Removal of Heavy Metals from Soil using *Oryctes rhinoceros* Larvae

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Abstract

Heavy-metal contamination is a dominant environmental concern in Taiwan, where metals such as Cu, Zn, and Ni persist in soils, resist biological degradation, and accumulate through trophic transfer. Conventional remediation methods often face trade-offs between cost, efficiency, and preservation of soil integrity, underscoring the need for biologically driven alternatives. This study evaluates the feasibility of using *Oryctes rhinoceros* larvae as biological reactors for heavy metal removal, examining physiological responses, metal uptake, and interstage distribution across the larval, pupal, and adult phases.

Larvae exposed to metal-amended substrates for ten weeks exhibited metal-specific physiological effects. Zinc treatments induced elevated mortality, while high-Ni exposure markedly suppressed feeding and growth. Despite these stress responses, larvae removed 40–80% of the metal load, with accumulation proportional to exposure and reaching up to 125.4 mg Cu, 91.4 mg Zn, and 595.3 mg Ni per individual. Metals are concentrated predominantly in the gut, although Cu demonstrated greater tissue mobility than Zn or Ni. Elevated Cu and Ni burdens did not impair pupation, whereas increasing Zn concentrations significantly reduced pupal success.

Metal partitioning during metamorphosis revealed substantial transfer into exuviae and pupal cases, accounting for up to half of the accumulated Cu and Zn, and nearly all the accumulated Ni. In adults, Cu exhibited broad tissue distribution, whereas Zn localized mainly in the head, legs, and residual tissues. A soil–substrate (1:1) validation test confirmed that both larval performance and removal efficiencies were consistent with soil-free conditions. Collectively, these results demonstrate that *O. rhinoceros* larvae possess substantial capacity for heavy-metal uptake and redistribution, supporting their potential as a viable bioremediation tool for contaminated soils.

Keywords

Heavy-metal pollution, *Oryctes rhinoceros* larvae, biological reactor, heavy-metal distribution, soil heavy-metal remediation efficiency.