Fisheries and Oceans Canada Pêches et Océans Canada

Uptake of Metals from Contaminated Soils into Berries

Prepared by: Faye d'Eon-Eggertson, Cher LaCoste & Hans Damman

Regional Office of Environmental Coordination, Fisheries & Oceans Canada

Introduction

The consumption of berries grown on contaminated soils is often identified as a potential exposure route for human and ecological receptors in a risk assessment. Berries can be challenging to sample because they are present for only a brief time during the growing season and sample sizes are often limited, leaving a gap in the risk assessment. Metals, including cadmium, nickel, lead, copper, and zinc, can present significant human and ecological health risks, but there is a paucity of reliable uptake factors related to soil concentrations.

We compiled co-located soil and berry data from 7 studies, including 66 berry samples from 17 different geographic areas. The results did not indicate a clear linear relationship between the concentrations of metals in the soil and those found in the corresponding berries, suggesting potential barriers to uptake or the presence of non-linear uptake relationships (Figure 1). The purpose of this study was to examine the relationship between metals in the soil and those in plant tissue in order to provide guidance when conducting risk assessments.

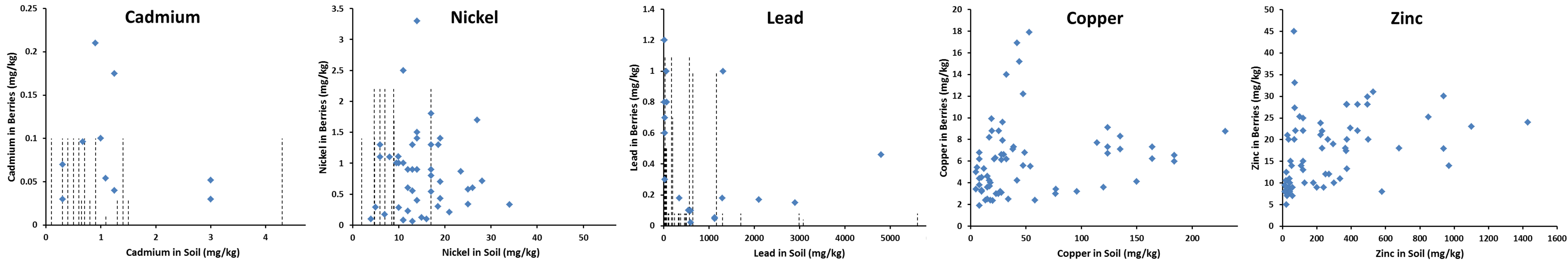


Figure 1: Concentration of metals in co-located soil and berry metal samples from previous studies. Dashed vertical lines indicate censored (below detection limit) values.

Methods

Setup

The study was conducted at Cape Beale Lightstation, near Bamfield, BC. This location has previously been identified as having high levels of metal contamination that was heavily weathered in the soil. In March of 2014, areas of high and low metal contamination on site were identified using field screening techniques. Soil was manually excavated from an area of high metal contamination and from an area of low metal contamination. We created soil with an intermediate level of contamination by mixing equal parts of the soils containing high and low concentrations of metals.

Forty-five 1L (6" diameter) pots were filled with soil from the low metal contamination soil pile (Low Contamination), 45 pots were filled with soil from the high metal contamination soil pile (High Contamination), and 45 pots were filled with a mixture of the two soils (Intermediate Contamination). Initial sampling indicated that the three treatments differed (Table 1).

The pots were randomly positioned in a greenhouse on site and were each sampled for metal concentrations.

Table 1: Initial soil metal results

	Low Contamination	Intermediate Contamination	High Contamination
Cadmium (mg/kg)	0.3	1	2.6
Copper (mg/kg)	23	144	390
Lead (mg/kg)	159	1153	3460
Nickel (mg/kg)	5.5	6.6	11.1
Zinc (mg/kg)	83	423	1240

Planting & Growing

In April 2014, one bare-root everbearing strawberry plant was placed in each pot. Each pot was fertilized and watered to field capacity. Nine plants that died in the three days following planting were replaced.

Plants were fertilized every three weeks and watered every 2-3 days depending on soil moisture levels.

Harvesting

As the strawberries ripened, they were collected in labeled sample bags and frozen. At the end of the study, due to sample volume constraints, 127 berry samples and 12 duplicate samples were sent to the lab for total dry weight metals analysis. In addition, for every fifth sample, the remaining aboveground plant tissue (shoots, leaves) was also sent to the lab for analysis (28 samples).

Results & Discussion

As in the initial data compilation, we found non-linear relationships between the concentrations of metals in co-located soil and berry metal samples.

Cadmium & Nickel

All of our soil samples contained levels of cadmium and nickel that were below the CCME soil quality guidelines for residential/parkland (10 and 50 mg/kg respectively).

