Fractional Atmospheric Nitrogen Losses in Municipal Wastewater Irrigation Systems

Stella Maris Sendagi and Herschel A. Elliott
Department of Agricultural and Biological Engineering (ABE), Pennsylvania State University (PSU), University Park, PA.

INTRODUCTION

Design municipal wastewater effluent (MWE) irrigation depth is often limited by the capacity of the soil to transmit water and nitrate (NO_3) concentration levels in the percolate water.

Nitrogen (N) based effluent irrigation depths (L_n) are usually determined from a "source-sink" N mass balance, Eq. [1] (Reed et al., 1995; Crites et al., 2006; Metcalf and Eddy, 2007) in which the fractional N loss due to atmospheric N losses (N_{loss}) is the most uncertain.

Effluent N | N Leaching term | Crop N uptake term | Atmospheric N losses

$$L_n C_n = C_p\left(L_n + P_r - ET_c\right) + 100U + N_{loss}\left(L_n C_n\right) \quad [1]$$

Suggested design N_{loss} values include: 0.15 - 0.25 (USEPA, 2006), 0.2 ("cold" climate) and 0.25 ("warm" climate) (Crites and Tchobanoglous (1998) for secondary (2°)-treated MWEs and 0.1 for tertiary (3°)-treated MWEs (Crites and Tchobanoglous,1998; USEPA, 2006). However, few investigations have verified these estimates.

RESEARCH OBJECTIVE:

Refine N_{loss} values for MWE irrigation design using a "source-sink" N mass balance.

Central Pennsylvania, North Eastern USA (Approx. Lat: 40° 49' 44.025''N and Long: 77° 52' 7.866''W).

Tall Fescue (*Festuca arundinacea*) irrigated with 2°-treated effluent containing 12 – 15 mg N L^{-1} (~60-80% NO_3-N) at a rate of 50 mm wk^{-1}.

Monthly mean MWE C:N ratio = 0.04 - 0.2 (2011 – 2012).

UAN (30% N) fertilizer applications: 122 kg N ha^{-1} (2011) and 112 kg N ha^{-1} (2012).

MATERIALS AND METHODS

The terms in Eq. [1] were rearranged to include runoff (R) and to express N_{loss} in the terms of the measured and calculated system parameters, Eq. [2]. Monthly N balances were completed from April to September in 2011 and 2012.

Effluent N | N Leaching term | Crop N uptake term

$$N_{loss} = \frac{L_n C_n - C_p\left(L_n + P_r - ET_c - R\right) - 100U}{L_n C_n} \quad [2]$$

Where:

Ln	=	MWE irrigation depth.	mm
C_n	=	Concentration of total N in MWE.	mg L^{-1}
C_p	=	Mean (n=12) concentration of NO_3-N in leachate from suction-cup lysimeters installed at 0.35m.	mg L^{-1}
P_r	=	Recorded rainfall.	mm
ET_c	=	Crop evapotranspiration (ET_c) was calculated using the Penman-Monteith method.	mm
R	=	Runoff was estimated using the curve number method.	mm
U	=	Crop N uptake. Monthly crop N uptake due to MWE was estimated as the difference between the measured uptake and the estimated N uptake due to fertilizer application. If the difference was > effluent N, U was assumed to equal effluent N. 100 = unit conversion factor.	kg N ha^{-1}

KEY REFERENCES
1. Crites, R.W. and G. Tchobanoglous. 1998. Small and decentralized wastewater management systems. McGraw-Hill, New York.
2. Reed, S. C., R. W. Crites, and E. J. Middlebrooks. 1995. Natural systems for waste management and treatment. 2nd edition. McGraw-Hill, New York.
3. USEPA. 2006. Chapter 8: Process design-slow rate systems. *In Land treatment of municipal wastewater effluents: Process design manual.* EPA/625/R-06/0162006. Office of research and development, Cincinnati, Ohio, USA.

RESULTS AND DISCUSSION

The sum of the crop N uptake and N leaching terms exceeded the applied effluent N in June and September 2011 and in May and August 2012 (Table 1).

