Treating farm dairy effluent to minimise impacts on New Zealand water quality

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1. INTRODUCTION

In New Zealand there are 14741 dairy farms with an average herd size of 208 cows per farm (Table 1). For the last couple of decades whilst the number of herds (i.e. number of farms) have reduced substantially, the increasing stocking rate and the increasing effective grazed area per farm have resulted in approximately 50% increase in total cow numbers. Increasing number of sheep and beef cattle farms have been converted to make room for such increase. Moreover, increasing knowledge in farm production techniques have also led to an increase in milk production per cow. For example the current milkfat production per cow is 173 kg/cow/season whilst in 1974/75 it was 128 kg/cow/season. Currently, New Zealand's contribution to world dairy production is only 2%, however, its contribution to the world dairy export market is 26%.

Table 1. Summary of New Zealand herd statistics since 1974/75

Season	**Herds**	**Total cows**	**Average herd size**	**Average effective hectares**	**Average cows per hectare**
1974/75	18540	2079886	112	<60	<2.0
1996/97	14741	3064523	208	86	2.5

Dairy Statistics 1996-1997

Milking season in New Zealand commences with calving in August and finishes in April in the following year (approximately 270 days/season). Farm dairy effluent is generated in farm dairies (dairy sheds) when milking premises and milk containers are washed down during the milking season. Approximately an effluent volume of 50 L/cow is produced during daily washing resulting in 10000 L of effluent/day/farm (10 m^3/day/farm).

2. FARM DAIRY EFFLUENT DISCHARGE REGULATION IN NEW ZEALAND

Raw farm dairy effluent has substantial amount of organic carbon, nitrogen and bacteria (Table 2). If discharged to waterways it can cause significant adverse effects on the water quality. High organic carbon and ammonium in effluent will cause oxygen depletion in river or stream water resulting in fish deaths. High nitrogen and phosphorus in effluent can cause algal bloom resulting in further oxygen depletion in water. When raw effluent is discharged to stream or river any disease causing pathogens present in the effluent may affect the water quality for stock watering or human consumption. Since raw effluent also has high suspended solids, the discharge to water will reduce water clarity.

The above concerns resulted in regulation of farm dairy effluent in the early 1970's in New Zealand. During this time MAF (Ministry of Agriculture and Fisheries) encouraged farmers to construct treatment ponds to treat effluent. In early 1980's the Water Catchment Boards started regulating effluent discharges. Since early 1990's Regional Councils (formulated in 1989 through a local government amalgamation of the Catchment Boards) have been regulating effluent

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discharges. Currently, all the Councils in New Zealand have specific rules to control farm dairy effluent discharges.

Table 2. Median quality of raw effluent and treated effluent discharged between ponds and ditches and to surface water

Variable	Units	Raw n=53	Pond 1 n=180	Pond 2 n=140	Pond 3 n=7	Ditch 1 n=14	Ditch 3 n=21
Temp	^oC	n.m.	18	16	16	18	16
pH	pH units	8.6	7.4	7.9	7.7	7.7	7.6
Cond	mS m^{-1}	261	260	171	117	323	174
DO	g m^{-3}	n.m.	1.5	4.0	2.7	1.3	4.1
BOD_5	g m^{-3}	2000	160	83	36	160	63
SS	g m^{-3}	4780	430	220	69	350	125
NH_4-N	g m^{-3}	130	150	69	42	170	80
NNN-N	g m^{-3}	n.m.	0.05	0.44	0.82	0.05	0.04
TKN	g m^{-3}	355	190	91	55	233	95
DRP	g m^{-3}	6.6	8.5	5.7	3.9	9.3	7.9
TP	g m^{-3}	49.1	29.7	20.0	9.4	50.0	22
DOC	g m^{-3}	369	115	68	45	161	100
TOC	g m^{-3}	567	176	87	54	241	105
COL	n/100 mL	n.m.	$1.1x10^6$	$2.5x10^5$	$6.3x10^4$	$2.4x10^6$	$2.3x10^5$
FC	n/100 mL	$2x10^7$	$5.4x10^5$	$3.5x10^4$	$3.4x10^4$	$7.0x10^5$	$5.1x10^4$

