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INCORPORATING BIOSOLIDS AND WASTEWATER AS A SOIL AMENDMENT INTO NUTRIENT BUDGETS AND THE ASSOCIATED ENVIRONMENTAL MANAGEMENT CONSIDERATIONS

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Abstract

Biosolids and wastewater contain varying amounts of nitrogen and phosphorus that can be used as a fertilizer/soil amendment. However, there are a number of management considerations that are different to conventional fertilizer. Biosolids and wastewater are a mixture of complex biological compounds with nutrients being bound within the material. The complex nature of the material means that only a percentage of the nutrients may initially be available for plant uptake or to be potentially leached. Nutrient release from the complex material requires the mineralisation process to occur for the nutrients to be transformed into forms that are soluble and mobile.

A conservative approach to application of biosolids and wastewater is often taken in regional plans and by regulators, using loading rates based on total nitrogen content and not the likely total mineralisable nitrogen content. Further complexity and misunderstanding can occur if the nitrogen loading rate is thought of as an equivalent of readily available fertilizer like Urea, where farmers may not see the plant responses that they were expecting. Only with time will a high percentage of the nutrients can be released, which has implications for both nutrient budgeting, environmental management and nitrogen leaching mitigation regimes that aim to limit overall nitrogen losses. Communication of fertilizer form and benefits needs to factor in the expected plant availability of the nutrients.

An additional consideration when using OVERSEER® to assess the leaching potential of application of wastewater and biosolids, is the cumulative impact of mineralisation beyond the application month and reporting year. The nutrient modeller may have to provide a fertiliser input equivalent for the historic applications and expected mineralisation. If the budget is being used for regulatory purposes this fertiliser input equivalent should be agreed with the regulator.

Introduction

Wastewater and treatment process biosolids e.g. waste activated sludge, dairy farm manures or grape marc, have valuable fertilising and soil conditioning properties; they are rich in nutrients and organic material. They can be applied to land to fertilise plants and improve the quality of soil. Approximately 320,000 wet tonnes of biosolids are currently produced by municipal wastewater treatment plants across New Zealand. Of this, an over 60% is disposed of in landfills or long-term storage (Horswell Et Al 2013). There are therefore future opportunities within NZ for land owners to utilise wastewater and biosolids as a soil amendment. However, there are some management considerations that need to be understood by land owners.

One factor that landowners need to be aware of when managing wastewater and biosolid is that the forms of the nutrients within wastewater and biosolids are different from Urea nitrogen fertilizer. Urea fertilizer supplies nitrogen in inorganic ammonic form ($NH4+$) which is plant available, whilst wastewater and biosolids can have a more complex nature, with nutrients being bound within organic material structure. Inorganic forms of nutrients are readily available post application while organic form nutrients are not readily available to plants and require mineralisation before they become plant available (soluble and mobile). In comparison to biosolids, wastewater will have a higher proportion of plant available nitrogen as Nitrate or Ammoniacal nitrogen depending on the upstream treatment system. Biosolids typically have a higher percentage nitrogen in organic form, with very little nitrate or ammoniacal nitrogen. Biosolids therefore require more mineralisation before the nitrogen is in a form that is soluble, mobile and plant available. The form of nitrogen is important to consider because it impacts on the potential plant response and also how much nitrogen is in the soil solution that has the potential to be leached following soil drainage events.

Figure 1 below using data from Metcalf and Eddy (1991) shows the cumulative mineralisation of sludge over 11 years and demonstrates that it can take up to 9 years before even 50% of nitrogen in an anaerobically disgusted sludge is released.

