Fate of BOD and Nitrogen in Land Application of Food Processing Wastewater

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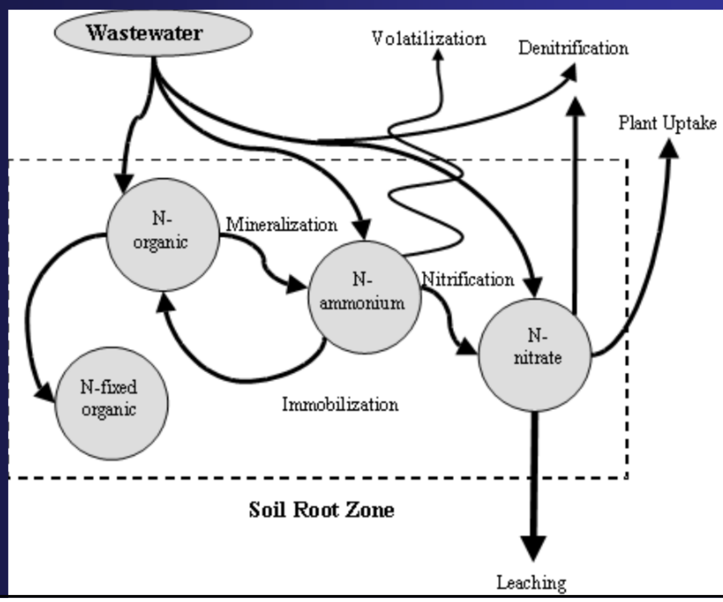
Introduction

- Most food processing rinse waters are applied to land for treatment and/or reuse.
- The waters normally contain N, BOD, and salts.
- Nitrogen and BOD loading are frequently the land-limiting constituents.
- More research is needed to determine the fate of N during land application of food processing water.
- One fate for N in soil is gaseous losses by denitrification and ammonia volatilization. This is favored in land application of high N food processing water.

Nitrogen Transformations



Gaseous Nitrogen Losses

- Ammonia volatilization is a chemical process in soil.
- Denitrification is a microbially mediated process whereby NO_{3-} is reduced to N_2O or N_2 gas.
- Soil factors that favor denitrification include
  - high soil moisture
  - anaerobic or low soil oxygen
  - neutral to slightly alkaline soil pHs
  - higher soil temperatures
  - available NO_{3-}
  - labile organic C.

Denitrification Rate Studies

Denitrification rates can be very high.

- Butler and Green (2006) – up to 100 kg N ha^{-1} d^{-1}.
- Clay textured soils favor denitrification - high moisture, low hydraulic conductivity and long residence times.
- Very high denitrification rates found in other land application studies (Russell et al., 1993; Henrich and Haselwandter, 1991)
- 50 to 80% N losses with BOD:N > 5 (Reed et al., 1998; Crites et al., 2000; CLFP, 2007).

Soil Column Study Objectives

1. Evaluate the fate of N applied with tomato cannery process water under similar environmental, cropping, and management protocols to the field site.
2. Evaluate other major constituents of environmental concern.
3. Support in-situ soil and groundwater monitoring of the field land application site.

Materials and Methods

Soil Used

- Riz Soil Series; fine, smectitic, USDA capability class IV soil.
- Collected in bulk just prior to the 2008 CW irrigation season from a site where land application has been occurring for over 10 years.

Soil Column Construction

- PVC pipes of 25.3 cm (6 in) diameter and 72 cm length (16 columns)
- Capped at bottom, washed sand 4 cm depth, holes drilled for percolate collection
- Riz soil packed into columns to two feet depth using bulk soil.
- Homogenous soil columns of known physical and chemical properties.
- Wetted to breakthrough to obtain field capacity moisture content.

Locations and Logistics

- The CW was obtained at the Pacific Coast Producers Inc., Woodland, California tomato cannery.
- The CW was collected in bulk several times and refrigerated at 2°C for transport to the column testing location 70 miles north in Palermo.
- The prescribed CW dosings (treatments) were based on the total nitrogen content.

