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Monitoring Recommendations

A systematic long-term monitoring program is crucial to understanding the fate and impact of management changes in regards to protection of ecosystems receiving selenium (Se) discharges. In addition to traditional variables like loads and water column concentrations, risk is affected by speciation, transformation to particulate forms, particulate concentrations, bioaccumulation, and trophic transfer to predators. These linked processes provide the necessary framework for monitoring. The principles of bioaccumulation and the approach used are applicable to modeling the San Francisco Bay-Delta and San Joaquin River ecosystems and predicting effects to birds and fish.

Monitoring, as conceptualized below and detailed in Luoma and Presser, 2000, would sample critical environmental components at a frequency relevant to each process to determine trends in Se contamination or changes in processes that determine fate and effects of Se.

- In any site-specific analysis of Se impacts, it is important that "site" be defined by all components of its hydrologic unit. Hydrologic models would serve as a basis for developing the infrastructure of this hydrologic unit. Specifically, the Bay-Delta ecosystem is connected to the San Joaquin River ecosystem, thus warranting consideration of the vulnerability of downstream water bodies when considering evaluation of upstream source waters. Toxicity problems may not appear equally in all components of a hydrologic unit because some components may be more sensitive than others. For example, the San Joaquin River, as a flowing water system may be less sensitive to Se effects (especially if selenate dominates inputs) than adjacent wetlands, the Delta or the Bay, where residence times and biogeochemical transformations of selenate are more likely.

- Multiple-media guidelines, in combination, provide a feasible reference point for monitoring. A linked or combined approach would include all considerations that cause systems to respond differently to Se contamination. The critical media defined here are water, particulate material, and prey and predator tissue. Monitoring plan components necessary for a mass balance approach include source loads of Se; concentrations of dissolved Se and suspended Se; Se speciation in water and sediment; assimilation capacities of indicator food chain organisms; and Se concentrations in tissues of prey and predator species. Determination of transformation efficiency and processes that determine Kds (distribution or partitioning coefficients) of Se in the Bay-Delta and San Joaquin River are crucial to relate loads to bioaccumulation, rates of transfer, and effects. Trace elements sequestered in bed sediments and in algal mats would be a part of recommended mass balance considerations.

- Invertebrates may be the optimal indicator to use in monitoring Se because they are practical to sample and are most closely linked to predator exposure. Knowledge of optimal indicators in the Bay-Delta and San Joaquin River are necessary to fully explore feeding relations. Resultant correlations with Se bioaccumulation in food webs are a part of this process.

- Determination of food web inter-relations would help identify the most vulnerable species. Specific protocols that include life cycles of vulnerable predators including migratory and mobile species would then document Se effects for the species most threatened.

- Selenium impacts in the Bay-Delta could increase if water diversions increase or if San Joaquin River inflows increase with concomitant increases in Se loading (i.e. the Se issue and the water management issues are tightly linked). The most significant impacts of irrigation drainage disposal into the Bay-Delta will occur during low flow seasons and especially during low-river flow conditions in dry or critically dry years. Dry or critically dry years have occurred in 31 of the past 92 years, with critically dry years comprising 15 of those years. Any analysis of Se effects must take the influences of variable river inflows into account.

- Little is known about Se concentrations in the Delta, yet this is the system that could be most impacted by Se discharges from the San Joaquin Valley. This is the transition zone between the Bay and the largest potential source of Se. It is an area of great biological value itself and an area of great emphasis in CALFED's restoration effort. The fate of Se in the Delta will be a key in determining the extent to which Se contamination will impede restoration of the estuary.

- The fate and effects of Se in the San Joaquin River are not well known. In short, if management and regulatory measures to restore the San Joaquin River ecological resources to their former level of abundance are to be effective, then the biogeochemistry of Se, ecological processes, and hydrodynamics in this system must be further investigated and understood. Adaptive management and monitoring for the San Joaquin River should be based on the biotransfer of Se and consider the environmental stresses imposed by present degraded conditions. Current discharge of agricultural drainage to the San Joaquin River via a 28-mile section of the San Luis Drain is under monthly and yearly load limitations. To determine whether load manipulation actually protects vulnerable predators, the following monitoring plan components are needed:
    1. an identification of vulnerable food webs;
    2. an identification of sites in the San Joaquin River most at risk from impacts of agricultural drainage;
    3. an effects analysis that includes food web components to predict effects on predators;
    4. an identification of elevated risk periods for effects based on hydrodynamics; and
    5. use of bioaccumulation as a basis for calculating protective loads or concentrations.

- A mass balance or budget of Se through the estuary is crucial because internal (oil refinery) and external (agricultural drainage) sources of Se are changing as a result of management. The ultimate fate of Se from past and current agricultural discharges is not known. At a minimum, a mechanism for tracking Se loading via oil refineries and the San Joaquin River is needed based on San Joaquin River, Sacramento River, and Bay-Delta hydrodynamics. Monitoring programs need to measure the on-going status of the system in terms of inputs, storage in sediment, through-put south via the Delta-Mendota Canal and California Aqueduct, and through-put north to the Bay.

- Storms and high-flow years will be times of increased regional discharge of drainage containing high concentrations and loads of Se. Violations of water quality criteria and load targets could result on a recurring basis, if the precipitation-dependence of the Se inflows is not recognized. The long-term effects of such occurrences on wetlands, wetland channels, the Delta and the Bay need to be better understood. The possibilities of long-term storage after such conditions and the efficiency of bioaccumulation during varying conditions of flow should be studied.

- In view of the analysis of the existing Se reservoir in the San Joaquin Valley, consideration of the degradation of groundwater aquifers needs to be a factor in management scenarios. Short-term management that results in more storage than leaching will result in more degradation of aquifers. Mass balance considerations should include a "storage" term, not only input and output terms. Monitoring and assessment of storage also will show if treating discharge on an annual basis will suffice to manage the current regional imbalance of water, salt, and Se.

- Treatment also may be important in determining source load impacts. Treatment technologies applied to source waters may affect both the concentration and speciation of the effluent. For example, a treatment process could decrease the concentration of Se in the influent, but result in enhanced Se food chain concentrations if speciation in the effluent changes to increase the efficiency of uptake.

Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of A Proposed San Luis Drain Extension, by Samuel N. Luoma and Theresa S. Presser, U.S. Geological Survey Open-File Report 00-416, is available at USGS libraries and from USGS Branch of Information Services, Box 25286, Federal Center, Denver, CO 80225 (phone 303-202-4200).