n.m. not measured

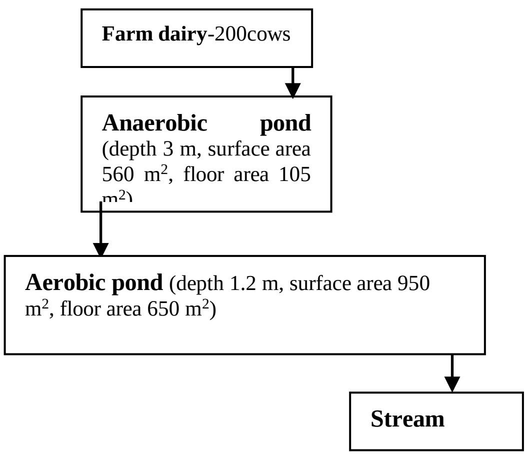
3. CURRENT FARM DAIRY EFFLUENT TREATMENT SYSTEMS IN NEW ZEALAND

3.1 Oxidation pond and barrier ditches

3.1.1 Oxidation ponds

An oxidation pond system consists of two ponds, the first pond anaerobic and the second aerobic. Anaerobic ponds are constructed deep below soil surface (more than 3 metres depth) and aerobic ponds are shallow (1.1 m depth) (Environment Waikato, 1995). Surface area of the anaerobic pond is much lower than that of the aerobic pond. Raw effluent is piped into the anaerobic pond first. Anaerobic pond provides an oxygen-depleted environment for effluent digestion and sedimentation of a substantial amount of effluent solids.

Figure 1 Oxidation ponds



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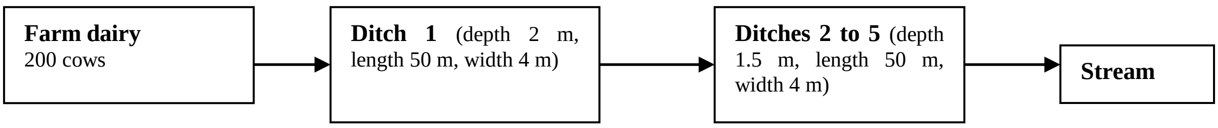
Under New Zealand conditions more than 90% of the suspended solids and BOD (biochemical oxygen demand) and 50% of the total effluent nitrogen are treated in the anaerobic ponds. The aerobic pond does further polishing and result in an effluent quality of 83 g BOD/m^3, 220 g SS/m^3 and 91 g total-N/m^3 (Table 2). Although a substantial amount of treatment has occurred in both ponds the quality of treated effluent is not yet suitable for discharging to waterways. Some farmers have constructed a third pond (aerobic) to mitigate adverse effects. The third pond does reduce pollutant levels further (Table 2).

3.1.2 Barrier ditches

As an alternative to oxidation ponds New Zealand farmers also use ‘barrier ditches’. Barrier ditches work similar to smaller but extended pond systems. Effluent passes through several ditches (each ditch being 50 m x 4 m) which separated by earth. The first ditch functions similar to anaerobic pond and remaining ditches provide facultative (aerobic and anaerobic) environment for effluent treatment. In general a minimum of 4-5 ditches are required.

Figure 2 Barrier ditches



Both oxidation ponds and barrier ditches are popular among the farmers because these systems are:

- Low cost systems
- Easy to design and construct
- Useful where land application is difficult due to soil or climatic conditions

3.1.3 Environmental impacts of pond or barrier ditches

a) ‘Dilution as a solution’

Dilution is one of the options available for minimising impacts from certain contaminants. Contaminants that require dilution are pathogens (indicator bacteria being either faecal coliforms or enterococci), ammonia (NH_3), BOD and suspended solids. If sufficient dilution is available in surface water these contaminants are not likely to cause adverse effects. Treated or untreated, farm dairy effluent carries animal pathogens. In New Zealand the environmental law (s107.f. RMA, 1991) requires that discharges shall not render fresh water unsuitable for consumption by farm animals. The implication of this law is that effluent discharges shall not result in a faecal coliforms level of > 1000 cfu (colony forming units) per 100 mL of surface water.

