



“Gheorghe Asachi” Technical University of Iasi, Romania



EFFECTS OF SINGLE AND COMBINED MICROPLASTICS AND HEAVY METALS (CU, PB) ON DIGESTIVE ENZYMES IN *PAPHIA UNDULATA*

**Beta Susanto Barus^{1*}, Anna Ida Sunaryo Purwiyanto¹, Ellis Nurjuliasti Ningsih¹,
Yulianto Suteja²**

¹Department of Marine Science, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indralaya 30662, Indonesia

²Marine Science Department, Faculty of Agriculture, Mataram University. Jl. Majapahit No. 62, Mataram, Nusa Tenggara Barat, Indonesia

Abstract

Microplastics (MPs) are among the most common contaminants in aquatic environments and pose significant risks to aquatic organisms. MPs can also act as vectors for other pollutants, including heavy metals, potentially intensifying their biological effects. This study investigates the impacts of two sizes of polystyrene MPs (20 μm and 150 μm), both individually and in combination with copper (Cu) or lead (Pb), on the digestive enzyme activities (protease, amylase, and lipase) of the hard clam *Paphia undulata*. Overall, digestive enzyme activities tended to increase between days 5 and 7 of exposure, followed by a decline toward the end of the observation period. Larger MPs (150 μm) induced higher enzyme activity compared to smaller particles (20 μm). Co-exposure to MPs and heavy metals produced significantly greater peak enzyme activity ($p < 0.05$) than exposure to MPs or metals alone. Among the combined treatments, MPs with Pb elicited stronger and faster digestive enzyme responses compared to MPs with Cu. Clams exposed to MPs with Cu displayed peak enzyme activity on day 7 (except for amylase), whereas those exposed to MPs with Pb showed peak activity earlier, on day 5. These findings demonstrate that MPs—especially when combined with Pb—can disrupt digestive physiology in *P. undulata*, potentially impairing growth, health, and survival. The accumulation of MPs and heavy metals in clams also raises concerns about trophic transfer to humans and other consumers within the ecosystem.

Key words: bivalves, copper, digestive enzymes, lead, microplastic

Received: December, 2025; Revised final: June, 2026; Accepted: July, 2026

* Author to whom all correspondence should be addressed: E-mail: betasusanto@unsri.ac.id; Phone: +628 1397777110