SUBLETHAL EFFECTS OF CADMIUM ON SCORPIONFISH: ENZYMES AND BLOOD CHEMISTRY

Studies of the partitioning of contaminants between various fractions of the cells of exposed organisms (e.g. this volume p. 38) assume that the contaminant portion associated with the enzyme fraction may be exerting toxic effects. If so, these effects should be detectable in assays for enzyme activity.

Using cadmium as a model trace metal contaminant, Steven M. Bay, Darrin J. Greenstein, Peter Szalay, Karen D. Rosenthal, and David A. Brown investigated the relationship between changes in cytosolic distribution of cadmium and its biological effects in scorpionfish. They measured enzyme activity, histology and blood chemistry in an effort to provide a quantitative measure of cadmium's initial toxic effects. The measurements also can demonstrate the relative sensitivity of different tissues and subcellular fractions.

Bay and his associates compared biological responses in four tissues of scorpionfish exposed for 28 days to 0, 10 and 20 mg/L cadmium in seawater. They measured the activity of four different enzymes in each of four different tissues—gill, intestine, kidney and liver. These tissue samples were also analyzed to determine cytosolic distribution of cadmium, copper and zinc. Similar measurements have been made using lower levels of cadmium (Bay et al., 1984).

The enzymes chosen represent different potential modes of toxicity and subcellular locations. Two enzymes that contained sulfhydryl groups essential to their function were: glyceraldehyde phosphate dehydrogenase (GAPDH), located in the cytosol, and succinate dehydrogenase (SDH), located on the inner mitochondrial membrane. Cadmium has a high affinity for sulfhydryl groups, which are essential to the function of GAPDH and SDH.

Two metalloenzymes whose activity was measured were superoxide dismutase (SOD) from the cytosol and alkaline phosphatase (ALP), found on the plasma membrane. Both SOD and ALP contain zinc and SOD contains copper; for both enzymes, the metals are important structural components. The researchers reasoned that these enzymes might be affected by cadmium because the cytosolic partitioning

