 mm is also amenable to collection and to citizen science efforts. One immediate recommendation is to either limit your introductory discussion to microplastics alone (removing any expectations that you will suggest a classification for the full spectrum of size classes), or define the terminology for plastics larger than 5 mm. As the document stands, you have left the reader and the science community with an incomplete classification of materials.

Concentration Units

The Review Team assessment of the concentration units proposed for water, sediment, organism, and SAV are presented separately, as follows. In general, while abundance of particles of any given size class are supported, the Review Team duly notes that using the *number of particles* (normalized on either a sample volume, area or weight basis) as the only measure of microplastic abundance in environmental media is problematic, since larger debris fragments into many smaller particles over time, thus rendering particle counts as only a snapshot in time. The Review team recognizes that, eventually, an understanding of mass balances of particles across a range of size classes is the goal.

Water

The Review Team unanimously agrees with the proposed concentration units of "Number of particles m^{-3} ".

Sediment

The Review team generally agrees with the proposed volumetric units (number of particles per volume) but recommends studies to additionally report the number of particles per dry weight of sediments for comparability. The noted exception to the use of volumetric units (units of number of particles per area for assessing risks of particles on the sediment surface to a number of organisms) is also supported.

Organism

The Review Team does not support the proposed units of mass of particles per individual, and instead recommends count of particles per individual for reasons of comparability, measurement, and toxicity. Units of mass of particles per individual is not common in the literature, exposure estimates are usually expressed in particles per volume of media (as in water, above), and a significant methodological challenge exists in measuring the mass of particles. One reviewer also points out that, "particle count may be more relevant to toxicity since tiny pieces of expanded PS will be much lighter than the same size and count of pieces of high-density PE – but if the toxicity is particle related the similarity in toxicity will be lost."

SAV

The Terminology Document did not clearly recommend one reporting unit, and recognized that, "Measuring microplastics within SAV beds mostly depends on the research objectives." The Review Team had no critique of this language.

Additional Suggestions

One important suggestion included the addition of measurement units for shoreline surveys. Plastic assessments per mile of beach may be the foundations of our insights into plastic pollution of our waterways and continues to be reported, and plastic abundance on beaches are commonly assessed for both recreational attractiveness and quality of the habitat at the interface between water and land. For these reasons, there may be a practical need to consider units of reporting assessments of shorelines.

Applicability to Development of an Ongoing Water Quality Monitoring Program

The Review Team generally agreed that the terminology in this document (except that for concentration units in biota) would allow for development of an ongoing water quality monitoring program looking at concentrations of microplastics in tidal and non-tidal waters. However, the Review Team importantly stresses that comparability across studies will come from researchers adopting common sampling and assessment protocols, not from a common terminology. While terminology provides a means of communicating results, those results are only truly comparable if the same volumes/mass/area of sample is being assessed, the same sampling gear is used, the same sample filters are applied, the same processing techniques and time in processing is used, the same counting techniques, etc. This was clearly presented in the following figure (provided by R.Hale):