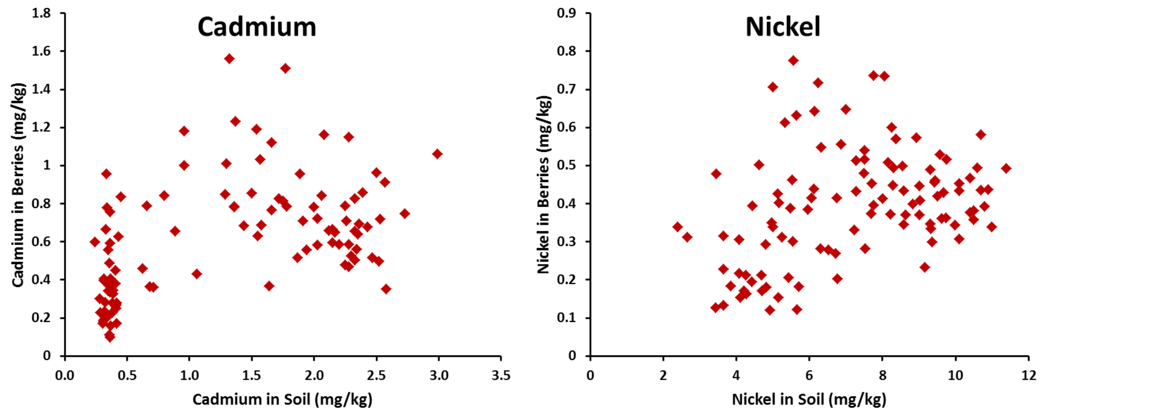


Figure 2: Concentration of cadmium (left) and nickel (right) in co-located soil and berry metal samples.

Lead

Our samples contained high concentrations of lead in the soil (the CCME soil quality guideline for residential/parkland is 140 mg/kg). Several berry samples contained high concentrations of lead; however the relationship between these high levels in the berries and the corresponding levels in the soil was unclear.

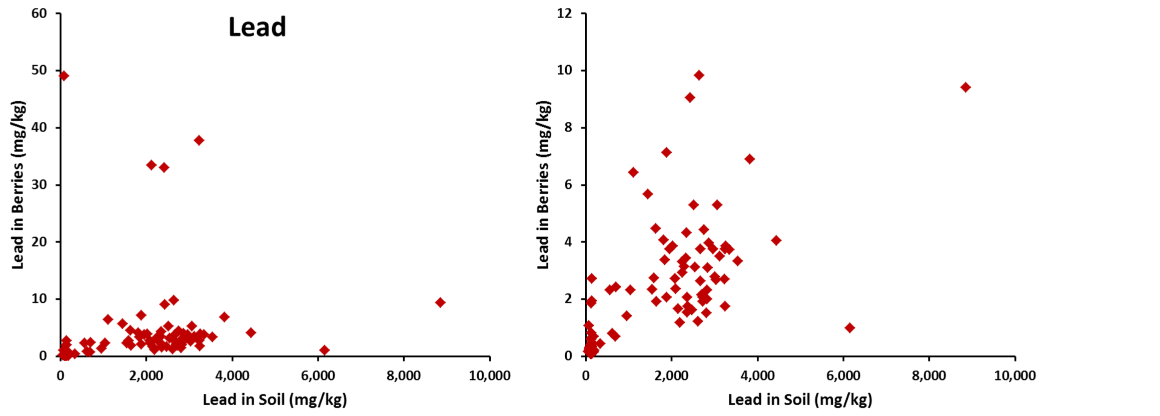


Figure 3: Concentration of lead in co-located soil and berry metal samples, with outliers removed in the right panel.

Copper & Zinc

Copper and Zinc are micronutrients which are essential for plant growth in very small quantities. The relationship between the concentrations of metal in the soil and in the berries suggests threshold effects or other non-linear effects. At low soil metal concentrations, there is a steep increase in the berry metal concentrations, and then there appears to be no further increase at higher soil-metal concentrations. This is noteworthy because in risk assessments, only berries grown in soils that exceed the CCME soil quality guidelines would warrant further testing.

