Mercury Uptake from Soil by Various Plant Species

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Discharged mercury (Hg) which enters the atmosphere from coal burning and smelting of copper, lead, and zinc ores settles with airborne particulate matter to contaminate the soil. The use of Hg compounds as herbicides in seed disinfection, and in plant disease control also adds to Hg levels in soils. Previous studies have assessed plant injury caused by exposure to vapours of Hg compounds (1, 2) and uptake of ^{203}Hg by pea roots (3). However, little is known about Hg levels and its distribution in food crops or the influence of differing amounts of the metal in soil. This paper reports on a growth chamber experiment undertaken to determine the influence of rate of Hg applied to soil from $HgCl_2$ on Hg levels and distribution in various parts of 8 food crops.

Materials and Methods

The cultivated surface horizon of Hazelwood silt loam used in this study had 11.8% oxidizable organic matter and 38.3 me/100 g of cation exchange capacity. The soil, initially 31.8% base-saturated, was limed with 5 g $CaCO_3$/1000 g soil to raise soil pH from 4.9 to 5.1. In a factorial experiment with 8 crops x 3 rates of soil Hg treatment (0, 4, and 20 ug Hg/g soil from $HgCl_2$) arranged in randomized blocks with 3 replications, plants were grown to maturity in 1 litre plastic pots containing 3000 g soil (oven-dry basis). Growth chambers regulated the temperature at 20 ± 2°C during a daily 16-hr photoperiod and 15 ± 2°C during darkness. Sufficient quantities of N, P, K, S, Ca, Mg, Mn, Zn, Cu, Fe, Mo and B were added to assure optimum growth of 6 leaf lettuce (*Lactuca sativa* L., cv. *crispa*, 'Salad Bowl'), 8 spinach (*Spinacia oleracea* L., cv. 'King of Denmark'), 3 broccoli (*Brassica oleracea* L., cv. *italica*, 'Waltham No. 29'), 3 cauliflower (*Brassica oleracea*, cv. *botrytis*, 'Snowball Y'), 3 pea (*Pisum sativum* L., cv. 'Dark Skin Perfection'), 12 oat (*Avena sativa* L., cv. 'Fraser'), 8 radish (*Raphanus sativus* L., cv. 'Early Scarlet Globe'), and 10 carrot (*Daucus carota* L., *sativa*, 'Chantenay Red Cored') plants per pot for 35, 55, 60, 70, 95, 100, 45 and 130 days respectively. Plants were separated

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into various parts (Table I), dried, ground, and digested with nitric-perchloric acid mixture (3) for determination of Hg by flameless atomic absorption spectrophotometry (4). The Hg concentrations in plants were expressed on a dry weight basis.

Results and Discussion

The results in Table I indicated that Hg levels in the plant parts increased as more Hg was added to the soil. Some plant parts were more dramatically affected than others. For 11 of the 22 plant parts, analyses of variance indicated that the treatment means, calculated over 3 replicates, showed significant differences at the 5% level. As shown by Duncan's multiple range tests for these plant parts, Hg levels in spinach leaves and roots, broccoli roots, pea vines, and carrot tops were significantly increased by application of 4 ug Hg/g soil, whereas only with addition of 20 ug/g soil, cauliflower roots, pea pods and roots, oat stalks, radish tubers, and carrot roots contained significantly higher Hg concentrations than corresponding plant parts harvested from control pots. Significant enhancement of Hg concentrations in spinach and broccoli roots at the low rate of Hg treatment was followed by a further significant increase in levels due to the high treatment rate. For several plant parts, markedly enhanced Hg levels occurred with addition of Hg to soil, but due to large variation between replicates, treatment means did not differ significantly at the 5% level. For others, some anomalous results were perhaps due to problems of sample contamination and difficulties encountered in Hg determinations. However, such findings warrant publication since they also provide an indication of Hg present in food crops grown on a soil polluted with moderate amounts of Hg.

Assessment of the differences in Hg uptake by various plant species and study of Hg distribution in specific crops were possible from comparisons between Hg levels in the plant parts for particular rates of soil Hg treatment. At the high rate of Hg added to soil, these differences between plant parts became most evident and the highest level of plant Hg occurred in cauliflower roots, 2.447 ug Hg/g. Root portions, noteably the zone for Hg accumulation in all crop, contained more than 1.0 ug Hg/g except for oat and lettuce roots which contained 0.426 and 0.387 ug Hg/g, respectively. Among edible plant parts, spinach leaves accumulated the most Hg, 0.695 ug Hg/g, and the level in radish tubers, 0.663 ug Hg/g, was nearly as high.

TABLE I

Influence of Hg in Soil on Hg in Various Parts of Eight Food Crops

Crop	Plant part	Plant Hg (ug/g) Control	4 ug Hg/g	20 ug Hg/g
Leaf lettuce	leaves	0.031 a[1]	0.017 a	0.045 a
	roots	0.112 a	0.175 a	0.387 a
Spinach	leaves	0.094 a	0.339 b	0.695 c
	roots	0.095 a	1.022 b	1.067 b
Broccoli	leaves	0.063 a	0.078 a	0.029 a
	roots	0.171 a	0.505 b	1.870 c
Cauliflower	leaves	0.079 a	0.068 a	0.061 a
	roots	0.019 a	0.197 a	2.447 b
Peas	seeds	0.001 a	0.002 a	0.003 a
	pods	0.005 a	0.011 a	0.042 b
	vines	0.110 b	0.187 c	0.085 a
	roots	0.011 a	0.160 a	1.415 b
Oats	grains	0.009 a	0.013 a	0.020 a
	husks	0.107 a	0.229 a	0.266 a
	leaves	0.176 a	0.193 a	0.199 a
	stalks	0.011 a	0.008 a	0.026 b
	roots	0.151 a	0.157 a	0.426 a
Radishes	tops	0.237 a	0.218 a	0.585 a
	tubers	0.013 a	0.026 a	0.663 b
Carrots	tops	0.024 a	0.061 b	0.072 b
	tubers	0.044 a	0.053 a	0.039 a
	roots	0.163 a	0.428 a	1.058 b

[1] Means, within a row of means, followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range test.

Distribution of Hg in carrot plants clearly indicated that Hg was accumulated in roots, the site for absorption of the metal from the soil, and was transported to the tops. However, less Hg reached the tuberous part of the plants. In oat plants, Hg levels declined in the following sequence: roots, husks, leaves, stalks, grain; indicating that the stalk served mainly as a transport from roots to husk and leaf portions of the plants with regard to Hg uptake by oats. When grown on soil treated with the high rate of Hg the lowest levels were determined in pea seeds and oat grains.

Summary

Mercury uptake by 8 food crops was studied in a growth chamber experiment involving 3 rates of $HgCl_2$ applied to soil. Mercury concentrations, on dry weight basis, in various parts of leaf lettuce, spinach, broccoli, cauliflower, peas, oats, radishes, and carrots were higher in root portions than the above-ground sections. Content of roots ranged from 0.387 ug Hg/g of lettuce roots to 2.447 ug Hg/g of cauliflower roots when 20 ug Hg/g of soil were applied. At the same treatment rate and among the edible plant parts, pea seeds and oat grain accumulated the least mercury while spinach leaves and radish tubers contained the highest concentrations, averaging 0.695 and 0.663 ug Hg/g of plant material.

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