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Characterization and toxicity assessment of industrial microplastics made of Bakelite

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Abstract Microplastic research has focused mainly on particles made of polymers from ordinary consumer plastic products while industrial plastics has been largely overlooked. However, industrial plastics as Bakelite can be of a great importance due to their extensive use and unknown impact on the environment. Hence the aim of the study was to characterize Bakelite microplastics and to evaluate their toxicity in term of particles and its leachate. According to laser diffraction analysis, the mean number particles size distribution was 7.64 ± 3.48 µm with $1.5 \cdot 10^6$ particles/mg. The specific surface area was 249 cm^2/g indicating low porosity. Bakelite microplastics were introduced into freshwater medium and the toxicity was evaluated. They did not affect specific growth rate and chlorophyll content, but significantly affected the root growth of duckweed. Further investigation showed that Bakelite microplastics do not cause mechanical effect on roots, but the leached chemicals were responsible for increased toxicity.

Keywords: microplastics, duckweed, ecotoxicity, aquatic ecosystem

1. Introduction

Bakelite is a thermosetting phenol formaldehyde resin, and it was created in 1907 by chemist Leo Baekeland as the first synthetic plastic material. Although Bakelite has been with the society over one century their environmental impacts are practically unknown. It is hardly recyclable and therefore many Bakelite items end up in landfill or in the worst case in the environment. Bakelite is quite brittle, and it can be rapidly degraded into microplastics under increased mechanical pressure or due to abrasion (Dankwah and Baawuah, 2015). However, the microplastic research has been mainly focused on microplastics generated from consumer products as plastic bags (PE), cosmetic microbeads (PE, PP), plastic bottles (PET), fibres (PET) and plastic packaging (PE, PP, PS) (SAPEA, 2019).

Microplastics can affect organisms by mechanical and/or chemical stress. The mechanical stress is caused by abrasion/retention due to particle size and shape, whereas the chemical effect is caused by leached chemicals that are usually used as additives during plastic production. The leaching of additives from plastics used as packaging is not expected while industrial plastics as Bakelite or PVC can potentially release toxic chemicals (Kalčikova et al., 2020). In this context, the aim of our study was to characterize Bakelite microplastics and to evaluate its ecotoxicity, and leaching property.

2. Materials and Methods

Microplastics used in this study were obtained from a local producer of plastics and they are later used for manufacturing of various plastic items for automotive industry. Fourier-transform infrared (FTIR) spectroscopy was used to obtain information about the polymer types present in microplastics. The surface of microplastics was inspected by field–emission scanning electron microscope (FE-SEM Zeiss ULTRA plus). The number particle size distribution was determined by the laser diffraction analyser Microtrac S3500 Bluewave. The mean number of particles per mg was determined by weighting of the specific amount of microplastics, they were photographed, and processed with the program AxioVision v4.8.2. The specific surface area of microplastics was determined by Micrometritics ASAP 2020, using the Brunauer–Emmett–Teller (BET) method (Rozman et al., 2021). The ecotoxicity of 100 mg/L microplastics and their leachate was assessed by the standardized OECD test No. 221: Lemna sp. Growth Inhibition Test (OECD, 2006) with duckweed *Lemna minor*. The leachate was prepared under the same conditions as the test with particles. After the incubation time (7 day) the microplastic particles were removed by filtration and leachate was used for the ecotoxicity test.

3. Results and Discussions

Microplastics were in the form of orange powder with several irregularities on the particle surfaces (Figure 1). According to FTIR analysis the material of microplastics was confirmed to be Bakelite (John Wiley and Sons, 2020). According to laser diffraction analysis, the mean number particles size distribution was 7.64 ± 3.48 µm (Figure 1) with 1.5·106 particles/mg. The specific surface area was 249 cm^2/g indicating low porosity. Our results are in agreement with our previous studies where various microplastics were characterized (Rozman et al. 2021, Kalčikova et al., 2017).

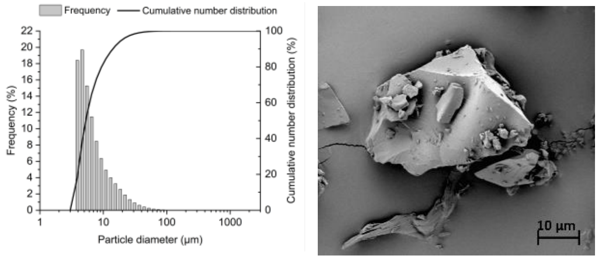

Figure 1. Number particle size distribution for Bakelite microplastics (left) and FE-SEM images (right)

Bakelite microplastics and its leachate did not show negative effects on the specific growth rate of duckweed. Similarly, photosynthetic pigment chlorophyll *a* was also not affected. This is in agreement with several studies (e.g., in Kalčikova et al., 2017, Mateos-Cárdenas et al., 2019). However, the roots of duckweed were reduced by 42 ± 7% in presence of microplastics and 37 ± 4% in the presence of its leachate. Our results confirmed that leaching of chemicals from Bakelite microplastics significantly influenced its toxicity.

The leaching of toxic compounds from microplastics is usually low, because majority of tested microplastics are form consumer products. However, Bakelite is industrial plastic material, and it is synthetized from phenol and formaldehyde, and hexamethylenetetramine is usually added as a crosslinking agent (Hocking, 2005). The presence of hexamethylenetetramine was indicated also in the FTIR spectra. It is also possible that unreacted phenol was leached into medium and affected the duckweed, since the phenol is very toxic to them (Barber et al., 1995).

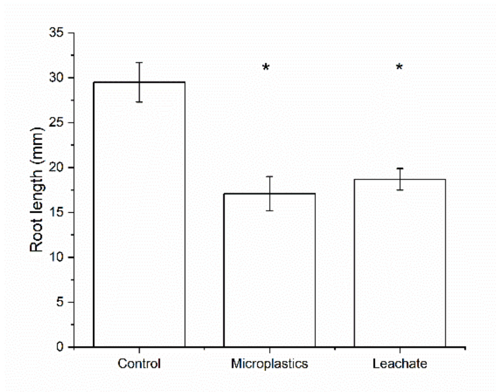

Figure 2. Root length of duckweed exposed to (a) microplastic, and (b) leachates. * Significant difference in comparison to control ($p < 0.01$), outliers are shown as ▪.

4. Conclusions

Although microplastics have been intensively investigated in the last decade, thermosets as Bakelite have been so far overlooked. Our research showed that microplastics made of Bakelite do not pose a threat only due to the mechanical stress, but the leaching of chemicals can significantly affect aquatic life. Therefore, there should be careful consideration regarding waste management of industrial plastics and how to handle them after the end of their utilization.

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