Urea Hydrolysis in Soils Along a Toposequence: Influences of Chemical Conditions

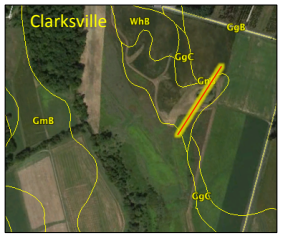
Kristin A. Fisher (kfisher3@umd.edu) & Bruce R. James
Department of Environmental Science & Technology, University of Maryland

Introduction

- Urea ($CO(NH_2)_2$) occurs naturally in both aquatic and terrestrial environments and is the dominant form of nitrogen fertilizer used in agriculture worldwide (Glibert et al., 2006).
- Elevated levels of urea have been measured in surface waters following heavy spring rains in agricultural watersheds, and often precede toxic algal blooms (Glibert et al., 2001).
- Numerous studies on the hydrolysis of urea in agricultural soils have concluded that the process is completed in a matter of days (Dawar et al., 2011; Khakurai and Alva, 1995; Singh and Yadev, 1981; Wali et al., 2003; Yadev et al., 1987).
- Therefore, there is a paradox in the published information on urea: conventional agricultural research indicates that it is unlikely that urea persists in the soil long enough to leach to surface waters, but elevated levels of urea in Chesapeake Bay are being measured adjacent to agricultural watersheds.
- No published studies have been found on urea dynamics in soils across the landscape of the Coastal Plain and Piedmont of Maryland, a region that produces and uses both urea fertilizer and large quantities of urea-containing poultry litter in agricultural watersheds that drain to the Chesapeake Bay.
- The purpose of my dissertation research is to determine whether soil chemical and environmental conditions that vary across the landscape may lead to runoff of urea to surface waters.

Materials & Methods

- Two research sites: Wye Island on the Coastal Plain (Typic Hapludult, Typic Endoaqualt) and Clarksville on the Piedmont (Typic Hapludult, Aquic Fragiudult, Fluvaquentic Endoaquept) in Maryland.
- One transect at each site included three points: an active agricultural field, a point along the grassed field border, and a point adjacent to surface waters.
- Each transect point included two sampling depths: one in the A horizon and one in the B horizon.



- Soils were sieved to 4 mm, maintained at field-sampled water content, and stored at room temperature (22°C).
- Subsamples were brought to similar moisture level and treated with HCl and $CaCO_3$ to achieve a range of pH values (3.5 – 8).
- Triplicate soil samples at each pH were mixed with a urea solution and the disappearance of urea was measured over time to determine a rate of hydrolysis at each site.

Results

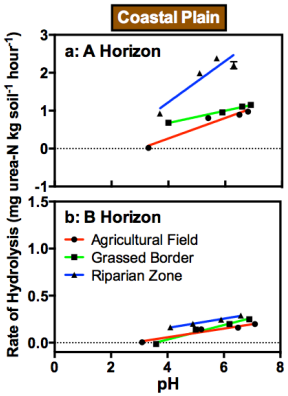


Figure 1: Comparison of urea hydrolysis rates in an **a)** A Horizon and **b)** B Horizon across a transect on Wye Island, MD, as a function of pH (n=3).

Table 1: Days required for 99% hydrolysis of 100 mg urea-N kg^{-1} soil in the Coastal Plain Soil (Fig 1) based on zero-order kinetics

	Ag Field		Grassed Border		Riparian Zone	
pH	A	B	A	B	A	B
4	15	72	6.1	130	3.4	26
5	7.7	40	4.9	37	2.3	20
6	5.1	28	4.1	22	1.8	16
7	3.8	21	3.6	16	1.5	14

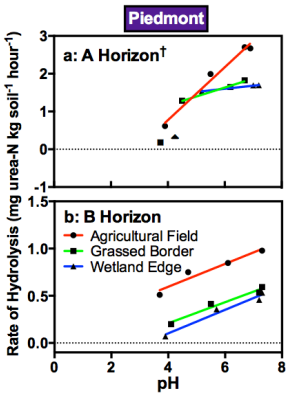


Figure 2: Comparison of urea hydrolysis rates in an **a)** A Horizon and **b)** B Horizon across a transect in Clarksville, MD, as a function of pH (†lowest pH values excluded in linear regression of Grassed Border & Wetland Edge)(n=3).

