Studying the environmental impact of nanoplastics: Strategies and limitations

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Understanding the environmental impact of nanoplastics is complex and requires the development of robust and standardised laboratory tests, which are essential for assessing their effects on broader, real-world scales, Monica Passananti explains

In recent years, the number of research studies on nanoplastics in the environment and their potential impact has increased substantially. However, research in this area is still in its infancy, and in some cases, there is still debate about the definition of the term 'nanoplastics'.

Although the majority of scientists define them as plastic particles (including fragments and fibres) with a size below 1 µm, sometimes nanoplastics are associated with nanomaterials, which generally have a size below 100 nm. [1] Although there is still little evidence of the presence of nanoplastics in the environment, the first study related to the marine environment was published in 2017 by Ter Halle and her co-authors. [2]

Nevertheless, the scientific community agrees that nanoplastics can be present in all environmental compartments. The main question arising is, therefore, "What are the environmental consequences of the presence of nanoplastics in the environment?". This is a complex question that does not have a unique or defined answer at present.

Nanoplastics can impact the environment differently from microplastics, mainly due to their smaller size and larger surface area. Furthermore, the analytical techniques and protocols used to study microplastics cannot be applied to nanoplastics. This necessitates the development of new methods for detecting them in complex matrices and studying their fate in the environment.

To answer this question, we must consider several factors. Two aspects in particular are crucial when assessing the interactions between nanoplastics and other chemical species present in the environment, as well as when evaluating the potential disruption to the environment's chemical equilibrium caused by their presence. The first is the need to develop procedures to better characterise the fate of nanoplastics in the environment, such as transformation, aggregation and transport. The second is the need for more detailed and accurate information on the occurrence of nanoplastics in the environment.

How to study nanoplastic transformation under environmentally significant conditions

Standardised guidelines are available for studying the chemical transformation of classic and emerging pollutants in the environment. These guidelines, such as the OECD test guidelines, outline the experimental procedures to be followed in assessing specific properties. For example, they can be used to determine the potential effects of solar irradiation on chemicals in surface water. However, such guidelines are not yet available for nanoplastics, which leads to non- comparable results.

The first problem that arises when trying to define a standardised protocol is identifying the test material. While the test material for other chemicals, such as pesticides or drugs, is unambiguous, the test material for nanoplastics can vary considerably. Laboratory experiments are often performed on commercially available nanoplastic samples, most commonly polystyrene monodisperse nanospheres. [3] These samples are useful for discriminating size effects and are a good starting material for obtaining preliminary results.

However, to obtain data that is more relevant to the environment, we need more realistic nanoplastic samples. The majority of nanoplastics in the environment derive from the degradation and fragmentation of larger pieces of plastic debris; therefore, they differ greatly from standard materials. They have already undergone a degradation process and are rarely spherical or monodisperse.

One possible solution to this problem is to prepare nanoplastic test material from microplastics using cryomilling.

Several cycles of cryomilling can produce nanoplastics that are similar in size and shape to the secondary plastics found in the environment, as opposed to the simplified, monodisperse spheres. [4] This grinding process must be followed by an ageing step to simulate degradation in the environment and create nanoplastics relevant to the environment.

Standardisation of this sample preparation is essential, and any alterations to particles resulting from sample treatments (e.g., filtration, concentration, analysis) must be considered. These alterations are not yet thoroughly researched, but they may influence the nanoplastics' chemical and physical properties.

The second step in studying the transformation of nanoplastic under environmental-like conditions is to develop a method that allows their reactivity to be quantified. These results are important as input data in models used to predict the chemical reactivity and the effect of nanoplastics in natural environments.

As plastics are resistant to degradation and their reactivity can change as their surface properties evolve, it may not be feasible to measure reactivity by tracking the disappearance of nanoplastics in laboratory-scale experiments. One simple approach to quantifying sunlight-induced degradation could be to measure the total organic carbon released into water from nanoplastic degradation over time. A more complex strategy is required to evaluate the reactivity of nanoplastics towards other naturally occurring species (such as oxidants and metals).

In these cases, a kinetic competition model must be developed to describe and measure the reactivity of nanoplastics within a complex reaction scheme. This approach is based on indirectly measuring the reactivity of nanoplastics by evaluating how a well-known molecule (a probe) reacts in the presence and absence of nanoplastics. [5] This method requires the development of a kinetic model for each species considered (e.g., singlet oxidants, hydroxy radicals and iron) and the optimisation of laboratory conditions, primarily the concentration of the probe and nanoplastic used.

These approaches require a significant amount of work to optimise and test, including inter-laboratory comparisons and the use of several types of plastic as the starting material. However, they are a step in the right direction towards standardising the study of the environmental fate of nanoplastics.

The second important aspect to consider when evaluating the environmental impact of nanoplastic is to understand its presence in all environmental compartments. Combining this information with nanoplastic reactivity could help predict the potential impact of nanoplastic pollution through models. However, the analysis of nanoplastics in complex environmental samples still needs to be optimised. In recent years, several researchers have tried to develop new methods that combine existing techniques to analyse nanoplastics. A combination of spectroscopic methods and mass spectrometry seems to be quite promising. [6,7]

Nanoplastics research Priorities

Although the environmental contamination caused by nanoplastics is becoming increasingly evident, driven by ongoing plastic production and the vast quantities of existing plastic waste, addressing its impact requires an urgent and collective effort from researchers worldwide. Only through broad collaboration we can develop effective methods of studying nanoplastics and accurately assessing their environmental impact.

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