

Toxicity assessment of thymol-loaded biogenic silica nanoparticles to aquatic organisms

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Thymol (THY) is a natural biocide with inhibitory effect on the growth of different organisms, such as bacteria, fungi, insect larvae, and weed. It has been applied in a much broader manner in the agricultural sector; however, its low solubility and instability in the presence of oxygen, light, and temperature hampers its use as a biocide. To circumvent these issues, we have proposed THY-loaded biogenic silica nanoparticle (BSiO₂#THY), but the toxicity of this system for aquatic organisms is unknown. In this context, this study evaluated the toxicogenetic effects induced by THY, BSiO₂ nanoparticle (NP), and

BSiO₂#THY on *Artemia salina* and zebrafish (*Danio rerio*) early-life stages. We also investigated the impact of BSiO₂ aggregation in the different exposure media (saline and freshwater). BSiO₂#THY (LC_{50-48h} = 1.06 mg/L) presented similar toxic potential as THY (LC_{50-48h} = 1.03 mg/L) for *A. salina*, showing that BSiO₂ had no influence on BSiO₂#THY toxicity. As BSiO₂ aggregated and sedimented faster in *A. salina* aqueous medium than in the other medium, this NP had lower interaction with this microcrustacean. Thus, BSiO₂#THY toxicity for *A. salina* is probably due to the intrinsic toxicity of THY. For zebrafish early-life stages, BSiO₂#THY (LC_{50-96h} of 13.13 mg/L) was more toxic than free THY (LC_{50-96h} of 25.60 mg/L); however, BSiO₂ NP has no toxicity for zebrafish early-life stages. The lower aggregation of BSiO₂ in the freshwater medium compared to the saline medium may have enhanced THY's availability for this aquatic organism. BSiO₂#THY also significantly induced sublethal effects as THY, and both were genotoxic for zebrafish. In conclusion, although BSiO₂#THY still needs improvements to ensure its safety for freshwater ecosystems, BSiO₂ NP seems to be a safe nanocarrier for agriculture.