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Selenium in a Wyoming Grassland Community Receiving Wastewater from an *In Situ* Uranium Mine

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Abstract. Water, soil, vegetation, grasshoppers, bird eggs, and bird livers collected at a 23.5-ha (58 acres) grassland irrigated with wastewater from an *in situ* uranium mine (study area) and a reference site in 1998 were analyzed for selenium and other trace elements. Selenium concentrations in the uranium mine wastewater applied onto the grassland ranged from 340 to 450 µg/L. Selenium in the upper 15 cm (6 in) of soil from the irrigated grassland at the mine ranged from 2.6 to 4.2 µg/g dry weight (DW). Mean selenium concentrations in soil and water were 5 and 15 times higher at the study area than at the reference site. Selenium concentrations in grasses and grasshoppers ranged from 6.8 to 24 µg/g and 11 to 20 µg/g DW, respectively. Selenium in red-winged blackbird eggs and livers collected from the study area ranged from 13.2 to 22 µg/g and 33 to 53 µg/g DW, respectively, and concentrations were well in excess of toxic thresholds. Mean selenium concentrations in grasses, grasshoppers, and bird eggs and livers were 5.8 to 30 times higher at the study area than at the reference site. Elevated selenium concentrations in water, soil, grasshoppers, and red-winged blackbird eggs and livers collected from the study area demonstrate that selenium is being mobilized and is bioaccumulating in the food chain.

Wastewater with high selenium concentrations can be produced with *in situ* mining of uranium ore as uranium-bearing formations are usually associated with seleniferous strata (Boon 1989). Boon (1989) reported that uranium deposits in Converse County, Wyoming, can contain up to 4,500 µg/g (ppm) of selenium. *In situ* mining of uranium is done by injecting a leaching solution of native ground water containing carbon dioxide and dissolved oxygen into the uranium-bearing formation through injection wells. The leaching solution oxidizes the uranium and allows it to dissolve in the ground water. Production wells intercept the pregnant leaching solution and pump it to the surface. The leaching solution also dissolves selenium present in the formation. The uranium is extracted from the pregnant leaching solution, and the water is reinjected into the ore-bearing formation. Water is recycled through the mining process several times and then is disposed of through deep-well injection, evaporation ponds, or land application through irrigation after treatment for removal of uranium and radium.

The Highland Uranium Project near Douglas, Wyoming, has reported waterborne selenium concentrations from 1,000 to 2,000 µg/L (ppb) in their *in situ* mining wastewater. The Wyoming Department of Environmental Quality (WDEQ) has permitted the mine to dispose of wastewater through land application. Wastewater is stored in holding ponds and is applied onto a grassland with center pivot irrigation systems. The grasslands irrigated with mine wastewater support several species of songbirds and their primary food source, insects. Given the high concentrations of selenium in the wastewater, an effort was made to determine if mobilization of this element was occurring in the food chain (*i.e.*, water > soil > vegetation > insects > birds).

The effects of selenium on aquatic migratory birds have been well documented (Eisler 2000; Ohlendorf *et al.* 1986, 1988; Skorupa and Ohlendorf 1991). Selenium concentrations > 2 µg/L in water are known to impair reproduction in sensitive bird species due to the high potential for dietary toxicity through food chain bioaccumulation. Little information is available on selenium bioaccumulation and toxicity in grassland species of passerine birds. Ohlendorf and Hothem (1995) report data on grassland species of passerine birds collected at Kesterson National Wildlife Refuge. Research on selenium mobilization and bioaccumulation in terrestrial communities has focused primarily on vegetation and ungulates (Raisbeck *et al.* 1996; Eisler 2000).

This study was designed to determine selenium concentrations in water, soil, and vegetation; terrestrial invertebrates; birds and bird eggs; to determine pathways of selenium in the food chain; and to document potential adverse effects to migratory birds resulting from selenium bioaccumulation.

Materials and Methods

Study Area

The Highland Uranium *in situ* mine is located in Converse County, Wyoming, and is located approximately 40 km (25 miles) north of Douglas and 38 km (24 miles) northeast of Glenrock (Figure 1). The