Ammonia (NH_3) is toxic to fish. Ammonia is in equilibrium with ammonium (NH_4^+) in effluent or water and both NH_3 and NH_4^+ are collectively known as ammoniacal-N. The equilibrium between NH_3 and NH_4^+ is affected by pH and temperature. Generally surface water pH is between 7.0 and 7.5 and is well buffered against any pH changes. Consequently, it is assumed that the temperature could be the driving force to release NH_3 from NH_4^+. For example at a water pH of 7.5 and temperatures of 10 and 25^{o}C the maximum allowable ammoniacal-N (NH_3 + NH_4^+) levels in surface water are 2.2 and 1.1 g/m^3 respectively. This example illustrates that under warm conditions the amount of dilution required to minimise toxic effects of ammonia is much greater.

Nitrogen is present in effluent as nitrate-N (NO_3-N), ammoniacal-N and organic-N. Approximately 40-50% of the total N in raw farm dairy effluent is in the form of organic form. During the treatment, in a two-pond system a majority of the organic-N is settled in the anaerobic pond resulting in more than 75% of organic-N reduction. Consequently, the total-N discharged from the two-pond system is 91 g/m^3. A high proportion of this discharged N is ammoniacal-N (75%). Preliminary trials suggest that there are nitrifying organisms present in the aerobic pond. Despite this there is little or no nitrate-N found in the discharge. Even if nitrate-N is produced the aerobic pond environment is conducive to denitrification process (particularly within the bottom 1 m depth) hence stripping nitrate-N to gaseous N forms.

The discharged ammoniacal-N is a good source of mineral-N and hence taken up by water weeds and algae. A proportion of the organic-N discharged will be mineralised as ammoniacal-N after several days. This is available for aquatic plants further downstream of the discharge point. Moreover, about 25% of the total-P discharged are in the form of dissolved reactive phosphorus (DRP), which is readily available for aquatic plants.

It could be argued that in New Zealand raw farm dairy effluent had not been discharged to waterways since the introduction of two-pond and barrier ditch systems by MAF (Ministry of Agriculture and Forestry). Nevertheless, Hickey *et al*. (1989) estimated that treated effluent discharged from either two-pond or barrier ditch systems would require >2700-fold dilution for faecal coliforms (bathing criterion) and to prevent nuisance algal growth. These researchers recommended that "the general design criteria applied to the pond treatment systems may be inadequate and that some revision is desirable". A more recent study performed on ponds and ditches effluent treatment performance also showed that the suspended solids (220 g/m^3) and ammonium-N (64 g/m^3) levels are too high for the treated effluent to be discharged to waterways (Selvarajah, 1996b).

b) Pond seepage

Improperly sealed ponds or ditches can leak a substantial amount of effluent into groundwater. Recently, Ray *et al.* (1995 & 1997) found that more 1000 L effluent/day could leak from improperly sealed ponds. These workers indicated that when earth materials with clay content of >8% are used as pond liner provided a good compaction is achieved, the leakage could be minimal. In New Zealand where pumice materials (volcanic ash) are found pond leakage could be a major problem. In such areas some farmers have been required to install artificial liners. In short it could be argued that the potential and actual negative impacts of the ponds or barrier ditch systems on the receiving environment well outweigh the low maintenance and low cost benefits derived from these systems.

