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Uptake of Mercury from Soils by Western Wheatgrass Seedlings¹

Abstract

The uptake of mercury by western wheatgrass (*Agropyron smithii* cv. Rosana) seedlings from five eastern Montana soils amended with 1.0 ppm Hg applied as $\text{Hg}(\text{NO}_3)_2$ was investigated in a greenhouse study. Above-ground tissues showed plant/soil concentration factors of 0.01 to 0.1. Up to 21 percent of the soil-applied Hg was lost by volatilization during the 22-day growth period.

Introduction

With the development of the energy resources of the western United States have come concerns regarding the environmental impact of the emissions associated with power-generation on the grassland biome. Due to its volatility and known toxicity, mercury (Hg) emitted from both coal-fired and geothermal power plants has been a metallic airborne pollutant of particular concern.

Coal from the Powder River Basin of northeastern Wyoming and southeastern Montana contains an average of 0.09 ppm Hg (Swanson *et al.*, 1974). The scrubbers and electrostatic precipitators used to control air pollution from coal-fired power plants are ineffective in the removal of Hg, present in the hot flue gas primarily as metallic mercury vapor (Hg^0), and about 90 percent of that in the coal is released to the environment (Billings and Matson, 1972; Montana State Department of Natural Resources and Conservation, 1974).

Numerous sites for the potential development of geothermally-powered electric generating plants exist in Oregon, California, Nevada, and New Mexico. Mercury present in geothermal reservoirs can be released to the surface environment with the live steam during drilling and venting, and from the spent steam in condensate ponds (U.S. Dept. of Interior, 1973; Siegel and Siegel, 1975).

Thus the potential for environmental contamination and bioconcentration of mercury exists in these energy development areas. Western wheatgrass (*Agropyron smithii*) is a widely distributed range species in the western United States and Canada, and is often the dominant species in the Northern Great Plains (Martin, 1969). Little is known regarding its uptake of heavy metals, a computerized search of Biological Abstracts since 1972 revealing only a single study (Munshower and Behan, 1971). The uptake of mercury from soils by western wheatgrass was therefore studied in a greenhouse experiment.

Methods and Materials

Five surface soils (Table 1) were collected from uncultivated sites in southeastern Montana, air-dried, and ground to pass a 2 mm sieve. The soil pH (1:2 soil:water), calcium

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TABLE 1. Chemical and physical properties of selected eastern Montana soils.

Soil Series	Classification	pH	CaCO ₃ equiv. %	Organic C, %	Total N, %	Extractable			Total Soluble Salts mmho/cm	Cation Exchange Capacity meq/100g	Total Hg µg/kg	Sand %	Silt %	Clay %
						P ppm	K ppm	Na meq/100g						
Arvada	Ustollic Natrargid, fine, montmorillonitic, mesic	8.1	0.08	1.6	0.10	3	526	0.87	0.43	22.2	60	35	25	40
Campspass	Typic Entroborall, fine, montmorillonitic	6.6	—	6.7	0.27	5	203	0.07	0.35	25.5	130	19	56	25
Heldt	Ustoric Camborthid, fine, montmorillonitic, mesic	8.3	3.32	1.7	0.12	1	186	0.08	0.35	11.4	183	27	48	25
Bainville	Ustic Torriorthent, fine, silty, mixed (calcareous), mesic	7.5	0.04	1.0	0.08	2	231	0.07	0.28	15.8	73	29	42	29
Terry	Ustollic Haplargid, coarse-beamy, mixed, mesic	8.3	0.20	0.9	0.10	1	84	0.07	0.31	8.4	<60	74	14	12

carbonate equivalent, organic carbon (Walkley-Black titration), total Kjeldahl nitrogen, extractable P (0.5 M sodium bicarbonate, pH 8.5), total soluble salts (saturation extract electrical conductivity), extractable potassium and sodium, and cation exchange capacity (1N ammonium acetate, pH 7) were determined (Kauffman and Gardner, 1976). Native soil mercury levels were determined by flameless atomic absorption spectrometry following digestion of the soil with aqua regia. Particle size analysis was by the pipette method (Day, 1965). The 1/3-bar moisture percentage was determined by the method of the U.S. Salinity Laboratory Staff (1954).

