ASSESSING THE RISK OF NUTRIENT AND MICROBIAL RUNOFF FROM RAINFALL FOLLOWING SURFACE APPLICATION OF SLURRIES AND MANURES WITH VARYING DRY MATTER CONTENT

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Abstract

Facilities that confine animals off-paddock are increasingly being used to house dairy cows over winter (non-lactation season) and strategically during the lactation season. This has resulted in greater amounts of manures and slurries being collected and subsequently applied back to land. Guidance on tactical timing of surface applied manures is based on our understanding of nitrogen (N), phosphorus (P) and faecal microbial losses to water via surface runoff and leaching relative to time of application and first rainfall event. This study investigated nutrient and faecal microbe (*E. coli*) loss in surface runoff in relation to increasing time between manure application and first rainfall event.

The trial was conducted using simulated rainfall and soil monoliths contained in wooden runoff boxes. Manures of varying dry matter (DM) content, ranging from 7 to 14%, were investigated. The greatest risk to water quality occurred when rainfall was received within two days of manure application. When the period between manure application and first rainfall event was 10 days or more, the risk to surface water quality was generally comparable to losses from grazed pasture. This was applicable to N, P and faecal microbial losses. In this trial, variation in DM content appears to have little effect on measured runoff concentrations.

Current guidelines recommend surface application of manures to soils no less than 2 days prior to rainfall. Results gathered from this trial support the need to ensure applications are made with a minimum of 2 days prior to rainfall. Planning for greater lengths of time between application and rainfall will further decrease the risk of nutrient loss yet to a lesser extent to that achieved in the first 2 days.

Introduction

We now have better understanding of the different manure and slurry (collectively referred to effluent solids) types produced on New Zealand dairy farms and how these are subsequently land applied (Houlbrooke *et al.*, 2011a). As farms intensify, there is an increasing amount of effluent solids collected due to the greater and more frequent use of feed-pads, stand-off facilities, animal shelters and farm dairy effluent (FDE) solid separation techniques.

AgResearch has developed a soil and landscape risk framework for the management of liquid FDE, generally < 2% DM (Houlbrooke and Monaghan, 2010). However, this framework does not directly apply to dairy effluents that have higher DM content and nutrient concentration. There is an increasing trend of applying these high DM effluent solids to pasture and therefore the development of New Zealand relevant good management practices (both tactical and strategic) to guide management is urgently required. In New Zealand regulatory authorities tend to use a maximum permissible nitrogen (N) loading rate of 150 kg N/ha/yr for dairy effluents which includes slurry and manure applications.

Higher DM content of solid effluents means a greater proportion will remain on the soil surface post application as opposed to infiltrating rapidly into the pasture root zone, such is as the case with FDE. Increasing the nutrient loading rate of a single slurry or manure application therefore increases the quantity that is potentially mobilised in subsequent surface runoff. Because solid effluent remains exposed on the soil surface for longer lengths of time relative to FDE, we hypothesise that days between application and first runoff event will influence nutrient loss. Our objectives in this study were to 1) determine the potential nutrient loss in runoff from slurries and manures applied to soils at various time intervals prior to an intensive rainfall event resulting in surface runoff conditions, and, 2) determine how the nutrient loss in runoff varies with changes in solid content of the effluent product.

Methods

Effluent solids of differing DM content were applied to soils at equivalent N loading rates of 110 kg N/ha. Due to varying N content found in each of the effluent solids, different volumes of effluent solids were applied in each DM treatment. This replicates on-farm procedures, where effluent applications are typically determined by N loading rates. Once applied, soils were left for 0, 1, 2, 5 10 or 20 days before simulated rainfall was applied. Resulting runoff was collected and nutrient concentration plus runoff volume were determined.

Effluent products were collected from the Telford Farm, Lincoln University, Balclutha. These included fresh manure, fresh urine and barn scrapings. Each of the three effluent products was then analysed for Total N, mineral-N, Total P and Total K concentrations and DM content by an accredited commercial laboratory (NZLABS [IANZ] in Hamilton). Effluent treatments were then derived by mixing the collected effluent products at various ratios to provide four effluent solid treatments ranging in DM contents: 3, 7, 9 and 14%. This represents the predominant range of DM content in many slurries and manures collected on New Zealand dairy farms (Houlbrooke *et al.*, 2011a). Nutrient concentration of the four effluent solids was determined within 48 hours of being land applied. A sample of each treatment was also collected immediately prior to land application and *E. coli* concentration (most probable number (MPN) per 100 mL) determined using the Colilert-Quanti-Tray system (IDEXX Laboratories, USA). The characteristics of the four effluent products used in this study are detailed in Table 1 and details of treatment loads in Table 2.

