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NUTRIENT CONTENT OF LIQUID AND SOLID EFFLUENTS ON NZ DAIRY COW FARMS

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Background

Since around 2000 there has been an intensification on New Zealand dairy cow farms. The number of dairy farms has declined from 13,892 for the 2000/01 season to 11,918 for 2015/16 (DairyNZ, 2016). However during the same period DairyNZ (2016) report that the average herd size has increased from 251 to 419 cows leading to higher stocking rates being carried (from 2.62 to 2.85 cows/ha). At the same time there has been an increased use of nitrogen fertiliser and a greater reliance on importing feed supplements such as maize silage and palm kernel expeller. As a result on-farm structures such as feed pads or animal shelters/housing have been constructed by farmers so that they can achieve better feed conversion efficiencies for this higher cost food. This has resulted in cows being concentrated on these structures, with impervious surfaces (usually concrete), for longer periods generating greater amounts of effluent on current farms than compared to farms pre-2000.

On-farm effluent management has become much more complex as farmers are faced with having to treat different forms of effluent as either liquids, slurries or solids. Liquid effluents are usually less than 5% dry matter (DM), slurries are usually between 5-15% DM and solids are greater than 15% DM (Houlbrooke et al., 2011). In addition Regional Councils have been enforcing more stringent environmental regulations, e.g., the requirement for greater effluent pond storage and the focus on nitrogen loading rates for effluents to pastures or crops. Therefore the modern NZ dairy farmer is challenged with the containment, treatment, and land application of a wide range of effluents with different physical and chemical characteristics.

Much of the published information of effluent composition, particularly liquid, is from pre-2000 data (Longhurst et al., 2000) which reflected mostly all-grass dairying. Laboratory chemical analysis have been collated and summarised to provide updated data that reflects current dairying practices concerning farm dairy effluent (from sumps and storage ponds), dairy slurries and solids (from feed pad scrapings, weeping walls, static screens and mechanically separated), plus similar slurry and solid effluents from animal shelters.

Data

The information presented here has been sourced from published papers (Longhurst & Nicholson, 2011; Houlbrooke et al., 2011; Longhurst et al., 2014; Heubeck et al., 2014), Eurofins laboratory analyses, commercial companies (Hi-Tech Enviro, Archway Ltd), and unpublished data held within AgResearch. Median and mean values are presented for the various analysis, where these are divergent it indicates greater variability within the data.

Sources of effluent

Farm dairy

The farm dairy has traditionally been the main source of effluent on NZ dairy cow farms where cows are typically milked for around 270 days per lactation. The effluent generated here is known as farm dairy effluent (FDE).

Feed pads

Effluent management is normally carried out by scraping the feed pad surface using tractor-mounted rubber scrapers to remove excreta. A minority of farms employ flood washing systems for cleaning the feed pads. Depending on the slope of the feed pad, excreta can be separated into liquid and solid components or simply scraped as slurry into a holding tank or storage pond for further treatment along with the FDE. As Regional Councils now require effluent to be contained, most farms scrape solids to a dedicated concrete storage bunker. These bunkers are normally uncovered and the solids are stored for about 3 months before land application.

Animal shelters

Animal shelters such as those with slatted floor have become a common site in the dairying landscape since 2002. The "slatted floor" construction allows stock excreta to be captured and stored in the concrete lined manure bunker. As bunker depths are 1.2 to 1.5m this allows excreta to be stored for many months before the requirement for emptying. The majority of farmers opt to remove the stored manure as a slurry, others prefer to drain the liquid fraction out to leave a more solid manure that can be land applied via a muck spreader.

Little data is available from deep litter barns, which utilise carbonaceous bedding such as wood chips. These sources of effluent have not been included in this paper as the main emphasis is on products that can be pumped or spread as raw manure solids. Likewise, so little data is presently available from free-stall barn effluents. In lieu of no data it would be expected that the animal shelter data presented here would not be too different from free-stall barn manure and could be used as a surrogate until meaningful data becomes available.

