Linkages of Hydrologeology Factors, Groundwater Redox Conditions, and Nitrogen Dynamics in Septic Areas

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ABSTRACT: This study presents a comprehensive analysis of monitoring data of water quality in eight sites of the Lower St. Johns River Basin (LSJRB), FL, where nitrogen due to septic systems is believed to be one of the causes for nutrient enrichment in surface water bodies. Nitrogen dynamics are controlled by both groundwater redox conditions and hydrogeology factors such as depth to water table, saturated hydraulic conductivity, and soil drainage characteristics. While the groundwater environment in the septic areas favors denitrification, with anoxic and mixed conditions in groundwater. However, the extent of nitrate reduction depends on the amount of dissolved organic carbon (DOC).

1. INTRODUCTION

About 26 million septic tanks are used in US to process about 4 billion gallon of wastewater per day[1]. Release of wastewater through septic systems constitutes one of the largest sources of nitrogen contamination in groundwater and surface water. Characterization of nitrogen dynamics in septic areas is critical to protection of water resources and public health. However, nitrogen dynamics are complex due to effects of hydrology, hydrogeology, and geochemistry processes and their interactions. Our current understanding of nitrogen dynamics is incomplete, partly because field collection of nitrogen data is costly and field data is always lacking. Based on a relatively comprehensive dataset, investigation of nitrogen dynamic in septic areas was conducted in this study with focus on the linkages of hydrogeologic and geochemistry factors.

2. STUDY AREA

The investigation was carried out in 10 neighborhoods in Lower St. Johns River Basin (LSJRB) namely: Foster Drive Pond (FD), Pumpkin Hill (PH), Riverview (RV), JEA WWTF Tree Farm (TF), Oakwood Villas (OV), Arlington Manor (AM), Hood Landing (HL), Julington Forest (JF), Manor Del Rio (MDR), and Siesta Del Rio (SDR). The latter three sites are connected and thus combined into one site, referred to as Julington Creek (JC) in this study. The Florida St. Johns River Water Management District (SJRWMD) supported field collection of groundwater quality data from 37 wells within the 8 sites (Fig.1) on a seasonally and/or biweekly basis during 2003 to 2010.