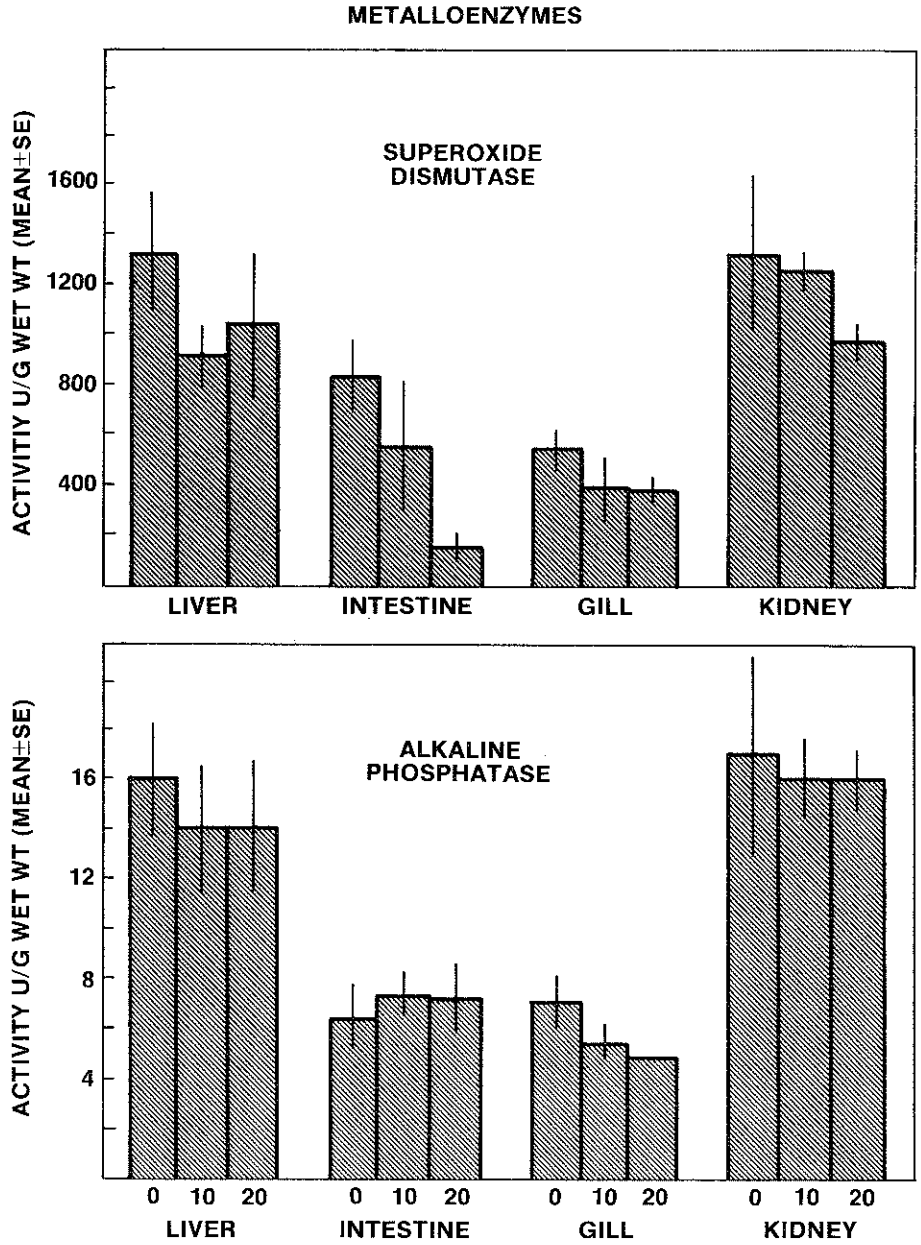

Figure 1. *Activity of metalloenzymes in scorpionfish exposed to 0 (control), 10, or 20 mg Cd/l.*

study (this volume, p. 38) showed that copper and zinc are markedly reduced in intestine subcellular fractions of fish exposed to high levels of cadmium.

Of the four enzymes studied, SOD's activity was most affected by cadmium exposure. In the intestine, SOD activity was reduced 82 percent following exposure to 20 mg Cd/L; its activity was also reduced in gill and kidney (Figure 1). The intestine was also the only tissue to show evidence of altered sulfhydryl enzyme activity (Figure 2); SDH activity was reduced while GAPDH activity was increased. ALP activity was demonstrably affected only in gill tissue (Figure 1).

The researchers also looked at blood chemistry of the scorpionfish. Plasma albumin, calcium and potassium were reduced, confirming that toxic effects were occurring in the fish, although the specific tissues affected could not be determined. Histological examination of the tissues indicated greater prevalence of abnormalities in gill and kidney and no abnormalities in the intestine or liver.

Bay and his co-workers derive the following conclusions from the enzyme activity measurements:

1. The cytosolic enzyme pool appears to be a site of toxic action for cadmium; the evidence is the greater effect of cadmium on the cytosolic enzyme SOD than on the membrane-bound ALP and SDH.

2. Both the enzymology and cytosolic partitioning data indicate that the intestine received the severest impacts. This agreement suggests that changes in cytosolic distribution may be used to assess impacts on the organism.

3. The changes in SOD activity as a result of cadmium exposure may be related to the observed reductions in enzyme pool copper and zinc concentrations (described in the partitioning study). Changes in SOD activity following cadmium exposure in mammals are usually due to reductions in cytosolic copper or zinc (Jamal et al, 1985).

4. Because there was usually no reduction in activity of GAPDH and SDH, the two sulfhydryl-containing enzymes, these results suggest that the binding of cadmium to sulfhydryl groups was not a principal mechanism of toxicity in this experiment.

