RAPID ON-FARM METHOD OF ESTIMATING NPK CONTENT OF EFFLUENTS FOR LAND APPLICATION

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Abstract
Land application is the preferred method of effluent treatment on New Zealand dairy farms. Intensification within the dairy industry since 2000 has meant that higher concentrated effluents are now being generated from dairy shed/feed pads for land application. However, vital pieces of information are missing for appropriate land treatment as farmers/contractors are faced with not knowing: 1) nutrient concentrations from different effluent sources, and 2) subsequent nutrient loading when effluents are applied to land.

Two rapid, on-farm methods (bulk density and electrical conductivity) for estimating nutrient concentrations from various effluent sources were evaluated throughout the Waikato in 2010. Results have shown that electrical conductivity provides a reliable estimate of NPK concentrations in effluents and so provide essential information for making sound decisions regarding land application.

Background
The majority of dairy farmers in New Zealand now use land application as the preferred method of farm dairy effluent (FDE) treatment. However, as dairy farmers have intensified their production systems over the past 10-15 years with higher cow numbers, greater use of supplementary feeds, increased use of feed pads, and higher rates of nitrogen fertiliser used, higher strength effluents are now being produced. Farms practicing daily effluent irrigations from dairy sumps are running into environmental problems when soil conditions are too wet for land application. Therefore, storage ponds with enough capacity to be able to hold 2-3 months effluent are being recommended as a buffer so that daily effluent applications can be avoided (Houlbrooke and Monaghan, 2010). Deferred irrigation can then be practised from these ponds at times better suited to match nutrients applied and pasture nutrient uptake requirements.

However, vital pieces of information are missing for appropriate land treatment as both farmers and contractors spreading effluents are now faced with the same unknowns: 1) what is the nutrient content of the effluent? and 2) what is the nutrient loading to land? To confound matters there are different treatment systems operating that each impact on the chemical composition of effluents.

Having an easy method to provide a good estimate of nutrient concentration means that excessive nutrient loadings (especially nitrogen (N) and potassium (K)) could be avoided. During 2010 an effluent study was conducted in the Waikato to evaluate if a simple system existed and built on an earlier preliminary study by Longhurst (2009).

Aims

1. To determine the nutrient concentrations in effluents from five different sources
2. To evaluate two rapid on-farm method of estimating nutrient concentrations
3. To develop a ready reckoner chart for estimating the nitrogen (N), phosphorus (P), and potassium (K) concentrations in effluents

Methods

FDE samples from 51 sites were collected by Hi-Tech personnel as they supplied their effluent management services to farmers around the Waikato region. The effluent samples covered a variety of feed systems, and effluent holding facilities, such as sumps and ponds, to reflect the common effluent management systems in practice. A small amount of background information from each site was also collected during each farm visit. These details included herd size, DairyNZ farm production system, pond storage size, time elapsed since pond last emptied and scale of stirring employed (light, medium, or heavy). Effluent systems covered in the study are presented in Table 1.

Table 1: Type and number of effluent management systems sampled.

System	Effluent management system	Sites sampled
1	Dairy sump, no feed pad, effluent sprayed daily	4
2	Dairy sump, with feed pad, effluent sprayed daily	4
3	Anaerobic pond – effluent stirred prior to land application	17
4	Holding/storage pond for deferred effluent irrigation	18
5	Aerobic pond – effluent not stirred prior to land application	8

A representative FDE sample was collected at each site and then subjected to two rapid on-farm methods of measurement:

1. The weight of sample in a 1-litre plastic jar was measured so that bulk density (weight/volume) could be determined.
2. The electrical conductivity of the effluent was measured using an Aqua One® Pro-Pen conductivity meter. These conductivity meters read EC between a 0.0-10.0 milli Siemens (mS/cm) range with a resolution scale at 0.1 mS (EC accuracy is = $\pm$ 0.2 mS/cm).

Chemical analysis of FDE samples were undertaken by NZLabs, Hamilton for: dry matter (%DM), total Kjeldahl nitrogen (TKN), ammonium N (NH_4-N), nitrate N (NO_3-N), phosphorus (P) and potassium (K).

