Selenium

The potential for selenium to severely affect fish and bird populations became clearly evident after the events at Belews Lake (North Carolina) and Kesterson Reservoir (California) in the late-1970s and mid-1980s, respectively. Since then, substantial research has been conducted on the fate and effects of selenium in aquatic systems, which have proven to be quite complex. The fate of selenium and its bioavailability to aquatic organisms are highly variable depending on site-specific biogeochemistry. The amount of selenium that is bioavailable at the base of the food web largely determines the exposure potential of sensitive fish and bird taxa, which are predominantly exposed to selenium via their diets. This means that there is a wide range of waterborne selenium concentrations among sites that could ultimately have adverse effects on fish and birds.

Windward's extensive experience in critically reviewing selenium toxicity studies with fish and birds has been used to recommend selenium guidelines for these taxa; we have also provided technical reviews of toxicity studies and draft ambient water quality criteria (AWQC) documents on behalf of the US Environmental Protection Agency (EPA). Our staff have supported clients in the development of selenium bioaccumulation models for linking tissue-based selenium guidelines to waterborne concentrations. And lastly, Windward has worked on several site-specific selenium risk assessments for clients in the mining industry.

Risk Assessments

Selenium is often a constituent of interest in various mining regions of the United States and Canada. Windward staff have conducted several site-specific ecological risk assessments of selenium in order to help clients with site management decisions. In one instance, Windward staff conducted a probabilistic assessment of potential selenium risks to aquatic shorebirds in the south shore wetlands of the Great Salt Lake in Utah. Bird egg exposures to selenium were quantified using a combination of measured and predicted concentrations. Predicted concentrations were estimated using site-specific dietary selenium data and diet-to-egg trophic transfer factors from several sites in the western United States. Probability distributions of egg selenium concentrations were developed using the Bayesian Monte Carlo analysis; the concentrations were then compared with species-specific probability distributions relating the probability of bird embryo deformities to egg selenium concentrations. in the resulting quantitative risk estimates allowed clients to focus resources on areas requiring corrective actions.

In another risk assessment at a coal mining site, Windward used multiple lines-of-evidence—including site-specific selenium, toxicity, and fish population data—to prioritize subareas for selenium and water management. Whereas consideration of only a conservative waterborne selenium guideline would have indicated widespread selenium risk, relevant site-specific data helped to determine that selenium risks were negligible in most subareas. This allowed site managers to focus on relatively small areas for targeted mitigation of selenium concentrations.

Toxicity Assessments and Criteria Reviews

Over the last two decades, as new laboratory and field results have become available, Windward staff have conducted several critical reviews of selenium toxicity data for fish and birds. These reviews have focused on the application of scientifically defensible and accepted methodologies, as well as consideration of environmentally relevant selenium forms and exposure pathways, in order to derive selenium effects thresholds that could be used in site-specific assessments and to support criteria development. Several of these evaluations and the resulting recommendations have been published in peer-reviewed scientific literature. Windward staff have also supported EPA in the technical review of several individual toxicity studies that were considered in the development of draft AWQC for selenium, as well as served as technical peer reviewers of the EPA's most recent draft AWQC for selenium.

Bioaccumulation Modeling

The strongest indicators of selenium risk to fish and aquatic-dependent birds are the selenium concentrations in their tissues. However, from a regulatory perspective, it is often necessary to relate selenium tissue concentrations to waterborne selenium concentrations, which are more amenable to monitoring and application in effluent discharge permits. This process can be complicated because relationships between selenium concentrations in water and organism tissues can be highly variable among sites. Understanding site-specific bioaccumulation potential can also be important when managing selenium at mining sites or other locations with selenium releases.

Windward staff and colleagues have developed various methodologies to model selenium bioaccumulation in aquatic food chains, including a site-specific methodology that relies on a combination of site-specific and non-site-specific data that describe relationships between selenium concentrations in co-located water and tissue samples. Another bioaccumulation-based methodology was developed in order to derive conservative waterborne selenium screening guidelines. This methodology uses large laboratory and field datasets to characterize the bioaccumulation and trophic transfer potential of selenium at each step in a model food chain, then applies quantile regression to back-calculate waterborne selenium screening guidelines from tissue-based selenium guidelines. Lastly, Windward staff have developed a biokinetic model framework to model pulse selenium exposures in aquatic food chains, as selenium concentrations in the environment often fluctuate seasonally and with storm events.