



## Short communication

## Characterisation of nanoplastics during the degradation of polystyrene



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## HIGHLIGHTS

- Polystyrene degrades into nanoplastics.
- The formation of nanoplastic particles increase over time.
- Results suggest a continuous process of plastic surface erosion.

## GRAPHICAL ABSTRACT



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## ABSTRACT

The release of plastics into the environment has been identified as an important issue for some time. Recent publications have suggested that the degradation of plastic materials will result in the release of nano-sized plastic particles to the environment. Nanoparticle tracking analysis was applied to characterise the formation of nanoplastics during the degradation of a polystyrene (PS) disposable coffee cup lid. The results clearly show an increase in the formation of nanoplastics over time. After 56 days' exposure the concentration of nanoplastics in the PS sample was  $1.26 \times 10^8$  particles/ml (average particles size 224 nm) compared to  $0.41 \times 10^8$  particles/ml in the control.

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## 1. Introduction

The release of plastic materials into the environment is recognised as an important pollution related issue (Sutherland et al., 2010; UNEP, 2011). Once in the environment plastics undergo abiotic and biotic weathering processes that cause their

degradation and fragmentation into increasingly smaller particles, commonly termed microplastics (MPs; often defined as fragments <5 mm). A number of environmental monitoring studies have quantified the environmental occurrence of MPs in surface waters (Faure et al., 2015), coastal sediments (Browne et al., 2011), beach sands (Liebezeit and Dubaish, 2012), freshwater sediments (Castañeda et al., 2014), and deep-sea environments (Woodall et al., 2014). MPs are also known to effectively sorb organic pollutants from surrounding water (Mato et al., 2001; Endo et al., 2005; Van et al., 2012). Therefore, internalized MPs might not only lead to

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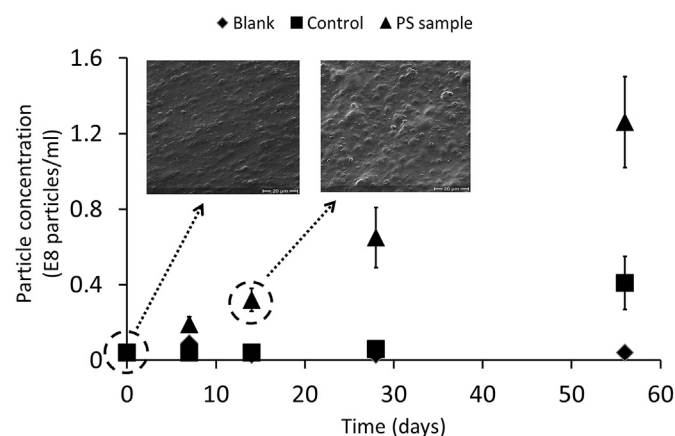
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direct physical injury, but also to a chemical exposure of the organism through the ingestion of pollutant loaded MPs (Ryan et al., 1988; Saal et al., 2008).

Recent publications have also suggested that MPs will subsequently degrade into nano-sized plastic particles (see Andradý, 2011; Lambert et al., 2013; Mattsson et al., 2015). The environmental impacts of nanoplastics will be different to those presented by microplastics, because of their smaller size makes tissue penetration and accumulation in organs a possibility (Mattsson et al., 2015). This is a potentially important issue given the current concerns regarding the environmental behaviour and ecotoxicity of engineered nano-materials (Lambert et al., 2014). Therefore, the aim of this work was to test the hypothesis that nanoplastic particles are formed during plastic degradation processes and that the concentrations will increase over time.

## 2. Methods

To investigate the potential formation of nanoplastics a time course study was performed using a polystyrene (PS) disposable



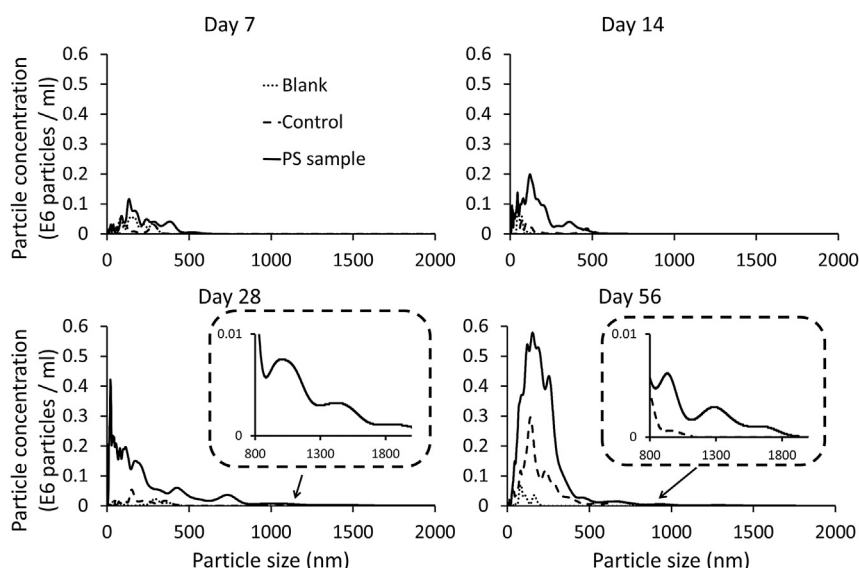
**Fig. 1.** Measured particle concentrations in the blank, control, and polystyrene samples. Particle concentrations were calculated by the NTA software and the  $\pm$  values represent the standard error associated with the measurement, with scanning electron microscope images for sample taken at day 0 and 14. Further details are provided as supporting information.

coffee cup lid. The PS sample was cut into 1 cm squares (using scissors), placed in glass vials, immersed in 20 ml demineralized water, and placed in a weathering chamber (Binder GmbH). The exposure conditions were kept static with the temperature set to 30 °C and 24 h exposure to light in both the visible and ultra-violet (UV; 320–400 nm) range. Samples were taken after 7, 14, 28 and 56 days, for each time point individual samples were established in triplicate alongside control samples (i.e. water only). A laboratory blank was also created on the day of each sample collection to document any contamination that may result from the analytical process.