Statistical analysis for all variables (N, P, K, and EC) required log transformations. A power curve in Microsoft Excel was used (i.e. a straight line on the log scale) for the regressions of P and N on EC. The FITNONLINEAR directive of GenStat (2010) was used to fit a two straight line spline for the relationship between K and EC, with the location of the knot (the point at which the two lines that make up the spline meet) being estimated by the procedure.

Results and discussion

Nutrient concentrations

A summary of effluent nutrient analysis from the 51 sites is presented in Table 2.

Table 2: Mean nutrient concentrations (kg/m^3) with standard deviation (in brackets).

Effluent System	%DM	Total N [1]	Total P	K	N:K ratio
Sump	1.1	0.31 (0.28)	0.04 (0.02)	0.21 (0.13)	1.2:1
Sump + feed pad	1.7	0.71 (0.28)	0.11 (0.07)	0.93 (0.41)	0.8:1
Anaerobic pond	2.4	0.68 (0.51)	0.07 (0.04)	0.38 (0.16)	1.7:1
Storage pond	1.9	0.65 (0.58)	0.08 (0.06)	0.44 (0.25)	1.4:1
Aerobic pond	0.5	0.15 (0.11)	0.02 (0.01)	0.18 (0.09)	0.8:1

[1] Total N = TKN + nitrate-N; NZLabs reported all NO_3-N results as < 5ppm (or 0.0005%)

Nitrogen concentrations were highest (average 0.71 kg/m^3) in the sump + feed pad samples, as were P and K concentrations. The anaerobic and storage pond samples had higher solids contents than the sump + feed pad samples yet N concentrations were lower indicating that gaseous losses may have occurred.

The addition of feed pad effluent to the FDE sump has a marked effect on all nutrient concentrations but most notably on increasing P and K concentrations. These increased P and K concentrations are most likely reflecting the massive increase in feed supplementation onto farms, particularly palm kernel expeller and molasses, which are high in P and K respectively.

Mean Total P concentrations found in the aerobic ponds (0.020 kg/m^3) are in close agreement with those found in other studies of 0.026 kg/m^3 (Hickey et al., 1989) and 0.023 kg/m^3 (Vanderholm, 1984). However, mean Total N (0.150 kg/m^3) concentrations are almost twice those reported (0.074 kg/m^3) by Vanderholm, (1984) reflecting the massive changes in nitrogen management that have occurred on NZ dairy farms during the intervening years.

Looking at the N:K ratio of effluents provides a useful guide as to whether to base application rates on the N or K loading. For example, the average sump + feed pad effluent (N:K ratio: 0.8:1) had a mean concentration of 0.71 kg/m^3, therefore applying around 211m^3/ha would supply the typical regional council maximum N loading of 150 kg N/ha/yr but over apply K (196 kg K/ha). Therefore, any N:K ratio lower than 2:1 is likely to apply too much K to land. Using this yardstick rule would limit effluent application rates to 150 and 75 kg/ha of N and K respectively.

The proportion of plant available mineral N to total N is presented in Table 3. As nitrate-N was below the level of detection (< 5ppm) all the mineral-N was in the ammonium form. Aerobic pond effluents had the highest proportion of mineral-N (47%), albeit at low concentrations. The reason for this would be that the aerobic pond has the lowest solids content and therefore likely to have the lowest amount of organic matter and therefore Organic N. Mean ammonium-N concentrations found in the aerobic ponds (0.070 kg/m^3) are in close agreement with those found in other studies of 0.063 kg/m^3 (Hickey et al., 1989).

Table 3: Forms of N in effluents: average concentrations (kg/m^3) and proportion of Total N (%).

Effluent System	Total N	NH_4-N	Organic N	Mineral N	Organic N
Sump	0.310	0.070	0.240	23	77
Sump + feed pad	0.710	0.210	0.500	30	70
Anaerobic pond	0.680	0.160	0.520	24	76
Aerobic pond	0.150	0.070	0.080	47	53
Storage pond	0.650	0.200	0.450	31	69

On-farm rapid methods of estimating nutrient concentrations

Bulk density

Under field conditions the effluent samples were weighed in one litre plastic sampling bottles. The one litre level coincided with the neck of the sampling bottle and the weight was recorded to one decimal place. Even so, the relationship between density and N concentration was too variable (R^2 = 0.25) under field conditions to be a reliable method for estimating nutrient concentrations (Figure 1). The relationship between density and nutrient concentrations in effluent was even weaker for P (R^2 = 0.20) and K (R^2 = 0.17).