Analysis of Tomato Cannery Water

Batch Sampling Date	pH	EC (dS/m)	TDS (mg/L)	NO_3^--N	NH_4^+-N	Total N	COD	BOD	SAR
				mg L^{-1}					
1 8-4-2008	6.0	2.4	1520	0.10	22.9	67.4	3458	2637	15.7
2 8-4-2008	6.3	3.5	2268	0.12	62.4	119.9	4952	3776	25.7
3 8-4-2008	6.3	4.0	2550	0.14	77.7	133.8	4795	3656	31.8
4 9-12-2008	4.5	3.5	2227	0.10	30.5	242.8	6226	6144	30.9
5 9-12-2008	4.5	3.5	2211	0.13	30.0	245.8	9339	6083	31.7

Sampling and Treatments

Percolate, and Plant and Soil Sampling

- Percolate sampling twice weekly.
- Plant and soil sampling at end of study.
- Four treatments: 313 kg N ha^{-1} Tomato Cannery Water
  471 kg N ha^{-1} Tomato Cannery Water
  627 kg N ha^{-1} Tomato Cannery Water
  373 kg N ha^{-1} Urea (Control)
- Four replications/treatment (16 columns in random design on wooden stand)
- Dosing set at 4.1 cm/week each column. Exceeded monthly potential evapotranspiration for August, Sept., and Oct. 2008 by 108, 141, and 205%, respectively.
- Dosing from August 8 through October 31, 2008.
- From Nov 14 to Nov 21, 2008 simulation of rainfall with 22 cm total applied.
- On December 5, 2008 plants harvested and columns cut up for soil sampling.

Fate of Nitrogen

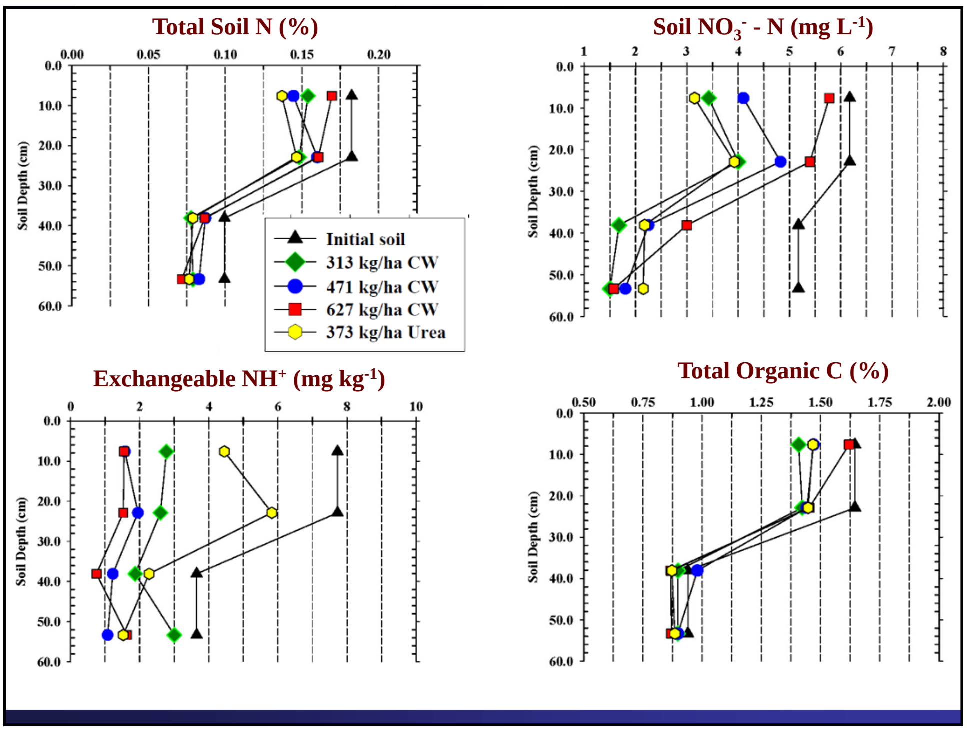
- Gaseous losses of N from the soil columns were very high with all treatments.
- Gaseous N losses were evaluated from two views:
  1. the amount of N added by the tomato cannery water (CW) and urea treatments
  2. the total N lost from the soil over the study period.
- Gaseous N losses were 50, 64, and 61% of the N applied by the CW 313, CW 471, and CW 627 kg N ha^{-1} treatments, respectively. The urea treatment (373 kg N ha^{-1}) indicated a -36% gaseous N loss that implied that crop N uptake exceeded the urea N additions by 136 kg N ha^{-1}
- The extra N came from indigenous soil N.

