Using dairy effluent to grow crops – an update for industry, farmers and consultants

Norris M, Johnstone P, Sharp J, Selbie D, Dexter M, Houlbrooke D, Longhurst B

July 2019

1   BACKGROUND

New Zealand's dairy farm systems produce large quantities of nutrient rich effluent which are captured from milking sheds, holding yards, feed pads, standoff pads and animal shelters. These products are often highly variable combinations of faeces, urine, teat washings, wash down water and bedding materials and are commonly grouped into three broad categories based on their dry matter (DM) contents: liquids (0–5%), slurries (5–15%) and solids (>15%). Management of these effluents is typically via land application to pasture which represents a cost-effective means of treatment, while at the same timing providing the opportunity to recycle nutrients in the effluent to grow pasture. Less common is the use of effluents as a nutrient source to grow high value forage and arable crops (e.g. maize, fodder beet, brassicas, cereals) which are commonly integrated onto the milking platform or support blocks. In a cropping context, using effluent either to supplement or replace fertiliser presents an opportunity to capitalise on a cost-effective nutrient resource while improving whole farm nutrient use efficiency.

The purpose of this guide is to summarise key aspects relating to the use of effluents to grow crops including effluent nutrient composition, nutrient supply, chemical characterisation and application considerations.

2   WHY USE EFFLUENT TO GROW CROPS?

- Farm dairy effluents (FDE) represent a readily available source of nitrogen (N), phosphorus (P) and potassium (K) as well as other macro and micro nutrients which may be used to grow high value arable and forage crops. With the average dairy cow producing about $25 of nutrients as FDE per year at the shed, the annual nutrient value for a 400-cow dairy herd is estimated to be about $11,500[1].
- Application of effluent to crops represents another platform for management and an opportunity to transfer nutrient loading pressure from pasture effluent blocks. With their high nutrient demand, many forage and arable crops are an excellent sink for the nutrients present in effluents.
- Using effluent to grow crops is a way to increase whole farm nutrient use efficiency and presents an opportunity to 'close the loop' on nutrient management. Key nutrients which are 'recycled' include N, P, and K as well as macro nutrients and trace elements such as calcium (Ca), magnesium (Mg) and sodium (Na).
- Effluents, especially slurries and solids are also rich in organic matter. Therefore, land application of FDE will have a beneficial effect on soil properties such as organic matter content, cation exchange capacity, water holding capacity and soil structure.

3   TYPES OF EFFLUENT

There are three major types of effluent (Figure 1) which are most commonly defined based on their relative DM contents:

- **Liquid** – Also termed FDE, is comprised of animal excreta, teat washings and wash down water that is collected from the dairy shed and holding yard. It is typically a product capable of being pumped and sprayed as liquid with irrigation equipment (about 0–5% DM). Given the high water content, land application of FDE is typically confined to effluent management blocks which are usually in close proximity to the milking shed.
- **Slurry –** Excreta produced by livestock while in yard or housing (plus additives such as water and spilt stock feeds). It has a semi-liquid consistency that allows it to be sprayed under pressure from a slurry tanker. Slurries can also be augered or discharged by gravity (about 5–15% DM). These effluents are not suitable for application through irrigation pipes given their higher DM content.
- **Solid –** Organic manure (excreta and/or bedding) that can be semi-solids or solid manure that cannot be pumped but can be stacked in a freestanding heap (generally >15% DM). Solids are typically land applied using muck spreaders. Key sources include herd homes, composting barns, feed pad scrapings, mechanically separated solids, weeping walls and stand-off pad solids.

Figure 1. Examples of the three main effluent types including (a) liquid effluent being sprayed with irrigation equipment, (b) slurry effluent being land applied with a slurry tanker and (c) solid effluent stacked in a freestanding heap.

4 NUTRIENT COMPOSITION OF EFFLUENT

Dairy effluents are heterogeneous products which vary considerably in their chemical and physical characteristics, even between effluents classed as the same type. This variation reflects the range of factors which influence their composition including: breed and class of livestock, time of year, amount and type of supplementary feeding used, cleaning method for effluent, management of effluent before land application (including rainfall and water management) and time in storage.

Key points relating to effluent nutrient composition

- Total nutrient concentrations tend to increase in the order liquid<slurry<solid (Table 1). This reflects the fact that nutrients are 'diluted' as the water content increases.
- The proportion of nutrients present in inorganic (or plant available) forms will vary from effluent to effluent. For example, liquids typically contain higher concentrations of inorganic N which is more susceptible to losses during storage (volatilisation) and following application to land (volatilisation, leaching or runoff). In contrast most of the N in solid effluents is typically present in more stable organic forms which are not immediately plant available (see Section 5). Figure 2 provides an example of the range in nutrient concentrations from a selection of effluents from the Waikato region.
- Given the physical and chemical heterogeneity of effluent, it is important that products are tested prior to application to determine their nutrient composition. A description of common test methods provided by commercial labs is provided in Section 6. Dry matter alone should not be used as a default proxy for nutrient availability.

Table 1. Summary of typical dry matter (DM) contents and total concentrations of nitrogen (N), phosphorus (P) and potassium (K) in effluents classed as liquids, slurries and solids taken from around the Waikato region between 2014 and 2016[2]. n = number of sites sampled. The range in observed values is shown in parenthesis.