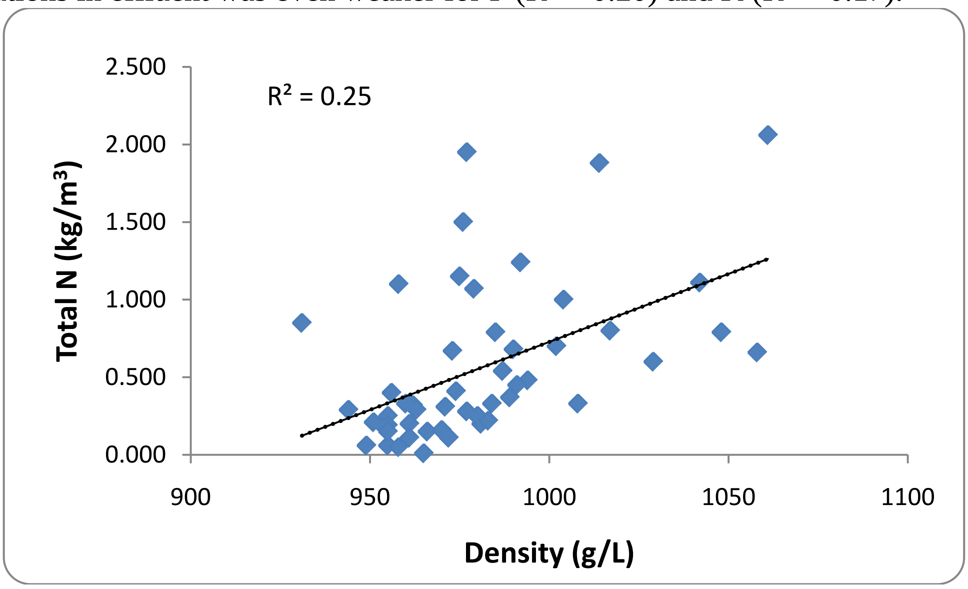

Figure 1: Relationship between density and N concentrations.

Electrical conductivity

Under field conditions measuring electrical conductivity was a simpler procedure than measuring bulk density and produced more reliable results. The relationship between EC and N, P, and K (raw data) are presented in the following graphs (Figures 2-4). In all three graphs the trend showed that as concentrations got higher, variability increased. The data was therefore log transformed and spline relationships using the Genstat program were derived between EC and N, P, and K concentrations (Figures 5-7). The most reliable relationship exists between electrical conductivity and potassium concentrations (R^2 = 0.89, Figure 7).

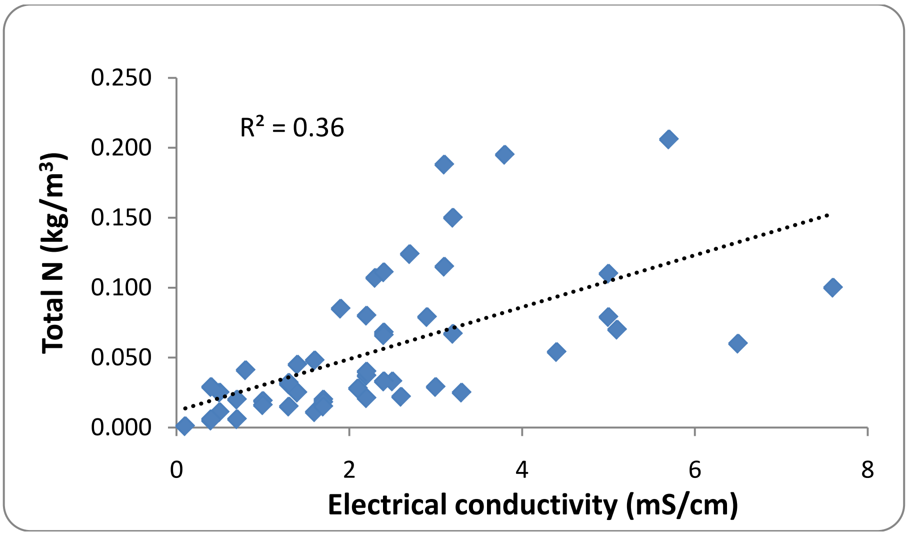

Figure 2: Electrical conductivity and nitrogen concentrations.