Table 1. Nutrient and dry matter (DM) concentrations in the four solid effluent treatments used in this study.

DM	Nitrogen			Total P	Total K	*E. coli*
	Total-N	NH_4-N	NO_3-N			mpn/100mL^
(%)	(%)	mg/L		(%)	(%)	(log_{10})
3	0.16	762	5.4	0.04	0.11	7.19
7	0.26	614	10.3	0.06	0.17	7.24
9	0.36	1353	10.2	0.07	0.33	6.94
14	0.51	1561	13.5	0.10	0.46	7.38

^mpn/100mL= most probable number per 100mL

Table 2. Loading rates of nitrogen, phosphorus and potassium applied to soils

Dry Matter	Nitrogen		Phosphorus	Potassium
(%)	kg/ha			
	Total N	Min-N^		
3	115	53	28	79
7	102	25	25	69
9	117	43	23	107
14	114	34	23	102

^ Min-N = combined loading of NH_4-N & NO_3-N

Results and discussion

Volume of Surface Runoff

At the start of the experiment (i.e. days 0 and 1) the volume of runoff collected was generally similar to the amount applied (Figure 1). This would be expected given that all soils were close to field capacity. As the time to first rainfall event increased, the percentage of applied rainfall collected as runoff decreased. We expect this was due to the greater soil water deficit that had developed and therefore a greater portion of rainfall would have been stored in the soil profile. Interestingly, the runoff volume collected on day 20 was greater than that collected on days 5 and 10. We have little explanation for this other than to hypothesis the development of hydrophobic conditions or surface crust formation on the soil surface that would decrease surface infiltration. Importantly there was no difference between DM treatments.

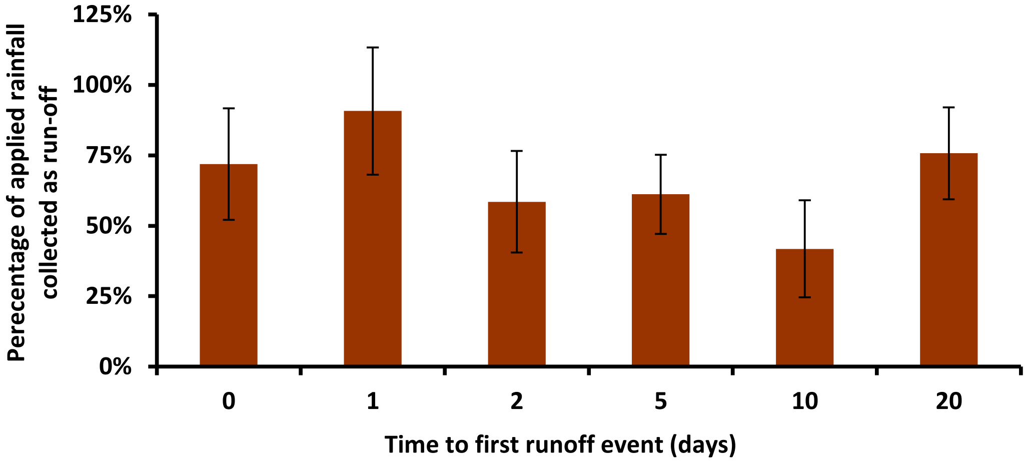

Figure 1. Percentage of applied rainfall collected as runoff. Figures have been averaged across all soil monoliths receiving water on a given day. Error bars represent 1 Std Dev.

Loss of E. coli

The concentration of *E. coli* in runoff was highest when timing of effluent solid application and rainfall occurred on the same day (Figure 2). For all DM treatments, *E. coli* concentration in runoff declined significantly (P<0.05) as the period between manure application and rainfall increased to 5 days. There was a significant (P<0.05) reduction in *E. coli* loss when rainfall was delayed from 5 to 10 days however losses were generally no different when left for a further 10 days (i.e. Day 20) before rainfall. On Day 0, 1 and 2, DM content of the manure had no significant effect on *E. coli* concentration in runoff. As time since application increased, *E. coli* concentration appeared to be inversely related to DM content. However, differences were small and likely to be of limited biological significance (i.e. no difference due to DM content). In our trial, runoff *E. coli* concentration after 10 days of no rainfall was generally equivalent to dairy grazed pastures. However, concentrations tended to be approximately one order of magnitude greater than what might be expected from non-grazed soils as reported by Muirhead and Monaghan (2012).

