"Dispose and forget" never works with land treatment systems

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ABSTRACT

New Zealand has several major rural industries which produce wastewaters not suitable for discharge to surface water, and has faced major problems regarding the disposal of the wastewater in an environmentally sustainable manner. Historically for the meat industry, land application has generally been promoted as the most practical solution for the disposal of wastewater. Although the understanding and application of land treatment and disposal systems for meat processing wastewater has developed considerably over the past 30 years, historical land treatment systems in many parts of New Zealand have received nitrogen applications well in excess of the generally accepted nutrient uptake of the crops.

The focus over the years has shifted from using land as a method of disposal of wastewater to an integrated land use approach, where nutrients are utilised for crop recovery or assisting with improved farm production. However, the activities of the past have resulted in negative environmental effects still seen today.

This paper examines the common practices of the past in terms of wastewater disposal to land and the effects that have been experienced for many years after the historical practices have stopped. Examples from within the New Zealand meat industry are examined, where land application of wastewater has shown persistent environmental effects. This paper also examines current land treatment practices, identifying examples where adverse effects are still resulting and areas that could potentially be investigated to improve operations.

Keywords: wastewater, irrigation, land disposal, treatment, nitrogen, loading rates.

INTRODUCTION

In New Zealand, some form of use of land for the disposal of wastewaters from rural based industries, especially the meat industry, have been undertaken for a long period of time (Keeley & Quin, 1979, Russell & Copper, 1987, Johns, 1995). Over the last 30 years there has been an increase in the use of land treatment systems. After the implementation of the Resource Management Act 1991 (RMA), land treatment systems have been promoted as satisfying recognised cultural values and being promoted as having the ability to provide renovation of nutrients within soil-plant systems (Luo *et al*, 2004). Although land treatment of wastewater serves many useful purposes, such as the recovery of nutrients, irrigation of crops and replenishment of groundwater, there is a potential risk of increasing the level of pollutants into the receiving environment, resulting in long term adverse effects.

The use of land based treatment systems remains one of the preferred disposal routes for meat processing wastewater. This is because meat processing wastewater is normally regarded as dilute organic fertiliser due to it containing significant quantities of plant macronutrients, specifically nitrogen, phosphorus and potassium. Many of the rural based meat processing plants have access to large parcels of land and utilise land treatment systems in some form. Historically meat companies have utilised high rate application methods such as traditional border dyke irrigation, however, these systems have been progressively replaced by modern sprinkler systems as restrictions on nitrogen loading rates have been progressively tightened. The practice of irrigating meat processing wastewater with high nitrogen concentrations is still common throughout the country.

This paper examines the historical land disposal practices within the meat industry and the resultant effects of nitrogen on the receiving groundwater for rural based meat processing plants. A series of case studies have been utilised to identify historical and current issues that have resulted from land disposal practices.

BACKGROUND TO NITROGEN LOADING RATES

The nitrogen loading rate is the most common limiting factor for wastewater irrigation systems within the New Zealand meat industry. The key consideration for most modern systems is "*what level of nitrogen loading provides for sustainable nitrogen application with negligible environmental effects?*"

One of the main effects of a poorly managed wastewater irrigation system is the loss of nitrogen into groundwater and the subsequent increase in nitrate levels. Nitrate contamination in groundwater is of particular concern when levels exceed the maximum allowable value of 50 mg/L nitrate for drinking water as short term exposure (equivalent to 11.3 mg/L as nitrate-nitrogen) (MoH, 2005). In addition to the issues associated with drinking water, nitrate can also result in nutrient enrichment in surface water when the groundwater discharges into surface water. Elevated nitrate levels in surface water bodies may lead to periphyton growth reducing surface water quality. As a result of recent studies, nitrate is also considered to be more toxic than was previously thought to freshwater aquatic species and limits of 1.7 mg/L as nitrate-nitrogen may be implemented as a default to protect freshwater aquatic species (Hickey & Martin, 2009).

In establishing nitrogen loading rates for meat industry wastewater irrigation systems, there was a general acceptance, based on studies undertaken by the then Meat Industry Research Institute of New Zealand (MIRINZ now part of AgResearch), that when anaerobically treated meat processing wastewater is used, an upper limit to nitrogen application is reached at about 500 kg N/ha/yr and with primary treated meat processing wastewater, the upper limit appeared to be 1,000 kg N/ha/yr (Russell, 1986). Many of the earlier land disposal systems adopted the nitrogen loading based on this study.