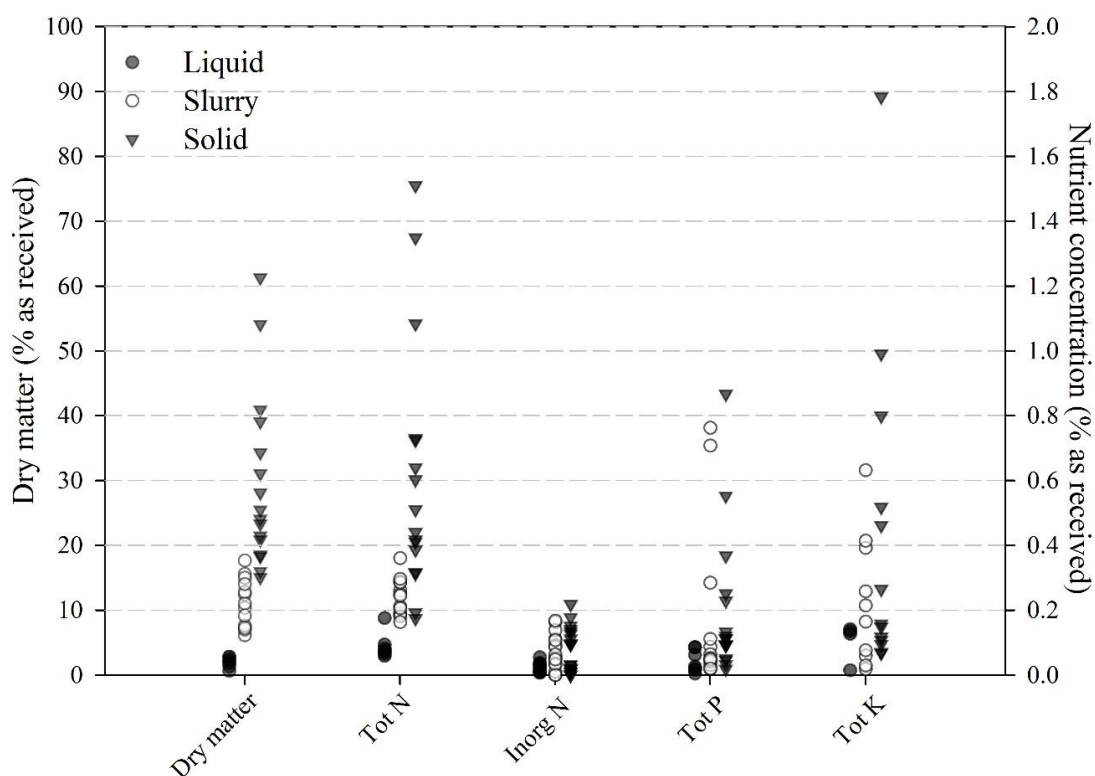| Effluent type	DM	Total N	Total P	Total K
	% "as received"			
Liquid (n = 14)	1.3 (0.2 – 2.9)	0.06 (0.01– 0.18)	0.015 (0.005 – 0.027)	0.094 (0.016 – 0.142)
Slurry (n = 20)	11.8 (6.2 – 18.6)	0.26 (0.07 – 0.60)	0.06 (0.020 – 0.112)	0.306 (0.019 – 0.763)
Solid (n = 26)	26.5 (15.1 – 61.3)	0.52 (0.18 – 1.51)	0.12 (0.019 – 0.369)	0.467 (0.069 – 1.784)

Figure 2. Dry matter (DM) contents and concentrations of total nitrogen (Tot N), inorganic nitrogen (Inorg N), total phosphorus (Tot P) and total potassium (Tot K) in 36 effluent samples taken from around the Waikato region between 2014 and 2016. Note the variation in Tot N (0.06 – 1.51%), Inorg N (0.0006 – 0.22%), Tot P (0.005 – 0.37%) and Tot K (0.02 – 1.78%) concentrations[2].

4.1   What are typical nutrient application rates?

The total amount of nutrient applied on a field scale (kg/ha) is determined by the nutrient concentration of the effluent and the application rate. It can be calculated using the following equation:

Nutrient application rate (kg/ha) = nutrient concentration (% "as received") x 10 x total volume applied (m³)/area (ha).

Example: 12 m³ of slurry with a total N content of 0.32% is being applied to 2 ha of land. What is the land application rate in kg N/ha?

N application rate = 0.32% x 10 x 12 m³/2 ha = 19 kg N/ha

In this calculation a bulk density of 1 g/cm³ (or 1000 kg/m³) is assumed. This is usually the case for liquid and slurry samples, however, for solid manures densities may be less than 1 g/cm³ if the sample is dry and contains material with a low bulk density (e.g. sawdust or woodchips).

Figure 3 shows the quantity of nutrient present in a 12,000-L application tank. The use of effluents with low nutrient concentrations (typically liquids) to meet crop demand may not be economically viable unless effluent irrigation with existing infrastructure is available.