High crop N uptake estimates in these months were likely due to the difficulty in isolating crop N uptake due to only effluent N.

Table 1. N_{loss} estimates and N balance parameters.

Month	N_{loss} estimate	Effluent N	N leaching term	Crop N uptake term
		mm mg L^{-1}		
April & May 2011	0.14	4517.2	894.9	2992.0
June	-1.4	1682.2	386.9	3560.0
July	0.21	1949.4	535.5	994.0
August	0.09	2871.1	360.5	2250.0
September	-0.4	2179.9	212.0	2826.0
April, 2012	0.23	2636.1	169.0	1873.2
May	-0.1	2039.9	240.5	2062.0
June	0.05	382.8	37.0	326.0
July	0.14	1507.3	72.4	1223.6
August	-0.1	1918.6	826.3	1334.4
September	0.72	2030.1	287.9	282.0

The N_{loss} estimate in September 2012 (0.72) was high due to the small crop N uptake and N leaching terms compared to the effluent N (Table 1).

N_{loss} values of 0.05 in June 2011 (Fig. 2) and May 2012 (Fig. 3), and 0.1 in September 2011 (Fig. 2) and August 2012 (Fig. 3) were assumed since the growth proportions of 0.3 (May) and 0.2 (June), and 0.12 (September) and 0.15 (August) for tall fescue are comparable.

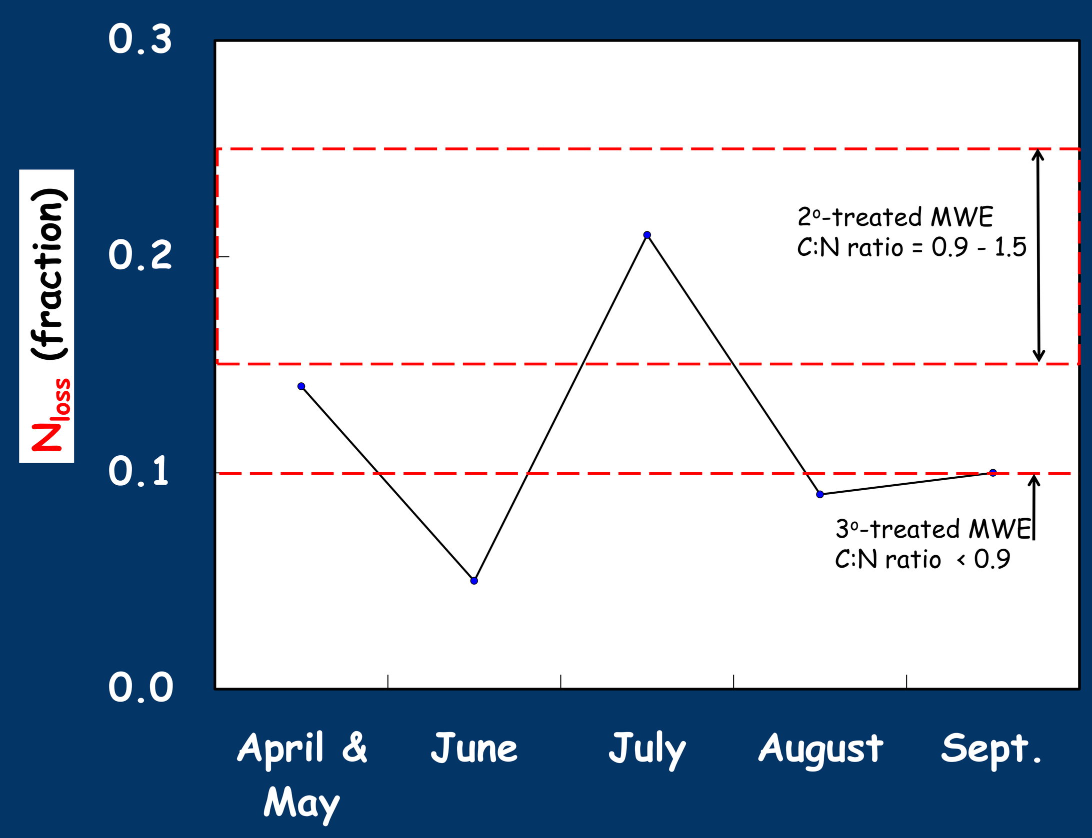

Figure 2. N_{loss} estimates in 2011. Dashed lines indicate range of design N_{loss} values.

