EFFLUENT MANAGEMENT PRACTICES IN REREWHAKAAITU, ROTOMAHANA AND OKARO LAKES CATCHMENTS

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Abstract

Improving the water quality in sensitive lake catchments is an ongoing issue for the New Zealand dairy industry. In three catchments in the Rotorua Lakes region, dairy farmers have taken a proactive stance in understanding nutrient flows from their farms. Over the past five years individual farm nutrient management plans have been implemented along with on-farm mitigations to reduce nitrogen, phosphorus and sediment losses. An outstanding issue remained concerning the lack of quantitative data relating to effluent management. During spring 2013 the majority of catchment farmers (>90%) took the opportunity to have land application depths measured and nutrient loadings quantified.

This paper summarises the findings of land application of effluent from either dairy sumps or storage ponds through five different application delivery systems. These measurements provide data on effluent spreading distribution, application depth, concentrations of major nutrients and nutrient loadings.

The main form of effluent delivery system encountered was the travelling irrigator. The mean application depths of travelling irrigators at fast, medium and slow settings were 12, 18, and 24mm respectively with corresponding nitrogen loadings of 36, 63 and 125 kg N/ha.

Chemical analysis of effluents sourced from dairy sumps had concentrations of 0.40, 0.05 and 0.40 kg/m^3 for N, P and K respectively, compared to 0.36, 0.06 and 0.40 kg/m^3 respectively for pond effluent. Over-application of nutrients (>150 kg N/ha per irrigation) could occur when a thicker effluent (~ 1% DM) was applied at a slower rate. During the course of the study other issues related to effluent application were also identified and are discussed.

Keywords:
Land application, farm dairy effluent, nutrient loading, effluent delivery systems

Background

Managing nutrients on dairy farms is an on-going challenge for the industry as it intensifies to remain profitable yet strives to minimise potential environmental impacts. In recent years the nutrient management of those farmers dairying in sensitive lake or river catchments has increasingly come under the spotlight from the public and regional councils. This has been particularly so in the Rotorua Te Arawa Lakes region where improving water quality has been of paramount importance. The Bay of Plenty Regional Council (BOPRC) follows an intensive monitoring regime for checking on water quality status of each lake using the trophic level index (TLI). Farmers in the catchments of the three south-eastern lakes

(Rerewhakaaitu, Rotomahana and Okaro) have long recognised the need as land-owners for taking responsibility for nutrient management on their properties.

Several projects have been implemented over the past decade that have focused on understanding the impact of nitrogen (N), phosphorus (P), and sediment in the catchments (Parker 2006, 2010, 2013; Birchall & Paterson, 2011; Longhurst et al., 2009). Project Rerewhakaaitu 3 focused on nutrient budgets and the development of individual Nutrient Management Plans (NMP) with on-farm mitigations being subjected to auditing (Longhurst et al., 2012; Hawke et al., 2013).

Specific mitigation actions identified to reduce nutrient loss from land to waterways from the Rerewhakaaitu Catchment Plan (Parker, 2013) were to establish a programme to calibrate farm dairy effluent (FDE) irrigation delivery systems on all farms in the catchment and ensure adjustments are made to achieve the most uniform and efficient delivery of farm nutrients. This paper reports on the effluent measurements undertaken during spring 2013. The response from farmers was remarkably high with farmers in the neighbouring catchments of Lake Rotomahana and Lake Okaro also requesting the same measurements undertaken.

Aims

1. To measure the application depth of the current effluent irrigation system
2. To collect effluent sample for chemical composition so that nutrient loading could be determined.
3. To identify any short comings in the existing effluent delivery system

Approach

During October-November 2013 individual farms were visited to undertake the FDE calibrations. One farm was sampled in January 2014 as it has a large storage pond that is only emptied out periodically by an agricultural contractor. At each site collection trays were laid out on pasture at right angle to the direction of the delivery system (for travelling irrigators) or across the radius of the spreading width (for rain guns and pods). The distance travelled was measured and time taken to apply effluent recorded. Effluent from the individual collection trays was bulked in a 10L container from which a representative 1L sub-sample was collected for laboratory analysis. All effluent samples were analysed by Eurofins, Hamilton for dry matter (%DM) N, P, potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and sodium (Na).