Note: Effluent application rates should be carefully calculated to ensure that total N loading does not exceed regulatory thresholds. For example, in the Waikato region this is 150 kg N/ha/yr[3].
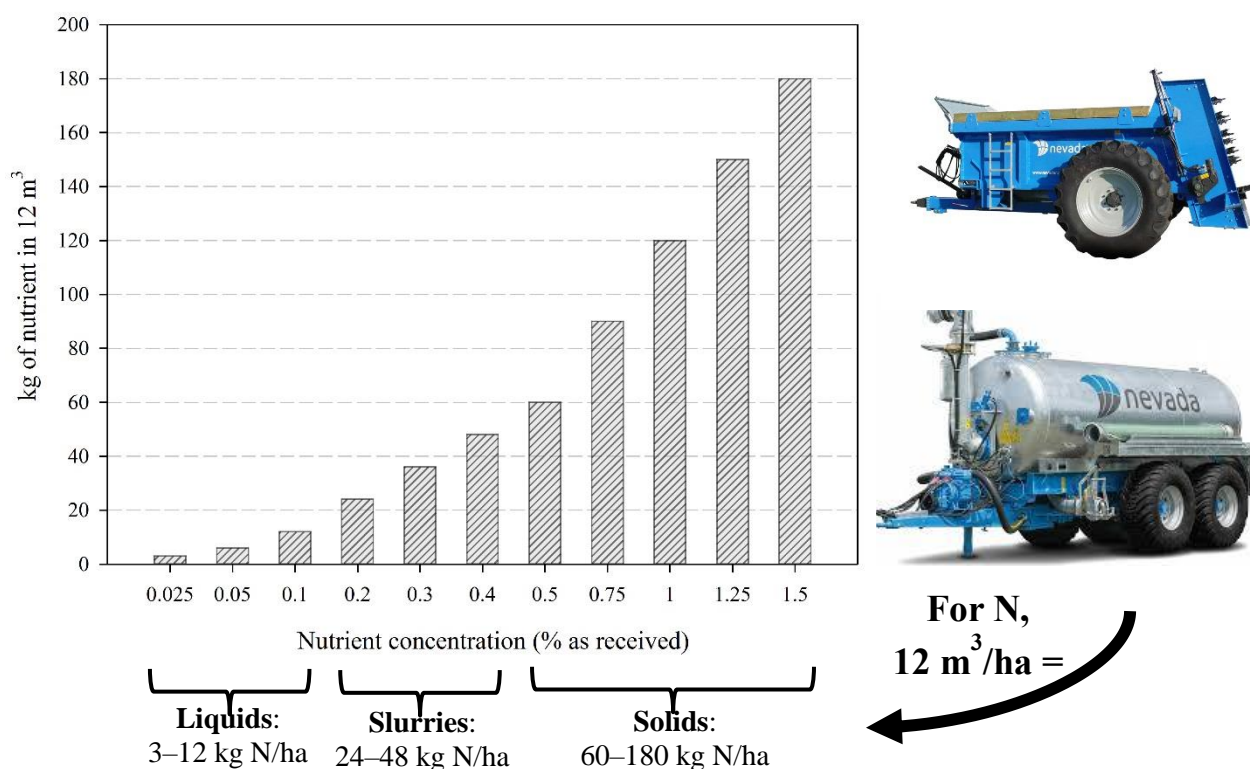
Figure 3. Quantity (kg) of nutrient present in a 12 m³ effluent slurry tanker or muck spreader at total concentrations of 0.025 to 1.5% "as received". A bulk density of 1 g/cm³ is assumed. Typical nitrogen (N) concentration bands and associated application rates for liquid, slurry and solid effluent types are presented for reference.

5 UNDERSTANDING EFFLUENT NUTRIENT SUPPLY

When considering nutrient supply from FDE, it is important to understand that not all of the nutrients applied will be immediately available to crops. This is because a proportion of the applied nutrient is present in organic forms which need to be broken down into inorganic or mineral forms before being available for plant uptake. This is particularly important for N which is the nutrient usually required by crops in the largest quantities. For many effluents, a considerable proportion of the total N pool (up to 90%) is present in organic N forms which are temporarily unavailable for plant uptake. Additionally, the dynamic nature of the N cycle means that effluent applications can considerably alter soil N supply patterns.

Nutrient supply dynamics for other nutrients, while still important, are of less interest in effluent amended soils because background fertility levels are usually adequate in well managed systems (a soil test will confirm this) and nutrient concentrations of available forms are usually at sufficient levels in FDE (particularly for K). More careful consideration should be given to P and S requirements because concentrations of these in FDE are often low compared with plant maintenance requirements, especially if solid separation takes place.

5.1 Forms of nitrogen in effluent

Forms of N in effluent may be broadly classified as either inorganic or organic. Inorganic N forms include nitrate-N, nitrite-N and ammonium-N and are immediately available for plant uptake. Most inorganic N found in effluents is present in the ammonium-N form (typically >95 %). Organic forms of N include a complex mix of N-containing compounds, some of which can be readily mineralised into inorganic forms (these are termed 'labile' compounds) and some of which do not readily mineralise (these are termed 'non-labile' or 'recalcitrant' compounds). Each effluent has a unique N composition with varying ratios of inorganic N: organic N and varying quantities of labile and non-labile organic N forms. In general, the proportion of N present in organic N forms increases in proportion to DM content (Figure 4). Hence, effluents classed as liquids will have a greater proportion of their total N present in inorganic (or plant available) forms compared with effluents classed as solids. *Given the variation in effluent types and composition, collecting a sample for laboratory analysis before land application is an essential step in determining the amount of N being applied and its potential availability in the short term to crops.*
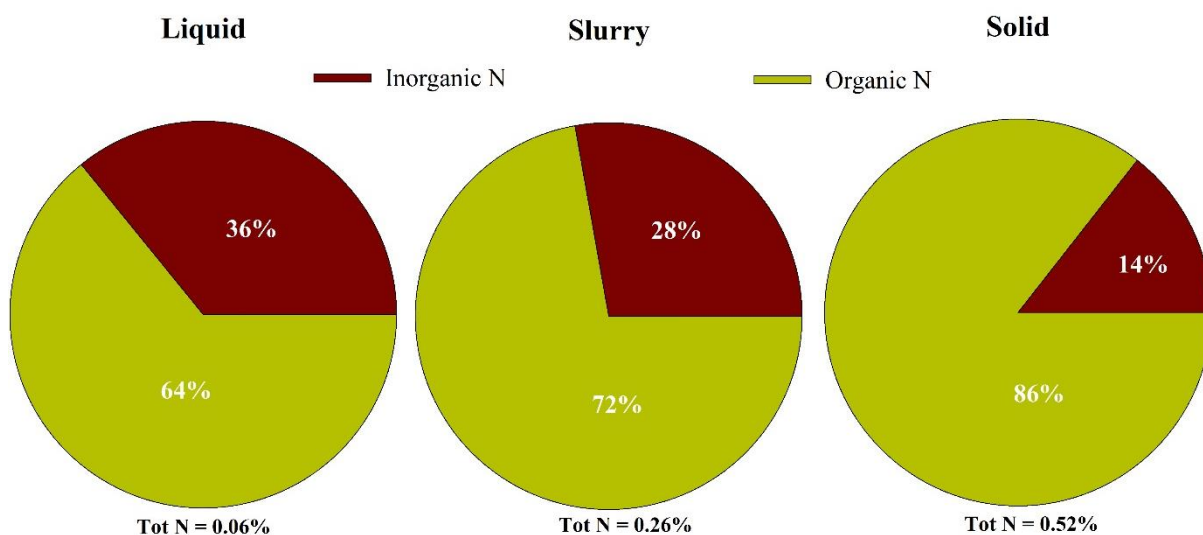

Figure 4. Proportion of inorganic and organic nitrogen (N) in 14 liquid, 20 slurry and 26 solid effluent samples from the Waikato region, 2014 – 2016. Total N = average total N content (% "as received") for the respective sample sets[2].