Since the implementation of the Resource Management Act in 1991, the requirement to consider the effects on the receiving environment has resulted in a general reduction in nitrogen loading rates and a trend towards land treatment rather than land disposal. Depending on the land use activity, loading rates can now vary anywhere from 150 kg N/ha/yr as a permitted baseline on grazed land to 650 kg N/ha/yr on non-grazed system.

THE IMPACT OF HISTORICAL PRACTICES

While historical nitrogen loading rates may have decreased, to bring the wastewater irrigation systems more into line with the treatment capacity of the land and the landuse activity, the effects of historic loading rates are still being witnessed today and will continue to do so for years to come. A case study is presented below to illustrate the residual effects of historic nitrogen loading rates from the irrigation of meat industry wastewater.

Hawkes Bay case study example

A large meat processing plant in Hawkes Bay disposes partially treated wastewater onto land. Since the establishment of the meat plant in 1981, land disposal of wastewater has occurred, initially as border-dyke irrigation and then progressively converted to low pressure spray irrigation.

Border dyke irrigation was undertaken on 19 ha of farmland until 1984 and then increased to a total of 69 ha of farmland until 1994. On average, during this period the nitrogen loading rate was very high at approximately 2,400 kg N/ha/yr initially and then reducing to 1,300 kg N/ha/yr for additional land. Following the increase in land treatment area in 1994, the irrigation methods were changed to spray irrigation resulting in the average nitrogen loading rate being reduced to around 750 kg N/ha/yr. Since 1995, when the land area available to the discharger increased to 212 ha, the average nitrogen loading rate is estimated at 400 kg N/ha/yr. Fig. 1 shows the historical average nitrogen loading rate since the establishment of the processing plant.

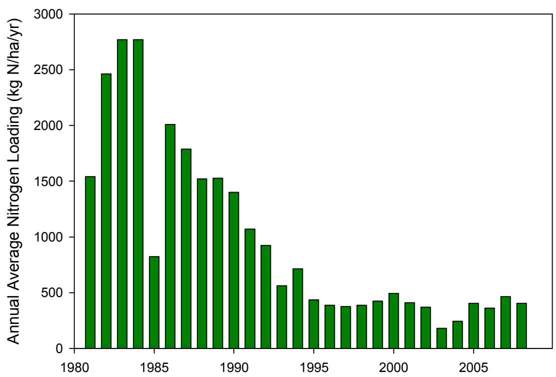

Fig 1. Historical nitrogen loading trend.

Recent concerns from the regulatory authority regarding the elevated groundwater nitrogen concentrations prompted the meat processing plant to review its land disposal operations and assess the likely effects of the loading on the groundwater concentrations.

The results of groundwater monitoring carried out at the site since 1999 have identified elevated nitrate levels in the groundwater that have been attributed to historic wastewater irrigation activities at the site. The elevated nitrate levels have been occurring in groundwater down-gradient of the historically heavily loaded irrigation blocks, within the deeper intermediate aquifer, progressively increasing since 2000.

Two boreholes down-gradient of the disposal site in the shallow (unconfined) and intermediate (semi-confined) aquifers have exhibited increasing nitrate-nitrogen levels. For the shallow aquifer (depth = 15 m) the nitrate-nitrogen concentrations increase sharply between April and December 2000, to a peak of approximately 30 mg/L, before falling between December 2000 and February 2007 to pre-2000 levels of around 1 mg/L; nitrate-nitrogen concentrations have been below 1.0 mg/L and relatively stable since this time. For the intermediate aquifer (depth = 45 m), the nitrate-nitrogen concentrations in this bore appear to have been increasing gradually since 2001 (when monitoring began), from 2.8 mg/L in March 2001 to 17 mg/L in March 2009. This is illustrated in Fig. 2.

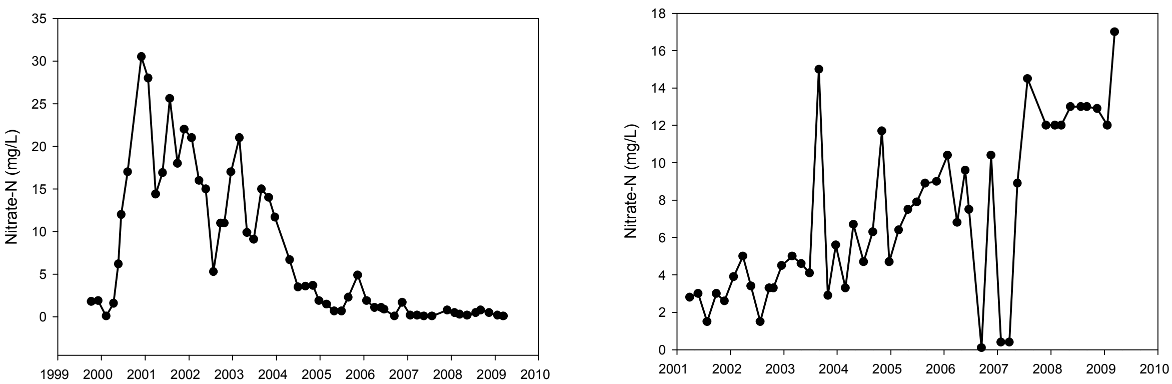

Fig. 2. Groundwater nitrate-nitrogen trends in shallow (left) and intermediate (right) aquifer.