Data from the effluent application depths at each site follows and results are compared with the distribution uniformity (DU). The Effluent Design Code of Practice (DairyNZ, 2011) uses the upper quartile distribution uniformity (DUuq) as a measure of FDE land application spreading uniformity. Reducing the DUuq means minimising over-application of FDE while maximising the average depth that can be safely applied. This is calculated from the average of the highest quarter of depth measurements divided by the average depth measurement. A value of 1.25 or below is the desired DUuq target.

Results and Discussion

In total, effluent measurements were undertaken at 35 sites; 10 of the sites were spraying directly from the farm sump and 25 were irrigating from storage ponds. A variety of effluent delivery systems were used in the catchments. The main delivery system encountered was the travelling irrigator (27); other systems included: pods (2), stationary rain guns (2), travelling rain guns (3) and a slurry tanker.

Travelling irrigators

Measurements from the 27 travelling irrigators relating to speed, application depths and distribution uniformity are summarised in Table 1. The results show that the average speed travelled on the fastest setting, 60 m/hour, was almost three times that of the slowest setting (19 m/hour). When the irrigator passes slowly across a paddock the application depth is twice that of an irrigator set on the fastest setting. Whenever possible, speed settings on travelling irrigators should be set on the fastest setting to minimise the risk of over applying nutrients. There was no difference in the DUuq relating to speed of travelling irrigators.

Table 1: Overall mean application measurements from travelling irrigators (n=27).

Travelling irrigator setting	Traveller's speed (m/hour)	Application depth (mm) Mean	Application depth (mm) Highest	Distribution uniformity (DUuq)
Fast (19)	60	12	20	1.5
Medium (4)	36	18	29	1.5
Slow (4)	19	24	39	1.5

Other delivery systems

Measurements from the other delivery systems relating to speed, application depth and distribution uniformity are summarised in Table 2. The travelling rain guns were classified into two groups: one farm had a recently developed Cobra irrigator while two measurements were from the same agricultural contractor, undertaking periodic emptying of storage ponds.

Table 2: Overall mean application measurements from other delivery systems (n=8).

Effluent delivery system	Application depth (mm) Mean	Application depth (mm) Highest	Distribution uniformity (DUuq)
Rain guns (2)	14	37	1.9
Pods (2)	11	19	1.6
Travelling rain guns (3)	5	14	1.7
Slurry tanker (1)	1	2	1.9

The highest application depths from the rain guns tended to be localised around its stationary position i.e., within 1-2m of the spray head. The mean application depth from each system decreased in the order: rain guns (14 mm), pods (11 mm), travelling rain guns (5 mm), slurry tanker (1 mm), however the sample size was small (n=8), so additional measurements should be carried out. The DUuq for these other delivery systems was higher than it was for travelling irrigators.

Infiltration rate and application depth

Even though the catchments were relatively small in area there was a variety of soil types (Rijkse & Guinto, 2010). Table 3 summarises the data according to soil type and DUuq to determine if application depths were likely to cause ponding. Ponding was assessed based on FDE application depth and soil physical properties. However, results indicated that all the soils were either of Recent or Pumice origin and that the infiltration rates were high (> 72 mm/hour), therefore ponding was unlikely to have occurred at the application depths measured. The one exception, surprisingly, was in the case of the slurry tanker, where the mean application depth was only 1.2 mm, but the instantaneous application rate was high (applied in 3.5 seconds) and this could potentially lead to short-term ponding. If the catchments had other soil types with lower infiltration rates, then there would have been a greater likelihood of ponding at some of the higher application depths.

Table 3: Potential for ponding after FDE applications when compared to soil infiltration rate.

Soil type	Soil infiltration rate (mm/hour)	Distribution spreading uniformity (DUuq)	Soil infiltration rate after applying DU (mm)	Length of timing of ponding (minutes)	Actual depth of ponding (mm)
Rotomahana mud	>72	1.57	46	0	0
Kaharoa ash	>72	1.81	41	0.4	0.2
Taupo pumice	>72	1.36	52	0	0
Matahina gravel	>72	1.59	45	0	0
Tarawera gravel	>72	1.48	49	0	0