Liquid effluents

Sump and pond FDE

The data on liquid effluents from sumps and storage ponds presented here comes from a wide variety of sources. The majority of samples would be from the North Island with a heavy weighting to the South Auckland, Waikato and Bay of Plenty regions. In most cases it is not clear how the samples were collected, ie., if a sump sample was this collected directly from the sump or in a paddock being sprayed with FDE from the sump?; likewise for pond samples. The best representative effluent sample is to have the collection from what is being sprayed on the pasture. Collecting an effluent sample directly from the sump is problematic due to individual shed management. Is the holding yard pre-wetted? is a dung scraper on the backing gate employed? what is the volume of washdown water used? Therefore the composition of a grab sample of sump effluent will vary during the milking operation and can be strongly influenced from different washing phases from either the holding yard, dairy shed or milk plant.

Collecting a representative pond sample is also difficult due to the sheer volume of liquid. It is difficult to mix a pond if a grab sample be being obtained due to the stratification that occurs throughout the pond depth. A more representative sample can be collected if the pond is mechanically stirred first.

Laboratory results on the physical and chemical properties of liquid effluents (from dairy sumps and storage ponds) are presented in Table 1.

Table 1. Physical and chemical properties of liquid FDE (%).

	%DM	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Na**
FDE - sumps								
Median	0.43	0.039	0.007	0.047	0.004	0.012	0.007	0.004
Mean	0.81	0.047	0.008	0.056	0.006	0.023	0.008	0.005
Count (n =)	63	77	77	77	39	39	39	39
FDE - ponds								
Median	0.28	0.019	0.003	0.029	0.003	0.007	0.004	0.011
Mean	0.40	0.025	0.004	0.032	0.004	0.008	0.005	0.011
Count (n =)	94	133	133	133	133	104	104	63

The pH was analysed on some FDE and median values were found to be 7.3 for sump samples (n =12) and 7.2 (6.8-8.1) for pond samples (n = 39). This shows that FDE is a slightly alkaline effluent and therefore regular application to dedicated blocks on a farm should see a rise in soil pH over time. Median carbon values were 0.46% for sumps (n=12) and 0.23% for ponds (n=12). Median mineral-N values were 0.014% for sumps (n=38) and 0.012% for ponds (n=56).

For both sources of liquid effluent the median values reported in Table 1 are lower than the mean values for %DM and N with less variability for the other nutrients. For example, the median N values were 0.039 and 0.019% for sumps and ponds respectively. Interestingly the corresponding median K values were 0.047 and 0.029% for sumps and ponds respectively, indicating that potassium concentrations now appear to be consistently higher than those of nitrogen in FDE. These findings differ from earlier studies (Longhurst & Nicholson, 2011) where except for when feed pad effluent were combined with sump FDE the effluents were N-rich. Overall the %DM values found were similar to the mean of 0.9% reported by Longhurst et al., (2000). Likewise, mean N concentrations are similar to 0.027% (range 0.019-0.051%) reported by Longhurst et al., (2000) as was the range for the other major nutrients; P (0.002-0.008%) and K (0.016-0.071%).

Nutrient concentrations in pond effluent over time

Regular analysis of nutrient concentrations in effluent has been undertaken on three dairy farms each over a period of three years. Two of the farms were in the Waikato and had herds over 750 cows. Sump effluent from these farms went through some form of solid separation before entering the storage ponds. Mean annual N concentrations ranged between 0.13-0.15 kg N/m^3 for Farm 1 and 0.13-0.20 for Farm 2. No information was available for the Farm 3 but mean annual N concentrations ranged between 0.30-0.40 kg N/m$^{3.}$ These higher N concentrations could be due to: 1) no prior solids separation, 2) feed pad present, 3) smaller pond (i.e., less dilution from rainfall). It is also unclear whether the effluent samples were collected from the ponds or from paddocks being sprayed with pond effluent.

Results of the NPK concentrations throughout the year are presented in Figure 1. What is clear from these samplings is that K concentrations are consistently higher than N throughout the year. The reason for this is likely to be two-fold: 1) K is from the cow urine and therefore is mostly present in the liquid fraction of effluent, 2) volatisation losses of N occur (> 30%) with pond storage. The trend and concentrations for %N is very similar to that reported previously by Longhurst et al., (2000).