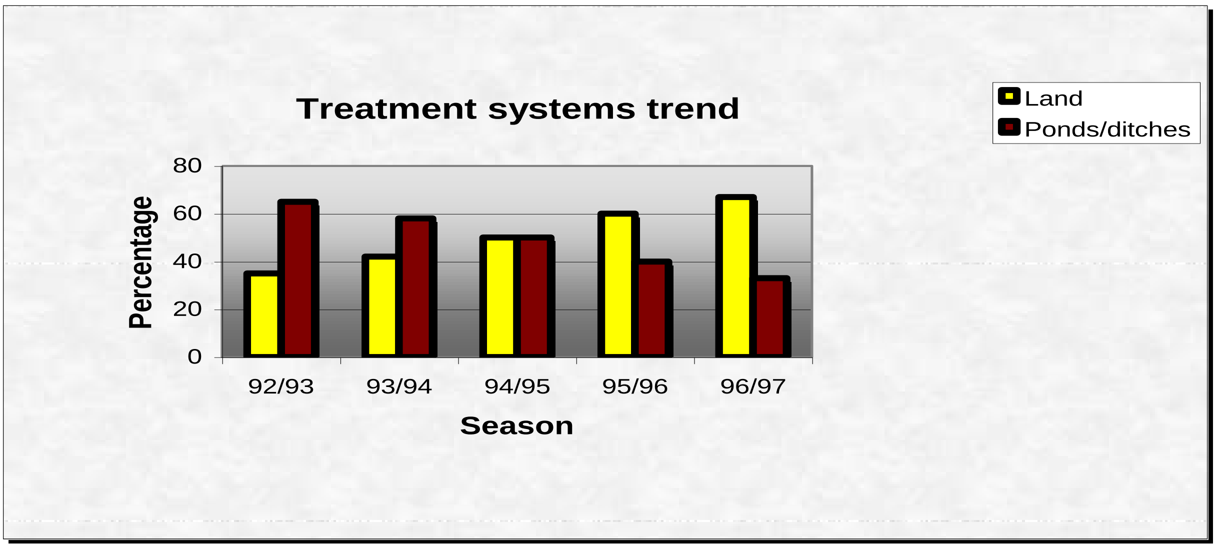
3.2 Land treatment systems

There are approximately 6000 dairy farms in the Waikato Region in New Zealand. Prior to the introduction of the farm dairy effluent rules, more than 80% of the dairy farms were discharging treated farm dairy effluent to waterways. Assuming all farms were discharging untreated effluent to waterways with a lactation period of 270 days, an average herd size of 200 cows and farm dairy N output of 20 g N cow^{-1} d^{-1}, approximately 6480 tonnes of N yr^{-1} would have been discharged to waterways. With an effective grazing area of 70 ha per farm and the current average regional dairy pasture fertiliser-N use of 55 kg N ha^{-1} yr^{-1} the effluent-N loading would have been sufficient to supply 30% of the dairy farms' fertiliser-N need in the Waikato Region. This information strongly supports effluent discharge to pasture, i.e. use of land treatment system.

Effluent irrigation to pasture has become very popular in New Zealand since introduction of the Resource Management Act in 1991. Regional Councils have been encouraging farmers to irrigate effluent onto pasture by allowing the discharge as a 'permitted activity' (i.e. no resource consents or license required). Farmers who have been using land-based systems have been using tankers, pot spreaders and travelling irrigators to spread effluent from a sump (raw effluent collection area) or holding pond (an ex pond/barrier ditch system). When effluent is irrigated from a holding pond, contractors have been employed to irrigate effluent.

Currently in New Zealand the most preferred and used effluent treatment system is effluent irrigation onto pasture. For example within the last three years in the Waikato Region alone about 3000 farmers (50% of the Waikato farmers) have adopted effluent irrigation systems. The key conditions for compliance monitoring of effluent irrigation are whether the farmer has sufficient land area for irrigation and that there is no visual sign of excess effluent application. Based on an effluent survey performed during 1995 summer for a 200 cow herd, about 7.4 ha is required for farm dairy effluent irrigation at 150 kg N ha^{-1} yr^{-1}. The effluent loading rate of 150 kg N/ha/year is based on a nitrogen model developed by Selvarajah (1996a).

Figure 3 Increasing trend in effluent irrigation in the Waikato Region, New Zealand



The environmental authorities in New Zealand (i.e. Regional Councils) also believe strongly in waste minimisation and utilisation of waste. The **advantages** of using effluent irrigation are numerous:

- Farm dairy effluent is a liquid containing valuable fertiliser N, P, K and S. Applying effluent at the rate of 150 kg N/ha/year will also supply 25 kg P/ha, 105 kg K/ha and 20 kg S/ha. It has been estimated that the fertiliser value of effluent for a 200 cow herd farm will be more than NZ$2500 per year (Environment Waikato, 1997).
- Effluent irrigation to pasture adds organic matter to soil and increases earthworm activity.