FDE nutrient composition

Effluent samples were analysed for solids content (% DM) and chemical composition. Each sample was collected over the entire effluent spreading event and therefore provided a good representation of what was being land applied. The effluent collections were timed to occur during the spring flush, based on when peak loadings occur (Longhurst *et al.*, 2000), so as to provide the farmers with the maximum nutrient concentrations likely to be found. Table 4 summarises the mean concentrations found from dairy sump and storage pond effluent samples. The %DM content of sump and pond FDE were very similar as were most of the nutrients except for Ca. Calcium has probably settled in the pond sludge along with the P as it is more likely to be associated with dung rather than with urine. The chemical composition found in these FDE samples were similar to those reported by Longhurst *et al.* (2000) from 40 sump samples in the Waikato (0.8% DM, 0.45, 0.075, 0.32 kg/m^3 of N, P, K, respectively).

Table 4: Mean concentrations (kg/m^3) found from dairy sump (n=10) and storage pond (n=25) effluent samples.

FDE source	Dairy sump		Storage pond	
Nutrient	Mean	Range	Mean	Range
%DM	0.67	0.10-2.00	0.70	0.10-2.60
N	0.40	0.06-1.12	0.36	0.11-0.86
P	0.05	0.02-0.09	0.06	0.02-0.15
K	0.40	0.07-1.13	0.40	0.14-0.76
S	0.04	0.01-0.08	0.03	0.01-0.13
Ca	0.26	0.02-1.80	0.11	0.04-0.38
Mg	0.05	0.01-0.08	0.05	0.02-0.10
Na	0.04	0.02-0.07	0.03	0.02-0.07

Little data is available on previous work related to effluent management in the catchment apart from four farms that had effluent concentrations measured as part of Project Rerewhakaaitu 2 (Parker, 2006). The FDE concentrations found then had the following average values (kg/m^3): 0.24 N (0.19-0.35); 0.04 P (0.01-0.06); 0.32 K (0.29-0.37). There appears to have been an increase in overall nutrient composition which has reflected the increased use of imported feed supplements on the catchment farms since 2006.

Nutrient loading

Combining the data from the effluent measurements and chemical analysis allows nutrient loadings to be calculated (Tables 5 and 6). Results in Table 5 illustrate clearly how when the travelling speed of irrigators is slow that the nutrient loading increases sharply. The N loading for paddocks can quickly near the maximum 150 kg N/ha limit while K pasture maintenance requirements can be exceeded. The highest nutrient loadings were 299, 52, 184, and 45 kg/ha for N, P, K and S respectively, on a farm where the traveller's speed was slow (12 m/hour), spreading width narrow (15 m diameter) and the effluent concentrated (2.6% DM). FDE treated paddocks are likely to receive lower inputs of P and S therefore require additional nutrients from fertiliser depending on soil test results.

Table 5: Nutrient loadings in FDE (kg/ha) from travelling irrigators.

T.I. setting	N	P	K	S
Fast	36	6	42	3
Medium	63	12	69	6
Slow	125	21	88	17

Table 6: Nutrient loadings in FDE (kg/ha) from other effluent delivery systems.

Delivery system	N	P	K	S
Rain gun	40	8	47	4
Pod	26	5	38	2
Travelling R.G.	19	4	25	3
Slurry tanker	11	1	14	1

Farmers should be aware that, in general, when FDE appears dark in colour and leaves sediment in a container, that it is likely to be nutrient rich (Figure 1). An easy check in the paddock is to look at broadleaf weeds, has the FDE left a thin coating or is there matting on the leaves? In these situations the FDE application depth should be lowered to avoid overloading the pasture's ability to take up applied nutrients and to avoid the potential contamination of water bodies through nutrient leaching and/or run-off.

