STUDIES ON THE ORIGIN, DISTRIBUTION AND MOBILITY OF CADMIUM IN PASTORAL SOILS

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Soil Science at Massey University

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1998

ABSTRACT

Cadmium (Cd) is a toxic heavy metal with no known biological function. Exposure of the human population to Cd is predominantly through cigarette smoke and Cd-containing foodstuffs. Many phosphatic fertilizers contain Cd and their application to land used for food production results in increased concentrations of Cd in the soil. The fate of this Cd in soils is poorly understood. In this study, factors influencing the concentration and residence time of Cd in pastoral soils were investigated.

Total Cd concentrations in topsoil samples (0 - 7.5 cm) from a regularly fertilized farm were found to range between 0.07 and 0.91 mg Cd kg^{-1} (arithmetic mean of 0.36 mg Cd kg^{-1}). The top soil Cd concentration was unrelated to soil type or parent material but correlated well with total phosphorus and total carbon. In a study of the distribution of total Cd throughout the profiles of 17 soil types on the farm, Cd concentrations generally decreased with depth and soil parent material contributed little to topsoil Cd loads.

A comparison of pedologically matched fertilized and unfertilized soils on the same farm confirmed that phosphatic fertilizer was the dominant source of Cd. Fertilized sites showed a 3- to 20-fold increase in soil Cd loading. Increased Cd concentrations were detectable to 15 cm. These increased Cd loads were easily accounted for by an estimated phosphatic fertilizer input of 6 g Cd ha^{-1} yr^{-1} over 7 decades.

Soil Cd concentrations were also influenced by stock camping behaviour, although the magnitude of this effect was much less than that due to fertilizer.

To investigate conditions under which Cd may move deeper in the soil profile, laboratory-based leaching studies on repacked soil columns using various electrolyte leaching solutions were conducted. Columns leached with 2.5 mM $CaCl_2$, $CaSO_4$ and $Ca(NO_3)_2$ showed some limited movement of Cd, but columns leached with 2.5 to 7.5 mM KCl showed no significant redistribution of the added Cd. Under the soil conditions studied (pH_{H2O} 5.45), cation exchange appeared the predominant driving force behind Cd mobility, not anion complexation. On the same soil, Cd mobility increased linearly

as leachate $CaCl_2$ concentration increased. By 50 mM $CaCl_2$ most Cd was leached from the column. In view of the dominance of Cl^- in coastal soil solutions, this mobility under the influence of $CaCl_2$ may be important.

In a further experiment, four soils differing in physical and chemical properties were leached with 2.5 mM $CaCl_2$. The wide range of Cd mobility seen, could be explained by differences in soil pH (pH_{H2O} 4.95 - 6.02). The movement observed in these columns was adequately modelled using a simple convection-dispersion equation and adsorption isotherms. The movement of Cd observed and modelled in these laboratory studies suggests that leaching is likely to be a much more important mechanism of Cd loss from the soil profile than removal of animal products. This work was supported by findings from a field-based mass balance study of Cd inputs and accumulation in soil developed under pasture on a Wharekohe podzol. Despite clear accumulation of fertilizer-derived Cd in the surface of these pastoral soils, up to 44% of the applied Cd remained unaccounted for. The most likely reason for this was leaching.

Accurate modelling of the residence time and plant availability of Cd in soils will rely on a quantitative understanding of the factors influencing Cd mobility in soils. This is an area requiring further research.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to the following people:

My supervisors, Prof. Russ Tillman, Assoc. Prof. Mike Hedley and Dr. Julian Lee for their advice and guidance.

John Rounce for his efforts in helping me to understand and operate the graphite furnace. Lance Currie for his support and technical assistance during my laboratory work. Anne West for her tolerance and understanding of my requests for new, uncontaminated lab-ware, and her invaluable help with innumerable questions and requests, as well as poster presentations. Bob Toes and Ian Furkert for their ever-willing help with practical difficulties and challenges. Ian Painter from Ag Engineering for his good humoured assistance in producing extra equipment for several aspects of these studies.

Dr. Dave Scotter for his enthusiasm and help with respect to my leaching studies and numerical modelling. Dr. Alan Palmer for his assistance with soil profile descriptions and his patience in correcting my interpretations of his short-hand. Professor Robert Brooks for kindly accepting a request to read through the final draft of one chapter and then stoically ploughing through several more. Dr. Jenni Edwards for her help and contribution to the studies of soils from the Wharekohe chronosequence.

Anne West, Willie Martin, Joe Whitton and Harry Percival for additional laboratory analyses, and Mike Bretherton for assistance with computing queries.

Special thanks to my Mum for her stoic support and many nights of sacrificed sleep during the endless months of often tedious and frustrating laboratory work. Thanks also to Denise and Marian, the wonderful secretaries in the Soil Science Department, in particular for their assistance during the 12 months I spent away from Palmerston North; and thanks to my Dad for his tolerance and support over that year I was at home.

And finally, a grateful thank you to all my friends and colleagues who kept me going during the times when finishing this thesis began to look like an impossibility.

Special thanks also goes to the C Alma Baker Trust for financial support of the project.

Since writing the above, I have additional thanks to make to the wonderful staff of the Palmerston North Hospital. I am especially thankful to the doctors and nurses of Ward 24 who cared for me and maintained my spirits during the several weeks I spent there recuperating. I also wish to thank my friends who came to visit during that time for their cheer and laughter.

To all of the above mentioned persons:

This is the thesis that WOULD be completed ... eventually!

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LIST OF SYMBOLS

(Chapter 7)

C	= solute concentration ($M\ L^{-3}$)
C_{tot}	= total concentration of solute in unit soil volume ($M\ L^{-3}$)
D	= dispersion coefficient ($L^2\ T^{-1}$)
D_s	= molecular diffusion coefficient in soil ($L^2\ T^{-1}$)
K_d	= distribution coefficient ($L^3\ M^{-1}$)
q_s	= solute flux density ($M\ L^{-2}\ T^{-1}$)
q_w	= Darcy flux density ($L\ T^{-1}$)
R	= retardation coefficient (dimensionless)
S	= amount of solute adsorbed by the soil matrix ($M\ M^{-1}$)
t	= time (T)
V	= average pore water velocity ($L\ T^{-1}$)
z	= diffusion distance (L)
θ	= volumetric water content ($L^3\ L^{-3}$)
λ	= dispersivity (L)
ρ_b	= soil bulk density ($M\ L^{-3}$)