The soils, in 70 g (oven-dry basis) portions, were amended with 1.0 µg Hg/g soil using ²⁰³Hg-Hg(NO₃)₂ applied with sufficient water to reach the 1/3-bar content, and contained in plastic cups without drainage holes. There were 3 replicates per soil per treatment. After a 24-hour equilibration period, twenty seeds of "Rosana" western wheatgrass were applied to the surface of the soil and covered with 40 g of moist sand. The plants were grown in a chemical fume hood located in a greenhouse. Distilled water was added on alternate days to make up for evapotranspiration losses and to bring the soils back to the 1/3-bar moisture content. No fertility amendments were made to the soil either initially nor during the course of the experiment. Natural illumination was supplemented by incandescent lights (G.E. Gro-Sho; 16-hour-day length) whose heat was dissipated by a flowing-water filter cell. Twenty-two days after planting, the above-ground tissue was harvested, radioassayed using a NaI γ-scintillation spectrometer (Packard model 5230), and dried at 80 C. Tissue Hg concentrations were calculated from the specific activity of the added Hg assuming no dilution by the endogenous soil mercury pool.

In order to assess the extent of volatile loss of the added Hg from the soils during the course of plant growth, soil mercury content was monitored by radioassay of the entire soil mass using a small animal, whole-body, liquid scintillation spectrometer system (Armac model 446, Packard Instrument Co.). A special sample holder established a reproducible counting geometry in the sample well. The samples were counted using the 0.28 Mev γ-radiation of the ²⁰³Hg after soil amendment and again after tissue harvest.

Results and Discussion

Plant/soil concentration factors ($CF = \frac{\mu\text{g Hg/g tissue}}{\mu\text{g Hg/g soil}}$) for Hg in the above ground

portion of western wheatgrass seedlings range from 0.01 to 0.1 (Table 2). Tissue Hg concentrations were lowest for the Campspass and Arvada soils, the soils highest in organic matter and clay respectively, and highest in the high-lime Heldt soil. No toxicity

TABLE 2. Uptake of Hg by above ground portion of western wheatgrass seedlings grown for 22 days on soils amended with 1.0 µg Hg/g soil. Tissue concentrations shown are means of 3 replicates ± standard error, and are calculated on a dry matter basis.

Soil Series	ng Hg/g DM
Arvada	31 ± 2.3
Campspass	12 ± 6.4
Heldt	96 ± 22
Bainville	40 ± 5.8
Terry	37 ± 8.3

symptoms or yield reductions with respect to control plants grown on unamended soils were evident. Tissue yields on the Arvada and Campspass soils were about double those on the Terry soil, with the Heldt and Bainville yields falling in the intermediate range.

The volatile loss of Hg, presumably as Hg⁰, from soils amended with divalent mercury has been reported by several investigators (Rogers, 1975; Hogg, 1976). At the end of the 22-day growth period, from 9 to 21 percent of the initially-applied mercury had been lost from the soil-plant systems (Table 3). As the above-ground portion of

TABLE 3. Percent of initially-added Hg remaining in soil (corrected for plant removal) at end of 22-day plant growth period.

Values reported are means of 3 replicates \pm standard error.	
Soil Series	% Hg remaining
Arvada	90.8 \pm 0.4
Campspass	93.4 \pm 0.2
Heldt	83.8 \pm 0.2
Bainville	90.6 \pm 0.5
Terry	79.4 \pm 0.6

the seedlings are exposed to Hg vapors emanating from the soil, the Hg found in the aerial tissue is probably the result of both foliar interception of volatilized Hg (Zimmerman and Crocker, 1933), as well as translocation from the roots.

The concentration factors reported here are similar to those found for bromegrass (CF=0.05-0.06) grown for 49 days on soils amended with 10 μ g Hg (as HgCl₂)/g soil (Hogg, 1976), and for wheat and barley (CF=0.04-0.11) grown to the heading-out or mature stage on soils amended with 0.5 μ g Hg as Hg(NO₃)₂/g soil (Lee, 1974). Cadmium (Cd) is the Periodic Table neighbor of Hg in group IIb, and Munshower and Behan (1971) report a CF of 0.8 (based on acid extractable soil Cd) for western wheatgrass growing 20 miles from a zinc-cadmium smelter in Montana. Cd is generally considered to be more plant available than Hg (Lagerwerff, 1972).

In spite of the potential for both foliar and root uptake, only limited quantities of Hg were found in the above-ground portion of western wheatgrass grown on Hg-amended soils. Western wheatgrass would not appear to represent a source for food chain magnification of environmental mercury.

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