Nitrous oxide emissions from bioreactors, crops and waterways

A comparison of nitrous oxide (N_2O) emissions from a bioreactor and adjacent crop shows that N_2O emissions from the bioreactor are minor compared to those from the crop. Bioreactors have an overall benefit of removing nitrate from water leaving agricultural crops, without increasing total N_2O emissions.

Nitrous oxide emissions

Nitrous oxide (N_2O) is a greenhouse gas, 265 times as potent as carbon dioxide (CO_2) in terms of its global warming potential and its impact[1].

Nitrous oxide is an intermediary product in the denitrification process (Figure 1). The proportion of N_2O produced relative to di-nitrogen gas (N_2) is determined by the relative activity of nitrous oxide producing and reducing enzymes[2].

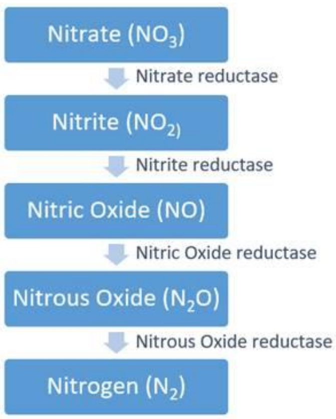

Figure 1 Stages in the denitrification process, illustrating where nitrous oxide can be produced.

Nitrous oxide from bioreactors

Bioreactors are designed to remove nitrate (NO_3^-) through denitrification in low oxygen conditions in the presence of a carbon source, such as woodchips. The majority of nitrate entering a bioreactor is transformed into harmless di-nitrogen gas (N_2). Incomplete denitrification within a bioreactor can produce nitrous oxide emissions, instead of N_2. Christianson et al. 2013 identified that less than 0.32% of the nitrate removed from bioreactors was emitted as N_2O[3].

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Nitrous oxide from crops

The current official N_2O Emission Factors (EF) for the sugar and horticulture industries of Australia are 1.99% and 0.85%[1]. This means that for every 100 kg N fertiliser applied to 1 ha of land, it is estimated that approximately 2 kg N and 0.85 kg N is emitted as N_2O during the course of the season for sugar and horticulture respectively. This is equivalent to 199 mg N/m^2 and 85 mg N/m^2 for sugar and horticulture respectively.

Comparing emissions from a bioreactor and a pineapple crop

Nitrous oxide emissions were measured directly for a three week period from two bioreactor walls at the Glasshouse Mountains in South-East Queensland. The bioreactors are downslope of a pineapple field (Figure 2) receiving 520 kg N/ha over a 15 month growing season.

Figure 2 Denitrifying bioreactor walls (beneath green buckets, bottom LHS) adjoining a pineapple field in Glasshouse Mountains.

Over a three week period of consistent nitrate leachate (average 14 ppm) entering the bioreactors, 0.3 mg N/m^2 was emitted as N_2O from the surface of the bioreactors. This totalled 8.4 mg N for each of the 28 m^2 bioreactors.

Nitrate concentrations entering the bioreactors were measured throughout the 15 month growing season. Based on these measurements, it was estimated that <100 mg N was emitted as N_2O from each bioreactor, compared to 4.4 kg N emitted as N_2O from 1 ha of the adjacent pineapple crop during the 15 month growing period. As a direct comparison, if the bioreactor was 1 ha in area, it would have emitted less than 0.04 kg N as N_2O.

THE PINEAPPLE CROP EMITTED 100 TIMES THE N_2O OF THE BIOREACTOR.

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Nitrous oxide is highly soluble and is transported into bioreactors in leachate and runoff. Results from the Glasshouse Mountain site[4] confirm that dissolved N_2O levels within the bioreactor are significantly lower (to the point of being negligible) compared to the concentration of N_2O in the incoming waters.

Comparing emissions from bioreactors and waterways

A proportion of nitrate entering waterways is also indirectly lost as N_2O. This is represented as emissions factors (EF) from agricultural nitrogen leaching and runoff. Nitrous oxide EF vary between waterbodies[5] (Table 1).

It is estimated that globally 0.75% of nitrate (N) inputs to rivers are converted to N_2O and this is the combined default EF_5 figure used by the Intergovernmental Panel on Climate Change (IPCC) [2].

Overall EF in soil-covered bioreactors varied from 0.37-0.55%[3] (combined N_2O emitted directly from the bioreactor plus estimated N_2O emitted downstream). This is a similar EF to surface drainage (0.4%)[5]. Preliminary data from a bioreactor bed in the Burdekin indicates a tenfold reduction in dissolved N_2O at the outlet (0.03%) compared to the N_2O in the water flowing into the bioreactor from the crop. This suggests the bioreactor is converting N_2O into N_2.

Table 1 Comparison of N_2O emissions factors from a variety of waterbodies, bioreactors and crops.

System type	**N_2O emissions factor EF (reference)**
Lakes and ponds	0.12% ([4])
Rivers	0.3% ([4])
Surface drainage	0.4% ([4])
Soil-covered bioreactors	0.37-0.55% ([3])
Combined EF_5 default value used in IPCC	0.75% ([2])
Groundwater and springs	0.79% ([4])
Horticulture crop	0.85% ([1])
Sugarcane crop	1.99% ([1])

As shown in Table 1, EF differ between different aquatic and terrestrial systems and the EF from soil-covered bioreactors is comparable to receiving waterbodies (surface drainage and rivers).

The overall emissions with a bioreactor in place are no greater than the estimated N_2O emissions if the nitrate entered downstream waterways directly, rather than being treated in a bioreactor[2]. Therefore bioreactors do not increase overall N_2O emissions per gram of nitrate lost from crops.

The case for a treatment train approach to nitrogen management

The potential for nitrogen to be lost from a crop, to runoff, leachate and N_2O emissions, highlights the need to improve nutrient use efficiency in agricultural production. The N_2O emissions from a bioreactor is minimal compared to emissions from agriculture and bioreactors do not increase emissions relative to what would occur in receiving waterways. Therefore bioreactors have an overall benefit in reducing nitrates entering waterways without increasing overall N_2O emissions.

There is a need for a treatment train approach to manage the source (i.e. nutrient management) combined with treatment systems to intercept and treat residual pollutants lost through surface or groundwater.

For more information

Information on emissions from crops and bioreactors was provided by Professor Peter Grace from Queensland University of Technology. Contact pr.grace@qut.edu.au

References:

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