5.2 Key drivers of nitrogen supply in effluent amended soils

Because effluents are organic materials, the net effect of their application on N supply to crops depends on a complex range of factors that influence microbial turnover of N in the soil. The two key processes which drive N supply patterns are:

Mineralisation – is the general term for the microbial conversion of organic N to inorganic N as either ammonium (NH_4^+) or nitrite/nitrate (NO_2^-/ NO_3^-) and occurs when there is excess N in the substrate (in this case effluent) relative to microbial demand.

Immobilisation – is the general term for the microbial assimilation of inorganic N to organic N and occurs when the amount of N required by microorganisms is greater than that present in the substrate (in this case effluent).

The three key factors which have the greatest effect on mineralisation-immobilisation processes are:

1. _Effluent composition, in particular C:N ratio:_ Generally, substrates with C:N ratios of less than 20:1 will result in net mineralisation while those with C:N ratios higher than 30:1 will tend to immobilise soil N.

Implication: As a general rule of thumb, short term N supply as a percentage of total N applied decreases in the order liquids>slurries>solids. This reflects the higher proportion of inorganic N present in liquid compared with solid effluents and the generally higher C:N ratios of products with higher dry matter contents.

2. _Temperature:_ The rate of biological processes increases with increasing temperature which means both mineralisation/immobilisation processes will occur more rapidly in warm versus cool soils. At low (< 5 °C) temperatures, the rate of nitrogen mineralisation is drastically reduced.

Implication: Short term N supply from effluents applied in spring/summer will be greater than from autumn/winter applications. Note there is an important temperature interaction with soil moisture as rates of N supply may be reduced under warm conditions if moisture is limiting.

3. _Moisture:_ Soil moisture has a strong influence on the activity of microorganisms involved in mineralisation and immobilisation processes. The optimum soil moisture for mineralisation is around field capacity, with rates of mineralisation reduced at both low soil moisture and when soils are water logged.

Implication: N supply will be enhanced in systems where soil moisture contents are optimised for crop production (e.g. irrigated systems) or where there is consistent, year-round rainfall. Effluent which is incorporated into the soil profile will be exposed to a more consistent moisture environment compared with effluent which is surface applied.

5.3 Predicting nitrogen supply from dairy effluent applied to cropping soils

A key question in using FDE to grow crops is "how much N will be supplied from the applied effluent?" Predicting this N supply forms the basis for subsequent N management decisions. For example, if N supply from the applied effluent meets crop N demand, then no additional N fertiliser will be required. In contrast, if effluent N supply is less than crop N requirements, then supplementary fertiliser N applications will be needed to achieve the target yield (see Section 7). In some cases, application of effluent may result in a net N immobilisation effect which would be detrimental for crop production if not accounted for.

Recent research conducted under the Forages for Reduced Nitrate Leaching programme (Critical Step 2.16[2]) has identified that routine analytical measures can be used to categorise effluents into one of three groups defined by their influence on crop N management decisions (Table 2). Effluents may be classified as those which result in:

- Positive net N supply (Type A products)
- Neutral net N supply (Type B products)
- Negative net N supply (Type C products).

The analytical measures required to determine the effluent type include:

- Total N
- Total C
- Inorganic N

Calculated measures required to categorise an effluent include:

- C:N ratio = Total C/Total N
- % of total N in inorganic forms = Inorganic N/Total N x 100 *
- Organic N = Total N – Inorganic N
- C:Organic N = Total C/Organic N.

Ensure that analytical measure units are the same before performing calculations. Further details on measuring effluent characteristics and unit conversions are provided in Section 6.

*Inorganic N is the sum of nitrite, nitrate and ammonium. Most inorganic N (typically >95%) is present in the ammonium-N form.

Table 2. Effluent nitrogen (N) supply categories based on Carbon (C):N ratio and the percentage of total N as Inorganic N.

		% of total N in inorganic forms	
		High (>25)	Low (<25)
C:N Ratio	Low (<20)	Type A	Type B
	High (>20)	-	Type C

Type A Products: *Positive net N supply*. Application likely to increase soil mineral N levels in the short term (0–6 months). Net N supply may be estimated using Table 3. Product may be used as a N source for growing crops, soil conditioner and a source of other macronutrients (P, K, S).

**Table 3. Lookup table to estimate nitrogen (N) supply from Type A products.
Values in the table represent N supply as a percentage of total N applied.**

		% of total N as Inorganic N					
		20	30	40	50	60	70
C:Organic N	10	38	46	54	61	69	77
	20	24	34	43	53	62	72
	30	10	22	33	44	55	66
	40		9	22	35	48	61
	50			12	27	41	56
	60				18	34	51

Type B Products: *Neutral net N supply*. Application likely to have a minimal (i.e. neutral) effect on soil mineral N levels in the short term (0–6 months). Product may be used as a soil conditioner or as a source of other macronutrients (P, K, S) with limited risk of inducing a N deficit.

