Management of Nitrogen Leaching Levels as Compliance Limits for Land Treatment of Wastewater

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ABSTRACT

Land treatment of wastewater is considered by many regulatory authorities in New Zealand as the best practicable method for the utilisation of wastewater nutrients, especially nitrogen. As a result of policies developed by many regulatory authorities, a considerable number of land treatment systems are operating with limits generally assigned to nutrient loading rates. However, the leaching of nitrogen into the groundwater and the subsequent impact of groundwater on surface water is changing the way regulators are thinking about sustainable nutrient loading onto land. This is especially relevant where normal pastoral grazing may be undertaken in conjunction with land treatment operations.

Nitrogen leaching criteria may change the way nitrogen loading onto land will be managed in future and will affect many large industrial wastewater dischargers that utilise land treatment on farmland that has grazing.

This paper examines nitrogen leaching levels as an important control for land treatment of agro-industrial wastewater. Case studies are presented from two different food and by-products processing industry sites to demonstrate the relevance of leachable nitrogen fraction as a method of control for wastewater application to land.

Keywords: nitrogen leaching, land treatment, wastewater, groundwater

INTRODUCTION

Land treatment based wastewater disposal systems are common place throughout New Zealand. As a result, many large industries in the food sector are taking advantage of land treatment for the management of wastewater generated from their factories.

One of the ongoing challenges that industries face is the complimentary use of farmland as an active operational farm, especially dairy farming. This conflict is now leading to issues in terms of the management of the nitrogen application rate to ensure that there is minimum leaching from the farmland.

With continued intensification of dairy farming, these land use activities are resulting in nitrate concentrations in the shallow groundwater exceeding acceptable levels, including drinking water standards on some occasions. During summer periods, surface water bodies are generally influenced by the shallow groundwater and as such. the background nitrate levels in many surface water bodies are already at levels which may exceed aquatic guidelines.

The regulatory authorities are now relying heavily on nitrogen leaching estimation models, and to this end, Overseer® Nutrient Budgets (Overseer®) is being seen as the default on farm management and decision support tool for the management of nitrogen loading. While nitrogen management models take into account nitrogen loading rates, stocking rates, grazing and cropping activities, they are not so effective at predicting the effects of soil type. Due to limited resources, most farmed systems are unable to utilise monitoring systems to calibrate nitrogen models, and therefore nitrogen models, in their current form, can only ever be an approximation of nitrogen leaching rates. However, models are being widely relied upon to determine “sustainable” fertiliser and wastewater application rates with limited confirmation of the actual leaching rates.

Some regulatory authorities are starting to apply nitrogen leaching caps to manage the losses of nitrogen from farming system. For the case studies examined in this paper, the relevant regulatory agencies are considering either an absolute limit for the baseline nitrogen leaching from dairy farms or a marginal increase from the current accepted baseline.

There is a general agreement that the nitrogen leaching from pastoral dairy farms is around 50 - 65 kg N/ha/yr (Green *et al*, 2004, Lilburne, *et al*, 2010, Menneer *et al*, 2004, Power *et al*, 2006). Generally well managed farms would have nitrogen leaching losses of around 50 kg N/ha/yr. It must be noted that past studies have shown that when dairy farms have no external nitrogen fertiliser application, the nitrogen losses could be as much as 40 kg N/ha/yr (Ledgard *et al*, 1997).

Depending on the extent of marginal increase allowed beyond the existing intensive farming systems, there may be very little opportunity to apply wastewater as land treatment in conjunction with pastoral grazing, especially for intensive dairy farming systems. This means that when land treatment is undertaken, the landuse may need to change such that zero grazing is implemented, with the crop harvested and taken off the land treatment site. This may open up more issues for the utilisation of the harvested crop in the event that there is a reluctance of use of the crop as a feed for dairying due to perceived market risks

The two case studies presented show that land use will need to change significantly to allow continued use of existing farmland as a land treatment system.

