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Integrated treatment of farm effluents in New Zealand's dairy operations

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ABSTRACT

Maintaining growth through intensification in the New Zealand dairy industry is a challenge for various reasons, in particular sustainably managing the large volumes of effluent. Dairy farm effluents have traditionally been treated using two-pond systems that are effective in the removal of carbon and suspended solids, however limited in their ability to remove nutrients. In the past these nutrient-rich two-pond treated effluents were disposed of in surface waters. Current environmental concerns associated with the direct discharge of these effluents to surface waters has prompted in developing technologies to either minimise the nutrient content of the effluent or apply effluents to land. Here, we discuss various approaches and methods of treatment that enable producers to sustainably manage farm effluents, including advanced pond treatment systems, stripping techniques to reduce nutrient concentration, land application strategies involving nutrient budgeting models to minimise environmental degradation and enhance fodder quality. We also discuss alternative uses of farm effluents to produce energy and animal feed.

1. Introduction

With the world human population estimated to increase from 5.4 billion in 1990's to 8.5 billion by 2025, an increase in food production of 60–70% will become necessary to meet world food demands and minimise malnutrition (Power and Dick, 2000; Bolan et al., 2004a). Faced with a continuous decline in suitable land area for crop production, increased demands for animal products are likely to be met through more intensive agricultural production systems. Greater volumes of effluent and manure by-products associated with farm intensification will in turn need to be dealt with in ways that conform to increasingly stringent environmental regulations.

Confined production of beef and dairy cattle, poultry and swine represent major sources of manure and effluent by-products in most countries (Power and Dick, 2000). In many countries, dairy and piggery farm effluents are treated biologically using two-pond systems. This treatment should remove much of the biological oxygen demand and the suspended solids of the waste. The two-pond systems, however, are not primarily designed to remove nutrients, such as N, P and K. Nutrients remaining in farm pond effluents are significant pollutants and when discharged to streams stimulate weed and algal growth, and result in the eutrophication of the waterways (Houlbrooke et al., 2004a; Wang et al., 2004).

In New Zealand, with the introduction of the Resource Management Act (1991), discharge of effluents to surface waters is now a controlled or a discretionary activity that requires resource consent (Selvarajah, 1999; Wang et al., 2004). Commonly, resource consent approval will require effluent nutrient concentrations to be minimised before entering surface waters. This can be achieved by nutrient stripping of effluents via tertiary treatment, or through land disposal. In New Zealand, many Regional Councils encourage land application of farm effluents (Houlbrooke et al., 2004a).

Returning dairy and piggery shed wastes directly to land has become the most common method of treatment in most parts of the world. This will invariably minimise the impact of effluent discharge on receiving aquatic environments while also providing a valuable source of water, nutrients and carbon to soils. In many instances this may also be the cheapest and most socially/culturally accepted form of final treatment (Wang et al., 2004). In the United States for example, around 900 million Mg of organic and inorganic agricultural recyclable by-products are generated each year, of this approximately 45.4 million Mg is dairy and beef cattle manure, and 27 million Mg is poultry and swine manure. These manure by-products contain around 7.5 million Mg of nitrogen (N) and 2.3 million Mg of phosphorus (P), a significant amount when compared to the 9 million Mg of N and 1.6 million Mg of P applied to agricultural land in the form of commercial fertilisers (Camberato et al., 1997; Walker et al., 1997; Smith et al., 2000).

In New Zealand, dairy and piggery effluents generate annually about 9000 Mg of N, 1250 Mg of P and 14,000 Mg of potassium

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(K) (Bolan et al., 2004b). Judiciously applied, these agricultural effluents and manure by-products can improve soil properties such as plant nutrient availability, soil pH, organic matter content, cation exchange capacity, water holding capacity, and soil tilth, leading to increased crop and pasture yields (Eck and Stewart, 1995).

Optimum use of effluent and manure by-products requires knowledge of their composition and treatment processes, not only to maximise their benefits, but also to minimise environmental damage (Houlbrooke et al., 2004a). Environmental concerns associated with the land application of effluent and manure by-products from confined animal industries encompass all aspects of non-point source pollution, including contamination of surface water with soluble and particulate P, leaching losses of N in subsurface drainage to groundwater, movement of microbial contaminants, reduced air quality by emission of volatile organic compounds, and increased metal input to soils (Bolan et al., 2004c; Bhandral et al., 2007; Houlbrooke et al., 2008). Maintaining the quality of the environment therefore must be a major consideration when developing management practices to effectively use effluent and manure by-products as a nutrient resource and soil conditioner in agricultural production systems (Sharpley et al., 1998).