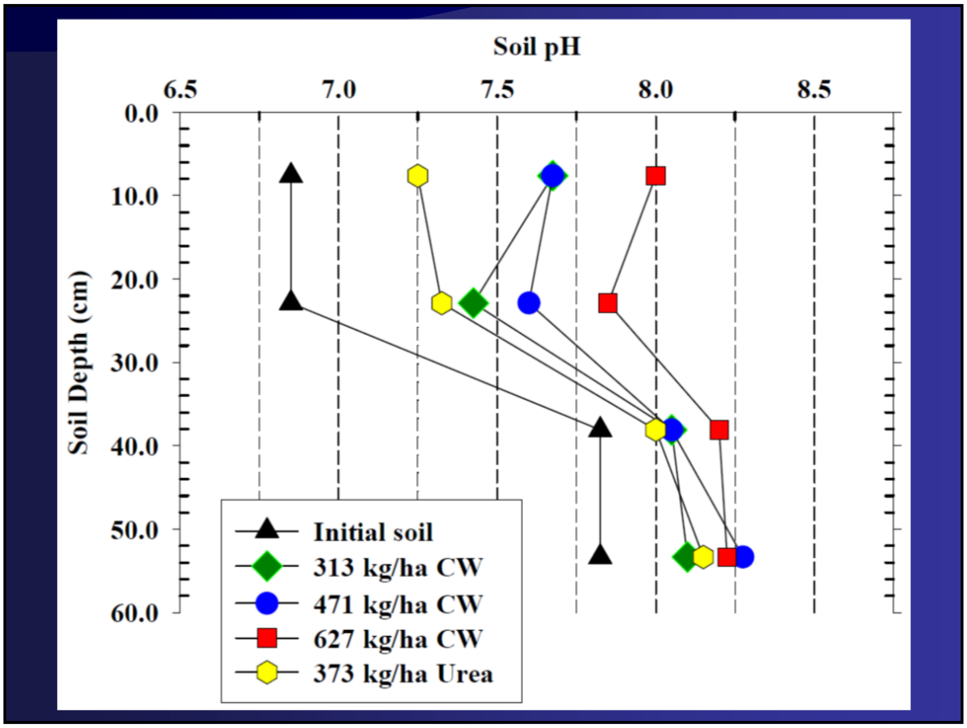
Nitrogen Mass Balance

Treatment	Initial Indigenous N (kg/ha)	Indigenous N after Cannery Water	Indigenous N Loss	Cannery Water N added	Crop Uptake	Leaching N losses	N Gaseous Loss from Cannery Water	Total (Indigenous + CW) Gaseous N Losses
	-------------------------	-------------------------	-------------------------	------------------kg ha^{-1}	-------------------------	-------------------------	-------------------------	
CW 313	11882	9668	2214	313 (100%)	149 (48%)	6 (2%)	158 (50%)	2372
CW 471	11882	9994	1888	471 (100%)	165 (35%)	6 (1%)	300 (64%)	2188
CW 627	11882	10388	1494	627 (100%)	236 (38%)	7 (1%)	384 (61%)	1878
Control 373	11882	9270	2612	373 (100%)	505 (135%)	4 (1%)	-136 (-36%)	2476

- We attributed that most of this N loss was due to biological denitrification by heterotrophic bacteria.
- Some ammonia volatilization likely occurred with the CW treatments.

