Aquatic hazard assessment of Bakelite microplastics

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Over the last 70 years, plastics have become an indispensable material that have permeated almost every aspect of our lives and currently the annual world production of plastics reaches 368 million tons (Plastic Europe 2020). However, the enormous production and often improper waste management of plastics have led to global pollution of the environment (Zalasiewicz *et al*., 2016). Most plastics found in the environment are common packaging materials such as polyethylene, polypropylene, and polystyrene. Therefore, environmental research on plastics focuses mainly on these types of plastics (Kalčíková and Žgajnar Gotvajn, 2019). However, thermosets such as Bakelite are of particular concern because they have been manufactured for more than a century and during that time there has been no waste management, resulting in enormous quantities of Bakelite items being disposed in landfills and/or the environment. Due to the high toxicity of the monomers and additives used in its manufacture, it has a high potential to affect aquatic life (Pilato, 2010). In this context the aim of the study was to assess the aquatic ecotoxicity of Bakelite in form of small fragments (microplastics) used in automotive industry. We tested ecotoxicity of Bakelite microplastics as well as their leachates by using various aquatic organisms.

First, microplastics used in this study were extensively characterized (Figure 1). They were in the form of an orange powder and FTIR analysis confirmed that the material was Bakelite. The average particle size was 8 µm with low specific surface area 249 cm^2/g (Rozman *et al*., 2021).

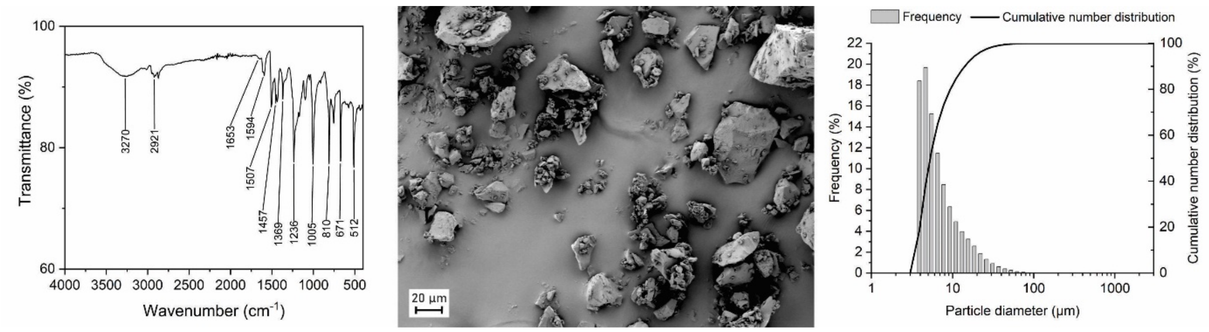

Figure 1. FTIR spectrum of Bakelite microplastics (left), imaging (centre) and their particle size distribution (right).

All ecotoxicity tests were conducted with 100 mg/L Bakelite microplastics by using various aquatic organisms: crustacean *Daphnia magna* (ISO 6341, 2012), plant *Lemna minor* (OECD 221, 2006), bacterium *Allivibrio fischeri* (ISO 11348-3, 2007) and microalga *Pseudokirchneriella subcapitata* (OECD 201, 2011). The leachates were prepared in the same manner as the corresponding ecotoxicity tests. Bakelite microplastics were added to the medium specific for each organism to reach a concentration of 100 mg/L and incubated under the same conditions as toxicity tests with particles (e.g., temperature, light, time). After the incubation period, the particles were removed by filtration and the leachates were used for the ecotoxicity tests.

Bakelite microplastics and their leachates affected all tested organisms to varying degrees (Table 1). The organisms most affected by Bakelite microplastics were the algae *P. subcapitata*. However, microscopic observation showed a false inhibition of *P. subcapitata* caused by the formation of heteroaggregates between algal cells and Bakelite microplastics, resulting in a decrease in algal concentration in the water medium. The leachates significantly affected the mobility of *D. magna* and after 24 hours the inhibition reached 100%. Similarly, bacteria *A. fischeri* were also more affected by leachate than by microplastics. Both organisms are very sensitive to phenol (Amresco, 2010), which was most likely leached from Bakelite. Microplastics and leachate affected *L. minor* similarly; specific growth rate was not affected, while roots were significantly shorter in treatments with microplastics and leachate compared to the control treatment. Microplastics were also monitored on organisms' tissue and microplastics adhered to plants and crustaceans, but according to results it is the most likely that chemicals leached from Bakelite can be of increased concern.

Table 1. The effects of 100 mg/L Bakelite microplastics and its leachates on test organisms.

Organism	Exposure time	Inhibition (%)	
		Bakelite microplastics	Leachate
Daphnia magna			
Mobility	24 h	16 ± 2	100 ± 0
Lemna minor			
Specific growth rate	168 h	0 ± 0	0 ± 0
Root length	168 h	42 ± 7	31 ± 4
Allivibrio fischeri			
Bioluminiscence	30 min	12 ± 0	29 ± 1
Pseudokirchneriella subcapitata			
Specific growth rate	96 h	44 ± 10	11 ± 5

Despite the long and intensive production of Bakelite, this plastic is rather unexplored in the field of ecotoxicity. Our results showed that Bakelite can leach toxic chemicals, most likely phenol and phenol-like compounds, when in contact with aquatic media. Bakelite microplastics may also adhere to aquatic organisms, but the effects of the particles appear to be of lower importance compared to the effects of the leached chemicals. It is therefore necessary to focus on proper waste management of Bakelite items such as old consumer products and Bakelite coatings currently used by various industries, as well as to consider leaching when Bakelite microplastics are used as part of building materials such as cement mortar (Usahanunth and Tuprakay, 2017).

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