Fate of Colloid-Particulate Elemental Selenium in Aquatic Systems

(Funded 2002-2003)

Principal Investigators:
Yiqiang Zhang
Department of Environmental Sciences
UC Riverside
(909) 787-5218
yqzhang@orange.ucr.edu

William T. Frankenberger
Department of Environmental Sciences
UC Riverside
(909) 787-3405
williamf@orange.ucr.edu

Executive Summary:
The biogeochemistry of selenium (Se) in wetland systems is very complex because it can exist in four different oxidation states (-II, 0, IV and VI) and as a variety of organic compounds. The bioavailability of Se as a toxicant in aquatic systems is largely dependent on the speciation of Se present. Organic Se, Se-[IV], and Se{VI] are available Se forms to aquatic biota, which has been proved by many studies related to Se ecotoxicity. Elemental Se (Se[0]) has been commonly considered as an unavailable form of Se in aquatic systems because of its low solubility, however, this consideration has never been proved.

In 1987, the United States Environmental Protection Agency (EPA) established a water quality criterion of 5 μg Se/L as a safe level to aquatic predators. It has become clear that dietary Se also is a major contributor to the toxic levels for aquatic predators. Therefore, both water-borne and dietary Se are available to aquatic biota. In aquatic systems, sediment is the largest reservoir of Se, accounting for more than 90% of total Se. Se[0] is an important Se pool in sediment and accounts for about 30-60% of total Se in the sediment. This Se[0] can be a contributor to its toxic levels for aquatic biota. Several studies have shown that particulate Se[0] in sediment can directly be assimilated by aquatic biota and can also be available indirectly to biota through its oxidation to inorganic Se[IV] and Se[VI]. These studies have provided valuable information regarding the bioavailability of particulate Se[0] and its fate in sediment. However, the fate of colloid Se[0] in sediment and colloid-particulate Se[0] in water has not been studied.

Formation of Se[0] in aquatic systems generally involves a two-step reduction process from Se[VI] to Se[IV], and then to colloid-particulate Se[0]. In a pilot scale Se bioremediation system conducted in the San Joaquin Valley, microbial Se[VI] reduction to Se[0] was found to proceed rapidly in a series of four columns. About 98% of Se[VI] and Se[IV] in agricultural drainage water was reduced. However, flocculation and precipitation of Se[0] in the columns proceeded very slowly. Se[0] can easily flow out of the columns. Se[0] accounted for 91-96% of total Se in the outflow water at days 184 and 186. Long residence time of colloid-particulate Se[0] in the water can make colloid-particulate Se[0] directly available to aquatic biota, and indirectly available to biota by its oxidation to inorganic Se[IV] and Se{VI]. Therefore, a detailed study on the fate of colloid-particulate Se[0] is needed in order to understand the bioavailability of Se[0] in aquatic systems.

We propose to investigate the fate of colloid-particulate Se[0] in aquatic systems by monitoring the change of colloid-particulate Se[0] in open water, water-sediment and water-plant-sediment systems and determining transformation of colloid-particulate Se[0] in water and precipitated Se[0] in sediment. The drainage water and sediment will be collected from the western San Joaquin Valley. Colloid-particulate Se[0] produced from the microbial reduction of Se[VI] in drainage water in the presence of rice straw will be used as a natural colloid-particulate Se[0] source. This is a two-year study. In the first year, a series of batch experiments on the fate of colloid-particulate e[0] in the open water and the water-sediment systems will be performed in the laboratory microcosms. Particulate Se[0] (≥0.4 μm), colloid Se[0] (<0.4μm), Se[VI], Se[IV] and organic Se will be determined in each water sample. Transformation rates of colloid-particulate to other Se species in the water and the sediment, and the precipitation rate of Se[0] to the bottom sediment will be determined. pH and Eh will be monitored after each collection of the water samples. In the second year, experiments will be performed on the fate of colloid-particulate Se[0] in the water-sediment-plant system. Se species in the water samples will be determined with time. At the end of the experiment, plant, algae and sediment samples will be collected for Se analysis. After completing all of the experiments, valuable information will be generated on the fate of colloid-particulate Se[0] in aquatic systems. This information may help scientists to better understand the bioavailability of colloid-particulate Se[0] in aquatic systems.