Type C Products: *Negative net N supply*. Application likely to decrease soil mineral N levels in the short term (0–6 months) through N immobilisation processes. Product may still be used as a soil conditioner or as a source of other macronutrients (P, K, S).

5.3.1   Worked examples

Example 1 – Type A effluent

The following analytical results are returned for a slurry effluent sample. What is the likely short term (0–6 months) N supply from this product?

- Total N: 2.1 g/100g DW
- Total C: 37.2 g/100 g DW
- Inorganic N: 1.2 g/100 g DW.

To determine effluent type (A, B or C) we first need to calculate the C:N ratio and the percentage of total N in inorganic forms.

- C:N ratio = Total C ÷ Total N = 37.2 ÷ 2.1 = 17.7
- % of total N in inorganic forms = (Inorganic N ÷ Total N) x 100 = (1.2 ÷ 2.1) x 100 = 57%

The effluent has a C:N ratio <20 and a % of total N in inorganic forms >25. Using Table 2, the effluent is classed as 'Type A'.

To calculate the likely short term N supply, we need to use Table 3. However, we first need to calculate the ratio of C:Organic N.

C:Organic N = Total C ÷ (Total N - Inorganic N) **=** 37.2 ÷ (2.1 - 1.2) = 41.

The effluent has a C:Organic N ratio of 41 and the proportion of total N in inorganic forms is 57%. Based on Table 3, N supply from this effluent will be about 48% of total N applied. This means that if 100 kg N/ha was applied as effluent N, about 48 kg N/ha would be available for the crop in the first 6 months after application.

See Section 11 for a case study: proposition for using dairy effluents in cropping.

Example 2 – Type B effluent

The following analytical results are returned for a slurry effluent sample. What is the likely short term (0–6 months) N supply from this product?

- Total N: 1.8 g/100g DW
- Total C: 33.5 g/100 g DW
- Inorganic N: 0.25 g/100 g DW.

To determine effluent type (A, B or C) we first need to calculate the C:N ratio and the percentage of total N in inorganic forms.

- C:N ratio = Total C ÷ Total N = 33.5 ÷ 1.8 = 18.6
- % of total N in inorganic forms = (Inorganic N ÷ Total N) x 100 = 0.25 ÷ 1.8 x 100 = 14%

The effluent has a C:N ratio <20 and a % of total N in inorganic forms <25. Using Table 2, the effluent is classed as 'Type B'. This means that an application of this product will likely have a minimal effect on soil mineral N levels in the short term (0–6 months).

Example 3 – Type C effluent

The following analytical results are returned for a solid effluent sample. What is the likely short term (0–6 months) N supply from this product?

- Total N: 1.4 g/100g DW
- Total C: 43.0 g/100 g DW
- Inorganic N: 0.10 g/100 g DW.

To determine effluent type (A, B or C) we first need to calculate the C:N ratio and the percentage of total N in inorganic forms.

- C:N ratio = Total C ÷ Total N = 43.0 ÷ 1.4 = 30.7
- % of total N in inorganic forms = (Inorganic N ÷ Total N) x 100 = (0.10 ÷ 1.4) x 100 = 7%

The effluent has a C:N ratio >20 and a % of total N in inorganic forms <25. Using Table 2, the effluent is classed as 'Type C'. This means that an application of this product will likely reduce soil mineral N levels in the short term (0–6 months) through N immobilisation processes.

6   MEASURING EFFLUENT CHARACTERISTICS

Because effluents are so variable in their physical and chemical characteristics, it is important that they are analysed prior to application to determine their nutrient profile. This provides crucial information on how much nutrient is being applied and its likely availability to crops. This is particularly important in a cropping context where a shortfall in nutrient supply (particularly for N), can negatively affect productivity and quality. Conversely, over application can result in undesirable environmental outcomes (see Section 7). A summary of analytical measures offered by commercial testing laboratories is provided in Table 4.

6.1   Sampling considerations

The nutrient composition of effluent from any given source may vary considerably over the season. Therefore, it is advised that samples for nutrient analysis are taken prior to each application according to the following recommendations:

- Liquids – Sampling from under effluent irrigators is the most relevant to what nutrients are being applied to land. It is not recommended to sample from dairy sumps due to high variability. Several sub-samples should be combined into a composite sample, stirred thoroughly and a final sample poured into a clean, labelled 1-L container for laboratory analysis.
- Slurries – Products are typically sampled from scraped feed pads, animal shelters or housing. Eight sub-samples, each of 1 L, should be poured into a larger clean container (10 L), stirred thoroughly and a sample poured into a clean, labelled 1-L container for laboratory analysis.
- Solids – 6 to 8 sub-samples of stockpiled materials or individual samplings within a stand-off pad or animal shelter should be collected below the surface, then combined and mixed thoroughly before final sample collected for laboratory analysis (1kg).

Table 4. Summary of laboratory test measures use to determine effluent chemical characteristics[1].

Test	Units	Uses
Dry matter	g/100 g *"as received"*	Total dry matter content (slurry and solid samples)
Total solids	g/m^3	Total solids content (liquid samples)
Total recoverable P, Ca, Mg, K and Na	g/m^3 (liquids), mg/kg dry weight (slurries, solids)	Total elemental P, Ca, Mg, K and Na – includes inorganic and organic components
Total C	g/m^3 (liquids), g/100 g dry weight (slurries, solids)	Total C content – used to calculate C:N ratio
Total N	g/100 g dry weight	Used to quantify the total N concentration of slurry and solid samples. Includes all inorganic and organic N components and used to calculate total C:N ratio.
Total Kjeldahl Nitrogen (TKN)	g/m^3	Used as a proxy for the total N content of liquid samples. Includes ammoniacal N and organic N components.
Inorganic N	g/m^3 (liquids), mg/kg dry weight (slurries, solids)	This is the 'plant available' N component of the effluent which includes ammonium-N, nitrite-N and nitrate-N. Most inorganic N in effluents (>98%) is present as ammonium-N.
Calculated measures[2]		
C:N ratio	-	Total C/Total N
Organic N	g/m^3 (liquids), mg/kg dry weight (slurries, solids)	Total N - Inorganic N

[1] Different laboratories offer different testing suites. Contact a laboratory rep to discuss which tests are available and best suited to your product. See Section 8 for a list of New Zealand laboratories which offer effluent testing.
[2] These measures are calculated from supplied test results.