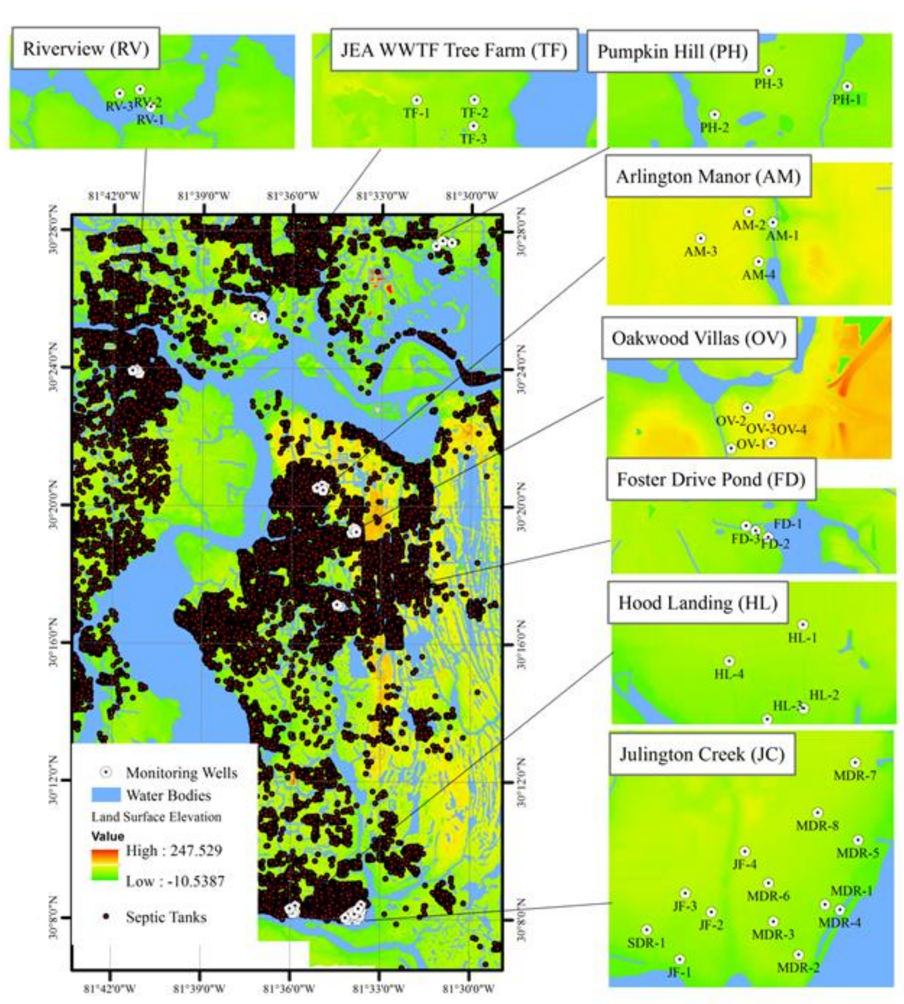

Figure 1. Locations of monitoring wells within eight sites in the Lower St. Johns River Basin.

3. METHODS

Redox classification: Redox conditions were evaluated on the basis of oxygen, nitrate, manganese ion, iron ion, and sulfate concentrations using the classification system of McMahin and Chapelle[2]. Threshold concentration values of redox indicators are 0.5 mg/L for O_2, 0.5 mg/L for NO_3–N, 0.05 mg/L for Mn, 0.1 mg/L for Fe, and 0.5 mg/L for SO_4.

Statistical analysis: Nonparametric, rank-based methods were used for the statistical analysis, as they do not assume any distributions for the data. Specifically speaking, Spearman correlation coefficient was used to assess relations between different variables, Kruskal-Wallis test was used to evaluate difference of samples from two or more groups, and Loess curve was used to approximate the trend of data points[3].