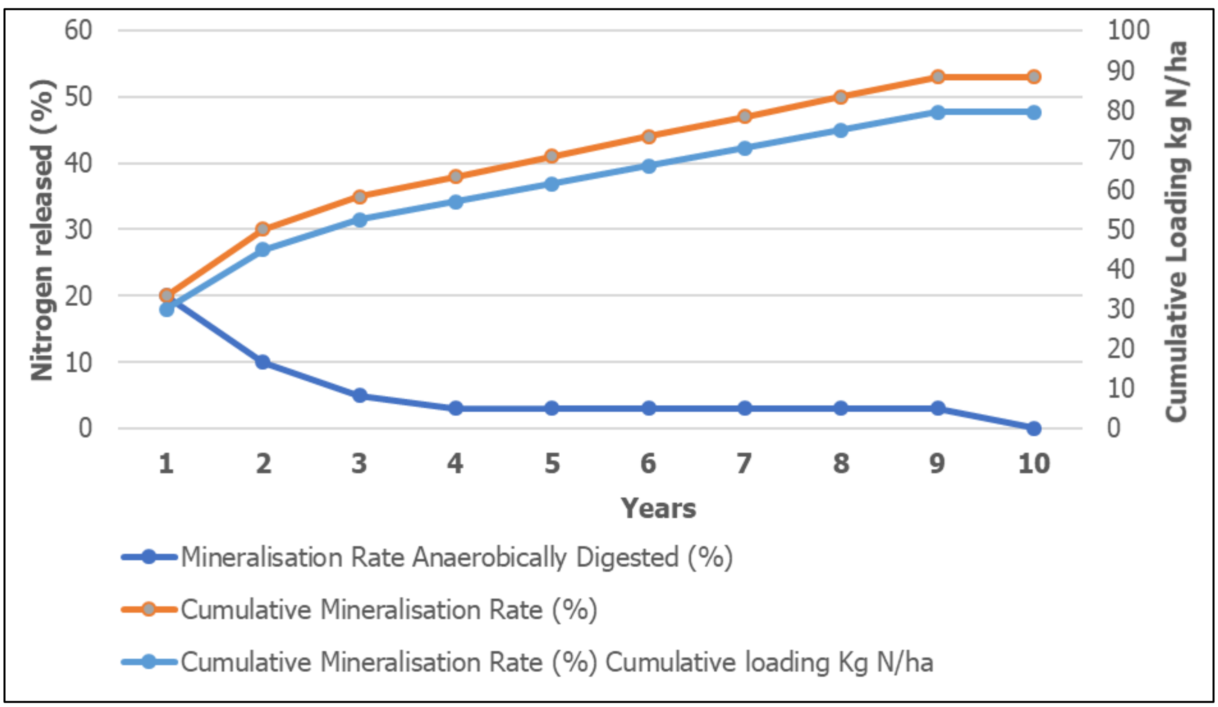


Figure 1: Cumulative Mineralization Rate of Nitrogen in Anaerobically Digested Sludge

The source of the wastewater/biosolids and prior treatment processes impact on ultimate nutrient availability (Metcalf and Eddy, 1991). Table 1 shows the difference between mineralisation rates after application of two sludge types (raw sludge and anaerobically digested sludge). The nutrients associated with material that are easily mineralised in the anaerobically digested sludge have already been digested to a certain degree during the anaerobic treatment process, so once applied to land the rate of mineralisation is slower than raw sludge.

Table 1: Mineralisation Rates of Raw Activated Sludge versus Anaerobically Digested Sludge (Metcalf and Eddy 1991)

Time after Sludge Application (yr)	Mineralisation Rate Raw Waste Activated Sludge (%)	Mineralisation Rate Anaerobically Digested Sludge (%)
1	40	20
2	20	10
3	10	5
4	5	3
5 to 10	3	3

Regional Plans Treatment of Nitrogen Application Rates

The key to beneficial use of wastewater and biosolids is appropriate risk management. In order to minimise the risks associated with the land application of biosolids, quality control and management practices are required (NZWWA, 2003). A conservative approach to application to minimise potential adverse effects is often taken by Regional Councils in their regional plans when dealing with wastewater and biosolids.

Consented loading rates of nitrogen in kg/ha are typically based on total nitrogen content and not the expected nitrogen that is available after mineralisation. The same nitrogen loading rates are often used for both liquid and solid wastes (e.g. Southland Water Plan 2018 and Proposed Marlborough Regional Plan 2018). These plans limit the total amount of nitrogen that can be applied (e.g. 150 or 200 kg/ha) via a straight forward consenting pathway as the nitrogen loading rate is thought of as an equivalent to fertilizer.

Many regional councils now require land owners to model their predicted nitrogen loss using OVERSEER® for compliance with a permitted activity rule or landuse consent activities. One of the management considerations when using OVERSEER® is around how the nitrogen content of wastewater and biosolids should be modelled in OVERSEER®. There are currently no standards for the way that wastewater and biosolids are modelled and there are different options for how to model these land applications. The modeller has options for inputting the form of nitrogen that the biosolids or wastewater can contain. The options include ammoniacal, Urea, nitrate or as Organic nitrogen.

OVERSEER Modelled Example

To demonstrate the potential implications of different ways of including biosolids and wastewater into nutrient modelling, an OVERSEER® model was created to assess the difference in nitrogen loss rates from adding waste activated sludge (WAS) as Organic nitrogen vs equivalent nitrogen content as Urea fertiliser. An application rate for both nitrogen forms of 150 kg N/ha/yr was used. The model was based on a 200 ha, 600 cow dairy unit in Southland. Four 50 ha blocks were set up using two common Southland soil types: a Wyndham and Makarewa soil. Nitrogen was applied in 50 kg nitrogen applications in September, November and March in the form of dilute <16 % WAS to two blocks and Urea to the other two blocks.