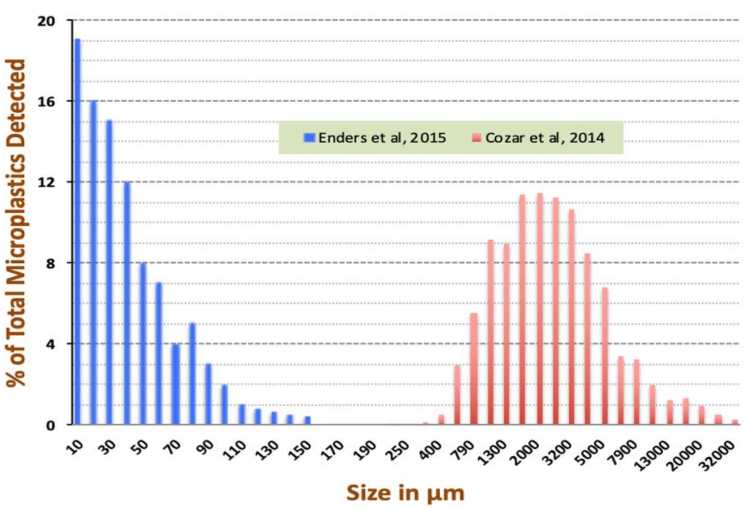

Fig. 2 Microplastic size distributions depend on sampling location (geographically and vertically in the water column) and analytical methods applied. For example, Enders et al. (2015) pumped North Atlantic surface waters through a 10 µm filter and then analyzed microplastics with Raman microspectroscopy. Cózar et al. (2014) collected floating microplastics with a 200 µm net during the Malaspina global circumnavigation. They selected candidate microplastics with a dissecting scope and evaluated composition of random particles with Raman spectroscopy. Selection of surface waters, use of large mesh nets (>200 µm), and FTIR detection (minimum

detection limit 20 µm, but often larger) has been common and hence will underestimate the contribution of small microplastics or dense polymers that sink.
From Hale et al., 2020.

The Review Team also provided many valuable comments regarding different analytical techniques and their alignment with terminology schemes (e.g., mass, shape, size); their specific comments are provided in full at the end of this document and are recommended reading.

Specific Comments

1) *Given your knowledge of the state of the science, do you feel the suggested units of concentration and size classification scheme are appropriate to adopt as standard terminology for research in the Chesapeake region? Appropriate in this context means two things: utility and commonality. For utility, is the terminology useful for studies focused on assessing the impacts of microplastics on the bay. Commonality addresses whether or not the terminology being proposed is the same terminology that is being used for studies being conducted elsewhere. It's very important that we are able to compare data with other aquatic systems in order to provide perspective on the levels of MP contamination in the bay.*

Specific Comments from review panel:

C. Rochman: I agree with the suggested units of size for the same reasons outlined in the report. If a monitoring strategy is defined for CB, I suggest reporting the quantity, size and shape of particles in addition to chemical ID for a representative subsample. I also suggest aiming to do manta, yes, which has a cut-off of 333 µm, but I also suggest some bulk water sampling down to a size range to 20, 45 or 100 µm based on analytical capability. I mostly agree with what is recommended for concentration units for monitoring. I 100% agree for water sampling. For sediment, I generally agree but to be comparable I'd also weigh the sediments dry to report both # of particles per volume and dry weight. For biota, I very much disagree. The concentration that was chosen is not common in the literature and thus the data will not be comparable to other studies. It's also methodologically challenging to get mass of particles unless you are using pyr-GCMS. I also think it's LESS relevant for toxicity since many exposure estimates are by count which is the first half of the ERA. I also think particle count is more relevant to toxicity since tiny pieces of expanded PS will be much lighter than the same size and count of pieces of high density PE – but if the toxicity is particle related the similarity in toxicity will be lost. I'd suggest using count per individual, which is most common. I also like count per gram of organism as an additional unit to report.

J. McDevitt: I thought the document was carefully researched and the recommendations were logical, and I appreciate the thought that went into it and the effort to ensure appropriate consistencies with other definitions (which are discussed in detail in the document). The recommendations were generally appropriate both in utility and commonality, albeit with one major concern discussed below. Also, I think the general approach is well-suited for ongoing water quality monitoring programs, but again, subject to the same major concern that I think needs to be fixed, which I think is far more important than any recommendations around the edges. Again, overall, I think the general classification scheme makes sense, but I'm looking for one word to be changed.

My main concern is the classification of conventional microplastics (widely defined as plastics less than 5 mm, or in some cases 1 mm) into two discrete classes, one of which still retains the name "microplastics". It is fine to break microplastics into two or more classifications based on size, as the authors recommend. However, one of those subsets should not be named "microplastics", which at this point has become a generic term. Logically and mathematically, it would makes sense to define microplastics as plastics between 1 micron and 1,000 microns, and nanoplastics as plastics between 1 nm and 1,000 nm. That said, given the sufficient precedent and NOAA definition, I agree with the authors that it makes more sense to define microplastics as having an upper limit 5 mm, rather than 1 mm, to ensure consistency of the generic term microplastics with NOAA's definition. However, the document puts a lower limit on the definition of microplastics, defining microplastics as plastics between 1 micron and 5 mm. I think that lower limit will lead to problems going forward.

