Heavy metals, such as lead, copper, cadmium, zinc, and nickel, are among the most common pollutants found in both industrial and urban effluents. High concentrations of these metals cause severe toxic effects, especially on organisms living in the aquatic ecosystem. Cadmium (Cd), lead (Pb) and copper (Cu) are the heavy metals most frequently implicated as environmental contaminants, and they have been shown to affect development, growth, photosynthesis and respiration, and morphological cell organization in seaweeds. This study aimed to evaluate the effects of 50 and 100 μM of Cd, Pb and Cu on growth rates, photosynthetic pigments, biochemical parameters and ultrastructure in Gelidium floridanum. To accomplish this, apical segments of G. floridanum were individually exposed to the respective heavy metals over a period of 7 days. After 7 days of experimentation, control, Cd-, Cu-, and Pb-treated G. floridanum showed altered morphological features with reduction in the amount of branches, noticeable discoloration, algal necrosis, and reduction in the content of photosynthetic pigments. When observed by transmission electron microscopy, control samples of G. floridanum showed cortical cells to be somewhat vacuolated, mostly filled with chloroplasts (Fig. 1a) and a large quantity of floridean starch grains close to the chloroplasts. However, after culturing G. floridanum in 50 and 100 μM of Cd for 7 days, cortical cells appeared more vacuolated with increasing cell wall thickness, exhibiting concentric layers of microfibrils. Chloroplasts showed a few changes in ultrastructural organization (Fig. 1b), and the number of plastoglobuli increased in the chloroplasts. In contrast to Cd exposure, copper treatment caused more dramatic ultrastructure changes in G. floridanum, with cortical cells showing a large reduction in cytoplasmic cell volume. The cell wall showed increasing thickness with deposition of concentric layers of microfibrils, and spots of black deposits appeared, most likely Cu. The chloroplasts were degenerated and disrupted, and the presence of plastoglobuli was observed (Fig. 1c). After Pb treatment, the cortical cells of G. floridanum showed a few changes in shape and increased cell wall thickness. In the cortical cells, an increase of vacuole volume could be observed. On the other hand, chloroplasts showed no changes in ultrastructural organization (Fig. 1d). These results indicate that Cd, Pb and Cu negatively affect metabolic performance and cell ultrastructure in G. floridanum and that Cu was more toxic than either Pb or Cd.

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Fig. 1: Transmission electron microscopy micrographic images of G. floridanum. a. Detail of chloroplast (C), showing the thylakoids near the mitochondria. b. Observe the irregular shape in thylakoid membranes (*). c. Note the disrupted chloroplast (C) with the presence of plastoglobuli (P). d. Observe the absence of changes in chloroplast.