Results and Discussion

Table 2 below presents the OVERSEER® output for nitrogen loss from the four blocks. Overall nitrogen loss per ha was very similar between all blocks with all blocks modelled as having equivalent nitrogen surpluses.

Table 2: OVERSEER® Nitrogen Loss Estimation for Fertiliser vs Sludge

Block Details	Wyndham Fert	Makarewa Fert	Wyndham WAS	Makarewa WAS
Nitrogen Summary				
Total N loss (kg/yr)	1,279	1,389	1,340	1,458
N loss per ha (kg/ha/yr)	26	28	27	29
N in drainage (ppm)	10	10	10	11
N surplus (kg/ha/yr)	185	189	184	189
N added (kg/ha/yr)	180	180	180	180

Figures 2 and 3 below show the change in the nitrogen pools for Urea and WAS applications. The Urea is 100% plant available whilst the WAS applications over the year is 88% plant available. Whilst OVERSEER® is modelling the organic nitrogen as having a lower % of available nitrogen at each application event, the 88% availability is still significantly higher than what is expected from the mineralisation of WAS in the first year, as demonstrated earlier in Figure 1 and Table 1. Only between 20-40% of the WAS is expected to be available in the first year, therefore OVERSEER® is overestimating the amount of nitrogen available within the reporting year that the application is made and maybe more reflective of a long term applications of WAS over a 5 to 10 year period.

Figure 2: Nitrogen Pool Graph – Modelled Urea Applications

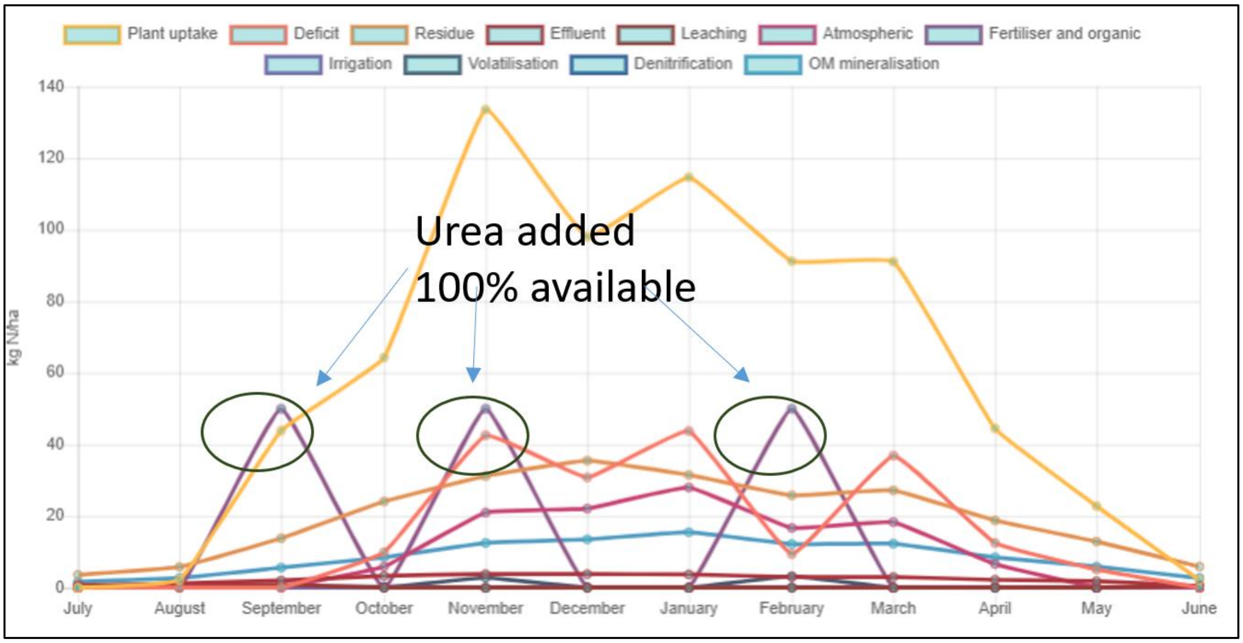
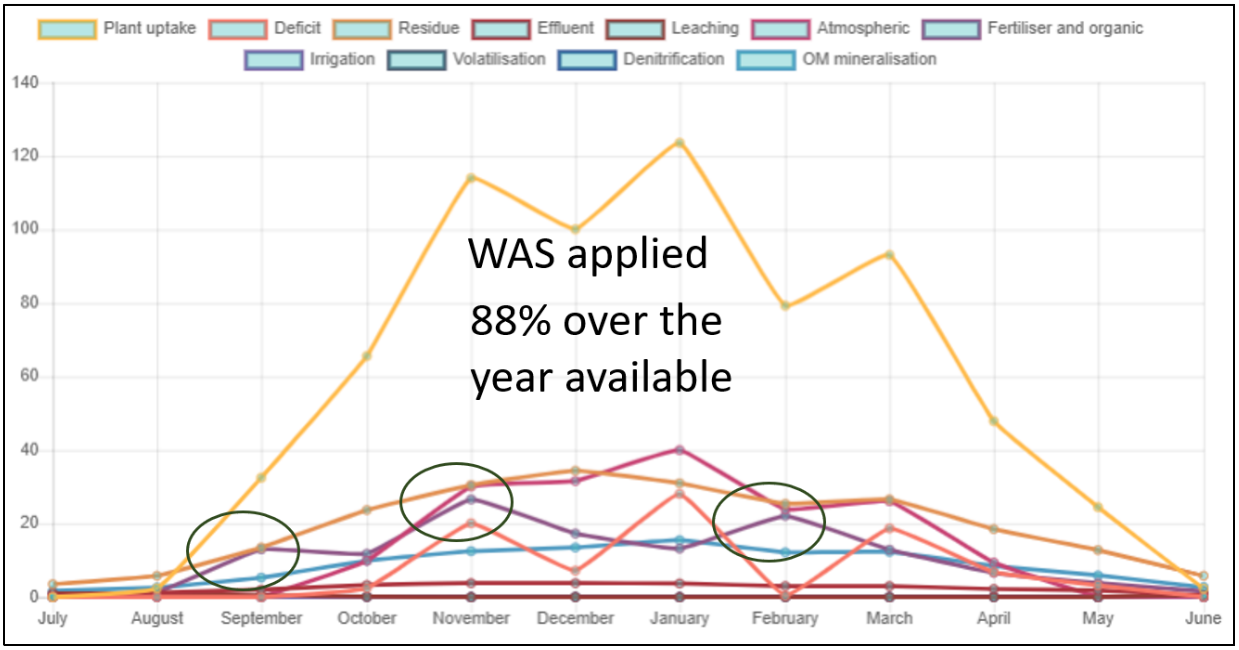