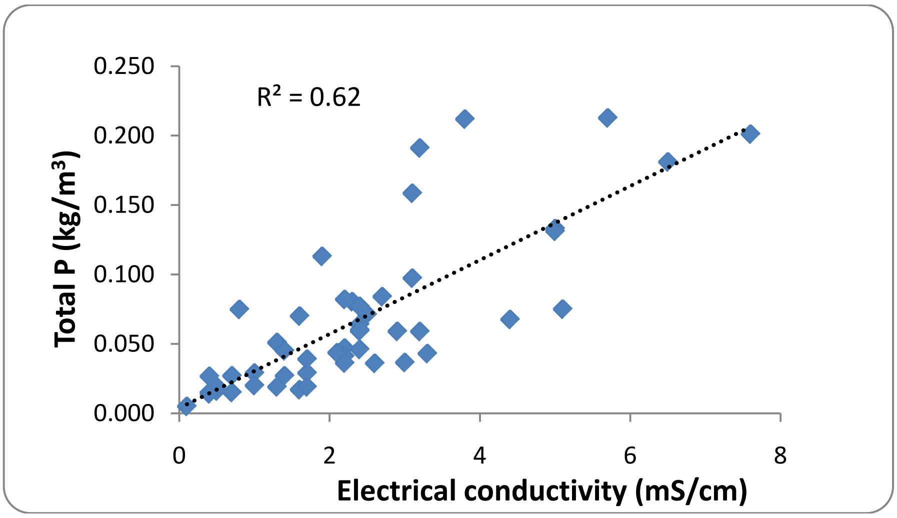

Figure 3: Electrical conductivity and phosphorus concentrations.

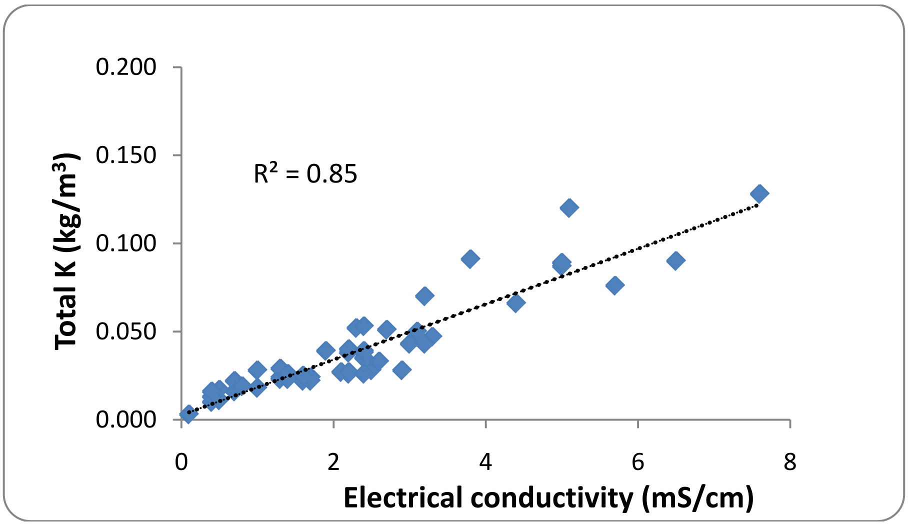

Figure 4: Electrical conductivity and potassium concentrations.