A single microplastic particle can give rise to hundreds or thousands of nanoplastics (as defined in the document). Once analytical tools improve, it is easy to image a given sample containing, for example, hundreds of microplastics and thousands (or tens of thousands) of nanoplastics (again, as defined in the document). This will introduce a lack of commonality with studies conducted elsewhere. Those studies often rely on a different definition of microplastics which lacks a lower limit (e.g., NOAA's definition), and thus they would categorize the same sample as containing thousands (rather than hundreds) of microplastics. Alternatively, perhaps there is conclusive evidence that plastics less than 1 micron are problematic for human health, or crab health, or coral reef health. Using the definitions described herein, this might lead to people saying "Nanoplastics are the real problem, not microplastics", which would confuse audiences contemplating a broader definition of microplastics.

I think it makes sense to classify microplastics into different groups, as suggested in the document, and that division is likely to be increasingly relevant going forward, especially as analytical techniques improve. In particular, I think it is important to do so in order to address the second review question regarding development of an ongoing water quality monitoring program looking at concentrations of microplastics in tidal and non-tidal waters. However, the term "microplastics" should not be used for one of those sub-classifications.

Accordingly, I would much prefer "Microplastics" defined as plastic particles less than 5 mm, and broken up into two or more subsets. One of those two subsets could be Nanoplastics as defined in the document (i.e., between 1 nm and 1,000 nm). The second subset (referred to as "Microplastics" in the document), could retain the same definition as in the document (i.e., 1 micron to 5 mm), but the authors should pick a different name (e.g., "Demiplastic", or anything else that strikes their fancy, as long as it is not "microplastics").

Alternatively, breaking Microplastics into three subsets would allow for subsets that are more naturally correlated to the metric system. For example, the three subsets could be: Nanoplastics (1-1,000 nm), Mikronoplastics (1 micron to 1,000 microns), and Milliplastics (1-5 mm), as shown in the schematic diagram below. This system would also facilitate commonality with papers defining microplastics as less than 1 mm in size. In other words, Microplastics would cover all plastics less than 5 mm, and would be broken up into two or more groups, each of which would still be a Microplastic. This would ensure potential harmony with other studies using a less restrictive definition of “microplastic”, while still providing classification via subsets that are likely to become more important and relevant going forward. I strongly recommend this change.

P. Tango: What I see as the focus in the document versus how I thought about it after reading the document are two different things. You say right up front in your title that you are focused on “microplastics”. Your first sentence of the document however dives into a more general place, plastic debris, the universe of environmental plastics. You proceed to review multiple classification schemes and discuss classification with gradients from macro to nano, then at the end you recommend classification not just for micro, but micro and nano, all while having a title and many, many references to the term ‘microplastics’ throughout the document. In most places you used the term microplastics it seemed more appropriate to me for the use of a more general term on the family of plastics of concern. For me, what I see is a presentation on size classification for environmental plastics and not just microplastics.
If you are going to focus solely on the boundary conditions of size for microplastics to the exclusion of all other categories then I would suggest de-emphasizing discussion about all the other classes and their size ranges and focus on the issue of boundaries between other size classes and the specific class you might be after – just microplastics. Figure 2 is a beautiful illustration of size classes and the boundaries without the multiple tables you go into dissecting and describing.
That said, I personally don’t see as much value in being specific to providing all this research to define the boundaries on a single size class of plastics when we seem to need a classification across the size spectrum of all plastics to describe study results. Studies of fully visible large ocean plastic trash are as likely to continue as are work on mixtures of the smallest size classes. By proposing a size classification for nano and micro, are you by extension classifying everything else >5mm as macro? You left that out. Can you suggest that given your review of the literature, we propose defining 3 classes of plastics for common terminology rather than leave the reader and the science community with an incomplete classification of materials?