- Effluent can be either directly applied from the dairy shed or from holding ponds or oxidation ponds.
- If managed properly effluent irrigation to pasture will minimise stream/river water quality degradation.
- There have been attempts to improve oxidation pond discharge quality by installing tertiary treatment systems (e.g. wetland, aeration of aerobic pond etc which will be discussed briefly below). Regardless of these sophisticated techniques the discharge quality is not suitable for sensitive river/stream environment.
- A consistent message from the indigenous Maori is that the purification of effluent through land is much more acceptable option than the direct discharge of effluent to waterways.

The major **disadvantages** of land application systems are:

- Difficult to use on land with high slope
- High initial cost
- Not suitable under wet weather conditions

Since the introduction of the effluent rules in the Waikato Region there have been few reported cases of raw effluent deliberately discharged into waterways. Since 1993 there have been five prosecutions related to raw effluent discharge into water bodies. Most cases were related to poorly managed land based systems with raw effluent run-off to waterways due mainly to no effluent pumping. These prosecutions had a 100% success rate with a range of fines being from $2000 to $25000. It must be noted that dairy farmers have been prosecuted prior to the introduction of the farm dairy effluent rules. According to the records 9 farmers were prosecuted between 1989 and 1992. One case worth noting was where a farmer was prosecuted for a poorly managed land based system and fined $25000 in 1991.

Effluent irrigation is not just restricted to pasture only. Effluent can also be irrigated to cropping soils, trees (e.g. *Eucalyptus*). A recent study showed that farm dairy effluent irrigated to Eucalyptus trees produced greater amount wood biomass. These trees are used as a source of fuel at farms.

3.2.1 Environmental impacts of well managed land treatment systems

In general if effluent irrigation is well managed, the adverse effects on water quality should be minimal. The following points are worth noting in terms of a well managed effluent irrigation system:

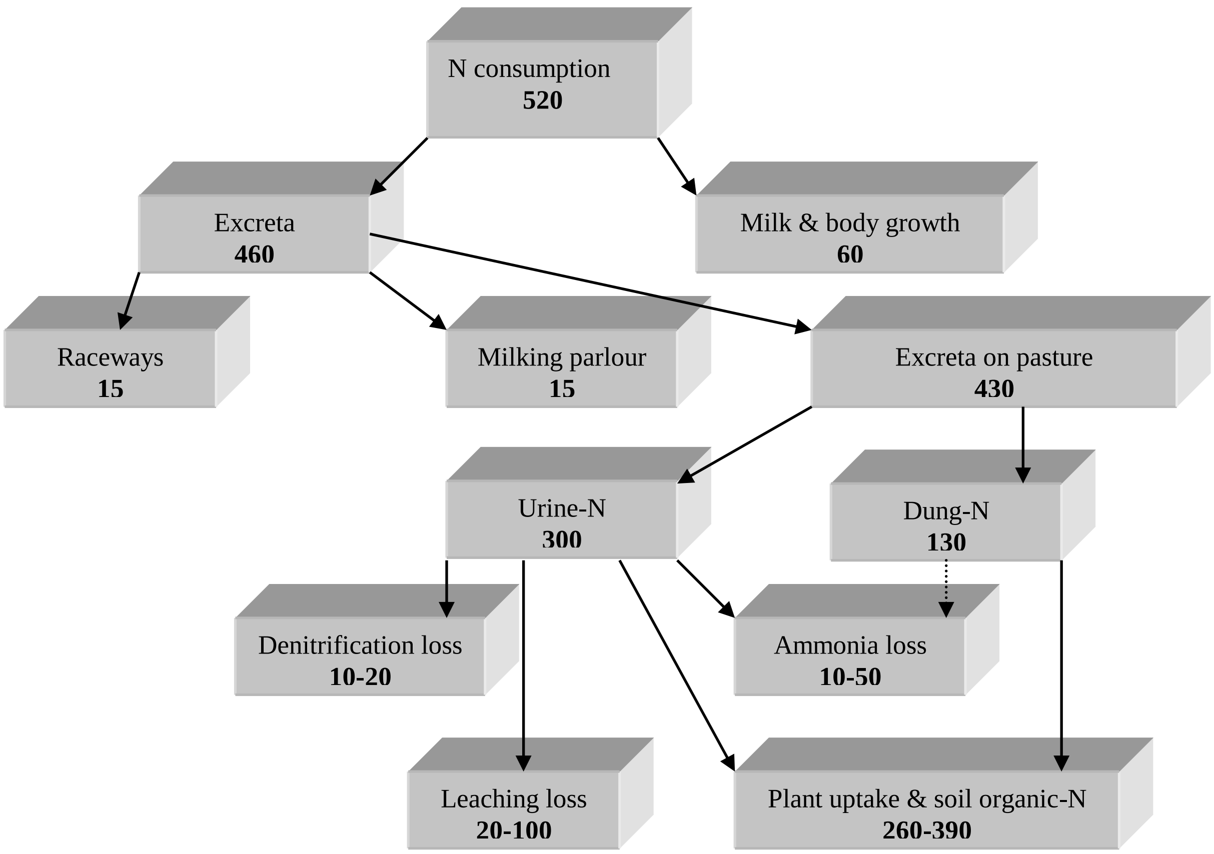
- Nutrient loading, particularly N loading is matched with the land use type (e.g. grazed pasture 100-150 kg N/ha/year, hay or silage paddocks 400-500 kg N/ha/year, Eucalyptus 200-250 kg N/ha/year)
- Hydraulic loading is matched with the infiltration rate and field capacity of soil (as a rule of thumb an application rate of 5-10 mm/hour and 25 mm of total loading per application)
- No surface ponding or runoff of effluent
- Land or soil management to suit effluent irrigation (e.g. grazing or harvesting of pasture should not be allowed at least for more than 2 weeks following effluent irrigation)
- Fertiliser-N is not applied where effluent is irrigated