CASE STUDY 1 - CANTERBURY

Site and Wastewater Loadings

An industrial site is located in the rural area of the Selwyn Waihora Catchment. Due to a planned increase in production, the increase in wastewater volume would result in a substantial increase in nitrogen load from the site. The annual volume associated with the increase in nitrogen load is estimated at 1.6 ML.

The industrial site is surrounded by agricultural pastoral land suitable for intensive farming, namely dairying. The soils are moderate to well drained stony silt loams that overlay sandy gravels. These soils provide a conducive plant growth environment. There is an annual deficit of 200 mm of water as a result of high evapotranspiration rates and low rainfall. To achieve maximum plant growth, irrigation is often required through the months of September to April. The partially treated wastewater is discharged onto grazed pasture.
The farming activities are irrigated and unirrigated crops with some grazing over an area of 255 ha. The average nitrogen application is 25 kg N/ha/yr, and this loading rate needed to increase to 110 kg N/ha/yr to accommodate the additional wastewater load.

Nitrogen Acceptance Constraints

In the Canterbury region environment, a combination of generally high water tables and free draining strata means that nutrient leaching to the aquifer is considered a risk that must be controlled and minimised. The management and discharge of nutrients to land is controlled by the regional planning rules generally aligned into a number of nutrient allocation zones. The nutrient allocation zones are separated into three risk categories which are defined green (meets water quality objectives), orange (at risk) and red (water quality objectives not met). The majority of the Canterbury Plains/mid-Canterbury is classified as red, meaning that water quality objectives are not met. Rather than managing the application of nitrogen to land, the regional plan rules aim to manage the loss of nitrogen to the aquifer. For activities located in red zones (farming, wastewater application to land) the nitrogen loss to the aquifer is tightly controlled and increases to existing nitrogen losses are deemed a prohibited activity.

For the site location being in the Selwyn Waihora Catchment, designation as a red zone means that the region's expectation is that the nitrogen load limits are controlled by an annual capacity allowance for the nitrogen loads from farming, industrial and community sources. The catchment has a designated baseline loading limit based on consented losses where available. Where consent is not required (i.e. agricultural land), the baseline is to be estimated from the average losses between the period from 2009 – 2013. Further variation in losses need to be less than 10% of the average losses. Given the strict controls around nitrogen discharges in this zone, any new or additional nitrogen discharges must not increase nitrogen losses to the aquifer.

Consideration for Managed Land Treatment

In order to allow continued operations of the factory and to allow expansion, a range of options for the treatment and discharge of this water were considered including piping and discharging to a river, piping and discharging to the ocean and irrigation to land with no further treatment.

Given that substantial treatment would be required for any acceptance of treated wastewater discharge to surface water together with the economics of treatment and construction of viable disposal routes, irrigation to land was determined as the preferred option.

As the site is located within a nutrient red zone, the farm operation must ensure that nutrient losses to the aquifer are no more than baseline values. Overseer® modelling for the 2011 – 2014 period was completed to establish nitrogen baselines for the farm properties. Because any increase to the nitrogen loss baseline was deemed as a prohibited activity, the land use had to be changed.

To ensure that nitrogen baseline losses were not increased, the farm had to switch to a cut and carry system. The farm systems were modelled in Overseer® using a cut and carry scenario with either planted lucerne or grass. Both planting options were able to maintain nitrogen losses that did not exceed the baseline.

CASE STUDY 2 - WAIKATO

Site and Wastewater Loadings

An industrial site is located in the Hauraki Plains. The site produces highly nitrogenous wastewater requiring substantial treatment prior to disposal either to land or into surface water. The current activities are controlled by a series of resource consents that allow the use of the dual discharge system. The dual discharge has been in use for 21 years, with progressive increase in land treatment in the vicinity of the industrial site with up to as much as 280 ha of land utilised during the summer months (October – May) coinciding with low flow in the river. Treated wastewater is discharged to the river during winter months. The annual volumes expected to be disposed onto land is around 0.4 ML.