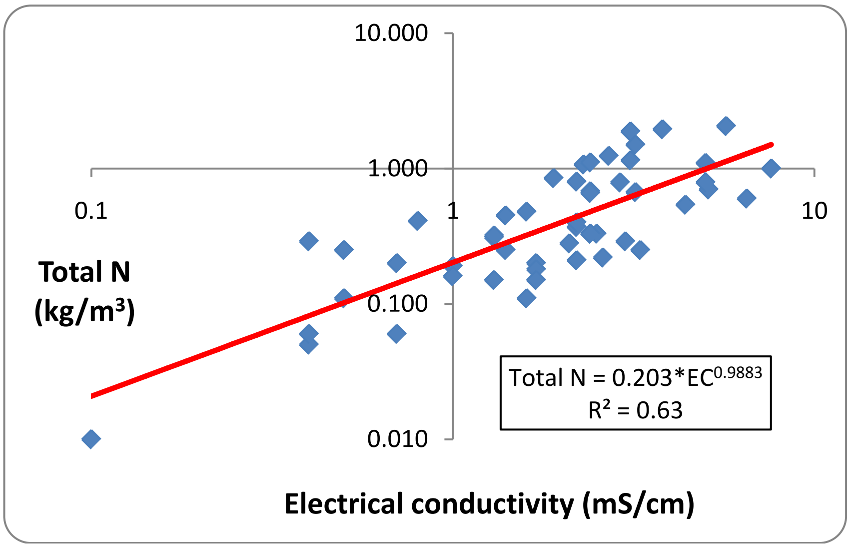

Figure 5: Electrical conductivity and nitrogen concentrations (log transformed).

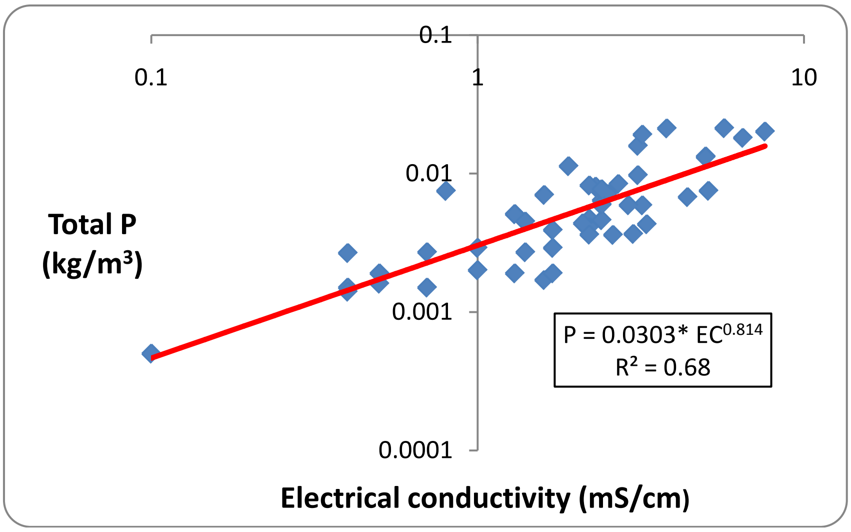

Figure 6: Electrical conductivity and phosphorus concentrations (log transformed).

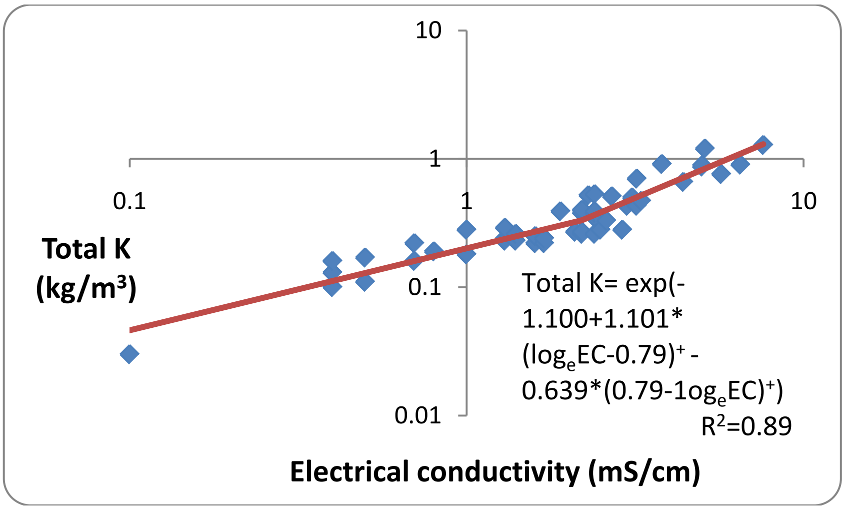

Figure 7: Electrical conductivity and potassium concentrations (log transformed).