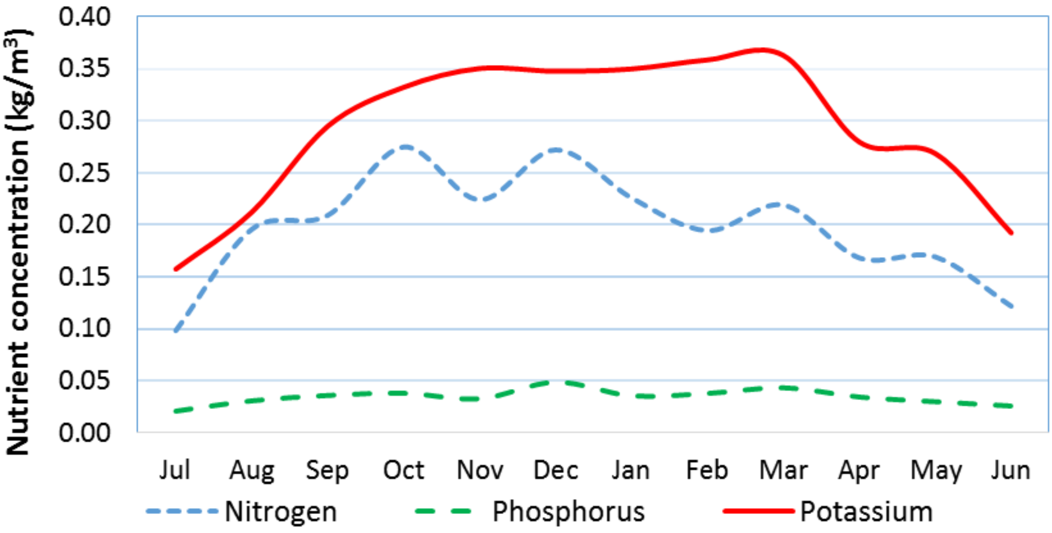

Figure 1: Mean nitrogen, phosphorus and potassium concentrations in pond effluent over year. Data over three years from three sites.

Relationship between nitrogen and %DM

The relationship between %DM and nitrogen concentration of effluents has been noted previously. Kaufler & Corban (2009) found that N v DM yielded a highly significant regression coefficient ($R^2 = 0.97$) and noting that most of the N was in the organic form and therefore associated with the dry matter. FDE (sumps and ponds) data of %DM and %N in this review was also found to be highly correlated ($R^2 = 0.75$) (Figure 2).

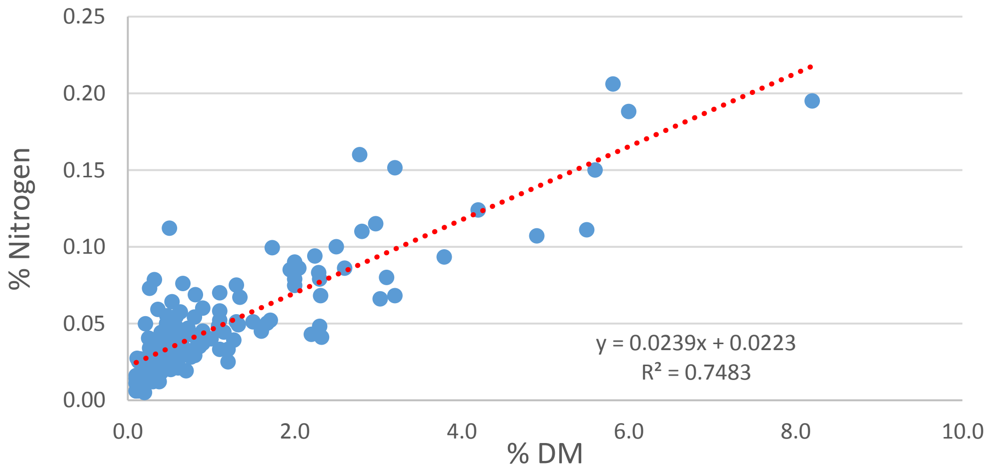

Figure 2: Correlation between %N and %DM of sump and pond FDE.

Slurries and solid effluents

Animal shelters

All the animal shelter analysis of both slurries and solids reveals a K-rich effluent (Table 2). The reason for this is likely to be as the effluents are stored in the manure bunker for several months (possibly up to a year) volatisation losses are occurring. These effluents are nutrient rich as, being sheltered from rain, they are not diluted by water.

Table 2. Physical and chemical properties of animal shelter effluents (%).