For the 11 weeks of CW dosing, losses were 24.4 to 32.1 kg N ha^{-1} d^{-1}





Fate of BOD

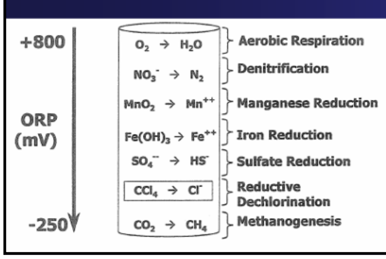
- The BOD applied equated to 77-day cannery season BOD loading rates of 110, 165, 210, and 0 kg BOD ha^{-1} d^{-1} for the CW 313, CW 471, CW 627 and urea treatments, respectively.
- The treatment BOD averages in the percolates were 8.4, 12.1, 16.0, and 12.2 mg L^{-1} for the CW 313, CW 471, CW 627 and urea treatments, respectively. BOD treatment averages were not significantly different.
- Overall, low BODs and a lack of increase in soil organic C after treatments meant BOD overloading did not occur.
- Recent research using fruit cannery water (Johns and Bauder, 2007) and fruit cannery water mixed with secondary municipal wastewater (City of Lodi, 2009), found no groundwater contamination nor soil quality concerns at nearly identical BOD loadings used in this study with soils of higher hydraulic conductivities.

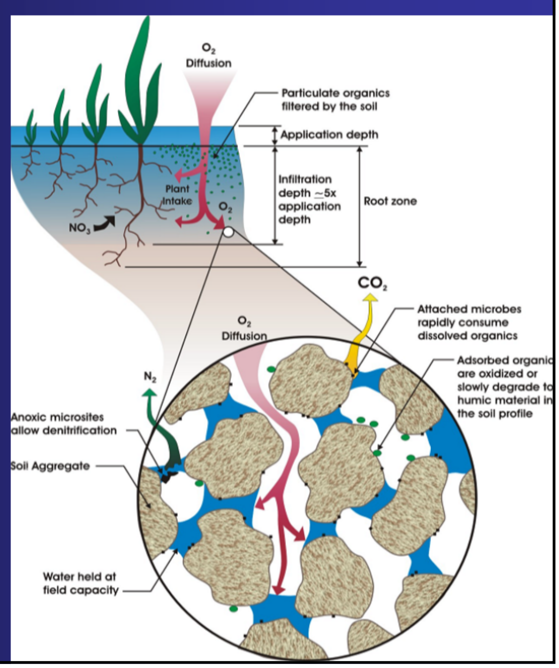
What’s Happening In the Field?

Distribution uniformity effects

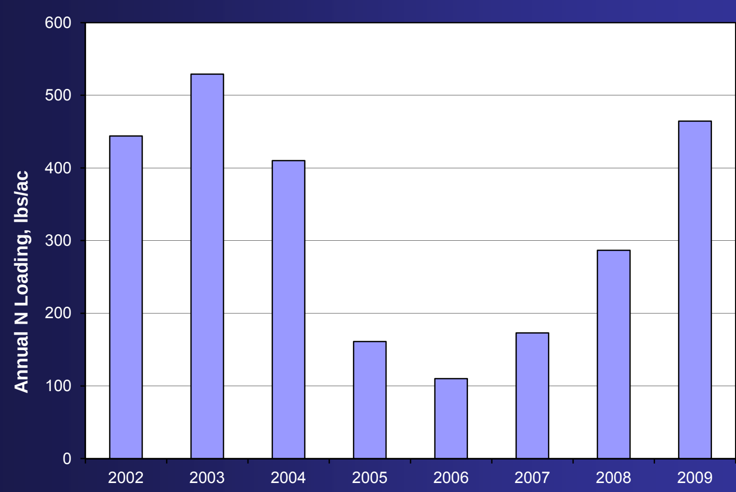
Biodegradation in Wastewater Land Application

Wet-dry cycling has a large effect.