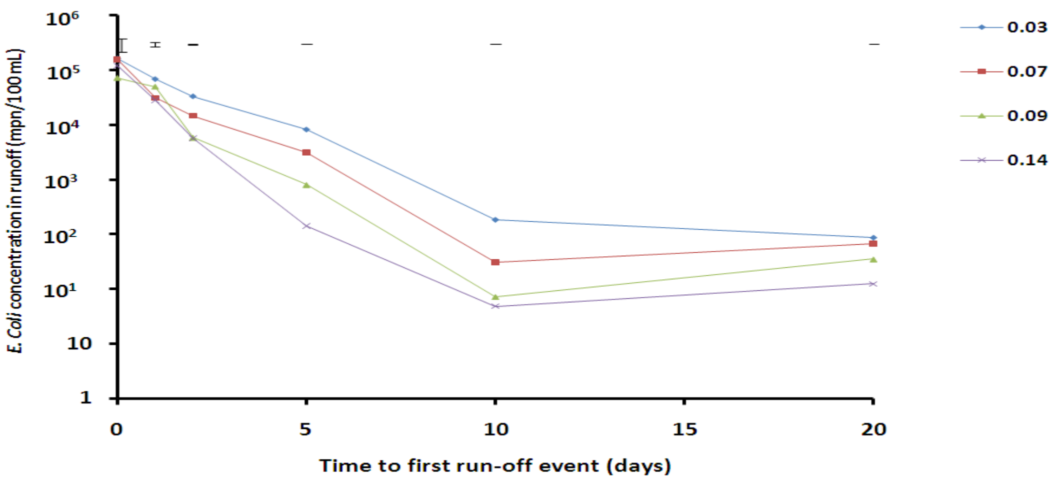

Figure 2. *E. coli* concentration (mpn/100 mL) in runoff from soils amended with effluent solids of varying dry matter content and varying length of time between application and rainfall. Error bars represent $LSD_{(5\%)}$.

Loss of Nitrogen

The concentration of total N in runoff collected on Day 0 and Day 1 was similar across all treatments except the 3% DM treatment which was substantially lower, presumably due to greater surface infiltration of the effluent applied (Figure 3). For all DM treatments, runoff N concentration declined significantly (P<0.05) as rainfall was delayed by 1 day and 2 days respectively. As this period increased beyond 2 days, there was no significant (P<0.05) change in the N concentration for the 5, 10 and 20 day periods between application and rainfall. This was apparent across all DM treatments suggesting limited effect of DM on the observed trend in N loss.

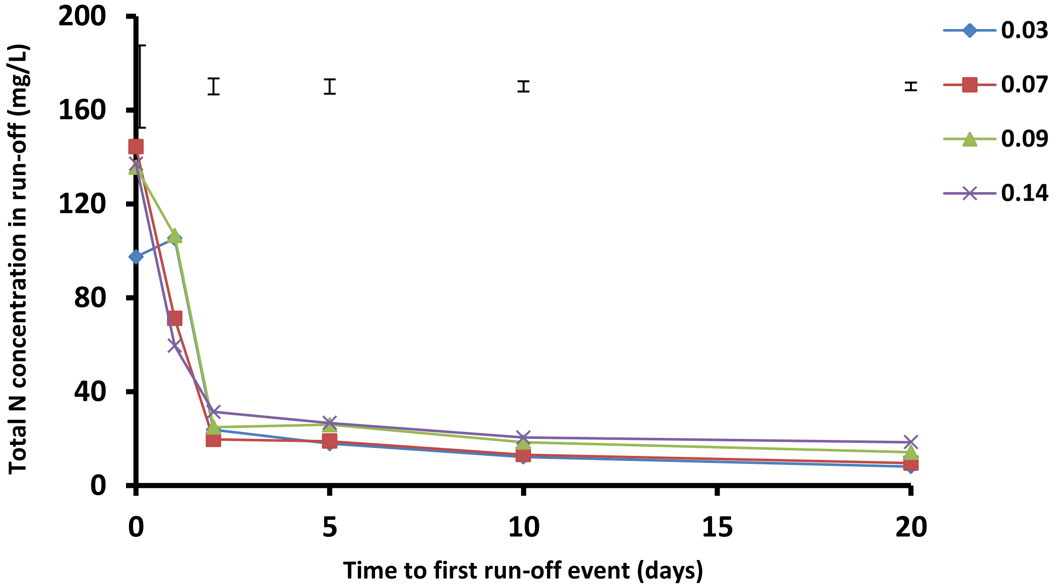

Figure 3. Total nitrogen (N) concentration (mg/L) in runoff following the application of manure of varying dry matter content and time till first runoff event. Error bars represent $LSD_{(5\%)}$. Statistical differences between concentrations on Day were not determined due to large variation between replicates.