It is believed that these increases are likely to be attributable to the use of border-dyke irrigation as the primary method of wastewater disposal with a very high nitrogen loading onto a smaller parcel of land in the 1980s-90s. It is thought that the delay between the response in the shallow well and in the deeper well is due to differing travel times of the groundwater in the shallow and intermediate aquifer.

It would appear that the groundwater nitrate levels in the shallow aquifer have now receded to background levels, however, the nitrate level is either rising or has reached a plateau in the intermediate aquifer. It is considered that with time (and in parallel to ongoing nitrogen loading rates being low) the nitrate concentrations in the intermediate aquifer will decrease.

A simple groundwater modelling assessment showed that the peak nitrogen concentration observed in the shallow aquifer took approximately 15 years from the time of deposition of the nitrogen onto land and the plume effect could take up to 36 years to pass the monitoring location some 1,900 m from the furthest extent of the disposal area. For the intermediate aquifer it could take up to 43 years for the plume to fully pass based on travel time from the furthest point of disposal. Using the available data the potential peak plume nitrogen concentration is estimated at 26 mg/L. It is possible that the peak plume concentration has either been reached in the intermediate aquifer, with current concentrations at 17 mg/L or is expected to be observed within the next few of years. Because of the plume length and low flow velocity, the peak nitrogen concentrations may be observed over an extended period of time before declining.

The site is now disposing nitrogen at an average rate of 400 kg N/ha/yr on a cut and carry system. With continued nitrogen loading at this rate, once the plume has passed, it is estimated from the available data and the model that the current and proposed application rate may result in an estimated groundwater concentration of approximately 2 mg/L, similar to background levels upstream of the land treatment system.

The key issue for the site is appreciating the legacy of very high historical nitrogen loading that will need to monitor until the plume breakthrough occurs in the surface water. Given that some of the shallow groundwater daylights into a stream some 4 km downstream of the site, it is likely that the site and/or the regulatory authority will be subjected to long term off-site monitoring for a period of at least 60 years.

Other examples

As early as 1979, Keeley and Quinn reported that surface irrigation of meatworks-fellmongery wastes at a meat processing plant in Canterbury resulted in the loss of virtually all applied inorganic nitrogen (estimated at 360 kg N/ha/yr) to groundwater. The investigation carried out by Environment Canterbury in 2004 (Hayward & Hanson, 2004) for the same site suggests that a distinct band of high nitrate concentrations 2 km wide and 13 km long exist in the groundwater downstream of the land disposal site. The median nitrate-nitrogen concentrations downstream of the meat processing plant in the shallow groundwater was in the range of 8 – 25 mg/L with a median concentration of 20.8 mg/L between 1999 and 2003. The groundwater nitrogen concentrations have been aggravated by the presence of two other meat processing plants discharging to land. Hayward and Hanson concluded that extensive nitrate contamination exists in the groundwater in the vicinity of the three meat processing plants.

A site in Taranaki showed very high levels of nitrogen in the groundwater downstream of the disposal sites. Historical nitrogen loading rates varied between 450 – 700 kg N/ha/yr. With a reduction in applied nitrogen, the groundwater nitrate-nitrogen concentrations reduced from a peak of 120 mg/L in 1994 to 30 mg/L in 2007.

THE EFFECTS OF CURRENT PRACTICES

Since the 1990's, the marked decrease in nitrogen loading rates associated with meat industry wastewater irrigation systems has seen a significant reduction in the levels of nitrate in groundwater, as shown by the Hawkes Bay case study. Notwithstanding this, there are several examples within the New Zealand meat industry where the reduced and currently accepted nitrogen loading rates are still resulting in elevated nitrate levels within the receiving groundwater.