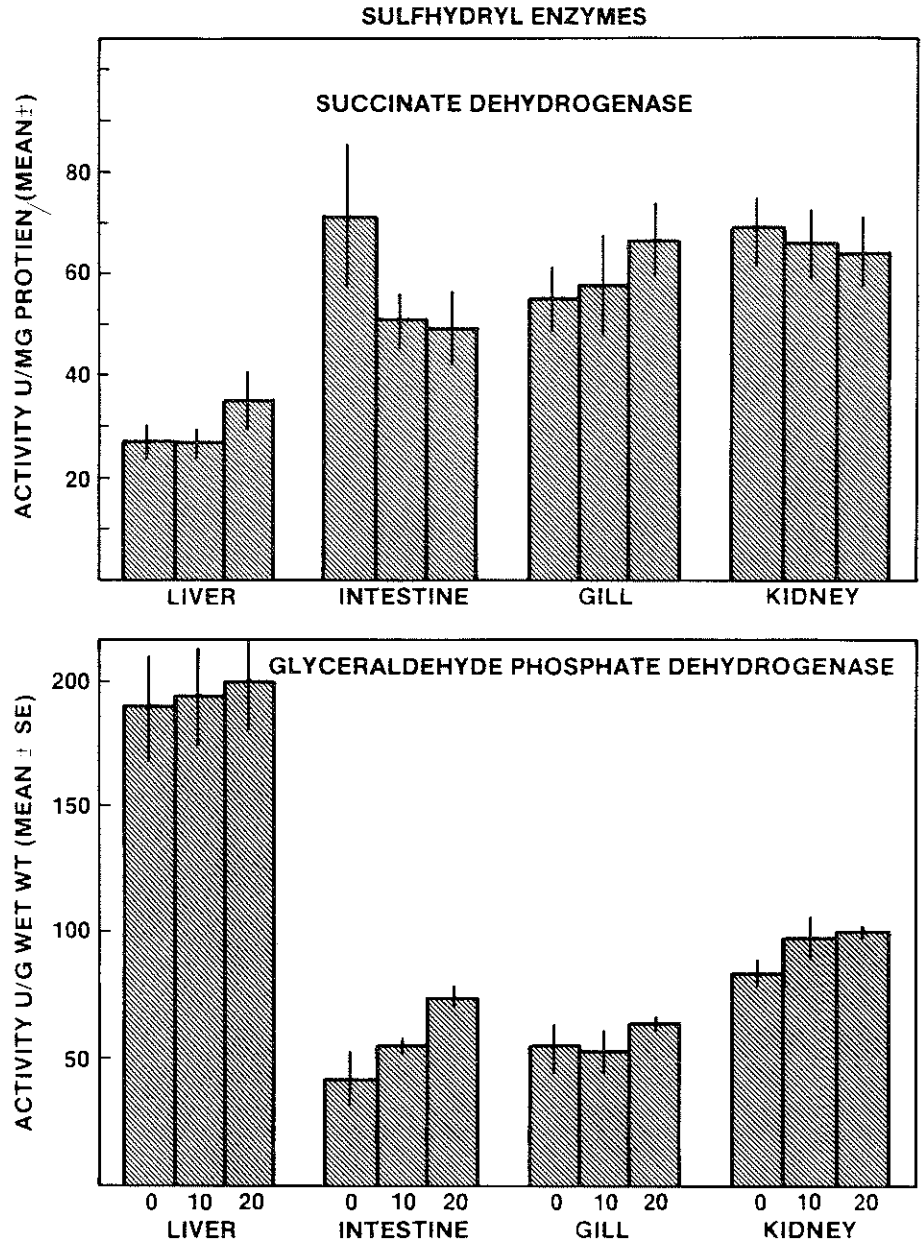

Figure 2. Activity of sulfhydryl enzymes in scorpionfish exposed to 0 (control), 10, or 20 mg Cd/l.

This experiment demonstrates the value of enzyme activity measurements in elucidating the mechanism and location of toxic effects in marine animals. Blood chemistry data can also indicate toxicity; however, it is often difficult to relate changes in blood chemistry to impacts on specific tissues. Histological examination can be used to locate affected tissues. However, the data is often semi-quantitative; and the technique may not be equally precise for different tissues. Because different tissue types may not show the same kinds of lesions, a quantitative comparison of tissues based on pathology is difficult.

The absence of observed histological changes in the intestine of scorpionfish may have been due to this tissue's rapid cell turnover and metabolism, resulting in large variations in cell structure.

References

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Jamal, I. S. and J. C. Smith. 1985. Effects of cadmium on glutathione peroxidase, superoxide dismutase, and lipid peroxidation in the rat heart; a possible mechanism of cadmium cardiotoxicity. Toxicol. Appl. Pharmacol. 80:33-42.