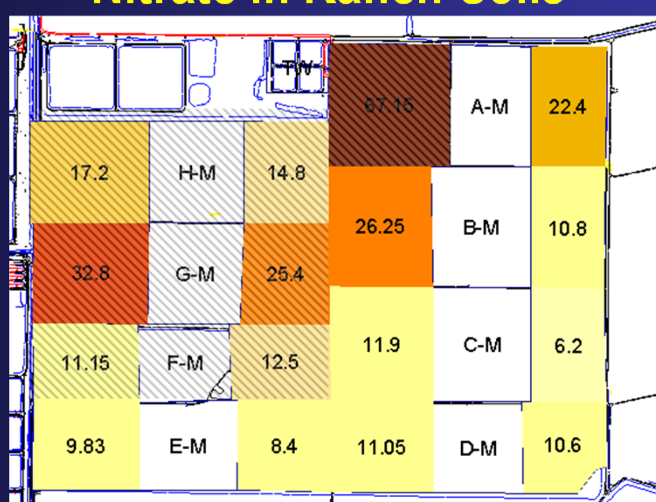




Field Wastewater Nitrogen Loading

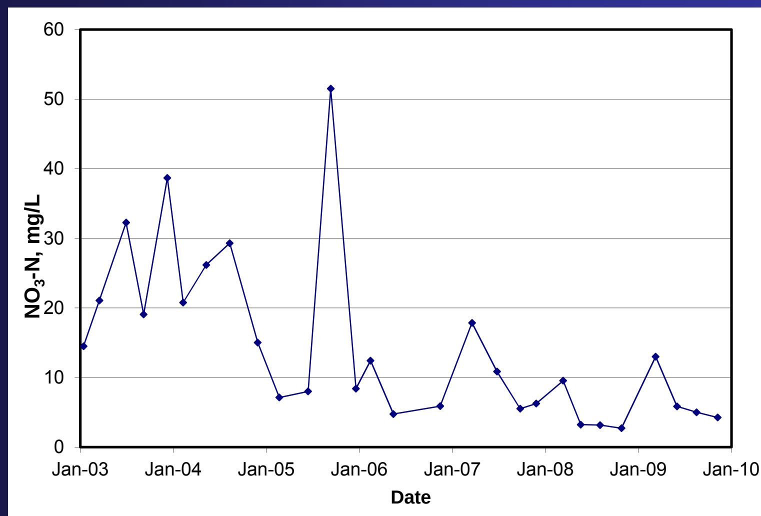


Nitrate in Ranch Soils



→ Fields that received waste solids (hatched) showed higher residual soil nitrate levels. N in solids has greater opportunity than N in wastewater for conversion and retention as nitrate.

Downgradient Groundwater Nitrate

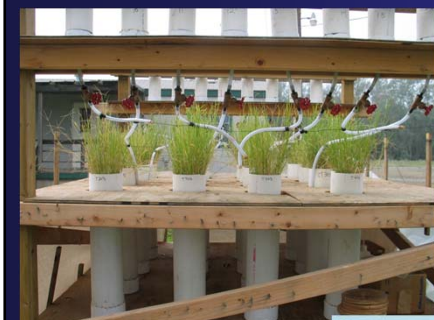


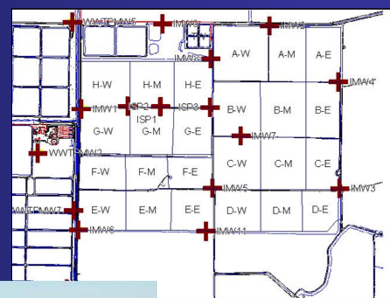
→ variable, but generally decreasing groundwater nitrate

Conclusions

1. N gaseous losses in column tests were 50% or greater of the N applied to a clay loam soil irrespective of N loading. Urea amended soil also exhibited high gaseous N loss.
2. Gaseous N loss is mostly attributed to biological denitrification.
3. Soil properties such as high moisture retention, long soil residence times, and high amounts of available soil C resulted in high denitrification rates.
4. At field scale, application variability and solids applications may increase residual nitrate in soils.
5. There was no evidence to indicate that the levels of BOD applied posed any environmental concerns to soil quality and groundwater.

Questions?





Results and Discussion

Crop Biomass Extrapolated from Soil Columns to Field.

Treatment	Bermudagrass Above-Ground Biomass Yield (kg ha^{-1})
CW 313	7880
CW 471	8220
CW 627	10480
Control 373	15440