Ready reckoner

From the equations presented in Figures 5-7 an estimate of the N, P, and K concentrations can be derived for any electrical conductivity reading (Figure 8). As noted earlier, the most reliable relationship exists between electrical conductivity and potassium concentrations. Remember that this procedure will only give an estimate of the NPK nutrient concentrations and that chemical analyses performed at an accredited laboratory will always give the actual concentrations.

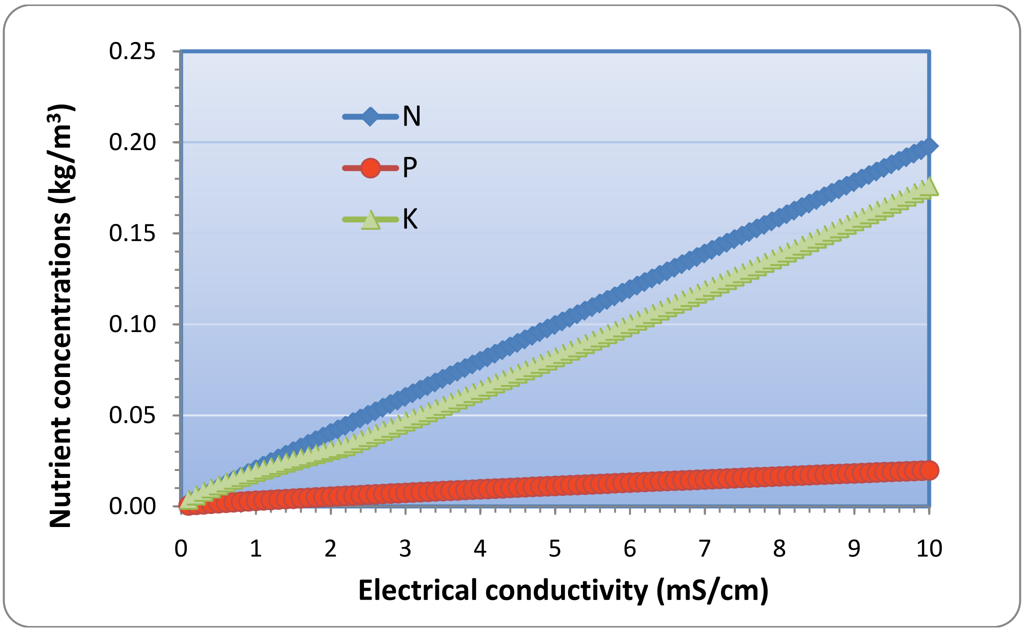

Figure 8: Calculated nutrient concentrations for given electrical conductivity reading. Note that nutrient concentration estimates above EC 7.6 mS/cm have been extrapolated.

Conclusions

Findings from the survey of 51 effluent samples from a cross-section of Waikato dairy farms operating under field conditions has shown that measuring electrical conductivity is a more reliable method of estimating the nitrogen content of effluent. Using the electrical conductivity approach provided greater accuracy than using the bulk density approach for estimating NPK concentrations in various effluents.

It is recommended that electrical conductivity should be measured on effluent samples throughout the year as imported feeds or changes in cows' diet are likely to alter effluent nutrient composition.

In the absence of any reliable system for estimating nutrient content in effluents until now, the use of a conductivity meter is a step forward in effluent management.

The outcome of this approach will give an estimate of nutrient concentrations in effluents but chemical analyses performed at an accredited laboratory will always give the most accurate results. However, there can now be greater certainty for calculating the amount of nitrogen being land applied in effluents which then lowers the risk of exceeding Regional Council maximum nitrogen loadings to pasture, or, of overloading pastures with excessive rates of potassium.

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