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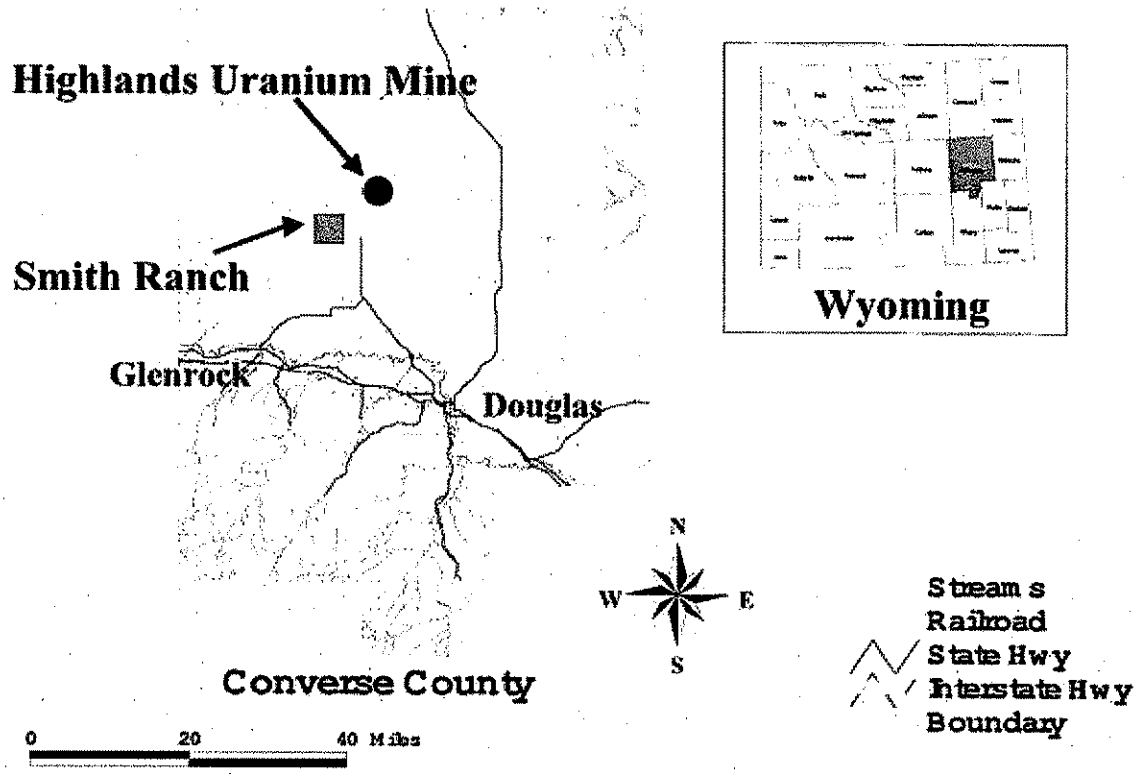

Fig. 1. Location of the Highland *in situ* uranium mine (study area) and the Smith Ranch (reference site), Converse County, Wyoming

wastewater storage reservoir is approximately 2 ha (5 acres) in size with a maximum depth of 3 m (10 feet). The center pivot irrigates 23.5 ha (58 acres) of grassland. The irrigator is a low profile system with 107 cm (42-inch) drop pipes and is 264 m (865 feet) in length. The irrigator completes a rotation every 21.8 h and applies approximately 0.68 cm (0.27 inches) of wastewater on the grassland per revolution. A small berm from 15 to 30 cm (6–12 inches) high encircles the irrigated area to ensure that the wastewater remains on site. The irrigated area is nearly flat and is dominated by grasses, such as brome (*Bromus tectorum*), foxtail barley (*Hordeum jubatum*), blue grama (*Bouteloua gracilis*), common buffalo grass (*Buchloe dactyloides*), western wheatgrass (*Agropyron smithii*), and needle and thread (*Stipa comata*). Soils in the irrigated area consist of clay and clayey-loam Bidman and Ulm soils. These soils are slowly to moderately permeable.

The area receives an average of 30 cm (12 inches) of precipitation per year, of which 45% falls during the months of May, June, and July (HPRCC 2001). The evapotranspiration rate is 58–63 cm (23–25 inches) per year (Martner 1986). Temperatures range from −40°F in the winter to 100°F in the summer (WRCC 2001). The prevailing winds are from the west and southwest with predominant speeds ranging from 17 to 33 km (11–21 miles) per h.

A center pivot irrigated area located on the Smith Ranch approximately 16 km (10 miles) southwest of the Highland uranium mine, was selected as the reference site (reference site). Alfalfa (*Medicago sativa*) is irrigated at the reference site. The radius of the irrigated area is 274.5 m (900 feet).

Bird Surveys

Bird surveys were conducted once a week between 0800 and 1200 MDT between May 5 and September 3, 1998. Stations were placed 200 m (658 feet) apart and 200 m out from the center pivot. Surveys were performed by one of two observers or both observers together. Counts at each station typically lasted 5 min but were extended to 10 min if abundance was low. All birds observed (seen or heard) within 75 m (246 feet) of a count station were identified to species.

Nesting Study

Songbird nests were located using random passes with a hand-held drag-line and through incidental flushes of females from nests. Each nest located was flagged 10 m (32.8 feet) out from the nest in alignment with the center pivot of the irrigation system. Nest locations were flagged 10 m away to avoid detection of nests by predators. For each nest located, clutch size was recorded and one egg was randomly collected. Eggs were dissected and embryos aged and examined for deformities. The egg contents were submitted for trace element analysis.

Trace Element Study

Vegetation, soil, water, and terrestrial invertebrate samples were collected from the study area and the reference site. All equipment used to collect water and soil samples was rinsed with deionized water and acetone prior to collection of each sample. Eight water samples were collected from the wastewater storage reservoir, the center pivot and from standing water within the irrigated grassland of the study area during June and August 1998. Two water samples were collected from the center pivot at the reference site in July and August 1998. Water samples were collected using 1-L chemically clean polyethylene jars with Teflon-lined lids. The pH of the water samples collected for