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Incinerating nano-enabled thermoplastics linked to increased PAH emissions and toxicity

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Source: Singh, D., Schifman, L. A., Watson-Wright, C. *et al.* (2017). Nanofiller presence enhances polycyclic aromatic hydrocarbon (PAH) profile on nanoparticles released during thermal decomposition of nano-enabled thermoplastics: potential environmental health implications. *Environmental Science & Technology*, 51 (9): 5222–5232. DOI: 10.1021/acs.est.6b06448.

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Advances in nanotechnology mean that a rapidly increasing number of products are being produced using engineered nanomaterials, for example, nano-enabled thermoplastics. Many of these nano-enabled products are destined to reach their end-of-life through waste incineration or accidental fire. Now, an original study has revealed that the presence of nanofiller in thermoplastics significantly enhances both the concentration and toxicity of polycyclic aromatic hydrocarbons (PAHs) produced during thermal decomposition at the product's end-of-life, resulting in concentrations of total PAHs and more toxic PAHs that are up to eight times higher than those found in pure (non nano-enabled) thermoplastics. This finding has significant environmental health implications.

A wide variety of nano-enabled products, including thermoplastics (polymers that become pliable on heating and solidify on cooling, and can do this repeatedly), cosmetics, building and construction materials, and biomedical and electronic devices are made using nanofillers, such as carbon nanotubes, zinc oxide nanoparticles, to mention a few. However, little research has been conducted on the potential environmental health implications of nanofiller presence in products — especially research that accounts for the complete product lifecycle. It is particularly important to determine any potentially dangerous effects occurring at the end-of-life of nano-enabled products, as we are generating ever-increasing volumes of nano-waste, some of which will be disposed of in incineration facilities via thermal decomposition.

A team of scientists set out to assess the effects of nanofiller presence on the organic chemistry of lifecycle particulate matter (LCPM) released through the thermal decomposition of nano-enabled thermoplastics. Specifically, the researchers investigated how the presence of nanofiller influenced the PAH profile of released LCPM. PAHs are important by-products of thermal decomposition of thermoplastics, as some types are classified as probable or possible human carcinogens. For this reason, the scientists analysed the 16 priority PAHs identified by the US Environmental Protection Agency.

To achieve their goal, the research team developed and used an integrated exposure generation system (INEXS) that they had developed in an earlier study. Using this platform, they performed a systematic investigation of the thermal decomposition of a variety of nano-enabled thermoplastics under controlled-combustion conditions. They were also able to generate LCPM particles, which were subsequently subjected to PAH analysis and toxicological evaluation.

The results indicate that nanofiller presence in thermoplastics significantly enhances the concentration of PAHs formed on the released nanoparticulate matter during thermal decomposition. For example, polypropylene and polycarbonate thermoplastics enabled with carbon nanotubes (PP-CNT and PC-CNT) both exhibited concentrations of total PAHs nearly eight times higher than those exhibited by their pure equivalents.

The findings also reveal that the concentration of high molecular weight (HMW) PAHs — which are more toxic than low molecular weight PAHs — increases along with the total level of PAHs. For example, PP-CNT exhibited a nearly eight times increase in HMW PAHs compared to pure polypropylene, while PC-CNT showed a nearly three times increase in HMW PAHs compared to pure polycarbonate.

Continued on next page.

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Incinerating nano-enabled thermoplastics linked to increased PAH emissions and toxicity *(continued)*

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According to the researchers, these effects may be the result of the catalytic properties of the metal/metal oxide nanofillers combining with the nanofiller's high number of active surface sites to drive higher PAH production. This nano-specific effect was confirmed through the *in vitro* cellular toxicological evaluation of LCPM from incinerated polyurethane thermoplastic enabled with carbon nanotubes (PU-CNT), which contained nearly double the concentration of PAHs than pure polyurethane, and a significantly higher concentration of HMW PAHs. Indeed, LCPM from the nano-enabled thermoplastic showed higher bioactivity and cellular toxicity compared to that from the pure thermoplastic, which can be attributed to the modified PAH profile.

Overall, the study provides important fundamental insights into the thermal decomposition behaviour of nano-enabled thermoplastics and the role of nanofiller presence on PAH formation. While this experiment examined thermal decomposition under well-controlled conditions and so did not simulate real-world industrial conditions, the findings nonetheless have important practical implications, especially from an environmental health perspective. In particular, the insights are relevant to strategies and practices aimed at minimising the occupational exposure risk of labourers working in incineration facilities, or for assessing and managing public health risk in contexts such as uncontrolled building fires where nano-enabled products are involved.