Note on reporting units

Liquid results are usually reported as g/m^3 and may be converted to a percentage "as received" basis using the following formula:
g/100 g "as received" = g/m^3 x volume weight/10000
Slurry and solid results are usually reported on a dry weight basis and may be converted to a percentage "as received" basis using the following formula:
g/100 g "as received" = **mg/kg dry weight** x dry matter (g/100 g "as received")/1000000
g/100 g "as received" = **g/100g dry weight** x dry matter (g/100 g "as received")/100

7   OTHER CONSIDERATIONS

7.1   Method of application

The method of land application depends on the type of effluent, with liquids generally sprayed using irrigation equipment, slurries pumped under pressure from slurry tankers and solids applied via muck spreaders. Key considerations include:

- *Application uniformity*: Poor application uniformity will result in spatial variation in nutrient supply which may have a negative impact on final crop yields.
- *Effluent incorporation*: Incorporation of effluent into the soil profile has a number of benefits including improved nutrient supply, reduced N loss through volatilisation and reduced risk of N and P losses during surface runoff events. The two primary methods of effluent incorporation are cultivation following application and direct injection (only suitable for liquid and some slurry effluents). The use of direct injection technology (e.g. trailing shoes) will be required where incorporation via cultivation is not possible (e.g. crop establishment via direct drill). The amount of ammonium-N lost through volatilisation after application has been estimated at:

  - 10% for full incorporation
  - 35% for shallow injection
  - 35% for trailing shoe
  - 70% for surface applied[4].

7.2   Timing of application with respect to N supply

Temperature and moisture are key variables which influence N supply from effluent amended soils. Consequently, effluent N supply is likely to be greater for spring and summer applications (assuming adequate moisture) compared with autumn and winter applications. In a cropping context, an important consideration with respect to application timing is the relationship between effluent N supply and crop N uptake dynamics. Careful consideration needs to be given not only to the total amount of N required but also when N is required by the crop. An example is presented in Figure 5 which illustrates that for a 22 t DM/ha maize silage crop, the total N requirement is about 280 kg N/ha, with approximately 60% of this N required during the rapid growth phase (days 50 to 90). Thus, in using effluent as an N source for this maize crop, a grower would need to evaluate whether effluent N supply would meet crop N demand, particularly during the rapid growth phase. If not, then supplementary fertiliser N may be required to achieve a target yield potential.

For effluents with a higher proportion of total N in organic N pools (typically slurries and solids), it is advised that applications take place at least 6 weeks prior to planting to reduce the risk of N immobilisation occurring during critical crop N uptake phases.
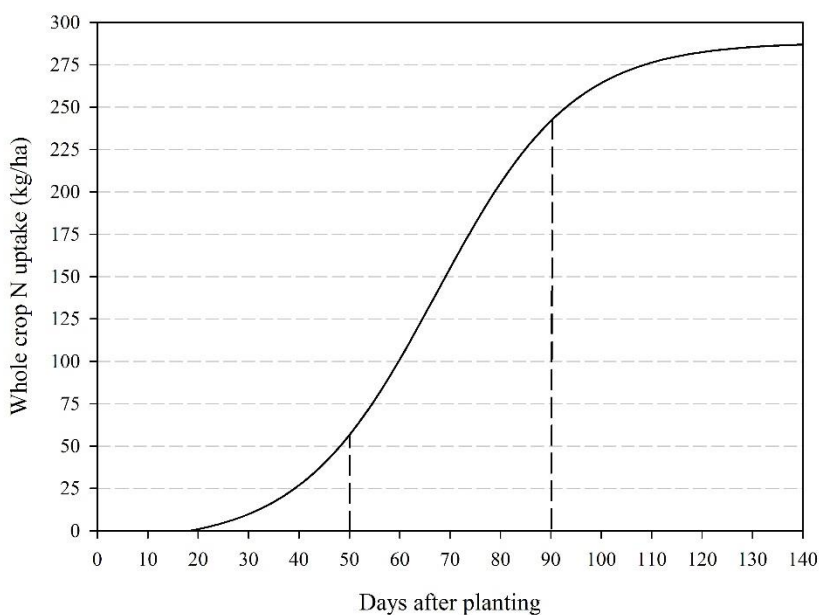
Figure 5. Example of a nitrogen (N) uptake curve for a 22 t DM/ha maize silage crop. About 66% of total crop N uptake (~185 kg N/ha) takes place during the rapid growth phase which occurs between 50 and 90 days after planting (dashed lines)[5].

7.3   Environmental considerations

Effluents contain nutrients (N and P) and organisms (*Escherichia coli*) which are considered to be contaminants when transferred to ground or surface water.

This transfer may occur through:

- Leaching: This occurs when contaminants are transported through the soil profile in drainage and lost from below the active root zone of the plant. This is the primary loss mechanism for N (i.e. nitrate leaching).
- Surface runoff: This occurs when contaminants are transported across the soil surface in overland flow. This is the primary loss mechanism for P.

Leaching of nutrients usually occurs when there is a supply excess relative to crop nutrient demand. Strategies to reduce the risk of leaching (especially for nitrate) include:

- Ensuring that the correct amount of nutrient is applied (informed by testing).
- Ensuring that there is an active sink for plant-available nutrients.
- Following good management practices when applying liquid effluent to high-risk soils (poorly drained, by-pass flow risk, sloping land). These include deferred (deficit) irrigation and low application rate tools.