I admit I find it challenging to have microplastics as an odd size classification range. By this I mean Hartmann’s 2019 classification is a natural logarithmic type scale, 10-fold increases separate nano from micro etc. That is a lot like other size classifications in aquatic ecology like zooplankton size classifications where size categories include:

- picoplankton that measure less than 2 micrometers,
- nanoplankton measure between 2-20 micrometers,
- microplankton measure between 20-200 micrometers,
- mesoplankton measure between 0.2-20 millimeters,
- macroplankton measure between 20-200 millimeters, and
- megaplankton, which measure over 200 millimeters (almost 8 inches)

For me, the proposed microplastic definition is a bit odd on its own right now just given more natural ways to distribution size categories used in aquatic ecology.
Since you are focused on size classification in this document, I do not see needing more than a brief text reference to shape, color, composition, etc. issues in the introduction, and maybe as a recommended future direction for improved classification as a closing statement in the summary. The text of Section 2.2 dedicated to these issues is not relevant to this discussion if you are focusing on size classification as the nut to crack right now.

Reporting units. This is going to be study dependent.

- For water – agreed, volumetric assessment wins by miles over area on microplastics and nanoplastics, however, area may have long-lasting value for the reporting of macroplastics unfortunately as we refer to the ocean heaps floating around, I can't discount the value of using area for large scale, large plastics reporting comparisons. I would add the shoreline assessments might use a more linear reporting unit – pieces per beach mile.
- For SAV – surface area seems logical.
- For sediment, there may be good reasons to use either area-based or volume-based reporting.
- What about beaches? Plastic assessments per mile of beach may be the foundations of our insights into plastic pollution of our waterways and continues to be reported (e.g." On UK beaches there are 5000 pieces of plastic & 150 plastic bottles for each mile", e.g., "Cambodia topped Albania, where volunteers collected 877 garbage samples per mile of coastline". Beach assessments will surely include microplastics https://response.restoration.noaa.gov/about/media/microplastics-national-park-beaches.html which might be reported per mile or might be reported in other units like the variety used for sediment. Given beaches are commonly assessed with recreationally interest and importance in the quality of the habitat at the interface between water and land, perhaps there is a need to consider units of reporting assessments of shorelines in your document too.

R. Hale: The definition of microplastics (MPs) to include particles between 5 mm and 1 µm is consistent with that widely used nationally and globally. However, it should be reiterated that plastic debris exists as a continuum of sizes. Particles >5 mm will fragment into a multitude of smaller MP particles over time (see Fig.1, as well as Hebner and Mauer-Jones, 2020).

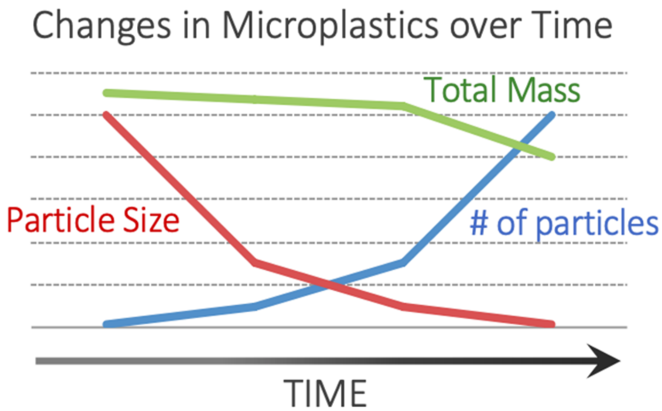

Fig. 1. Proposed relationship between microplastic size, particle number and total mass over time. We postulate that as particle size decreases and surface area increases, environmental reactivity will increase. This may result in a decrease in total mass due to enhanced biodegradation. From Hale et al., 2020.

In terms of sources, fate and ecosystem effects debris >5 mm should not be overlooked in research or environmental monitoring. Plastic debris >5 mm is also amenable to collection and to citizen science efforts. Large debris is the source of secondary MPs, which exceed primary MPs in both number of particles and mass. The fragmentation rate is a function of several variables. Further, minute particles (<1 µm; nanoplastics) may be very important in terms of ultimate debris fate (due to enhanced surface area) and toxicological effects (greater ingestion potential and ability to penetrate cell membranes) (Jiang et al, 2020). The term “MNP” (micro + nanoplastics) is becoming increasingly used to encompass the fuller range of particles.

At present, there are major difficulties in sampling and analyzing minute particles (Hale et al, in press). Our knowledge of MNPs in the environment is presently quite crude. Methods are evolving rapidly to reduce these barriers and improvements should be embraced. Research and monitoring standards should not be limited to comply with either the filtering capabilities of plankton nets (MPs >330 µm) or to conform to the limited number currently available studies for the Bay (see Fig. 2).

