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Effects of copper nanomaterials on marine benthic communities

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Copper nanomaterials (CuNMs) are used as an anti-bacterial and anti-fouling agent in numerous commercial and industrial products, including water purifiers, fungicides, wood and touch surfaces. The widespread popularity of copper nanomaterials in consumer products increases the risk for metal contamination and adverse effects in aquatic environments. Many information gaps exist on the potential toxicity of copper nanomaterials in aquatic ecosystems, particularly in marine environments. In the limited number of available studies, nano-copper oxide (CuO) was more toxic than bulk CuO to several invertebrates; however, the fate and effects on marine benthic communities is virtually unknown. Copper azole is a registered copper nanomaterial wood treatment used in structural lumber in above-ground, ground contact, fresh and marine water applications. For this research, we exposed field collected marine meio- and macrobenthic communities to copper azole spiked sediment in a novel exposure method that brings intact benthic cores into the laboratory and exposes the organisms via surface application of spiked sediments. Treatments included a Field Control, Laboratory Control, Low CuNM (51.9 mg/kg dry sediment), High CuNM (519 mg/kg dry sediment) and Dissolved Cu (copper sulfate at the "High" level). PERMANOVA results of macrofaunal community analysis indicate differences ($p < 0.05$) between the Low and High CuNM treatments, as well as differences between the Laboratory Control and the High CuNM treatment, and the Laboratory Control and the Dissolved Cu treatment. Differences were driven by three Podocopa ostracods, the bivalve *Gemma gemma* and the polychaetes *Exogone verugera* and *Prionospio heterobranchia*. Univariate measures were less sensitive with only the number of individuals (N) supporting the PERMANOVA results indicating a difference between the Laboratory Control and both the High Nano-CuNM and Dissolved Cu treatments. Meiofauna PERMANOVA results were less clear than the macrofaunal results: the Laboratory Control was different than the Low CuNM treatments ($p = 0.04$), and marginally different than the High CuNM ($p = 0.09$) and the Dissolved Cu treatment ($p = 0.08$). As in the macrofaunal results, the meiofauna univariate measures were not as sensitive, with only evenness (J') indicating a difference between the Lab Control and High CuNM. Differences in the meiofaunal community seem to be largely driven by nauplii,

nematodes, harpacticoids and oligochaetes. Findings of this investigation indicate CuNMs represent a source of risk to marine benthic communities comparable to dissolved copper and requires further study.