4. RESULTS

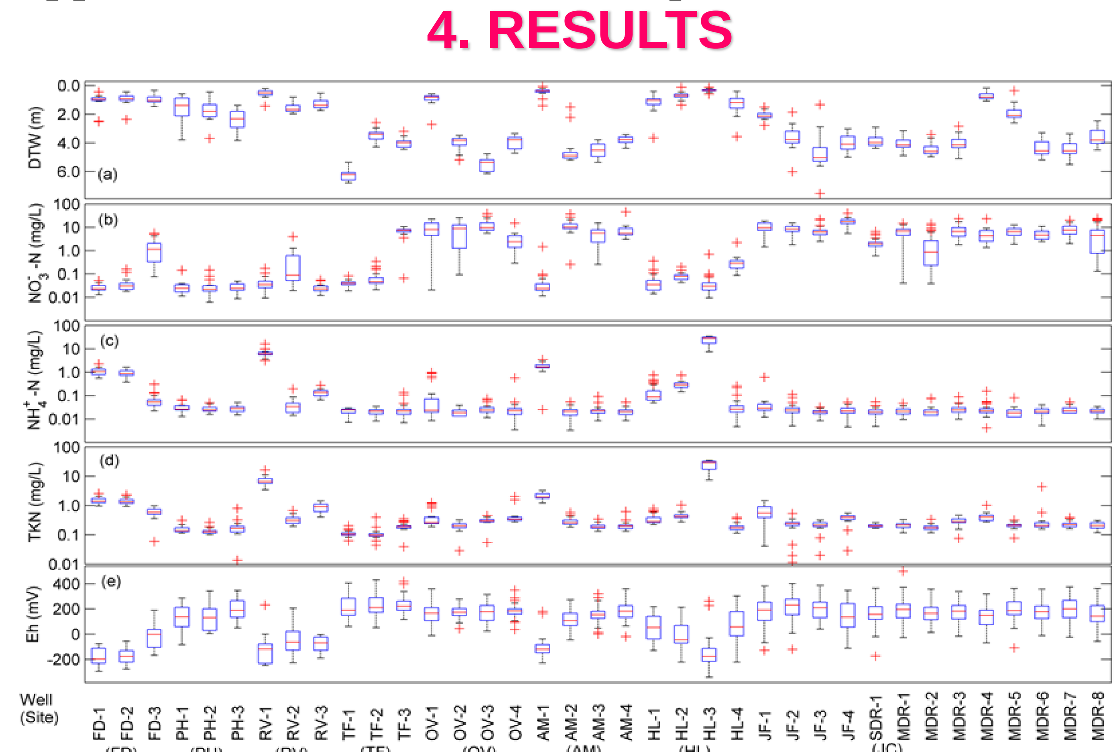

Figure 2. Variations of (a) depth to water table (DTW), (b) nitrate, (c) ammonium, (d) Total Kajeldahl Nitrogen (TKN), (e) redox potential (Eh) in wells of each site.

Figure 2 and Kruskal-Wallis test (results not shown) show that spatial variation of depth to water table (DTW), concentration of nitrogen species, and redox potential (Eh) is larger than seasonal variation of the variables.

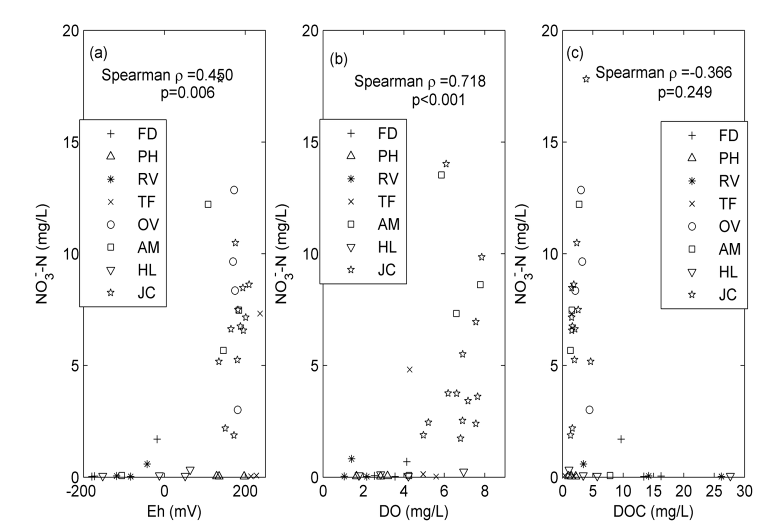

Figure 3. Relations between nitrate concentrations and (a) Eh, (b) DO, and (c) DOC using mean data. The solid lines in plots are loess curve fitted to the data.