At a site in the Waikato, the irrigation of treated wastewater onto land has occurred since 1994 at a compliance loading limit of around 300 kg N/ha/yr. The site utilises a combination of irrigation to land and discharge to surface water to manage hydraulic loads and take advantage of seasonal growth rates to maximise plant uptake of nitrogen. While it would appear that this wastewater irrigation activity can be managed within the land treatment capacity, groundwater nitrate-nitrogen levels have been as high as 66 mg/L. It is considered that while the flux rate of nitrate through the soil profile would normally have a negligible impact on groundwater nitrate concentrations, the slow groundwater movement in the area is resulting in the increase in the nitrogen concentrations, similar to a lake effect.

For the second site, in Taranaki, the nitrogen concentration in the groundwater seems to be high even when the nitrogen application rates reported have been between 140 – 253 kg N/ha/yr between 2001 – 2010. The groundwater nitrogen concentrations for this site have been monitored since 2000 and some of the groundwater monitoring bores has shown levels as high as 110 mg/L following winter.

From these recent examples, it appears that there are still some improvements required in establishing sustainable nitrogen loading rates onto land.

LOOKING FORWARD – ACHIEVING SUSTAINABLE LAND TREATMENT

It is interesting to note that the issue of sustainable nitrogen loading rates was identified in the first ever Land Treatment Collective Technical Session (Fietje, 1990) where one of the further research requirements was "*maximum nitrogen application rates for which there is no increase in leaching of surplus nitrates to groundwater*". It is considered that to ensure sustainable land treatment, criteria must be such that irrigated wastewaters do not increase the concentration of the leachate over and above that produced by normal farming practices. Essentially, the key requirement was to ensure that the amount of nitrogen applied is matched by plant uptake.

Since the implementation of the Biosecurity (Ruminant Protein) Regulations, 1999 and the inclusion of Clause 17A (Irrigation with wastewater from premises where ruminant protein is rendered, stored, or used), there is a general trend to provide some form of additional wastewater treatment prior to irrigation of meat processing wastewaters. This results in a higher portion of mineralised nitrogen in the wastewaters, which has the potential to leach more easily. Field investigation undertaken in Waikato suggests that there is a strong correlation between mineral nitrogen leaching and loading rates above 350 kg N/ha/yr (Burgess, 2003). Given that mineralised nitrogen is more prone to leaching (especially in its oxidised form) then it would suggest that loading rates need to be in-line with seasonal plant uptake rates rather than annual rates.

For the Hawkes Bay case study, an analysis of the nitrogen production rates and the estimated plant uptake is generally similar during the lower plant uptake months (May – September). This allows the site to manage the nitrogen loading in a sustainable manner. However, if wastewater production rates do not reduce during the winter months, then wastewater treatment to reduce nitrogen loading rates to plant uptake rates needs to be considered. This integrated approach is adopted by one of the sites in Waikato, where biological nitrogen removal is used to reduce the nitrogen concentrations in the wastewater prior to irrigation to land.

In dry areas where rainfall and fresh water irrigation rates can limit plant growth, consideration needs to be given to the concentration of nitrogen in the wastewater. If the nitrogen concentration is too high, then the rate of hydraulic application is reduced, limiting plant growth and subsequent plant uptake of nitrogen. The Australian effluent irrigation guidelines (MLA, 1996) suggest that the nitrogen concentration in the wastewater needs to be reduced prior to land treatment to allow an increase in crop yield and nitrogen utilisation. Generally the crop yields increase to optimum levels when the nitrogen concentrations are below 80 mg/L. This suggests that for many meat processing plants further nitrogen reduction by conventional wastewater treatment will be required to ensure that sustainable land treatment systems can be employed. Alternatively wastewater will need to be augmented with freshwater to ensure that nitrogen uptake is maximised.

For meat processing wastewater with high nitrogen concentrations sustainable land treatment needs to be integrated with other methods of nitrogen reduction prior to the disposal of wastewater. Clearly when the wastewater is disposed onto land at higher nitrogen concentrations, there is a significant increase in the potential for leaching of nitrogen.

SUMMARY

Loading rates of nitrogen onto land from meat industry wastewaters has historically been very high and deemed beyond the treatment capacity of the land. While there is evidence of reduced effects on the receiving environment as a result of a general decrease in nitrogen loading rates since the early 1990's, many sites are still experinecing the impact of historical overloading.

There is evidence that some of the current wastewater irrigation practices are continuing to result in elevated nitrate levels in the groundwater, even though the loading rates are within currently accepted levels. Further work is required to understand where these systems are failing and what amendments are required to operate the systems within the treatment capacity of the landuse activity.

Key considerations when assessing these systems could include assessment of seasonal plant uptake rates of nitrogen instead of annual rates, identification of any inhibiting factors for plant growth such as hydraulic or nutrient limitation, and assessment of the potential to reduce nitrogen loading rates through treatment and/or seasonal alternatives for treated wastewater disposal.

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