New Zealand dairy pasture systems comprise mainly a mixture of ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). The extent of plant uptake of N is influenced by pasture growth rate which is influenced by soil moisture, temperature and extent of grazing. Generally peak pasture growth and greater uptake of N occurs during spring, whilst the lowest uptake of N occurs during winter. Pasture performance is measured in terms of dry matter (DM) production. In most cases, increases in DM production are apparent for N application rates up to 550-650 kg N ha^{-1} y^{-1} - beyond which rate the yield decreases. At high N application rates pasture begins to accumulate N. Nitrogen accumulates in plants mainly in the form of protein. In addition to protein, NO_3-N can also accumulate in plants if there is excessive NO_3-N present in soils.

Compared with many other regions in New Zealand, the Waikato has optimal conditions for pasture growth. Many soils are derived from volcanic parent materials which when combined with typically warm, humid summers and mild winters ensure that Waikato soils are among the most productive in the country. Pasture uptake of N is approximately 520 kg N ha^{-1} y^{-1} in the Waikato region assuming that average pasture production is 13000 kg DM ha^{-1} and a high N content of pasture of about 4% on a dry weight basis.

Most farm advisers tend to focus on the high N uptake of pasture and ignore the animal excreta-N input. Figure 4 indicates that about 85-90% of the ingested pasture-N is excreted as animal urine and dung. More than 70% of the excreta is in urine-N form and often urine is deposited in a small area resulting in up to 1000 kg N/ha loading rate during each urination event. When grazed pasture systems are used for effluent irrigation it is important to account for the animal excreta input and effects.

Figure 4 Fate of N ingested by cows in a grazed dairy pasture system in the Waikato Region, New Zealand (kg N/ha/year)



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Selvarajah *et al.* (1994) estimated that in the Waikato Region approximately 60 kg N/ha/year could leach as nitrate-N into groundwater. More recently a field study in the same area demonstrated that on average unfertilised grazed pasture leached 60 kg nitrate-N/ha/year. Such leaching is caused by nitrate-N produced from animal urine according to the following reaction in soil:

$CO(NH_2)_2$ (urea) + $2H_2O \rightarrow NH_3\uparrow + HCO_3 + NH_4^+ \rightarrow NO_3^- + 2H^+$

The effluent-N loading rate could be determined by taking into account the N input as fertiliser or clover and the worst case N losses from the system. In the Waikato Region the clover-N input in a well-established pasture system has been estimated as 200 kg N/ha/year and the worst case loss has of N from the system has been estimated as 260 kg N/ha/year resulting in a 60 kg N/ha/year deficit. Consequently an effluent loading of 100 kg N/ha/year is highly justifiable. However, since the effluent has a high proportion of the organic-N an effluent loading rate of up to 150 kg N/ha/year has been used for regulatory purposes. If the pasture does not contain little or no clover the effluent loading rate could be 300-350 kg N/ha/year.

