Interpreting Selenium Concentrations

Introduction

The importance of selenium as an environmental contaminant has gained widespread attention among field biologists, scientists, and natural resource managers during the past two decades. Although the basic toxicological symptoms and the nutritional paradox of selenium (nutritionally required in small amounts but highly toxic in slightly greater amounts) have been known for many years (Draize and Beath 1935; Ellis et al. 1937; Rosenfeld and Beath 1946; Hartley and Grant 1961), it was not until the late 1970s and early 1980s that the potential for widespread contamination of aquatic ecosystems due to human activities was recognized (Andren et al. 1975; Cherry and Guthrie 1977; Evans et al. 1980; National Research Council 1980; Braunstein et al. 1981). As recently as 1970, selenium was being called the "unknown pollutant" in the context of what was known about its cycling and toxicity in the aquatic environment (Copeland 1970). Yet, within a few years, several major cases of selenium contamination would take place and reveal the need to interpret selenium concentrations in a variety of aquatic habitats. Two examples were the pollution event at Belews Lake, NC, in which an entire fish community (19 species) was eliminated due to selenium in wastewater from a coal-fired power plant (Cumbie and Van Horn 1978; Garrett and Inman 1984; Sorensen et al. 1984; Lemly 1985a, 1993, 1997; Sorensen 1986), and the episode at Kesterson National Wildlife Refuge, CA, in which thousands of fish and waterbirds were poisoned by selenium in agricultural irrigation drainage (Marshall 1985; Hoffman et al. 1986; Ohlendorf et al. 1986, 1988; Saiki 1986a, 1986b; Saiki and Lowe 1987).

The research studies that have resulted from these and other cases of selenium contamination provide a foundation for interpreting selenium residues in the various environmental components that influence bioaccumulation and toxicity. This chapter reviews key literature describing toxic effect levels, and gives guidelines for evaluating sele-
nium in water, sediments, food-chain organisms, and fish and aquatic bird tissues.

**Toxic Thresholds**

All values for tissue selenium residues in this chapter are given on a dry-weight basis. Data from references that only reported wet weights were converted to dry weight assuming 75% moisture, that is, by multiplying the wet-weight concentration by 4. It is important to understand that the values given as thresholds are levels at which toxic effects begin to occur in sensitive species of fish and aquatic birds; for example, centrarchid and salmonid fishes (eg, genus *Lepomis, Micropterus, Oncorhynchus, Salvelinus*), ducks (genus *Anas*), and wading birds (genus *Recurvirostra*). They are not levels that signify the point at which everything dies from selenium poisoning, that is, the point at which total reproductive failure or massive mortality of juveniles and adults occurs. At the threshold level, selenium-tolerant species will be unaffected.

**Water**

Selenium is strongly bioaccumulated in aquatic habitats; this results in a marked elevation of residues in food-chain organisms as compared to waterborne concentrations (Lemly 1985b; Maier et al. 1988; Ogle et al. 1988; Ohlendorf 1989). It is critical to know how much bioaccumulation can be expected for a given aqueous level of selenium in order to evaluate the potential for dietary toxicity and reproductive effects in predatory species of fish and wildlife. Laboratory studies show that organoselenium compounds (seleno-L-methionine) can be bioconcentrated over 200,000 times by zooplankton when water concentrations are in the 0.5 to 0.8 μg Se/L (parts per billion) range (Besser et al. 1989, 1993). Resultant selenium residues were over 100 μg Se/g, a concentration that far exceeds the dietary toxicity threshold for fish (3 μg Se/g). Organoselenium compounds can comprise a substantial portion of the total waterborne selenium concentration in aquatic environments (Chau et al. 1976; Cutter 1982, 1986, 1991; Cooke and Bruland 1987), although the complete range of chemical species is poorly described. The potential for bioaccumulation and toxicity due to organic selenium is very high.

Inorganic selenium (selenate, selenite) bioaccumulates more readily in phytoplankton than zooplankton, and residues of up to 18 μg Se/g can occur when waterborne concentrations are in the 7 to 10 μg Se/L range (Besser et al. 1993), resulting in bioaccumulation factors of about 3000. It is at the primary producer and primary consumer levels of the food chain (phytoplankton and zooplankton) that most of the