

NITROGEN BUDGET FOLLOWING APPLICATION OF NUTRIENT ENRICHED BIOSOLIDS TO AGRICULTURAL LAND: A LYSIMETER CASE STUDY

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Introduction

The production of sewage sludge (biosolids) in the UK is *c.* 1.5 million tonnes (dry-solid basis) per annum (Defra 2007). Approximately 60% of this amount is treated to standards suitable for agricultural recycling, 20% is disposed of by incineration, and the remaining 20% is used mainly for landfill and land reclamation. Recycling to agricultural land is usually regarded as the best practicable environmental option having also lower costs compared with the other disposal alternatives. In order to secure the agricultural route for disposal, a novel technique to produce urea enriched biosolids, namely organomineral fertilisers (OMF), was developed by a major water company in the UK. This consists of coating the biosolid in the form of granules (2 – 4 mm in diameter) with urea (46% N) to increase the existing N:P ratio of the biosolid; thereby, improving its nutrient composition. This technique was used to produce an organomineral fertiliser having 15% N, 4% P₂O₅, and 4% K₂O. This product is referred to as OMF₁₅. The purpose of this work was to investigate the N budget following application of OMF₁₅ (15% N), urea (46% N), and a combination of urea and OMF₁₅ in the ratio 1:4 to spring wheat (*Triticum aestivum L*) in lysimeters.

Materials and Methods

The work was conducted in lysimeters having 575 mm in diameter and 1000 mm in depth. These were filled with a sandy loam soil having 60% sand, 28% silt and 12% clay. The experiment comprises the use of OMF₁₅, urea, and a 1:4 mixture of urea and OMF₁₅ applied to spring wheat (*Triticum aestivum L*) at a single rate of 250 kg [N] ha⁻¹ which was split into two applications of 125 kg [N] ha⁻¹ each. The fertiliser was applied on the soil surface when the crop was at growth stage 39-40; i.e. flag leaf ligule visible (Tottman and Broad 1987). Crop establishment was recorded on 1st May 2008. Leachate was collected after every rainfall event for determination of nitrate [NO₃⁻] (Burkard 1995) and the amount of leachate measured and recorded. Soil analyses were also performed for determination of initial soil organic matter content [SOM], soil mineral N and total N (MAFF 1986; Methods no. 56, 53, and 49 respectively) before the fertiliser application and post-harvest. To aid the N budget calculation, N content in grain (MAFF 1986; Method no. 48) and grain yield were also determined. The straw was removed from the soil after the harvest. Measurements of nitrous oxide (N₂O) emissions were performed using the static chamber technique as described in Thorman et al. (2007). In this experiment, however, larger chambers were used (630 mm x 630 mm x 250 mm) and 60 minutes were allowed before taking the sample. N₂O concentration in the sample was determined by gas chromatography. The N₂O increase (ppm-v) over the 60 minutes period was subsequently used to estimate the N₂O emission rate. Background concentration of N₂O in the air was also measured. Fluxes were measured daily for a period of 4 days following N fertiliser application and every 2 weeks thereafter. Measurement of N₂O requires sampling to be done over a period of one year to account for temporal variability in N₂O emissions and also to comply with IPCC specifications.

Results

The nitrogen budget was estimated using the equation shown below. N losses by volatilisation were considered negligible although this is not totally true as these can be significant when using urea as a source of nitrogen especially when it is not incorporated (Darwich 1998). Sutton et al. (1995) reported that in arable rotations and in the absence of manure applications emission and deposition of ammonia are approximately the same. For the purpose of this work, N volatilisation is excluded from the equation. Atmospheric deposition of N is not considered as it was difficult to find a precise value for the experimental site.

$$\text{N Balance} = [\text{N-Fertiliser} + \text{N-Mineralisation}] - [\text{N Off-take} + \text{N}_2\text{O emissions} + \text{N-Leaching}].$$

The calculated N balances for the 3 treatments and the control are shown in **Tab.1** below.

Tab. 1. N balances for spring wheat (*Triticum aestivum* L) grown in lysimeters for a period of 135 days following application of OMF₁₅, urea, and urea and OMF₁₅ (1:4 dry mixture) at a single N rate of 250 kg [N] ha⁻¹, and a control with no fertiliser. Note: all values are expressed in kg [N] ha⁻¹.

Treatment	Fertiliser application	N-Mineralisation	Off-take	N ₂ O emission	N-Leaching	Balance
Control	0	94.9	97.1	4.34	0.19	-6.73
OMF ₁₅	250	94.9	183.9	4.51	0.12	156.37
Urea	250	94.9	181.8	3.96	0.25	158.89
OMF ₁₅ +Urea	250	94.9	177.4	4.62	0.10	162.78

N mineralisation was estimated using a mineralisation rate of 0.704 kg [N] ha⁻¹ day⁻¹ which was obtained in an incubation experiment run in parallel maintaining the soil at field capacity and at 25°C over a period of 3 months. This gives a total of 94.9 kg [N] ha⁻¹ for 135 days and corresponds to 1.87% of the total N in the soil. This N mineralisation rate may overestimate the amount of soil mineral N as it was obtained in controlled laboratory conditions. The total N content in the soil remained unchanged after the harvest in all treatments as there were not significant differences ($p=0.370$) with respect to the initial value at the start of the experiment (mean TN values of 0.145% and 0.143% respectively; $LSD_{5\%}=0.0083$). The differences in N off-take by the crop were due to differences in crop yield and total biomass production. Overall, N₂O emissions were statistically similar ($p=0.783$) for both the control and the treatments. However, they did differ between sampling events ($p=0.001$). This indicates that there is an effect of the fertilisation on the N₂O emissions immediately after application but the effects are not reflected when considering the entire 135 days period. The lower overall value of N₂O emissions recorded for urea may be indicating that other N losses (e.g. volatilisation) took place at a faster rate compared to denitrification therefore reducing the scope for N₂O emissions. In addition, no significant differences were found between the control and the treatments and between the treatments with respect to the amount of leachate (p values of 0.507 and 0.566 respectively). The same was observed for the N concentration in the leachate (p values of 0.292 and 0.827 respectively). However, significant differences were observed for N concentration in the leachate between sampling events ($p=0.027$). Similarly, this indicates an effect of fertiliser application on the N content in the leachate. However, this is not evident when analysing the whole period. It is clear that during the crop growing season, the largest N removal from the soil is due to the crop up-take. Webb et al. (2004) reported annual losses of N₂O in arable fields between 0.1-1.8 kg [N] ha⁻¹ y⁻¹. The emission values shown in **Tab.1** appear to be significantly higher although they only correspond to a limited period of time. During this period, indirect emissions of N₂O (e.g. emissions linked to leached-N) are expected to be negligible as N losses by leaching accounted for less than 0.01% of the total N applied. A large surplus of N balance after the harvest increases the scope for N losses; particularly, during the winter time which was not considered in this analysis. Webb et al. (2004) concluded that the largest potential reduction in N losses in arable situations is minimising N leaching. Therefore, it is important to account for this surplus balance in subsequent N applications in order to reduce the scope for direct and indirect N₂O losses and N leaching.

Conclusions

Losses of N by denitrification (N₂O) and leaching appeared to be consistently lower than N uptake by the crop during the crop growing season (spring and summer) under the prevailing experimental conditions. It is important to quantify these losses over a longer period of time to account for temporal variability. Large surplus of N in fertilised soil may lead to increased N losses during autumn and winter. This excess of N needs to be considered in subsequent N fertiliser applications.

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