Caution must be taken when effluent loading rate is dictated by N loading rate. For example at 150 kg N/ha/year loading rate about 105 kg N K/ha/year is also applied during farm dairy effluent irrigation. This amount of K is considered as excessive and found to be restricting Mg uptake by pasture. Pasture deficient in Mg will cause symptoms similar to 'milk fever' in lactating animals. In general about 50 kg K/ha/year is required for good pasture growth. If consideration is given to benefiting from both N and K in effluent a more appropriate effluent loading rate is 100 kg N/ha/year. If the pasture does not have any clover-N input the deficit of N could be supplemented by adding fertiliser-N.

3.2.2 Environmental impacts of poorly managed land treatment systems
If land based systems are not managed properly they can cause following problems:

- *Excessive application:* Excessive effluent application could result in effluent run-off into the adjacent streams causing death of fish and loss of water clarity and quality. Excessive effluent application will also result in pasture death and nutrient leaching.
- *Deep injection:* Effluent injection into soil is a common practice in Europe. Effluent is injected into soil to minimise ammonia losses and odour problems. In New Zealand and Uruguay ammonia is not considered as atmospheric pollutant and hence injection of effluent is not required. Effluent injected into soil below root zone will cause excessive nutrient leaching and groundwater contamination.
- *Spray drift*: Effluent spray irrigated under strong wind conditions could be a nuisance due to spray drift into neighbouring properties and waterways. Spray drift can carry potential diseases for animals and human.
- *Grazing rotation*: Allowing animals to prematurely graze on effluent irrigated pasture could spread diseases such as mastitis.

3.3 Tertiary treatment systems
Tertiary treatment systems are capable of treating effluent discharges from ponds and ditches to further reduce the pollutant levels. In New Zealand a considerable amount of research being performed to improve the treated farm dairy effluent discharge to waterways (Selvarajah, 1995).

3.3.1 Constructed wetland systems

Constructed wetland systems (9.5 m x 2 m) are shallow ponds (0.6 m depth) with 0.4 m of gravel planted with wetland plants such as soft stem bulrush. These systems are connected to the final discharge from either ponds or ditches. The system is based on natural wetland treatment processes. Naturally wetland systems are excellent in treating nitrate-nitrogen (NO_3-N) through denitrification processes. They can also settle a substantial amount of solids and in the process reducing phosphorus and organic-N discharges. One important point to note is that the wetland plants once fully established will uptake little or no nutrients and hence the treatment relies heavily on the anaerobic and partially aerobic environment available in the system. A recent wetland trial by Tanner *et el*. (1997) showed a reduction of up to 78% of suspended solids and up to 60% of total-N in pond treated farm dairy effluent was achieved. During dry periods wetlands also sustain a high evapo-transpiration losses resulting in little or no effluent discharge to waterways.

Disadvantages of using constructed wetland systems:

- Wetlands are not efficient in terms of treating ammoniacal-N and phosphorus
- Proper construction of wetland systems could cost (in New Zealand) from NZ$14000 to NZ$30000
- Regular maintenance and care are necessary for wetlands to be effective
- Discharge quality may not be suitable for sensitive streams and rivers
- Wildlife (i.e. ducks) input may increase faecal contamination

3.3.2 Tree bark trenches

A recent study showed that effluent discharges from ponds could be further treated by tree barks. A major reduction in total-N is achieved through ammonia absorption by barks when pond effluent was passed through tree bark trenches. Treated bark could be used as compost or mulch.

Disadvantages of using tree bark trenches:

- A substantial amount of tree bark is required. For example it has been estimated that for a 200 cow herd about 120 m^3 of bark is needed.
- Discharge quality may not be suitable for sensitive streams and rivers
- The technology is at its early stages of research

3.3.3 Zeolite beds

Zeolite is a naturally available mineral with an enormous capacity to absorb ammonium from effluent. Research being held to absorb ammonium by submerging zeolite minerals with pond effluent in shallow zeolite beds. Once ammonium is absorbed the effluent is discharged back into the aerobic pond. The absorbed ammonium in zeolite is be allowed to nitrify for several days. When pond effluent is discharged into nitrified zeolite, denitrification process will remove nitrate-N from zeolite.