Figure 3: Nitrogen Pool Graph – Organic Sludge (WAS)



OVERSEER® is quasi-equilibrium model, which means that the model makes predictions for a given management practice remaining 'relatively constant' over a medium time-period (Wheeler et al. 2006). In the worked example presented, the use of WAS and the lower nitrogen response expected should have been associated with a reduction pasture production, and thus animal production. This has implications for both nutrient budgeting, environmental management and nitrogen leaching mitigation regimes to limit overall nitrogen losses while maintaining production levels for the same level when shifting to biological nitrogen sources.

Over time a high percentage of the nutrients can be released from biological sources but the transitional period needs detailed consideration if production levels and consent nitrogen loading rates are to be met. Furthermore consideration is needed when using OVERSEER® to assess the leaching potential of nitrogen and the cumulative impact of mineralisation beyond the application month and reporting year, if intermittent or one off applications of biological materials is being made.

Future Approach

It is recommended that Regional Plans provide a differentiated approach and consenting pathways based on the form of nitrogen allowing for short- and long-term application rates of biological material. Reduced regulatory hurdles for land application of biological materials based on organic nitrogen availability rates could improve beneficial use of nutrients in these waste sources.

To support consistent and reliable predictions of nutrient losses from the land application of biological material, nutrient modelling protocols for inputting these slow release type fertiliser equivalents need to be developed. These protocols and modelling approaches should document the transitional system nutrient losses and the need from a production perspective for a mix of organic and conventional fertiliser.

Conclusions

Wastewater and biosolids have a complex biological structure and may have a high percentage of nutrients in organic form. The complex biological structures impact on the total nutrient availability and rate that nutrients can be leach or taken up by plants. Communication of fertilizer form to stakeholders needs to factor in the expected plant availability of the nutrients when assessing the risk and benefits of these biological materials.

Both land owners and regional councils would benefit from being aware of the implications of fertilizer form when modelling nitrogen loss from land. Changes and new modelling protocols may be required to more accurately predict and manage effect from the applications of wastewater and biosolids.

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