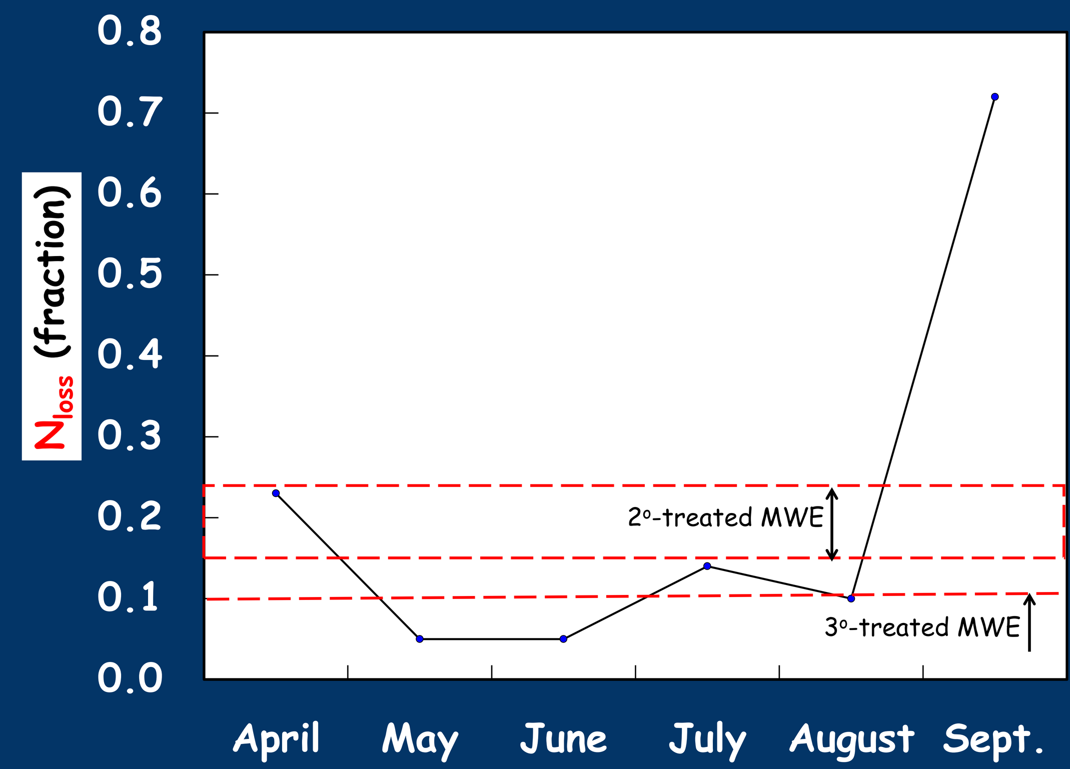

Figure 3. N_{loss} estimates in 2012. Dashed lines indicate range of design N_{loss} values.

Crop N uptake in June 2011 was likely more representative for the month than June 2012, due to the dry weather in 2012 and also because the grass field was not irrigated from 21 May to 21 June 2012.

The N_{loss} estimates in July were likely least affected by the fertilizer applications done in April and August.

The N_{loss} estimates were generally less than the suggested design N_{loss} values (Fig.2 and Fig.3).

CONCLUSIONS

- N_{loss} values of 0.05 in May and June, 0.1 in August and September, and 0.2 in April and July were deemed appropriate for the study site. However, additional research (in the absence of commercial fertilizer addition) is needed to validate and refine the values.
- For highly nitrified effluents with C:N ratios of <1, N_{loss} values lower than the design values could be used for design purposes.
- N_{loss} values could be improved by accounting for seasonal crop N uptake patterns.

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