

# Simultaneous effects of two fungicides (copper and dimethomorph) on their phytoremediation using *Lemna minor*

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**Abstract** Effects of two fungicides, copper and dimethomorph ((E,Z)4-[3-(4-chlorophenyl)-3-(3,4-dimethoxyphenyl) acryloyl] morpholine) on *Lemna minor* growth and phytoremediation were evaluated. The toxicity of copper and dimethomorph alone and in combination, was assessed by growth inhibition of *L. minor* cultures after 96 and 168 h. Copper had a severe impact on growth (max. inhibition: 90 % at 1,000  $\mu\text{g L}^{-1}$ ) while dimethomorph (as pure ingredient or formulated as Forum) did not (inhibition <45 % at 1,000  $\mu\text{g L}^{-1}$ ) after 168 h of treatment. When both chemicals were combined, synergism was observed after 96 h of exposure to copper and Forum. However, this interaction was a simple additivity after 168 h. Additivity

was also observed when the pure active ingredient (dimethomorph) replaced Forum in the mixture of copper and dimethomorph at 96 and 168 h. *L. minor* showed an excellent performance in removing copper from the medium since after 96 h, 36, 60, and 76 % removal were reached for 10, 20, and 30  $\mu\text{g L}^{-1}$  of Cu respectively. Copper accumulated in the plants. The removal of copper increased with Forum concentration. After 96 h copper (10  $\mu\text{g L}^{-1}$  initial concentration) elimination increased from 36.39  $\pm$  5.86–60.70  $\pm$  6.06 % when Forum concentration increased from 0 to 500  $\mu\text{g L}^{-1}$ . Accumulation of copper in plants was also increased by Forum but not by the active ingredient alone. Depuration of Forum by *L. minor* varied between 10 and 40 % after 96 h and it was generally more efficient than that of the pure ingredient. This depuration decreased in the presence of copper possibly due to the metal toxicity.

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## Introduction

Copper has been widely used in the formulation of pesticides to control mildew and other fungal diseases in several cultures all over the world. In winegrowing areas, such as the champagne region (France), “Bordeaux mixture” has been used for over a century, resulting in the contamination of waters, sediments and soils (Besnard et al. 2001). Dimethomorph, a cinnamic acid derivative, is a widely used systemic anti-sporulant fungicide that protects plants from downy mildew in agriculture and viticulture by inhibiting cell wall formation of fungi (Albert et al. 1988). The biochemical mode of action of dimethomorph is still