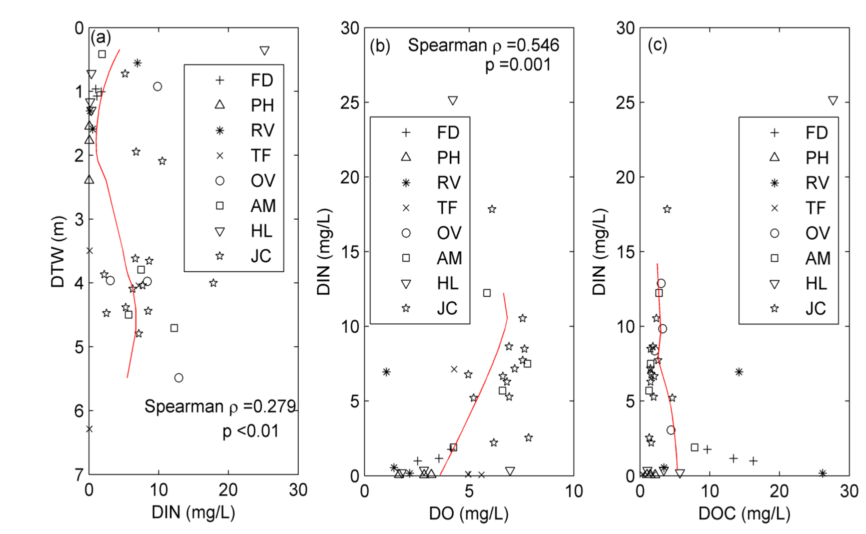

Figure 4. Relations between dissolved inorganic nitrogen (DIN) concentrations and (a) DTW, (b) DO, and (c) DOC using mean data.

Figures 3a and 3b shows low nitrate concentrations for DO < 4 mg/L or Eh < 100 mV, which indicates potential occurrence of denitrification. However, Figure 3c suggests that the extent of nitrate reduction is controlled by the insufficient dissolved organic carbon (DOC); nitrate concentrations are high for DOC concentrations smaller than 5mg/L.

Figure 4a shows that low dissolved inorganic nitrogen (DIN) occurs when DTW < 3m. Figures 4b and 4c suggest low DIN for DO and high DOC.

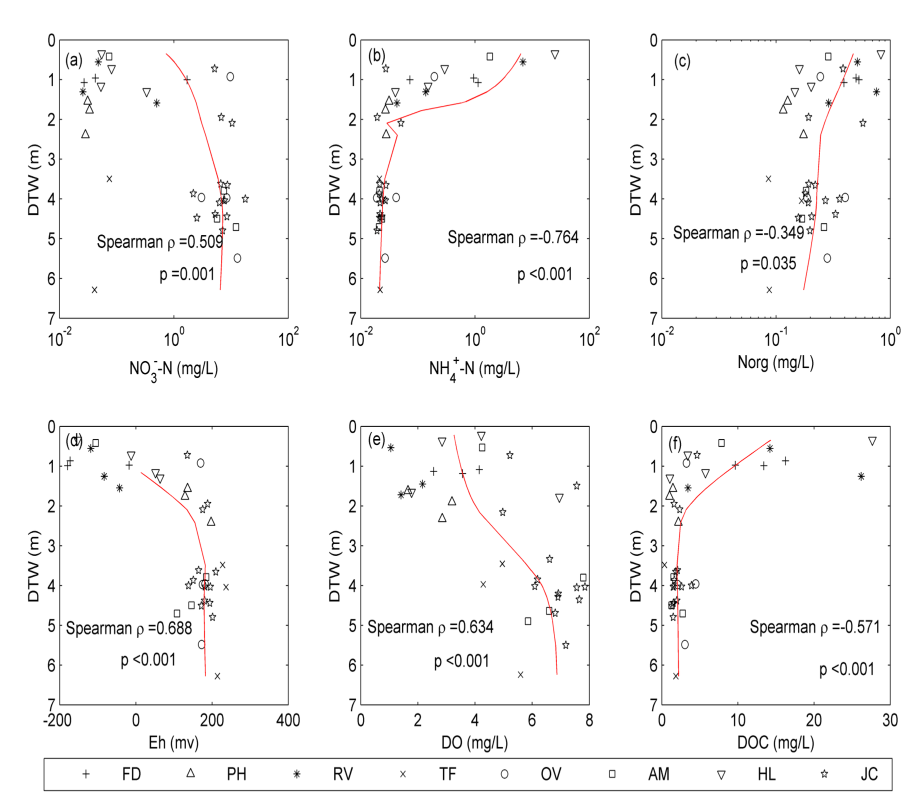

Figure 5. Correlation between DTW and concentrations of (a) nitrate, (b) ammonium, (c) organic N, (d) Eh, (e) DO, and (f) DOC.