	%DM	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Na**
Slurries								
Median	11.0	0.31	0.07	0.55	0.06	0.17	0.09	0.05
Mean	10.5	0.32	0.07	0.58	0.06	0.16	0.09	0.07
Count (n =)	58	60	55	54	53	42	42	42
Solids								
Median	19.9	0.53	0.14	0.71	0.08	0.23	0.12	0.10
Mean	22.0	0.53	0.14	0.66	0.09	0.23	0.12	0.10
Count (n =)	29	34	27	27	26	7	7	7

The pH was measured on some of the animal shelter effluents and median values were found to be 7.9 for slurries and 8.1 for solids. Carbon was measured on 50 slurry and 30 solid samples with median values of 4.0% and 6.2% respectively. Likewise median mineral-N values were 0.146% for 16 slurry samples and 0.183% for 15 solid samples.

The nutrient values reported here are similar to those previously published (Longhurst & Luo, 2007; Pow et al., 2010).

Feed pad scrapings

The laboratory results of 13 feed pad scrapings are in Table 3. Large variation will occur within feed pad scrapings mainly due to the timing of the sample, i.e., is the sample from fresh scrapings? or has the solids been in storage for some time, in some cases this could be close to six months? Most feed pad scrapings are scraped and stored in a dedicated concrete bunker which is usually uncovered from the elements.

Table 3. Physical and chemical properties of feed pad scrapings (%).

	%DM	**N**	**P**	**K**	**S**	**C**	**Min-N**
Median	20.7	0.52	0.12	0.71	0.07	7.5	0.05
Mean	21.7	0.52	0.11	0.58	0.07	8.1	0.06
Count (n =)	13	13	12	12	5	7	7

Results from Table 3 indicate that feed pad scrapings are K-rich, supporting findings by Houlbrooke et al., (2011). These scrapings are one of the most nutrient rich of all the slurry and solid effluents as they can contain higher amounts of spent feed.

Static screen solids

Only five laboratory analysis were available for static screen solids (Table 4). The solids content varied between 10.6 -15.5 %DM. So based on solids content it could qualify as a slurry however when based on physical characteristics and "fluffy" appearance it is a solid as it requires a muck spreader for land application.

Table 4. Physical and chemical properties of static screen solids (%).

	%DM	**N**	**P**	**K**	**S**	**C**	**Min-N**
Median	15.0	0.23	0.04	0.07	-	5.2	0.01
Mean	13.5	0.24	0.04	0.07	-	5.4	0.02
Count (n =)	5	5	1	1	1*	4	3

* Sulphur was analysed on only one sample and reported as <0.5%.

Weeping walls

Weeping walls have now become a common form of solid separation after being first promoted in Southland (Scandrett, 2005). The attraction for farmers being that it is a relatively low-cost passive system with no mechanical parts and therefore minimal maintenance costs. Laboratory results (Table 5) have been collected for 38 samples making these the best set of data.

Table 5: Physical and chemical properties of weeping wall solids (%).

	%DM	**N**	**P**	**K**	**S**	**C**	**Min-N**
Median	17.0	0.29	0.05	0.08	0.05	5.1	0.03
Mean	20.1	0.31	0.05	0.13	0.05	5.8	0.02
Count (n =)	38	38	32	32	31	20	20

Very limited data exists for weeping wall analysis. The mean %DM found here was slightly lower than the 23% reported by Houlbrooke et al., (2011) however their range was 11-38% DM indicating the impact of storage on solids drying. The mean N values of 0.31% reported here where however higher than the 0.24% reported by Houlbrooke et al., (2011).

Mechanically separated solids

Most of the mechanically separated solid analyses (Table 6) are believed to be from screw-press separators. There are several different makes and models of solid separators used by dairy farmers. While being more capital expensive and requiring greater maintenance costs they do produce a higher %DM solid (up to 40%) which has additional advantages when transport costs are factored into the operational expenses.

Table 6: Physical and chemical properties of mechanically separated solids (%).

	%DM	N	P	K	S	C	Min-N
Median	23.1	0.33	0.05	0.08	0.06	9.9	0.003
Mean	25.3	0.37	0.06	0.11	0.06	10.7	0.008
Count (n =)	25	25	21	21	8	15	19

The values reported here are in-line with those reported by Houlbrooke et al., (2011). What this report also showed was that there was a range of solids contents achieved (22-35% DM) depending on the type of mechanical separator employed.