The nitrogen application rate is controlled directly by a surface loading criteria of less than 300 kg N/ha/yr onto grazed (dairy) pasture. The farmland surrounding the industrial site has varying soil types, which result in some variation in the seepage of water through the soil profile. This is starting to present some challenges for the site with respect to maintenance of acceptable nitrogen loading to minimise leaching losses.

Nitrogen Acceptance Constraints

During recent investigations by the industrial site, it was recognised that the generally accepted nitrogen application rate of 300 kg N/ha/yr is resulting in nitrogen losses to the shallow groundwater system in varying amounts. An examination of the soil water leached showed average nitrogen concentrations ranging from 4 – 52 mg/L. On a generalised farm scale basis, the nitrogen loading of 300 kg N/ha/yr, an estimate of nitrogen leaching fraction was considered to be 87 kg N/ha/yr. This amount of nitrogen leaching was estimated by nitrogen leaching estimation model developed by Pattle Delamore Partners Limited and verified by Overseer®. The validation was also undertaken with on-site lysimetry and soil water quality assessment against annual water balance.

In order to establish the basis of the nitrogen leaching, a soils and soil-water leaching mapping assessment and its relevance was determined. It was concluded that nearly half the farm had soils that had lower nitrogen leaching at an estimated leachable fraction of 19 kg N/ha/yr (6% of loading rate), although the water loss to shallow groundwater was high from these soils. However, nearly one-third of the total farm contributed to average soil water concentrations in excess of 50 mg/L, contributing on an annual basis of a nitrogen leachable fraction of nearly 63% of the annual loading rate. For the remaining farm, the nitrogen losses into the shallow groundwater was estimated at 22% of the nitrogen loading rate. Although the weighted average of leachable fraction for the total farmland was considered manageable because the groundwater concentrations were not increasing and the resultant adverse effects on surface water was minor, it was deemed by the regulatory authority that the leachable fraction in itself needed to be reduced.

The regulatory authority has given a strong signal to limit the nitrogen leaching from the farmland that receives treated wastewater to be below 60 kg N/ha/yr. This means considerable changes to the management of the land treatment system will be required to allow reduction of the nitrogen leached beyond the root zone.

Consideration for Managed Land Treatment

In order to allow continued operations of the factory and to allow land treatment on existing dairy farmland, the application of wastewater will either need to reduce across the farmland or targeted variable nitrogen application rate will be required in order to satisfy the ceiling on leachable nitrogen.

The industrial site is working with the regulatory authority to set up a trial plot of 20 ha in the farm where the soil type could potentially allow more nitrogen application because current levels of leaching are low. This would mean that the nitrogen application rate in excess of 300 kg N/ha/yr may be allowed for a large parcel of the land where current levels of leached nitrogen is averaging at 4 mg/L. However, if trials result in higher nitrogen leaching, then the overall nitrogen loading rate will need to be reduced to below 300 kg N/ha/yr for this parcel of land. For the remaining farmland, the nitrogen application rate as part of land treatment system would need to reduce below 200 kg N/ha/yr to ensure that the nitrogen leaching is maintained below 60 kg N/ha/yr.

To enable the industrial site to continue to use the land treatment system, extensive monitoring programmes will need to be developed with ongoing calibration and validation of nitrogen leaching estimation models. This will impose further burden on the management of the land treatment system.

The implication in the medium term is that in order to maximise the use of the dual-discharge system and the land treatment, further nitrogen removal will be required at the site's onsite wastewater treatment system prior to discharge to land. This will require significant capital investment as well as ongoing treatment costs.

CONCLUSIONS

Land treatment systems have previously relied on surface nitrogen application rate as a method of control to minimise the amount of leachable fraction of nitrogen below the root zone.

Further controls are gaining acceptance that allow a nitrogen ceiling compliance limit on the amount that is leached. This imposes another level of management on industrial sites that generate a considerable amount of wastewater that may be required to be disposed onto land. Landuse changes will be necessary for land treatment system where grazing options may become very limited.

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