Loss of Phosphorus

Phosphorus concentration in runoff from all treatments decreased significantly (P<0.05) when rainfall was delayed by 1 and 2 days respectively from the time of effluent solid application (Figure 4). In a similar trial, Hanrahan *et al.* (2009) reported an 89% reduction in runoff total P concentration from soils amended with manures when rainfall was delayed from 2 to 5 days. This compares well with our observations indicating the vast majority of P is lost in runoff events occurring within two days of effluent solid application. There was no significant (P<0.05) difference resulting from longer periods between solid effluent application and rainfall.

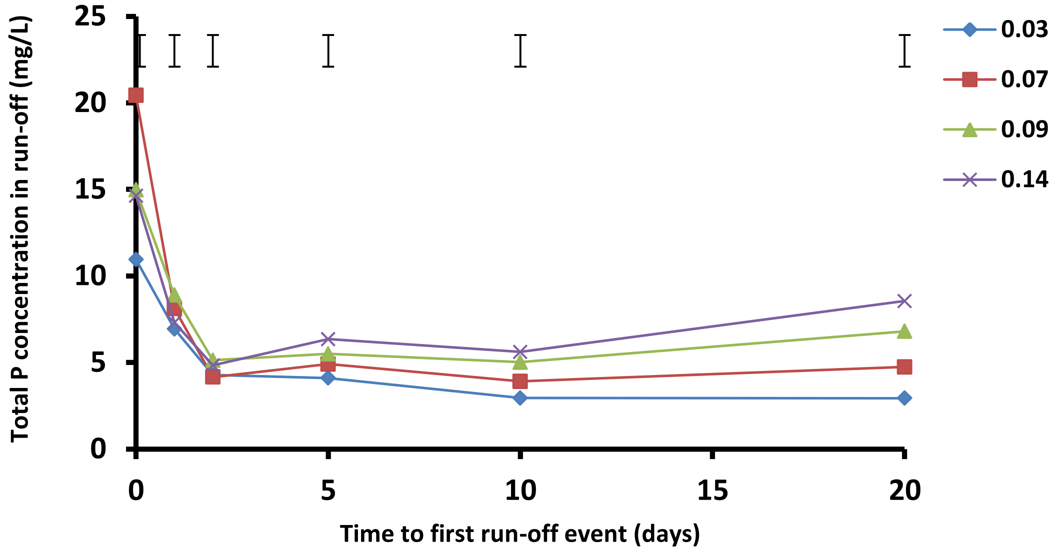

Figure 4. Total phosphorus (P) concentration (mg/L) in runoff following the application of manure of varying dry matter content and time till first runoff event. Error bar represents $LSD_{(5\%)}$.

Generally, there was no effect of DM content on total P loss with exception of Day 0 when P concentration from the 7% DM treatment was significantly (P<0.05) higher than other treatments. We expect this relates to the specific composition of the applied manure, particularly the ratio of dissolved P to total P although this was not measured.

Total P concentration in runoff increased slightly between rainfall on Day 10 to Day 20, however, generally this was not significant (P<0.05). We hypothesis this occurs as effluent solids breakdown and release dissolved P which is more mobile. In a similar study, Hanrahan *et al.* (2009) reported a significant increase in the proportion of Total P as DRP after only 9 days. After 14 months, Vadas *et al.* (2007) reported up to 60% of manure P had transformed from a non-water extractable to water extractable form. Importantly despite these transformation processes, total P loss between Day 10 and 20 was of considerably lower magnitude compared to differences between Day 0 to 2.

Conclusions

Current guidelines proposed by AgResearch, i.e. those devised largely from international literature (Houlbrooke et al., 2011a), recommend slurries and manures are surface applied to soils greater than 10 days prior to rainfall with an essential minimum of 2 days. Results gathered from this trial strongly support the need to ensure effluent solids are applied at least 2 days prior to rainfall in order to limit nutrient and faecal microbe loss.

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