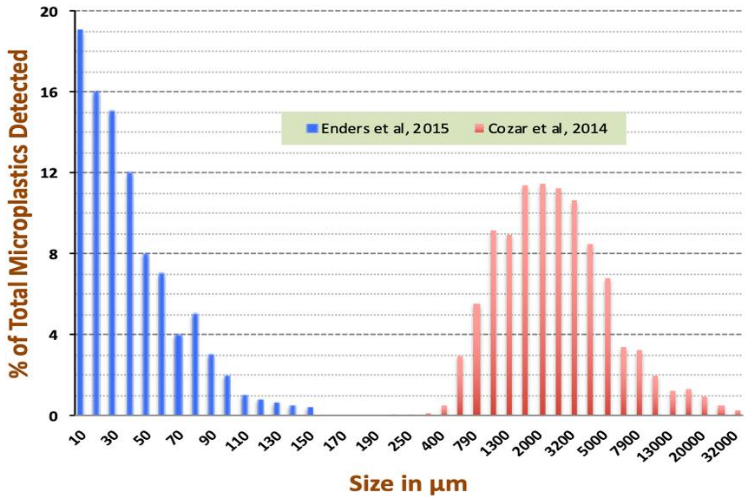

Fig. 2 Microplastic size distributions depend on sampling location (geographically and vertically in the water column) and analytical methods applied. For example, Enders et al. (2015) pumped North Atlantic surface waters through a 10 µm filter and then analyzed microplastics with Raman microspectroscopy. Cózar et al. (2014) collected floating microplastics with a 200 µm net during the Malaspina global circumnavigation. They selected candidate microplastics with a dissecting scope and evaluated composition of random particles with Raman spectroscopy. Selection of surface waters, use of large mesh nets (>200 µm), and FTIR detection (minimum detection limit 20 µm, but often larger) has been common and hence will underestimate the contribution of small microplastics or dense polymers that sink.
From Hale et al., 2020.

Using the *number of particles* (normalized on either a sample volume, area or weight basis) as the only measure of MP abundance in environmental media is problematic (Rivers et al, 2019). As larger debris fragments into many smaller particles over time, sample particle counts are a snapshot in time. MNP mass balances need to be understood. Further, the act of MP collection and purification may cause further fragmentation through abrasion (see methods in Efimova et al, 2018). Importantly, weathered plastic debris may be more fragile than the unweathered plastics (ter Halle et al., 2017). Recovery of the latter are commonly assessed in method validation exercises.

In terms of MNP impacts on the Bay, the terminology document appears to have large organisms (e.g. striped bass and SAV for the Potomac River risk assessment) in mind. It is possible that smaller organisms at the base of the food chain may be in more intimate contact with MPs and more affected than finfish. MPs <100 µm or even 10 µm (including nanoplastics) may be important in regards to toxic effects (Jiang et al, 2020), ultimate MP fate (due to enhanced surface areas) and possibility of ecosystem alterations.

2) *More specifically, does the terminology in this document allow for development of an ongoing water quality monitoring program looking at concentrations of microplastics in tidal and non-tidal waters? We call this question out specifically because it is of special interest for various partners in the Chesapeake Bay Program. We anticipate that many partners in the region may want to begin continuous monitoring programs for microplastic contamination in their jurisdictions. Incidentally, the 2019 report on the STAC workshop, "Microplastics in the Chesapeake Bay and its Watershed," recommended that the Chesapeake Bay Program utilize the existing monitoring network to monitor for microplastics.*

C. Rochman: I do think these units make a lot of sense for a monitoring program EXCEPT those proposed for biota. I think it's a methodological challenge and is hard to compare across studies.