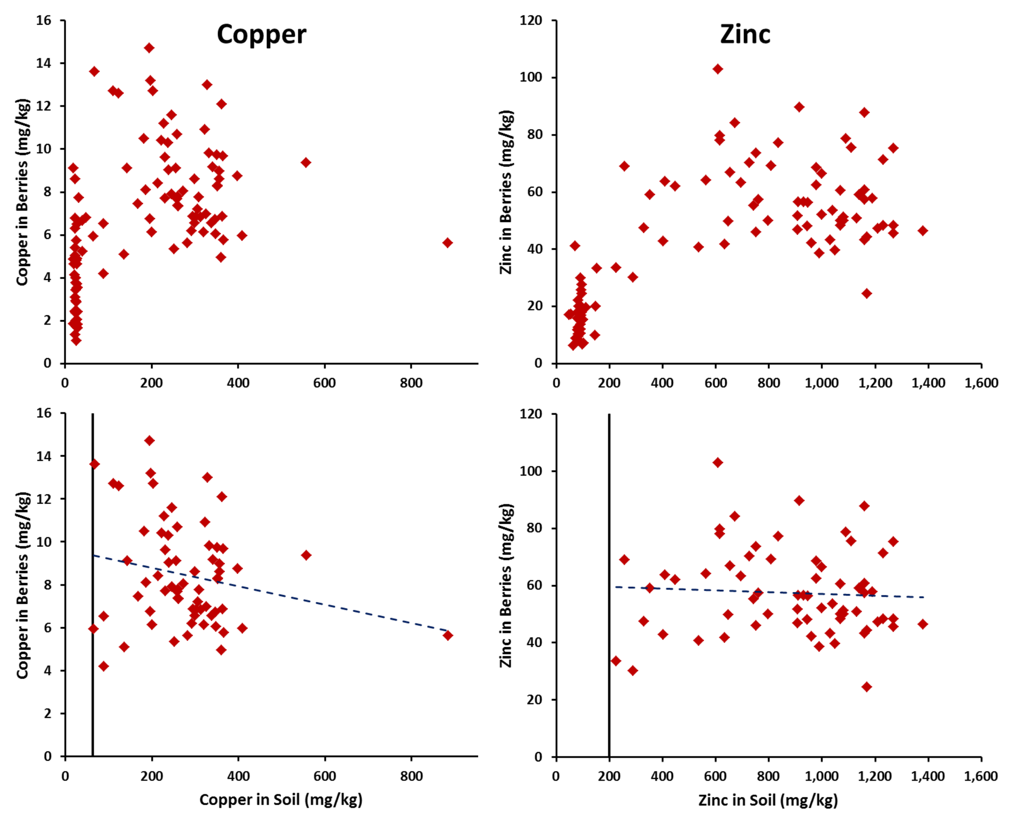


Figure 4: Concentration of copper (left) and zinc (right) in co-located soil and berry metal samples. The top panels show the full set of data while the bottom panels show only the samples where the soil metal concentration exceeded the CCME soil quality guidelines, with a linear regression.

Other Plant Tissue

The concentrations of cadmium, nickel, lead and zinc were higher in other above ground plant tissue (shoots, leaves) than in berry tissue. No difference was observed for copper.

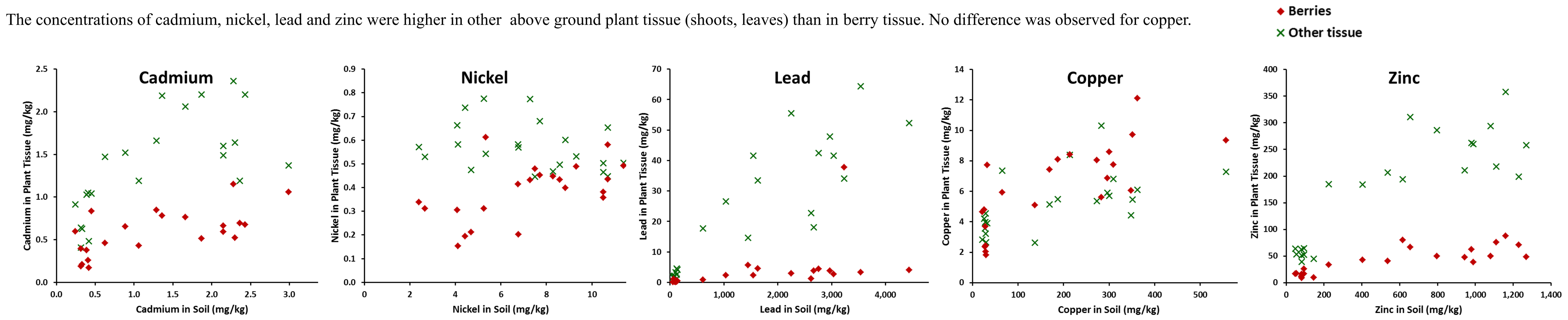


Figure 5: Concentrations of metals in berries (red diamonds) and other plant tissue (green Xs) from the same plants.

Fitting the Data

Existing literature on the uptake of contaminants by plants often uses concentration ratios (the ratio of the concentration of the contaminant in the plant to the concentration in the soil) as a measure of soil to plant transfer. Concentration ratios inherently assume a linear relationship centered at zero between soil and plant contaminant levels. The non-linearity we find in our results suggest that the use of concentration ratios may overestimate the true relationship between plant and soil contaminant levels when looking at the uptake of metals into berries. Figure 6 shows three different ways to fit the data.

