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Identification of relevant chemical and morphological descriptors of micro- and nanoplastics driving their toxicity

Current human risk assessment for micro- and nanoplastics (MNPs) particles requires comprehensive data on the relevant physio-chemical properties of MNPs that lead to ingestion and inhalation toxicity. To correlate particle properties with toxicity assays, we established measurement protocols for the visualization, characterization, and quantification of MNPs both separately and within complex biological matrices. These workflows involved correlative spectroscopy, microscopy, and biomedical investigations, including Raman, optical, fluorescence, and electron techniques, among others. Representative MNP materials, such as PS, PVC, LDPE, PET, and TPU, were used to assess the toxicity effects on human Calu-3 lung cells, podocytes (kidney cells), as well as on organ tissues from mice and zebrafishes exposed to MNPs. Raman spectroscopy (spontaneous and stimulated) was applied to unambiguously distinguish between MNP particles and the biological background of cells and tissues based on their specific chemical fingerprint. The Raman results were complemented by high-resolution imaging using scanning electron microscopy (SEM) and fluorescence for stained MNPs, mostly combined at the same regions of interest employing precise and automatic relocalization technologies from Horiba, such as Nano-Global Positioning System (nanoGPS) and Particle Finder [1]. In addition to the chemical composition, our correlative experimental approach supported by customized machine learning algorithms, enabled us to automatically determine the number, shape, size, morphology, and clustering of particles inside and on top of the cells and tissues in a statistically relevant manner. The MNP descriptors mentioned above, along with other descriptors like surface charge and reactivity, phospholipid interaction, dissolution rate, molecular weight, molecular mobility, and crystallinity, were correlated to various biomedical tests including cytotoxicity, interleukin-8 levels, inflammatory and macrophage responses, and gut microbiome alterations. It was found that MNPs can increase proinflammatory cytokines and disrupt the gut microbiome, reducing microbial diversity and shifting bacterial populations towards pro-inflammatory and potentially pathogenic species [2].

References

[1] G. Sarau et al., Context Microscopy and Fingerprinting Spectroscopy of Micro- and Nanoplastics and Their Effects on Human Kidney Cells Using NanoGPS and Particle Finder, Horiba Readout, 54 (2020) 23-32.
[2] V. Kopatz et al., Polystyrene micro- and nanoplastics aggravates colitis in a mouse model – effects on biodistribution, macrophage polarization, and gut microbiome, under review.

Figures

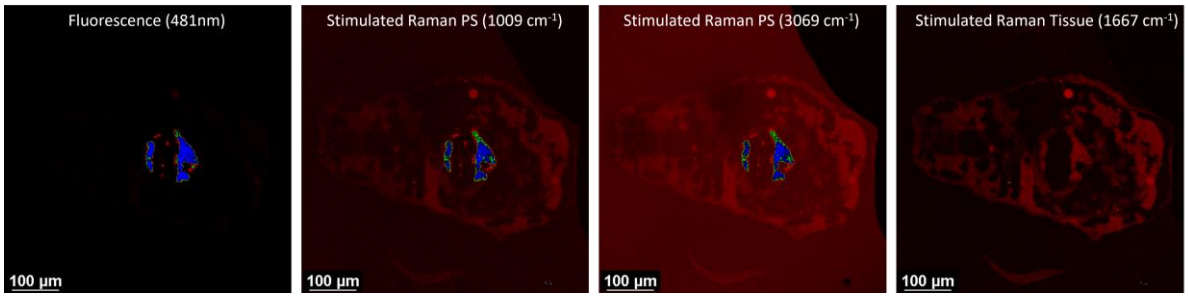

Figure 1: Correlative fluorescence and Raman measurements on a zebrafish sample with 50 nm PS particles in blue.