Given the potential value of farm effluents, increasing research resources are now being committed internationally to develop improved systems able to convert effluent- and manure-based wastes to a valuable and environmentally safe resource. This paper provides an overview of recent changes in New Zealand dairy sector, the volume and treatment of effluent produced in dairy operations and the integrated management of these effluents into farming practice in relation to sustainable production and environmental protection.

2. Recent changes in dairy sector

There have been major changes within the New Zealand dairy industry over the past 15 years, with growth as a sector increasing steadily over this time. Concurrently the contribution to agricultural gross revenue and agricultural exports has also expanded, resulting in large areas of pastoral land (especially sheep and beef farms) being converted to dairy farms. In the past 20 years, the number of dairy farms has fallen by 21% (LIC, 2008), yet average farm and herd sizes during this time have increased substantially. This trend is most prevalent in the South Island of New Zealand where the move from small single-operator farms to larger more complex syndicate-owned farming enterprises is more evident (Table 1). Although 'payout prices', $NZ dollar per kilogram of milk solids, have remained relatively stable, herd production and farm cost efficiencies have improved substantially (Table 1) (LIC, 2008).

Table 1
Major changes in New Zealand dairy industry (LIC, 2008).

Year	1950	1977	2006/07
No of herds	34,367	17,363	11,630
North Island			9343
South Island			2287
Cows/farm	54	112	337
North Island			296
South Island			505
Farm size (ha)		56	121
North Island			107
South Island			179
Milk (L/cow)	2387	2787	3791
Milk solid (kg/cow)	191	223	330
Milk solid (kg/ha)		653 (1992)	934
No of cows (million)	1.82	2.08	3.92
No of major cooperatives (NZ)	231	116	3

New Zealand's seasonal milk production relies predominantly on highly productive, rotationally grazed pasture and herds of high genetic merit. A warm climate and productive pasture enables the herd to graze year-round, avoiding the need for indoor housing and expensive grain feed supplements. Such systems have enabled farmers to produce milk substantially below average world costs, thereby giving New Zealand its advantage over competitors worldwide.

Currently the New Zealand dairy industry has approximately 11,630 herds, with 3.9 million in-calf cows and heifers, producing over 1.3 billion kilograms of milk solids. Although the vast majority (80%) of herds, and total cow numbers (2.76 million, 70%), are located in the North Island, farm sizes and herd types are typically bigger in the South Island (LIC, 2008). The 'average' North Island Dairy Farm is 107 ha in size, milking 296 cows and producing 1.1 million litres of milk, 95,674 kilograms of milk solids, per annum. In the South Islands, the average farm size is 179 ha, milking 505 cows and producing 2.1 L of milk, 184,705 kg of milk solids, per annum (LIC, 2008).

Although New Zealand contributes to only about 2% of world's dairy production, as a result of its relatively small population and small domestic market for dairy products, 95% of manufactured dairy products are exported and currently account for 33% of all dairy products traded worldwide (ABARE, 2006). New Zealand is the world's largest exporter of butter, skim milk powder and casein, and the second largest exporter of cheese and whole milk powder. This position in the global market has been achieved without reliance on production or export subsidies, and without protecting its domestic market from overseas competition. The dairy sector in New Zealand is dominated by cooperatives, a structure that reflects the perishable nature of milk, the sector's relative homogeneity and the economies of scale in processing, marketing and distribution. There are currently three core cooperatives operating in New Zealand — Fonterra Cooperative Group Ltd., Westland Cooperative Dairy Company and Tatua Cooperative Dairy Company. The milk produced by nearly all New Zealand dairy farmers is supplied to these cooperatives. Fonterra, owned by 11,680 farmers, collects 96% of New Zealand's milk production. Westland has around 370 suppliers and produces around 3% of New Zealand's milk supply, while Tatua's 124 suppliers provide most of the remaining 1%. In addition to these bigger export oriented companies, there are around 70 smaller companies operating in product or regional market niches across New Zealand. Under the Dairy Industry Restructuring Act (2001) Fonterra is required to supply up to 400 million litres of regulated milk, at a default milk price, to other independent milk processors to ensure that small processors are not forced out of the market (ABARE, 2006).

Maintaining production growth through intensification is a challenge for the dairy industry for several reasons, including environment concerns (i.e. restrictions on water for irrigation and issues with effluent management), greater competition for land, and weaker international dairy prices.

3. Quantities of dairy effluent produced

In countries such as Australia and New Zealand where open grazing is practiced, large amounts of animal excreta including dung and urine are deposited directly onto pasture land. On dairy farms however, approximately 6–10% of excreta is deposited in the milking shed and collecting yards. When the yards and milking area are cleaned with high-pressure hoses, farm dairy effluent is generated at approximately 50 L per cow per day (Mason, 1997; Selvarajah, 1999). External runoff from roof, milking shed yard and stock races contribute to the effluent collection although