P. Tango: Comparability across studies will come from researchers adopting common sampling and assessment protocols, not from a common terminology. Results can be comparable because of the same volumes/mass/area of sample is being assessed, the same sampling gear is used, the same sample filters are applied, the same processing techniques and time in processing I used, the same counting techniques, etc., The terminology provides a means of communicating results.
It could be the basis for program development if, in a request for proposals, the request highlights that we want to focus on one class of plastics, information specifically on microplastics as defined by this Tetra Tech reference. Sampling gear and methods would have to be proposed that efficiently target (but might not be limited to) estimating microplastics. We have done that with phytoplankton and zooplankton monitoring efforts in the past as there were specific programs separately targeting picoplankton from microzooplankton and mesozooplankton. Whatever break points you choose, as long as they are the best defensible thresholds to bracket that classification we have now, it should serve to direct program investment and development that targets particles of that size class. That is how any terminology could be used to direct the output of monitoring for consistency over time. If micro is the only size range of ecological significance that might work…but I would be cautious there as I think we already know that isn't necessarily the only size class that is impacting our world.
I believe it is unavoidable that any monitoring program is going to encounter more than 1um-5mm plastics in their sampling efforts. They may even target a broader range of sizes than microplastics alone in order to understand the distribution across size classes, transformations and degradation rates between classes and such. A good researcher will further subdivide results inside of the class of microplastics to gain more insights into particle size distributions and not rely solely on a 3-class system to report results. I can easily picture a frequency graph subsetting data within a class, the terminology would be applied after the results have been shown on the distribution to show categories by one or more classification systems and the breadth of results within the micro-class.
We would then benefit from a common naming convention for targeting particles and communicating results related to not just microplastics but particle sizes not in the micro class too. Presently you are providing an incomplete reference. I believe you can strengthen a

proposed classification structure by providing one or more classes above microplastics to provide scientists and communicators with a reference to the full breadth of what they may be tracking. Provide them a framework across a more complete spectrum of plastic sizes to allow them to fully describe their data and categorize their results. And yes, it can direct how monitoring could then be directed using targeted text in proposal requests with a reference documenting the size class of interest.

R. Hale: One must be mindful of data accuracy, precision and "completeness". All are crucial to obtain the true picture. High quality data for an overly "censored" range of MPs has its own "big picture" shortcomings (as shown in Fig 2 above). Compromises are often necessary, as monitoring programs are often inadequately funded. Granted, focusing on a limited size class may provide insights into changes in MP abundances over time and between locations (provided that distributions between size classes do not vary over these parameters). However, I am concerned with approaches that would restrict efforts to a narrow size range (e.g. sizes retained on plankton nets, i.e. >330 µm or excluding debris >5 mm). Towed nets excel at collecting large(r) debris. Collection efficiency may change with use during a tow, as mesh openings become plugged. Their utility for fibers, an important class of MPs, requires validation. Thus, use of available in-use monitoring techniques (e.g. reliance on plankton trawls) may produce an inaccurate impression of the true extent/nature of plastic contamination.

Use of water pumps (versus towed nets) for sampling, in conjunction with a graduated series of filter sizes, may generate more representative data than nets (Montoto-Martínez et al, 2020). Further work on the distribution of MPs in different water strata (not just the surface) and sediments is crucial (Kooi et al, 2016). MP sizes, shapes and polymeric composition distributions may vary with water depth, in sediments and in and between organisms.

Quantifying MPs in a sample using the *number of particles detected* alone may be a misleading metric (Simon et al, 2018; Rivers et al, 2019). For environmental contaminant quantitation, mass is the normal characteristic of choice for metallic (e.g. Hg, Pb…) and organic (e.g. PAHs, PCBs….) entities. For MPs in a sample, knowledge of the plastic mass present (and mass balance of MPs in the environment in general) would be invaluable. But mass has been a rarely determined in MP analyses (exceptions include thermal analysis such as GC pyrolysis and solvent extraction-based approaches - where particle shape and size data may be lost). This is, in part, because spectroscopic techniques (e.g. IR and Raman microscopy) have been favored tools. These allow polymer identification, as well as particle shape (sphere, fragment, fiber, film…) and size evaluation. Spectroscopic techniques also allow for the determination of particle area, but this has been infrequently performed to date (Simon et al, 2018). Areas could be summed across all particles of a polymer type present in a sample to provide valuable insights. Volume multiplied by polymer density yields mass. Differences in densities between most polymers are in the range of only 10%. However, thickness of individual MP particles, required for the volume estimate, may be a more difficult measurement. However, there may be analytical options for determining particle volumes more directly.

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