A PROVISIONAL ASSESSMENT OF RISK ASSOCIATED WITH HEAVY METAL ACCUMULATION IN NEW ZEALAND AGRICULTURAL SOIL

Effects of landfarming and fertiliser use on the heavy metal concentration in plants

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

This study investigated heavy metal accumulation in New Zealand agricultural soil (horticultural soil and landfarm-impacted soil), factors influencing their concentration in leafy vegetables and pasture, and the potential implications to food safety, animal welfare and human welfare. The study also sought to verify the hypothesis that "landfarming poses no threat to pasture and animal welfare" with respect to heavy metal accumulation. In addition, hemp phytoremediation potential was also explored for landfarm-impacted soil.

This study is a synthesis of two glasshouse trials that have, as a common denominator, heavy metal accumulation in New Zealand agricultural soil. The first project assessed cadmium accumulation in leafy vegetables (spinach, silverbeet and lettuce) grown on two New Zealand commercial horticultural soils while the second project focused on heavy metal accumulation in pasture (ryegrass) and a cash crop (hemp) grown on agricultural soil that had been amended with drilling waste. Bulk composite soil samples used for this glasshouse trial were collected from commercial horticultural farms in two locations (Pukekohe and Gisborne), while a landfarm-impacted soil and drilling waste from oil exploration and production sites was collected from the Taranaki region. Soil samples were crushed and potted into replicate pots containing (4kg). Lettuce, spinach and silverbeet were seeded in horticultural soils while ryegrass and hemp were seeded in impacted soils. All soil and plant samples were harvested and taken to the Soil and Earth Science laboratory, Massey University Palmerston North for analysis of heavy metal concentration (Cd, Zn, Cu and Ni) and dehydrogenase activity. Descriptive statistics and ANOVA of means was conducted using Minitab 17.

The total Cd concentration in the Pukekohe soil was 0.26 mg Cd/kg soil and that in the Gisborne soil 0.11 mg Cd/kg. The Cd, Cu, Ni and Zn concentration in the landfarm-impacted soil was 0.1 mg Cd/kg; 12.57 mg Cu/kg; below detection limit (BDL) for Ni and 29.99 mg Zn/kg respectively. These values were not significantly different to concentrations in an adjacent control soil collected at the same time for the pot experiment (0.1 mg Cd/kg, 11.5 mg Cu/kg, 29.14 mg Zn/kg, and Ni (BDL)). The Cd concentration in all leafy vegetables grown on the horticultural soil and sampled at two time points (spinach, silverbeet and lettuce) exceeded tolerable limits for Cd in agronomic crops (0.05 - 0.5 mg Cd/kg) with the exception of lettuce (in Pukekohe and Gisborne soil at final stage) and silverbeet (in Pukekohe soil at final stage). Spinach showed elevated Cd accumulation (0.27 mg/kg FW) above CODEX (2010) and FSANZ (2011) limits for the Gisborne soil. The heavy metal concentration (Cd, Zn, Ni and Cu) in hemp and ryegrass grown on the landfarm-impacted soil and control were not significantly different but within tolerable limits in agronomic crops (Cu: 5 – 20 mg/kg; Zn: 50 – 100 mg/kg; Ni: 1- 10 mg/kg). Soil pH is the dominant factor influencing metal bioavailability while organic matter content, and oxalate extractable Al and Fe oxide content (sesquioxides) also affects cadmium bioavailability in agricultural soils.

There was no evidence of a heavy metal (Zn, Ni, Cu and Cd) concentration above soil limits defined for the safe application of biosolids in horticultural and landfarm-impacted soils. This suggests that animal wellbeing (via soil ingestion) and food safety will not be affected as a result of land application of drilling waste and long history of P fertiliser use. However, cadmium and heavy metal management is necessary to prevent elevated accumulation over time. Elevated Cd concentration in spinach does not pose direct threat to human consumers but has the potential to limit the accessibility of this product in export markets.

A soil heavy metal concentration below biosolids guidelines in the landfarm-impacted soil implies that remediation of this land is not necessary. This observation was supported by data on soil microbial activity in the landfarm-impacted soil which showed no difference from the control soil. The data does not support the public perception and industry concerns that heavy metal accumulation in landfarm-impacted soil poses a health risk. In case of a continued halt in milk collection from landfarm-impacted sites by the dairy industries, a cash crop (hemp) with no exposure pathway and high biomass quality (under landfarm-impacted soil) that potentially has high economic value could replace the traditionally ryegrass system, changing the agricultural land use from a food one to a non-food one.

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Table of contents

Table of Contents

List of illustrations

List of Tables

List of Figures