Nutrient Accumulation in Soils Under Long-Term Farm Dairy Effluent Application

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Juliet Cox

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Abstract

Land-based application of farm dairy effluent (FDE) has been encouraged by regional councils since the introduction of the resource management act (RMA) in 1991. The problems associated with FDE irrigation are high levels of nitrate in ground and surface waters which can lead to human health issues where the groundwater is used as drinking-water and environmental degradation of streams, rivers and lakes. Regional councils impose nitrogen loading limits to reduce the likelihood of environmental problems from nitrate leaching. Long-term data investigating FDE application and the associated soil changes over time is currently unavailable and the nutrient budgeting tool OVERSEER® Nutrient Budgets 2 is validated against only short-term trials. Therefore, assumptions made in the model for long-term FDE application areas may not be correct.

The project investigated the soil chemical characteristics of six long-term (>6 years) farm dairy effluent paddocks and matched non-effluent paddocks in the Waikato and Bay of Plenty. Fieldwork involved the removal of five core samples from each paddock, with each core yielding six sub-samples of 75 mm depth. Soil analyses included bulk density calculations, cation exchange capacity, total carbon, nitrogen and phosphorus determination and Olsen P.

It was found that two sites had the same total cation exchange capacity in the effluent and non-effluent paddocks, but the proportions of the individual cations were different. A significant ($\alpha = 0.05$) difference in the exchangeable potassium concentration existed between the pairs of paddocks with much greater potassium found in the areas irrigated with FDE. No discernable difference in the concentrations of carbon and nitrogen was found between the topsoil of the effluent and non-effluent paddocks. This was due to the highly variable nature of the effluent and the soils themselves, and the large pool of nutrients in the soil, requiring a large change before a noticeable difference occurred. The total

nitrogen and phosphorus levels found in the soil profiles (0-450 mm) of the effluent and non-effluent paddocks were very similar, and reflects the large additions of fertilisers to non-effluent paddocks.

The OVERSEER® Nutrient Budgets model was used to produce nutrient budgets for farms from the Waikato and Bay of Plenty and predictions of accumulation of nutrients over time. Comparisons made between the OVERSEER® results and soil chemical analyses revealed that with the exception of potassium, it was not possible to accurately predict the nutrient concentration in the soil by extrapolation of OVERSEER® data. This was due to changes in management practices over time and the inherent variability of soils. If the model is to be used as a regulatory tool, accurate fertiliser records must be kept, along with frequent pasture and soil analysis. It is also advisable that a soil map of the farm area is completed in order to most accurately use the model.

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CHAPTER 1: **Introduction**

The intensification of dairying in NZ caused by increased herd numbers (LIC 2004) has led to a greater volume of farm dairy effluent (FDE) being produced each year. Previous management of FDE allowed its disposal to surface waters, which causes nutrient enrichment and degradation of the streams, rivers and lakes, called eutrophication.

With the introduction of the resource management act (RMA) in 1991, regional councils became more aware and accountable of the environmental effects of land management decisions and started to encourage the treatment of the FDE through the soil-plant system via land application.

The only constraint on the farmers with this new legislation is an annual maximum nitrogen loading. In the Waikato, this limit is set at 150 kg N ha^{-1} yr^{-1}, while in the Bay of Plenty; it is now at 200 kg N ha^{-1} yr^{-1} (Cameron & Trenouth 1999). These limits are designed to minimise the nitrate-nitrogen (NO_3^-) that is leached out of the system as high concentrations of NO_3^- in groundwater that is used as a drinking-water source have been linked with human health problems and to reduce the eutrophication potential in nearby streams and rivers.

Improper management of FDE systems can lead to these environmental problems and several computer programmes are available which enable farmers and consultants to estimate their annual nitrogen inputs, outputs and losses. This gives them the knowledge of the environmental consequences of some of their decisions such as timing of fertiliser application. One such computer model is OVERSEER® Nutrient Budgets 2 (v. 5.0.14.0), developed by AgResearch and available for free off the internet. The assumptions and calculations made in the model have been validated against the numerous short-term fertiliser and effluent trials conducted in New

Zealand (Ledgard *et al.* 1999). The model is not, however, validated against any long-term FDE investigations. The issues involved with FDE application are not as straight-forward as fertilisers as FDE contains varying concentrations of nutrients, in a liquid form, and with a carbon source. FDE is also often applied at inappropriate times such as when the soil is saturated and when pasture growth is slow.

The general purpose of the research was to investigate the validity of using OVERSEER® to give nutrient budgets for long-term FDE paddocks as actual leaching losses and storage in the soil may be different to those predicted by OVERSEER®. This was achieved by the following objectives:

1. investigate soil chemical properties under long-term (>6 years) irrigation of FDE and compare with non-irrigated areas.

2. use data derived from the soil chemical analyses and farmer interviews to produce nutrient budgets for sites using OVERSEER® Nutrient Budgets 2 (v.5.0.14.0).

3. attempt to use phosphorus as an indicator of the quantity of nutrients applied over time and predict soil accumulation rates.

4. use OVERSEER® data to extrapolate accumulation rates and compare with the results from soil chemical analysis.

5. evaluate the performance of OVERSEER® in prediction of nutrient movement in long-term organic nutrient application situations.

Previous research into the issue and sustainability of FDE irrigation onto land has focussed on the form and concentrations of nutrients, particularly nitrogen, phosphorus and sulfur, lost from the soil profile as drainage and overland flow (Cameron *et al.* 1999; Di & Cameron 2002). Few studies have investigated the changes that occur in the soil with FDE application.

The outline of this thesis follows the standard format, with chapter 1 being a short introduction to the subject, chapter 2 containing a review of the literature pertaining to FDE and irrigation of FDE onto land and chapter 3 describing the fieldwork and soil chemical analyses undertaken. Chapters 4, 5 and 6 involve the results and discussion part of the three aspects of the project: soil chemistry, the use of OVERSEER®, and the comparison and evaluation of OVERSEER® and the soil results. Chapter 7 concludes the research with a summary and recommendations for future work.