Surface runoff or overland flow usually occur when the soil is wetted beyond field capacity following rainfall (or irrigation). Strategies to reduce the risk of nutrient transfer via this mechanism include:

- Incorporation of effluent – this is perhaps the most effective strategy because nutrients and organisms in the effluent are 'mixed' through the cultivation layer rather than concentrated on the soil surface.

- ▪ Application timing – avoid surface applying effluents when the risk of surface runoff is high, for example during the winter period. The application of slurries and solids should be targeted to have at least 2 days buffer between application and rainfall events causing possible surface runoff.
- ▪ Buffer zones – if the risk of surface runoff is high (e.g. steeper slopes) and the site is located close to a surface water body (i.e. lake or river), establish a riparian buffer zone (e.g. 3–5 m) between the field and receiving water body.

8 EFFLUENT TESTING: LABORATORY CONTACTS AND RESOURCES

Hill Laboratories
Tel: 0508 44 555 22
Email: mail@hill-labs.co.nz
Information on effluent testing is provided at:
https://www.hill-laboratories.com/testing/other-testing/effluent-testing/.

Analytical Research Laboratories (ARL)
Tel: 06-835 9222
Email: customer.centre@ravensdown.co.nz
Information on effluent testing is provided at:
https://www.ravensdown.co.nz/services/testing/water-testing.

Eurofins New Zealand (formerly New Zealand Laboratory Services)
Eurofins New Zealand
Tel: 0800 387 63467
Email: AgriNZ@eurofins.com
Information on effluent testing is provided at:
https://www.eurofins.co.nz/agricultural-testing/laboratory-services/.

9 ACKNOWLEDGEMENTS

Programme funding:

Research was completed as part of the Forages for Reduced Nitrate Leaching programme with principal funding from the New Zealand Ministry of Business, Innovation and Employment. The programme is a partnership between DairyNZ, AgResearch, Plant & Food Research, Lincoln University, Foundation for Arable Research and Landcare Research.

10 REFERENCES

[1] Economic value of the NPK content in the effluent was calculated using annual estimates (kg nutrient/cow per year) of nutrients in FDE (Fertiliser Review Issue 35, 2015; http://agknowledge.co.nz/uploads/fert-review/FertiliserReview35_v2_low_res.pdf) and the Ballance Agri-Nutrients price list accessed on April 4, 2019 (https://ballance.co.nz/Fertiliser-Products/c/All-Product-Ranges).

[2] Data were collated from the Forages for Reduced Nitrate Leaching (FRNL) programme (Critical Step 2.16) with principal funding from the New Zealand Ministry of Business, Innovation and Employment and co-funding from research partners DairyNZ, AgResearch, Plant & Food Research, Lincoln University, Foundation for Arable Research and Manaaki Whenua – Landcare Research.. FRNL is a DairyNZ-led collaborative research programme across the primary sector delivering science for better farming and environmental outcomes. The aim is to reduce nitrate leaching through research into diverse pasture species and crops for dairy, arable and sheep and beef farms.

[3] https://www.waikatoregion.govt.nz/council/policy-and-plans/rules-and-regulation/regional-plan/waikato-regional-plan/3-water-module/35-discharges/355-implementation-methods-farm-effluent-discharges/.

[4] Houlbrooke D, Longhurst B, Orchiston T, Muirhead, R. 2011. Characterising dairy manures and slurries. Envirolink tools report AGRX0901 prepared by AgResearch for Surface Water Integrated Management (SWIM). October 2011. 114 pages.

[5] Curve was constructed using data from Pioneer. https://www.pioneer.co.nz/maize-silage/product-information/silage-technical-insights/fertiliser-application-for-maize-crops.html.

11 PROPOSITION FOR USING DAIRY EFFLUENTS IN CROPPING

Forage and fodder crops are playing an increasing role in supporting dairy production in NZ. These crops have a high nutrient requirement over a relatively short time period (< 6 months). Farmers normally supply the nutrient needs of these crops in part with inorganic fertiliser inputs. However, with more intensive dairying systems now commonplace across the country, farmers have ready access to a variety of organic fertilisers in the form of liquid, slurry or solid effluents.

Work in the FRNL programme has identified several types of effluent that are suitable to be incorporated into a cropping cycle for the purpose of supplying nitrogen (N). The rule of thumb developed suggests that the ratio of inorganic-N to total N in effluents should be >25% and the C/N ratio <20 to provide an immediate benefit for N supply within the cropping cycle. Effluent testing should be carried out prior to application to determine the amount of N being applied and its potential availability in the short term to crops (see Sections 5 and 6 in the guidelines).

Dairy farmers typically sow a crop as part of a re-grassing cycle and a basal fertiliser mix and/or lime can be applied during this stage. At planting it is common practice to apply starter fertiliser (e.g. DAP, 18-20-0) with the seed. After sowing and when crop demands for N are high, one or two side-dressings of N fertiliser (typically urea) are applied at 3-4 weeks and 7-8 weeks after sowing. Where dairy effluents have a role is at the basal fertiliser stage where they can be surface applied and then immediately incorporated with the cultivation.

Two scenarios are presented which detail the potential value of nutrients supplied by dairy effluents to grow crops with the focus on NPK values. Background soil N supply has been included in the budgets by assuming a default value of 100 kg N/ha. Soil testing should be carried out to determine N supply from organic (AMN test) and mineral sources (deep min N test) and fertiliser or effluent application rates adjusted accordingly.

Turnips

Turnips are a common forage brassica crop grown throughout the country for summer or winter grazing. Table 1 shows the nutrient requirement (NPK only) of a turnip crop and how this can be met using a combination of effluents (available on-farm), background soil N supply and inorganic fertiliser for a target crop yield of 8 tonnes DM/ha.