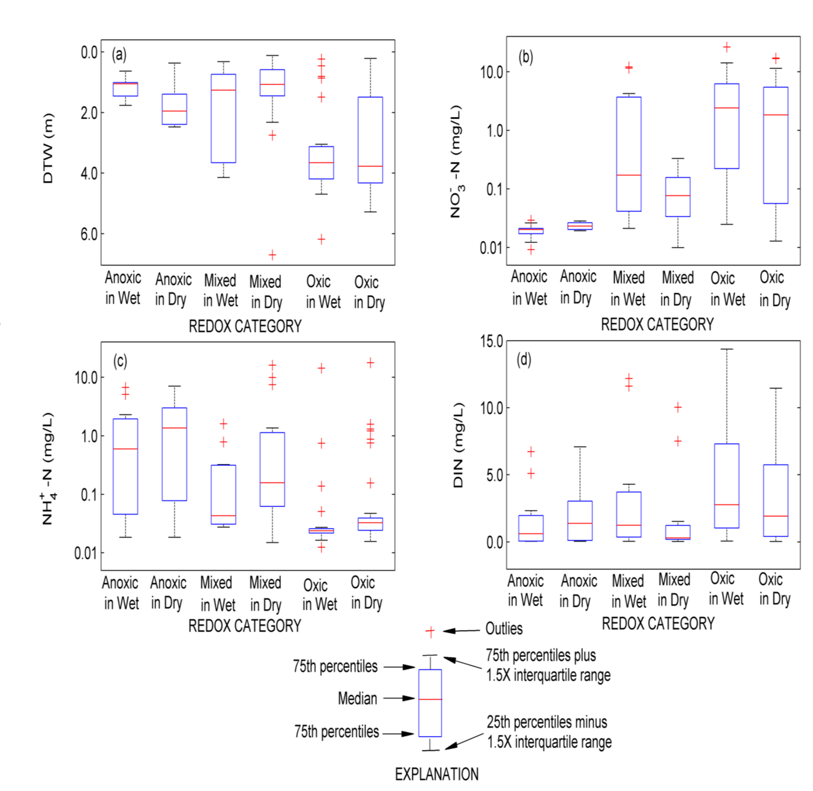

Figure 6. Boxplots of (a) DTW, and concentrations of (b) nitrate, (c) ammonium, and (d) dissolved inorganic nitrogen in different redox and hydrologic conditons.

DTW is closely related to geochemical variables of groundwater quality (Fig.5). DTW of 3m is a threshold for the vertical profiles of the geochemical variables, especially for the vertical distributions of ammonium and DOC concentrations. As a result, redox conditions change at DTW = 3m, anoxic with DTW < 3m. DIN concentrations in anoxic and mixed conditions were significant lower than in oxic conditions, which indicates the control of groundwater redox condition on the nitrogen removal.

Table 1. Results of non-parametric analysis of correlations of redox indicators and explanatory variables.

	Wet season				Dry season			
	O_2	NO_3-N	Mn	Fe	O_2	NO_3-N	Mn	Fe
	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ
Depth of water table below land surface	0.601(+)	0.495(+)	0.397(-)	0.577(-)	0.593(+)	0.504(+)	0.326(-)	0.522(-)
Distance to surface Waterbody	NS	NS	NS	NS	NS	NS	NS	NS
Ksat	0.618(+)	0.552(+)	0.416(-)	0.532(-)	0.551(+)	0.518(+)	0.377(-)	0.683(-)
Soil slope	NS	NS	NS	NS	NS	NS	NS	NS
Numerical soil drainage characteristics	0.591(+)	0.497(+)	0.401(-)	0.552(-)	0.498(+)	0.440(+)	0.355(-)	0.611(-)

Table 1 shows that redox conditions are are strongly correlated with DTW, saturated hydraulic conductivity (Ksat), and soil drainage classes, indicating close linkage of hydrologic factors and groundwater redox conditions in the septic areas.

ACKNOWLEDGEMENT

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