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Focus

Microplastics: Finding a consensus on the definition

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ABSTRACT

Polymer science is one of the most revolutionary research areas of the last century, instigated by the discovery of Bakelite, the first synthetic plastic. Plastic, once a revolutionary material, has gradually become a global environmental threat with ubiquitous distribution.

The term '*microplastics*' coined in 2004, is used to describe the smaller plastic particles recorded, however there is still no all-inclusive definition that accurately encompasses all criteria that could potentially describe what a microplastic is.

Here, the authors focus on the currently reported methods for describing and identifying microplastics and propose a new definition that incorporates all the important descriptive properties of microplastics. This definition not only focuses on size and origin, but also considers physical and chemical defining properties. While this manuscript may promote debate, it aims to reach a consensus on a definition for microplastics which can be useful for research, reporting and legislative purposes.

The discovery of Bakelite, the first synthetic plastic, in 1907, revolutionised polymer science and modern life, by introducing several polymers and plastic formulations to our daily lives, many of which are still available in the market nowadays (Shashoua, 2008). Plastic materials are extremely versatile due to their low density, low thermal and electric conductivity, resistance to corrosion, which allow these materials to serve as a water and oxygen barrier, while their low price also contributes for their easy and widespread manufacture, where they are used in a wide range of applications from food packaging to medical and technological applications.

However, what was and is still described as a revolutionary material has slowly become a global environmental threat with ubiquitous distribution in marine and freshwater ecosystems (Bergman et al., 2015; Wagner et al., 2018; Zeng et al., 2018). The natural occurring environmental conditions within these ecosystems, particularly ocean current dynamics, solar radiation, abrasion and interactions with vessels and organisms, cause plastic items to slowly degrade and fragment into smaller particles commonly known as *microplastics*.

Thompson et al. (2004) initially coined the term microplastics to describe the accumulation of microscopic pieces of plastic in marine sediments and in the water column of European waters. In 2009, Arthur et al., proposed an upper size limit to the initial term and microplastics where known as "*plastic particles smaller than 5 mm*". This definition was further refined in 2011, when Cole et al. (2011) distinguished microplastics, according to their origin, into primary (produced to be of microscopic dimensions) or secondary (resulting from degradation and fragmentation processes in the environment). The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), defines microplastics as '*plastic particles < 5 mm in diameter, which include particles in the nano-size range* (*1 nm*)' (GESAMP, 2015, 2016) and it helped further spreading the definition worldwide.

Over the last decade, the focus on the microplastic issue as a novel pollutant has seen a large increase in investments at a global scale, in this novel research field. Projects range from exploring sources and pathways (Mahon et al., 2017) establishing baselines in areas potentially impacted (Maes et al., 2017); establishing a consensus on standardised methodologies (Frias et al., 2018) identifying worldwide hotspots for microplastic accumulation (Eriksen et al., 2014; Jambeck et al., 2015; Lebreton et al., 2018), and exploration of ecosystem and potential impacts on both habitats and species (Rochman, 2018). The output of such projects has resulted in an exponential increase of microplastics literature (Bergman et al., 2015; Zeng et al., 2018), and increased attention of the media worldwide highlighting issues or the plastics pollution problem. Microplastic bans in the form of microbeads or others have been introduced in several countries (e.g. U.S.A. (California), U.K., Canada, New Zealand). In addition, several other countries are following suit and are in the process of drafting bills on microplastics (e.g. Ireland, Italy, India, Taiwan, South Korea). Its global dimension has resulted in microplastics being reviewed in relation to international policy and the global environmental pollution problem (Bergman et al., 2015).

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Considering all this attention and research to date, there is still no clear consensus on a definition that is extensive enough to encompass all necessary criteria to describe '*microplastics*'. This technicality causes several methodological challenges and it is common while reading review papers on microplastics that authors express the daunting task of comparing studies (Barboza et al., 2018; Bergman et al., 2015; Shim et al., 2017; Van Cauwenberghe et al., 2015; Wagner et al., 2018; Wesch et al., 2017; Woodall et al., 2015; Zeng et al., 2018).

Regarding size, there is still no agreement on the upper and lower size limits to microplastics, even though the most used definition is the one proposed by Arthur et al. (Arthur et al., 2009). Several authors refer to the lower size limits ranging from 1 to 20 μm ((Van Cauwenberghe et al., 2015); Ryan, 2015; de Witte et al., 2014) while the upper size limits used in research range from 500 μm to either 1 mm or 5 mm at the upper limit (Desforges et al., 2014; Dekiff et al., 2014).

In a recent publication focused on nanoplastics by Gigault et al. (2018), a strong contribution was made to the on-going debate described in several publications (Barboza et al., 2018; Bergman et al., 2015; Frias et al., 2018; Van Cauwenberghe et al., 2015) about the upper and lower size limits of '*microplastics*'. In this paper, Gigault et al. defined nanoplastics as "*particles resulting from the degradation of plastic objects*" and that "*nanoplastics exhibit a colloidal behaviour within size ranging from 1 nm to 1 μm*", therefore defining a lower size limit to microplastics (1 μm). Despite this contribution and bearing in mind the technological limitations of laboratory processing, particularly identifying microplastics under micro-Fourier Transformed Infrared Spectroscopy (μ-FTIR), the current potential size limit for identification ranges between 20 and 100 μm (Frias et al., 2018), but with technological advances this range will potentially be lowered to 1 μm.

Another aspect associated with defining '*microplastics*', which also follows a similar on-going debate, are microplastic types and shapes. The most commonly reported types of microplastics recorded in the literature worldwide are pellets, fragments and fibres (Frias et al., 2018), with films, ropes, filaments, sponges, foams, rubber and microbeads in decreasing order also important contributors to microplastic pollution. However, it should be noted that different countries will use different terminology to classify the same object or plastic type.

Other aspects such as colour are not considered to be crucial to defining microplastics, because colour differentiation is subjective, and it cannot contribute to the visual identification of microplastics by itself (Lusher et al., 2017). However, recording microplastic colour is considered important, for studies concerning aquatic organisms, as some species are thought to potentially ingest microplastics based on a colour preference behaviour (Wright et al., 2013).

Since microplastics were initially described, there have been some unsuccessful attempts to create an all-inclusive definition that consider not only size but also physiochemical properties such as solubility in water or chemical composition. Verschoor (2015) produced a comprehensive report considering specific microplastic properties, however, due to the large amount of scientific publications and reports on the topic, this report has mostly gone unnoticed at an international level. Also, an all-inclusive definition, which would reflect the research carried out by Verschoor (2015), would need to include terms such as 'synthetic solid particle or polymeric matrix'. This would allow for the inclusion of all solid synthetic polymers, in their individual or composite forms.

Therefore, the following definition for microplastics is proposed: "*Microplastics are any synthetic solid particle or 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*".

The authors see this definition as descriptively all-inclusive, and helpful for both comparative and monitoring microplastics worldwide.

Further technological advances are needed to solve the issues surrounding sampling, processing and identification of the very lower range limit of microplastics 1–20 μm. On this issue of size, one recommendation going forward is to report microplastic data in three size classes, which reflect current sampling and processing practices namely: 1 ≤ 100 μm; 100 ≤ 350 μm and from 350 μm to ≤5 mm, as this would allow for studies to be more easily compared. It is likely that current and future monitoring programmes will largely report microplastics ≥100 μm, and where only surface water is being monitored, microplastics ≥300 μm.

We hope that this manuscript will not only further contribute to the on-going international debates about this issue but will also contribute to reach consensus on a definition for microplastics.

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