

An innovative biomarker-based blood assay for monitoring micro- and nanoplastic exposure in occupational and environmental settings

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Background: Human exposure to micro- and nanoplastics (MNPLs) is increasingly recognized due to their ubiquitous presence; however, their assessment is still based on physicochemical particle detection. These approaches are analytically complex, poorly standardized, and largely unsuitable for routine application, resulting in a major gap in the ability to quantify exposure-related biological effects and to identify at-risk individuals. This limitation is particularly relevant in occupational settings but also affects vulnerable population groups and limits translation to broader environmental contexts.

Aim: To present an innovative biomarker-based strategy that overcomes current limitations in MNPL exposure assessment by enabling detection of early biological responses using a simple blood-based molecular approach.

Methods: A MNPL-specific gene expression signature was identified using an *ex vivo* human whole-blood exposure model combined with integrative omics analyses. Candidate biomarkers were selected based on their consistent response across white blood cell subtypes and different MNPL types and tested by a quantitative polymerase chain reaction. The approach has been validated in occupationally exposed workers, and performance benchmarked against conventional genotoxicity and inflammatory biomarkers.

Results: The biomarker panel reliably discriminated MNPL-exposed individuals from controls, being able to identify early, potentially reversible molecular alterations not captured by current particle-based methods. The assay is compatible with standard blood sampling workflows, requires minimal sample volumes, and significantly reduces analysis time and cost. The biomarkers provide specific biological information associated with MNPL exposure, supporting their applicability in occupational health surveillance and environmental human biomonitoring.

Conclusions: This innovative blood-based biomonitoring approach addresses a critical methodological gap in MNPL exposure assessment by moving beyond particle quantification and detection towards biologically meaningful indicators. It offers a scalable tool for occupational health programs and has potential to be extended to vulnerable human populations and to other species relevant for environmental and food-chain monitoring, supporting integrated and preventive risk assessment strategies.

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