Effluent ammonium $\rightarrow$ Adsorbed ammonium in zeolite $\rightarrow$ Nitrate-N in zeolite $\rightarrow$ Nitrogen gas

Disadvantages of zeolite beds:

- Zeolite minerals may not be easy to access
- Requires regular maintenance and operation
- Discharge quality may not be suitable for sensitive streams and rivers
- The technology is at its early stages of research

3.3.4 Mechanical aeration of aerobic pond

It has been observed that more than 95% of the second pond (aerobic pond) monitored for treatment performance had little or no nitrate-N (Selvarajah, 1996). The presence of nitrate-N in effluent is a sign of aerobic conditions. Since ammonia in effluent is toxic to fish it is preferred that ammonia to be oxidised to nitrate-N. Similar to urban sewage effluent treatment systems, a small-scale mechanical aeration in the second pond will aid nitrate generation from effluent ammonium. When mechanical aeration is ceased, nitrate-N will be denitrified due to high dissolved carbon in the second pond. An investigation to minimise pond odour by mechanical aeration showed that the median nitrate-N level was 12 g/m^3 and ammonium-N was 7 g/m^3 (Sukias, 1995). In comparison a typical second pond without aeration will have 70 g ammonium-N/m^3 and zero nitrate-N (Table 2). If farmers want to use mechanical aeration to treat the second pond effluent they have to consider the cost of electric power and ensure the pond banks are resistant to effluent wave action caused by mechanical aeration.

In countries where wind could be used to generate power mechanical aeration may be a treatment option. If mechanically aerated addition of constructed wetland system will help denitrify nitrate-N in aerated effluent.

4. RECOMMENDATIONS FOR THE URUGUAYAN DAIRY FARM ADVISERS

Increasing pressure has been put on exporting countries to improve the local environmental quality. Such pressure could be applied through non-tariff trade barrier by importing or the competing nations. Most European countries are in this category due mainly to the fact that they have stringent environmental regulations or are in the process of developing these regulations. As agricultural countries Uruguay and New Zealand are susceptible to such international pressure. In New Zealand global market access and non-tariff trade barrier implications are increasingly recognised. New Zealand is one of the few countries that currently enjoy a 'clean and green' image. New Zealand government and the citizens desperately want to maintain such a good image for the well being of the country. This is a big task because such a task requires a considerable amount of corporation between farmers, dairy industry and the regulators and a commitment to spend money to improve environmental quality.

If the Uruguayan dairy farmers currently do not have farm dairy effluent treatment systems it is timely to look at a range of options that suit their budget and the international environmental standards. This must be done despite little or no regulation of farm dairy effluent discharge by the Uruguayan government. Currently New Zealand holds a wealth of information and experience in treating farm dairy effluent. One of the keys to the success of farm dairy effluent management in New Zealand is that local farmers and the regulators recognising the need to enhance or maintain the environmental quality and identifying effluent as a valuable 'fertiliser', not as a 'waste' to be discharged into waterways. Using this excellent opportunity provided by the organisers to share New Zealand experience on farm dairy effluent treatment methods, as a New Zealander I will endeavour to create and maintain future link between Uruguayan dairy farm advisers and New Zealand knowledge base with regard to farm dairy effluent treatment.

I recommend the followings for the Uruguayan dairy farm advisers:

- Be familiar with the range of options for treating farm dairy effluent
- Understand nitrogen and other nutrient budget for grazed dairy pasture system
- Investigate the nutrient value of the raw and treated effluent in Uruguay
- Investigate the cost and environmental benefits of different treatment systems

- Sell the benefits of land treatment systems to Uruguayan farmers – this could be achieved through group or individual meetings with the farmers
- Understand the current Uruguayan environment and environmental issues
- Understand potential and actual environmental impacts of a range of treatment systems
- Understand effluent minimisation techniques and animal behaviour in the milking parlour
- Understand global market access issues and advise farmers about thinking **ahead** and to **proactively** minimise adverse environmental effects caused by farm dairy effluent and farming in general

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