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CRWQCB-CRBR EXHIBIT No. 3

TO: Jose L. Angel, Division Chief
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FROM: Maria De La Paz Carpio-Obeso, PhD
Environmental Scientist **SIGNATURE:**___s/ 3/22/02_____

DATE: March 22, 2002

SUBJECT: REVIEW OF LITERATURE REGARDING SELENIUM IMPACTS ON BIOLOGICAL RESOURCES

At your request, I conducted a review of literature addressing selenium impacts on biological resources. This memorandum provides you with my review findings.

Findings

Selenium (Se) is widely distributed in the environment and essential in trace concentrations for human, animals, and possibly plants. The range in concentrations between "required" and "toxic" is very narrow (Jacobs, 1989). Processes that control Se distribution are intimately linked to its speciation: selenate (Se^{+6}); selenite (Se^{+4}); elemental selenium (Se^{0}), and selenide (Se^{-2}). The concentration, speciation, and association of Se are dependent on the pH, redox condition, solubility of Se minerals, Se ability, and biological interactions. Selenium can occur in all oxidation states in aquatic environments, with specific physical and biological properties determining the relative abundances of the various species. The mechanisms by which Se accumulates in plants and animals, its metabolic pathways, and its modes of action are not well known. However, Se was identified as the major pollutant in Kesterson Reservoir that caused teratogenic impacts to waterfowl due to its bioconcentration, bioaccumulation, and biomagnification in the aquatic food chain.

Bioaccumulation and Effects on Wildlife

In aquatic systems, Se commonly bioconcentrates in plant and animal life. Selenium levels in plankton typically exceed Se concentrations in water 500 to 2,000 times. Selenium levels in benthic invertebrates exceed Se concentrations in water 800 to 2,000 times, and in fish they exceed selenium concentrations in water 1,000 to 35,000 times, depending on the species and tissue sampled. Selenium concentrations in sediments typically range from 200 to 400 times concentrations in water.

The biomagnification of selenium progressively increases with successive trophic levels (Lemly, 1989). One significant effect of Se toxicity that occurs in all levels of the food chain, is a decrease in the ability to reproduce.

Algae

Selenium toxicity in algae is usually determined by measuring alteration in cell division rates. The concentration of Se in algae ranges from 0.01 to 5 ppm depending on the variety. Blue algae bioconcentrates 5-50 ppm Se as selenate or selenite, and is more tolerant than green algae which bioconcentrates 0.01-0.5 ppm Se as selenate (Knight, 1987, 1988). Inorganic Se is toxic to algae, more as selenite than selenate. The no-effect concentrations of Se for algae range from 0.01 to 10 ppm as selenate, and are species dependent.

Knight 1989, compared the bioavailability of selenite, selenate and selenomethionine in common freshwater algae. The Se species that accumulate in algae at the highest concentration is selenomethionine, followed by selenite and then selenate. Selenomethionine decreased algal growth at 0.1 ppm, and halted growth at 0.3 ppm. Selenite and selenate significantly decreased growth at 3 ppm, and halted growth at 5 ppm (UC Salinity Task Force, 1992).

Knight and Kiffney 1990, studied the comparative bioaccumulation of selenite, selenate and seleno l-methionine in the cyanobacterium anabaena flosaquae. They found selenite more toxic than selenate, and selenomethionine more toxic than inorganic species.

Invertebrates

Invertebrates are important components of the aquatic food chain that produce energy assimilated by primary producers. They also provide a source of food for higher tropic levels. Similar to algae, invertebrates biomagnify Se, and transfer Se to secondary consumers.

Daphnia exposed to 200 to 800 ppb Se showed decreased growth rates, and longer times for first reproduction. Decreased feeding rates among filter feeders were observed by Knight, 1988. Maier et al., 1993 evaluated the acute toxicity of inorganic and organic forms of Selenium using selenate, selenite, selono-dl-methionine and seleno-dl-cystine. The results indicate selenate and seleno-dl-custine are equally toxic to Daphnia; selenite is highly toxic, and seleno-dl-methionine is the most toxic.

Maier et al., 1993 also evaluated the effects to Daphnia at various sulfate concentrations under the same toxicological conditions. Sulfate concentrations of 10.2 to 162.7 mg/L decreased Daphnia mortality associated with selenate. The mortality caused by selenite increased from 10.2 to 81.5 mg/L sulfate, and decreased at levels greater than 81.5 mg/L. Sulfate concentrations did not affect seleno-dl-methionine Daphnia toxicity (Maier, 1993).

Fish

The effects of Se in fish are dependent on the species. Typically, excess exposure to Se causes decreased growth, edema, and abnormal development of various tissues such as bone, liver, kidneys, and ovaries. High Se levels decrease blood iron concentrations and red cell volumes. Lesions formed from Se exposure are not reversible (Lemly, 1989). The threshold concentration that triggers symptoms of Se toxicity in warm water fishes is 12 μg/g (Saiki, 1992).

Birds

The adverse effects of Se exposure on waterfowl is widely publicized given that abnormalities in bird embryos are multiple and readily apparent. These deformities were fatal for the birds inhabiting the Kesterson Reservoir (Ohlendorf, 1990).

Skorupa, 1992, investigated Se thresholds for waterbirds by evaluating the relationship between Se concentrations, waterbird eggs, and the frequency of tetratogenesis. The results indicate mean egg Se concentrations greater than 3 ppm represent an increased risk of teratogenesis, and that mean egg concentrations greater than 20 ppm reflect a high level of risk to reproductive success. Estimated risk thresholds of 10 ppm (upper threshold for background levels) and 50 ppm (lower for high risk of embryo deformity) are used for individual eggs.

If you have any questions about this, I am available to discuss this matter at your convenience.

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