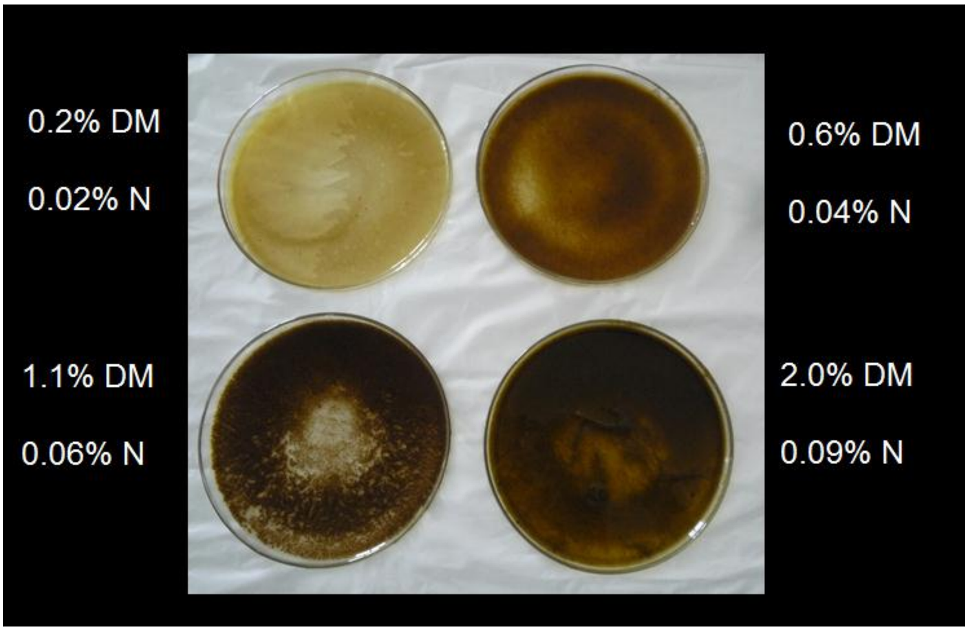

Figure 1: Colour and traces of sediment give clue to potency of FDE.

Issues related to effluent applications

A number of undesirable effluent management practices were observed during this project, such as:

- The most common mismanagement aspect was the condition of nozzles on the delivery systems. Many nozzles were split and not applying the FDE evenly. It is also likely that feeds, such as palm kernel expeller, cause excessive abrasion and can increase the nozzle's aperture. As a general 'rule of thumb' the nozzle rubbers should be replaced at the same time that dairy shed rubbers are replaced.

- A 'siphoning effect' was observed on one farm where the travelling irrigator was spraying in a paddock below the height of the storage pond. Once its run had finished the FDE continued to exit the stationary irrigator in a 'geyser-like' effect (Figure 2). All the FDE in the delivery hoses could potentially empty in this fashion creating a nutrient 'hot spot'. This situation could be remedied cheaply by installing a T-valve close to the pond pump. When FDE is being pumped, the flow keeps the valve shut. When the pumping stops, there is no pressure and the valve opens letting in air. When there is an air gap in the line no siphoning will occur and the FDE only drains from the pump to the pond (Gene Roberts, dairy farmer, pers. comm.).

Figure 2: Siphoning effect from stationary irrigator below storage pond.

However, in some cases this can be an excessive amount of FDE, so the use of a leakage eliminator at the irrigation equipment means that once the optimum pressure required for the delivery system to operate effectively drops, the flow is shut off. This, combined with taps at the hydrants, limits any unwanted spillage.

- When the pump is not capable of providing enough pressure and flow due to not being matched correctly to the effluent delivery lines and irrigation equipment, it will result in the FDE being squirted onto pasture rather than being sprayed (Figures 3 and 4). This result is usually seen in a 'donut' form of irrigation with much higher application depths on the periphery of the circle. The spreading width also tends to be narrower than normal for the delivery system, and excessive ponding can result.

Figure 3: FDE being sprayed correctly.

Figure 4: FDE being squirted incorrectly.

Conclusions

The most common form of delivery system was spreading FDE via travelling irrigators from storage ponds. The common application depth from delivery systems ranged between 4-16 mm. Providing that the FDE was not concentrated this practice is sound. A safe application depth for farmers to aim for is 10mm and in most cases up to 16mm is acceptable.

Whenever possible, speed settings on travelling irrigators should be set on the fastest setting to minimise the risk of over applying nutrients. When the application depth is very high (>25 mm), and the FDE concentrated, there is a high risk of nutrient over-loading and environmental contamination.

Regular maintenance of the effluent delivery system is required to obtain an even application of nutrients. To ensure the smooth operation and functioning of the irrigator requires attention to nozzle condition and putting in place safeguards to negate the impact of the inevitable mishaps and breakdowns.

Overall, farmers in the lakes catchments had made commendable efforts in upgrading their effluent management systems and were very cognisant of fact that they are dairying in sensitive catchments.

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