Nanoparticle tracking analysis (NTA) was used to determine the particle size distribution in the liquid samples. NTA is capable of analysing particles in the size range of 30–2000 nm. Analysis was performed using NanoSight LM 10 (NanoSight Ltd, Wiltshire, UK). To characterise each individual replicate PS sample, control, and blank in a representative manner three video images of each were taken. Video image length was set at 30 s and imaging was performed at room temperature. The video images were then processed using NTA 2.3 software, with the following parameters; detention threshold set to auto; blur set to  $5 \times 5$ ; minimum track length and minimum expected particle size were both set to auto.

## 3. Results and discussion

In this study the formation of nanoplastic particles was measured during the degradation of a disposable PS coffee cup lid. NTA allows individual particles to be analysed in liquid samples and its application on heterogeneous samples has previously been demonstrated (Filipe et al., 2010; Montes-Burgos et al., 2010; La Rocca et al., 2014). Fig. 1 shows an increase in the formation of nanoplastics over time and after 14 days a difference is observed between the PS samples ( $0.32 \times 10^8$  particles/ml) and the corresponding control sample ( $0.04 \times 10^8$  particles/ml). At day 56 the particle concentration in the PS solutions was  $1.26 \times 10^8$  particles/ml compared to  $0.41 \times 10^8$  particles/ml in the control. Weight loss of the PS samples up until day 56 was negligible. As observed by La Rocca et al. (2014) the main disadvantage of NTA is that it does not provide images of the visualized particles, and the structure of the particles cannot be evaluated. However, the SEM images depict bubbling on the PS material surface. This suggests that the



**Fig. 2.** Size distribution data of particles formed during the degradation of a polystyrene coffee cup lid measured by nanoparticle tracking analysis.

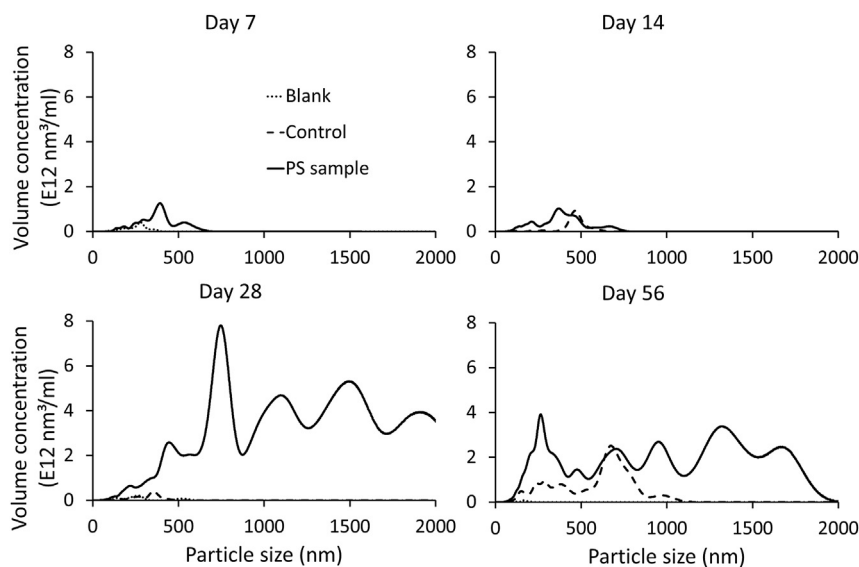


Fig. 3. Volume concentration of particles formed during the degradation of a polystyrene coffee cup lid measured by nanoparticle tracking analysis.

degradation process begins with a steady process of surface erosion leading to the continuous release of nanoplastics into the surrounding solution.

The increase in the formation of nanoplastics is further demonstrated by the particle size distributions (Fig. 2). The blank samples are used to represent background concentrations, while the control samples are used to define any naturally occurring particles that may enter the samples during the exposure period (e.g. atmospheric dust). The NanoSight platform also allows for the calculation of particle volume distribution (Fig. 3). As particle abundance increases exponentially with decreasing particle size (Fig. 2), this function can be used to represent the presence of larger particles and demonstrates the formation of particles up to 2000 nm. Particle size is an important property in determining the interaction of nano-particles with living systems (Montes-Burgos et al., 2010). A study by Browne et al. (2008) using the mussel *Mytilus edulis* indicated that small microspheres (3.0  $\mu\text{m}$ ) can be translocated from the gut to the circulatory system within 3 days and then persist in circulation for over 48 days. The short-term exposure used in this study did not find any significant biological effects (Browne et al., 2008). However, environmental exposure will occur over a longer time period and the formation of plastic particles below this size range during plastic degradation is highly likely.

#### 4. Conclusion

The aim of this work was to test the hypothesis that nanoplastics are formed during the degradation of a disposable PS coffee cup lid. The findings show that nanoplastics are formed during the degradation process of plastic materials, and that their increase in concentration over time is measurable. This work is part of a larger ongoing study that aims to assess potential differences in particle formation between polymer types, and the extent to which microbial communities can utilise particles in this size range.

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#### Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.chemosphere.2015.11.078>.

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