Overview

Now that data on the individual components of the different effluents has been presented we can now look at how they compare to one another. An effective way of doing this is by looking at various ratios (Table 7). Ratios such as carbon to nitrogen (C:N) are well known and indicate how quickly the effluent would decompose in soil. However other ratios such as N:P and N:K can be useful in gauging the basis on how application to land should be approached. For example while many Regional Council have an effluent loading to land limit of 150 kg N/ha/year there is no limit for P or K. Assuming typical pasture maintenance requirements for dairy farms of 150, 37.5 and 75 kg/ha of N, P, and K respectively then the normal pasture ratios would be 4.0 for N:P and 2.0 for N:K. Therefore if the N:P ratio was >4.0 it would mean that less P would be applied in effluent than required meaning that extra fertiliser P would be needed. Likewise if the N:K ratio was <2.0 then more K was being applied in effluent than needed. Therefore it would be more prudent to reduce the effluent amount applied to meet the pasture/crop K requirements and then top up with fertiliser N if necessary.

Another useful parameter is using the mineral-N analysis as a proportion of total N. This is a very good indicator of how much of the effluent is in plant available form and therefore is very important when effluents are applied to crops.

Table 7: Comparison of effluents using various indicators.

Effluent source	**C:N ratio**	**Min-N/TN %**	**N:P ratio**	**N:K ratio**
FDE – sump	12	36	5.6	0.8
FDE – pond	12	68	6.3	0.7
Animal shelter- slurry	13	47	4.3	0.6
Animal shelter- solids	12	35	3.7	0.7
Feed pad scrapings	13	10	4.5	0.7
Static screen solids	26	4	5.3	3.3
Weeping wall solids	15	10	5.5	3.6
Mechanically separated solids	29	1	6.6	4.1

The C:N ratios of 12-15 are similar for FDE, animal shelter effluents and weeping walls solids and indicate potential for rapid assimilation into the soil. However the higher C:N ratios (26-29) for the static screen and mechanically separated solids indicates likely slow decomposition of organic matter, therefore these should be considered as slow-release nutrient sources. This is confirmed by the very low proportion of mineral-N present in these effluents (<5%). Current research being undertaken as part of the Forages for Reduced Nitrate Leaching (FRNL) programme has shown that N supply is highly variable between effluent types. In summary total net N supply from 6 month lab incubations ranged from 4-74% for slurries and 2-35% for solids (Dexter et al., 2015). This programme aims to deliver an industry tool to help aid farmer decision making with regards the fertility value of a range of different slurry and manure products.

Both the feed pad scrapings and weeping wall solids have similar characteristics regarding N. The total N content for both effluents is relatively high but the proportion of mineral-N is low meaning that there is likely to be a “lag effect” before the N becomes plant available.

The N:P ratios for all effluents except the animal shelter solids was >4.0 meaning extra fertiliser P would be required to meet maintenance plant needs. Heubeck et al., (2014) reported P:N ratios for FDE ranging between 0.11-0.22. When these reverse ratios are applied for sump FDE and pond FDE the P:N ratios the fall within this same band with 0.18 and 0.16 respectively.

The N:K ratio reveals that the FDE, animal shelter slurries and solids and feed pad scrapings are all <2.0, in fact <1.0, meaning that excessively high amounts of K can inadvertently be applied to land. Conversely the static screen, weeping wall and mechanically separated solids have N:K ratios >3 meaning that fertiliser K inputs are highly likely needed to supplement these solids when meeting plant maintenance needs.

Conclusions

This review of liquid and solid effluents has found that the values found for sump and pond effluents are still of the same magnitude as those reported pre-2000. The only caveats being if feed pad scrapings go directly to a sump or effluent in a storage pond is being emptied prior to winter and pond depth is very low and can incorporate bottom sludge.

This review has also highlighted the fact that most effluents are K-rich materials. An easy way to gauge this is by looking at the N:K ratio of the effluents. When this ratio is <2.0 then, in most situations, more K is being applied to land than is likely to be required. Conversely much pastoral land has below optimum soil K values and therefore using effluent K could be an effective method of overcoming this limitation.

Static screen and mechanically separated solids should be considered as slow-release effluents where the N contained is not likely to become plant available in the year of application.

More information on the release rate of organic N into mineral N from manures and slurries would provide farmers with critical extra information useful for guiding tactical fertiliser decision making.

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