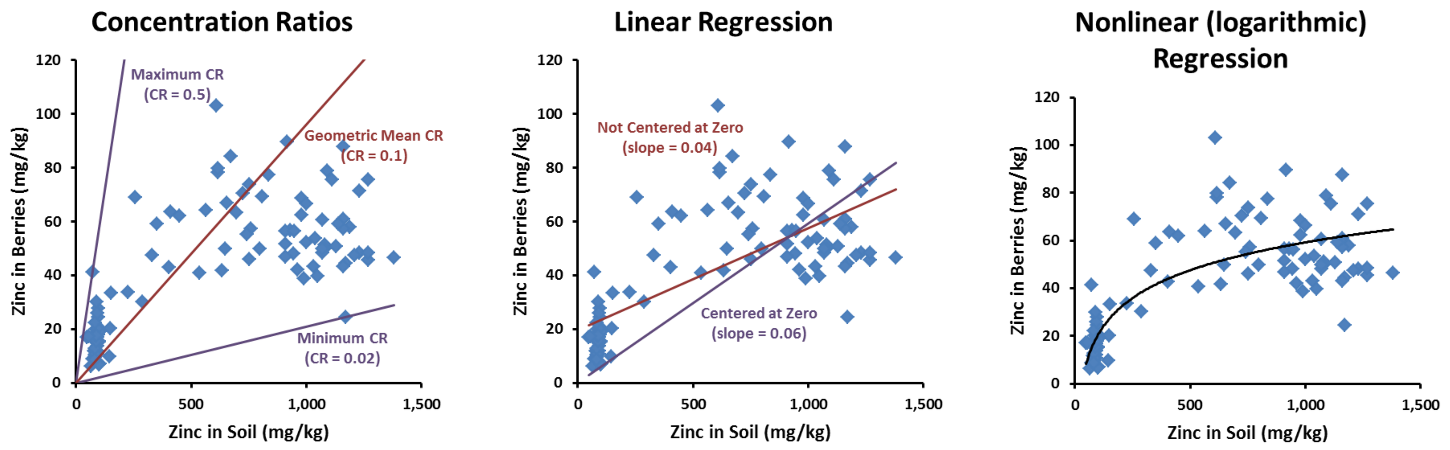
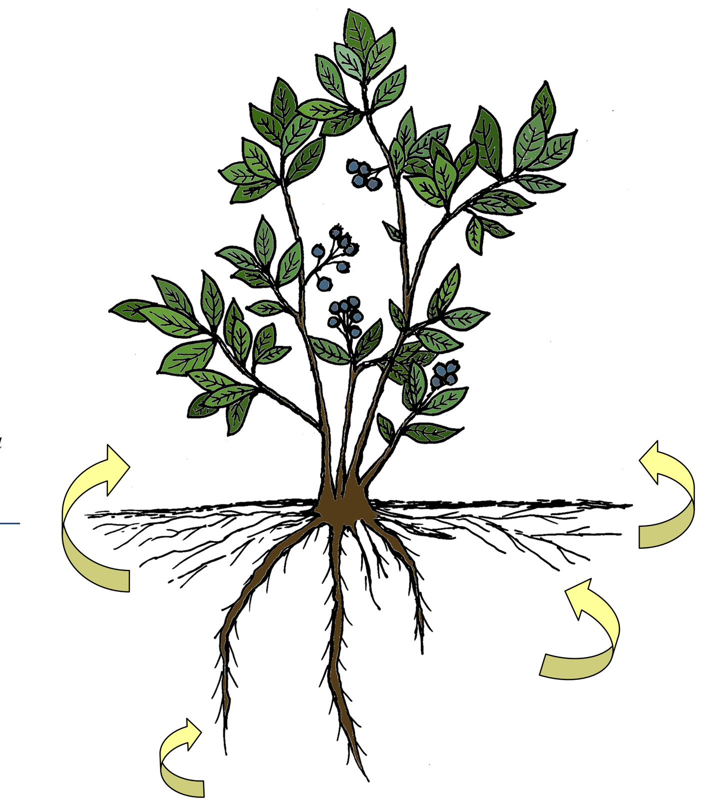


Figure 6: For our zinc results, the concentration ratios measured from the data (left panel), a linear regression fit to the data (centre panel), and a nonlinear regression fit to the data (right panel).



Conclusions

When conducting human health risk assessments for a wild lands type scenario, the consumption of berries is a common exposure pathway. It can be prohibitive to collect berry tissue (due to site accessibility, time of year cost, etc.) so risk assessors often model the concentration using simple concentration ratios with known concentrations in the soil. Based on the data collected during this experiment, this will lead to an overestimate of exposure and could impact remedial decision making. The use of nonlinear relationships is more suitable for the berries that were analyzed in this study. Whole plant tissue is a poor surrogate for berries and should be avoided or at least acknowledged that this will result in an overestimate of exposure.

Acknowledgements

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