Table 2: Days required for 99% hydrolysis of 100 mg urea-N kg^{-1} soil in the Piedmont Soil (Fig 2) based on zero-order kinetics.†

	Ag Field		Grassed Border		Wetland Edge	
pH	A	B	A	B	A	B
4	5.4	7.0	24‡	17	12‡	51
5	2.8	5.8	3.0	11	2.7	21
6	1.9	5.0	2.5	8.6	2.6	13
7	1.4	4.4	2.2	6.9	2.5	9.4

†Pooled slope used for B horizon soils. ‡Estimate based on individual experiment.

Discussion

In the Coastal Plain soil:

- In the A horizon, pH explained ≥ 94% of the variability in the rate of urea hydrolysis in the Agricultural Field and the Grassed Border, and 86% of the variability in the Riparian Zone (**Fig 1a**).
- In the B horizon, pH explained ≥ 94% of the variability in the rate of urea hydrolysis in all three landscape positions (**Fig 1b**).
- In both the A and B horizon, the rate of change in urea hydrolysis with pH was affected by landscape position (p = 0.062 and 0.056, respectively)(**Fig 1**).
- The hydrolysis of urea in the riparian soils was the fastest of the three landscape positions (**Table 1**).
- The hydrolysis of urea in the B horizons was much slower than the hydrolysis of urea in the A horizons (**Table 1**).

In the Piedmont soil:

- In the A horizon, pH explained ≥ 98% of the variability in the rate of urea hydrolysis in all three landscape positions when the lowest pH values for Grassed Border and Wetland Edge were excluded from the linear regression (**Fig 2a**).
- In the B horizon, pH explained ≥ 93% of the variability in the rate of urea hydrolysis in all three landscape positions (**Fig 2b**).
- In the A horizon, the rate of change in urea hydrolysis with pH was affected by landscape position (p = 0.004) when the lowest pH values for Grassed Border and Wetland Edge were excluded from the linear regression (**Fig 2a**).
- In the B horizon, the rate of change in urea hydrolysis with pH was not affected by landscape position (p = 0.88)(**Fig 2b**).
- The hydrolysis of urea in the agricultural soils was the fastest of the three landscape positions (**Table 2**).
- The hydrolysis of urea in the B horizons was slower than the hydrolysis of urea in the A horizons (**Table 2**).

Conclusions & Future Work

- We have found evidence for wide variations in the rate of urea hydrolysis in accordance with landscape position and pH.
- Liming agricultural soils to maintain a pH above 6 will reduce the likelihood that urea will leach to surface waters without being hydrolyzed.
- However, the proximity of some agricultural fields to surface waters and the reduction in urea hydrolysis rate that occurs in B horizons means that some urea may be leaching from the soil.
- Further study of riparian buffers and the rapidity with which they hydrolyze urea is needed to better understand how to minimize the leaching of fertilizer urea to surface waters.

References

Dawar, K., M. Zaman, J. Rowarth, J. Blennerhassett, and M. Turnbull. 2011. Urea hydrolysis and lateral and vertical movement in the soil: effects of urease inhibitor and irrigation. Biology and Fertility of Soils 47:139-146.
Glibert, P., J. Harrison, C. Heil, and S. Seitzinger. 2006. Escalating Worldwide use of Urea – A Global Change Contributing to Coastal Eutrophication. Biogeochemistry 77:441-463.

Glibert, P.M., R. Magnien, M.W. Lomas, J. Alexander, C. Fan, E. Haramoto, M. Trice, and T.M. Kana. 2001. Harmful Algal Blooms in the Chesapeake and Coastal Bays of Maryland, USA: Comparison of 1997, 1998, and 1999 Events Estuaries 24:875-883.

Khakurai, B.R., and A.K. Alva. 1995. Hydrolysis of urea in two sandy soils under citrus production as influenced by rate and depth of placement. Communications in Soil Science & Plant Analysis 26:2143-2156.

Singh, M., and D.S. Yadev. 1981. Transformation of urea and ammonium sulphate in different soils. Plant and Soil 63:511-515.

Wali, P., V. Kumar, and J.P. Singh. 2003. Effect of soil type, exchangeable sodium percentage, water content, and organic amendments on urea hydrolysis in some tropical Indian soils. Australian Journal of Soil Research 41:1171-1176.

Yadev, D.S., V. Kumar, M. Singh, and P.S. Relan. 1987. Effect of Temperature and Moisture on Kinetics of Urea Hydrolysis and Nitrification. Australian Journal of Soil Resources 25:185-191.