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BEYOND SURVIVAL: INNATE IMMUNE READOUTS IN ZEBRAFISH FOR ADVANCED BIOMATERIALS ASSESSMENT.

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The rapid expansion of bio-based nanomaterials for biomedical and industrial applications demands robust in vivo strategies to evaluate not only general toxicity but also subtle effects on the innate immune system. Zebrafish (*Danio rerio*) embryos are an attractive vertebrate model for this purpose, combining optical transparency, rapid extra uterine development and high genetic homology to humans, including conserved hematopoietic lineages and inflammatory pathways. In this context, we have shown that dechorionated embryos can be exposed to engineered nanoparticles or complex bioactive mixtures, and that their effects can be quantified through integrated endpoints such as macrophage and neutrophil recruitment, inflammatory and oxidative stress gene expression, and tissue regeneration capacity. On zebrafish inflammatory models obtained by lipopolysaccharide injection, sterile wounding and fungal filtrate exposure, lignin based and rice husk–derived silica nanoparticles were tested and found to be largely developmentally safe at relevant concentrations, while displaying distinct immunomodulatory profiles ranging from cytokine recruitment during acute inflammation to selective modulation of macrophage associated chemokines and neutrophil accumulation. These findings highlight that early immune endpoint, including the balance between pro inflammatory and pro resolving responses, are critical to discriminate truly biocompatible bio-based materials newly formulated that, although non-lethal, may perturb immune homeostasis. Overall, our work supports the use of zebrafish embryos as a predictive, ethically compliant tool to screen the immunological safety of novel bio-based nanomaterials, guiding safe-by-design strategies and informing Planetary-Health oriented risk assessment.

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References

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