In this scenario applying 29 t/ha of feed pad/barn scrapings (Type A product) would meet the required nutrient shortfall for N and P but undersupply K by about 75 kg/ha. Applying an animal shelter slurry at 55 t/ha (Type A product) would supply the crop's entire remaining N, P and K requirements. In this example, approximately $430-$660/ha in inorganic fertiliser costs could be saved by applying effluents to grow the turnip crop. No side dress N fertiliser would be required.

Table 11.1. Nutrient demand and supply scenario for an 8 t DM/ha turnip crop.

	N	P	K	NPK value
Crop requirements		kg/ha		$/ha
Nutrients required (kg/ha)	192	30	240	
Nutrient value[1] ($/kg)	1.35	3.50	1.37	
Fertiliser value ($)	259	104	329	$693
Fertiliser inputs				
DAP at sowing (100 kg/ha)	18	20	0	
Fertiliser total (kg/ha)	18	20	0	
Fertiliser value ($/ha)	24	70	0	$94
Soil N Supply (kg/ha)	100			$135
Total supply	118	20	0	
Nutrient shortfall (kg/ha)[2]	74	10	240	
Dairy effluent inputs				
Feed pad/barn scrapings (29 t/ha)[3]	75 (150) *	29	165	$430
Animal shelter slurry (55 t/ha)[4]	74 (148) *	39	308	$657

[1] The NPK value of nutrients was estimated using the cost of standard fertiliser products, e.g., Urea ($621/t; 46-0-0), Superphosphate ($315/t; 0-9-0), Muriate of Potash ($683/t; 0-0-50); fertiliser company prices, July 2019.
[2] Nutrient shortfall = Nutrients required - Total supply.
[3] NPK content (0.52-0.10-0.57).
[4] NPK content (0.27-0.07-0.56).
*Assumes a Type A product (see Section 5 in the guidelines) where 50% of applied N becomes available for crop uptake. Values in parentheses are the total amount of effluent N applied.

1.   Maize silage

Maize is a common fodder crop grown across the North Island and upper South Island for silage. Table 2 shows the nutrient requirements of a typical maize crop and how this can be met using a combination of effluents (available on-farm), background soil N supply and inorganic fertiliser for a target crop yield of 20 tonnes DM/ha.

For the maize silage scenario, applying 27 t/ha of feed pad/barn scrapings (Type A product) would meet the required nutrient shortfall for N and P but undersupply K by about 90 kg/ha. Applying an animal shelter slurry at 50 t/ha (Type A product) would supply the crop's entire remaining N, P and K requirements. In this example, approximately $400–600/ha in inorganic fertiliser costs could be saved by applying effluents to grow the maize crop. Only one side dress N fertiliser application would be required.

Table 11.2. Nutrient demand and supply scenarios for a 20 t DM/ha maize crop

	N	P	K	NPK value
Crop requirements		kg/ha		$/ha
Nutrients required (kg/ha)	256	46	240	
Nutrient value ($/kg)[1]	1.35	3.5	1.37	
Fertiliser value ($)	346	161	329	$835
Fertiliser inputs				
DAP at sowing (150 kg/ha)	27	30	0	
Urea side-dress (130 kg/ha)	60	0	0	
Fertiliser total (kg/ha)	*87*	*30*	*0*	
Fertiliser value ($/ha)	117	105	0	$222
Soil N Supply (kg/ha)	100			$135
Total supply	187	30	0	
Nutrient shortfall (kg/ha)[2]	69	16	240	
Dairy effluent inputs				
Feed pad/barn scrapings (27 t/ha)[3]	70 (140) *	27	154	$400
Animal shelter slurry (50 t/ha)[4]	68 (136) *	35	280	$597

[1] The NPK value of nutrients was estimated using the cost of standard fertiliser products, e.g., Urea ($621/t; 46-0-0), Superphosphate ($315/t; 0-9-0), Muriate of Potash ($683/t; 0-0-50); fertiliser company prices, July 2019.
[2] Nutrient shortfall = Nutrients required - Total supply
[3] NPK content (0.52-0.10-0.57).
[4] NPK content (0.27-0.07-0.56).
*Assumes a Type A product (see Section 5 in the guidelines) where 50% of applied N becomes available for crop uptake. Values in parentheses are the total amount of effluent N applied.

Note:

The total N loading to a crop from effluents needs to be checked against local regional council regulations regarding maximum N applications. Normally there is a 150 kg N/ha limit however under a cut and carry situation (such as with maize silage) 200 kg N/ha, and possibly higher, may be permissible.

Key points:

- Type A effluents applied pre-sowing are complementary to fertiliser inputs for meeting fodder and forage crop nutrient requirements.
- In addition to the NPK value, dairy solids contain other major elements (e.g., sulphur, calcium and magnesium) and trace elements (e.g., manganese and zinc) required by crops. An approximate value of these other nutrients is around $50/ha.
- Dairy slurries and solids also supply organic matter. This may be a more important consideration for paddocks which are regularly cropped.

Confidential report for:

FRNL Programme Output (CS 2.16)

Report approved by:

Matthew Norris
Scientist, Cropping Systems & Environment
July 2019

Warrick Nelson
Operations Manager, Sustainable Production
July 2019

For further information please contact:

Matthew Norris
Plant & Food Research Ruakura
Private Bag 3230
Waikato Mail Centre
Hamilton 3240
NEW ZEALAND
Tel: +64 7 959 4430
DDI: +64 7 959 4496
Fax: +64 7 959 4431
Email: Matthew.Norris@plantandfood.co.nz

This report has been prepared by The New Zealand Institute for Plant and Food Research Limited (Plant & Food Research). Head Office: 120 Mt Albert Road, Sandringham, Auckland 1025, New Zealand, Tel: +64 9 925 7000, Fax: +64 9 925 7001. www.plantandfood.co.nz