Prioritizing Aquifer Monitoring in North Dakota: A Nitrate Vulnerability Assessment Tool

Scott F. Korom Barr Engineering Company



Outline:

- The nitrate issue.
- What is denitrification?
- DRASTIC: a common assessment method.
- Results from our denitrification network.
- Defining feature of our nitrate vulnerability assessment tool.



- "Rising levels of nitrate in Minnesota drinking water are a costly challenge for homeowners" (9/6/15, St. Paul Pioneer Press).
- "Three out of four Minnesotans get their drinking water from groundwater," (MPCA).



 "Gov. Mark Dayton struggles to reconcile desire for clean water and a strong farm economy," (StarTribune 2/25/2016).



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- Last August: "I refuse to believe we have to • accept this kind of contamination because it's farm country. We don't accept it in mining country. We don't accept it in the metropolitan area. We are not just going to turn our backs and say we are going to provide free rein to people even if they are doing really important work. If that makes me an enemy of agriculture, I regret that, but there is too much at stake here," (Gov. Dayton, 8/15).



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- Last week, he had softened his tone, "Agribusiness is the mainstay of our economy."



"Complex water problems will require everyone's efforts," Gov. Dayton (StarTribune 2/27/2016).



"High Nitrate Levels Plague 60 Iowa Cities, Data Show" (7/7/15, Des Moines Register).



BOARD OF WATER WORKS TRUSTEES) OF THE CITY OF DES MOINES, IOWA,	NO.: 5:15-cv-04020
Plaintiff)	
vs.	
SAC COUNTY BOARD OF SUPERVISORS AS TRUSTEES OF DRAINAGE DISTRICTS 32, 42, 65, 79,	COMPLAINT
81, 83, 86, and CALHOUN COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS) JOINT TRUSTEES OF DRAINAGE DISTRICTS 2 AND 51 and BUENA VISTA COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT TRUSTEES OF DRAINAGE DISTRICTS 19 and 26 and DRAINAGE DISTRICTS 64 and 105	Filed 3/16/2015
Defendants.	BARR

BOARD OF WATER WORKS TRUSTEES OF THE CITY OF DES MOINES, IOWA, Plaintiff	NO.: 5:15-cv-04020
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81, 83, 86, and CALHOUN COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS	Filed 3/16/2015
JOINT TRUSTEES OF DRAINAGE DISTRICTS 2 AND 51 and BUENA	"Des Moines has
SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT	declared war on rural
TRUSTEES OF DRAINAGE DISTRICTS	Iowa," Gov. Branstad,
and 105.	1/13/15.
Defendants.	
	BAR

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Defendants.

"The key legal claim is the drainage districts... artificially collect, convey and discharge polluted groundwater into Iowa's rivers and streams imposing costs on the DMWW and others who use the water. This makes the districts point sources under the **CWA which need permits to** discharge – no different than the discharge coming out of a pipe at a municipal sewage treatment plant or a private factory," (N. Hamilton, 3/5/15).



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"146. Under natural hydrologic conditions very little nitrate is discharged from groundwater to streams, but artificial subsurface drainage short-circuits the natural conditions that otherwise keep nitrate from entering streams and rivers."



Denitrification $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$ Four Requirements (Firestone, 1982) O Nitrous oxides **2** Suitable bacteria Θ Restricted O_2 availability inorganic sulfide, and Fe(II)]



DRASTIC (Aller et al., 1987)

- **D** Depth to water
- R Recharge (Net)
- A Aquifer Media
- S Soil Media
- T Topography (Slope)
- I Impact of the Vadose Zone Media
- **C** Conductivity (Hydraulic) of the Aquifer

Weighted sum of hydrologic factors that are related to the movement of pollutants from the ground surface to aquifers.

Standardized System

Low Medium High

(NDDH, 1999)



Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer in Grand Forks County, Eastern North Dakota



W.M. Schuh et al. (2006) Water Resources Investigation No. 38 ND State Water Commission



Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer in Grand Forks County, Eastern North Dakota

"At measured nitrate loading rates there is sufficient pyrite-S in the EVA to support autotrophic denitrification for 11,000 to 175,000 years depending on location. These estimates assume non-preferential flow, and the gradual and uniform progression of nitrate."

W.M. Schuh et al. (2006) Water Resources Investigation No. 38 ND State Water Commission



Bedrock Shale and Aquifers with High e⁻ Donor Potential in Eastern North Dakota





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Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

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journal homepage: www.elsevier.com/locate/scitotenv ___

Modeling vulnerability of groundwater to pollution under future scenarios of climate change and biofuels-related land use change: A case study in North Dakota, USA

Ruopu Li *, James W. Merchant

Center for Advanced Land Management Information Technologies, School of Natural Resources, University of Nebraska-Lincoln, 3310 Holdrege Street, Lincoln, NE 68583-0973, United States

DRASTIC: "The model's simple formulation and the ease of integration with geographic information systems (GIC) make it well-suited for regional analyses of groundwater pollution potential. Another significant advantage of DRASTIC is it flexibility as it can be adapted to incorporate other factors, such as land use and land cover."







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						e donors (%)
ISM	Rate	Clay+silt	Inorganic S	Organic C		IS + OC +
Identification	(mg/L/yr)	(%)	(%)	(%)	Fe(II)	Fe(II)
Hamar, ND	< 1.3	9.2	0.011	0.040	0.048	0.099
New ProvS, IA	2.6	7.1	0.011	0.007	0.094	0.112
Karlsruhe-G, ND	3.5	4.4	0.190	0.044	0.277	0.511
New ProvD, IA	6.6	7.6	0.005	0.016	0.115	0.136
Robinson, ND	4.0 - 10.2	8.7	0.022	0.072	0.160	0.254
Luverne, MN	8.4	10.1	0.014	0.004	0.014	0.032
Akeley, MN	12.8	36.3	0.007	0.024	0.113	0.144
Perham-W, MN	12.8	4.4	0.017	0.000	0.389	0.406
Perham-M, MN	12.8	4.4	0.115	0.011	0.192	0.318
Karlsruhe-S, ND	15.0 - 28.1	3.3	0.177	0.016	0.447	0.639
Oakes-C, ND	22.4	9.3	0.020	0.990	0.287	1.296
Larimore, ND	33.8 - 83.8	20.2	0.232	0.333	0.261	0.826
Oakes-G, ND	102 - 214	12.8	0.047	0.194	0.467	0.707

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"A review of the published rates suggests that denitrification tends to occur more quickly when linked with sulfide oxidation than with carbon oxidation," (Tesoriero and Puckett, 2011).

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Two categories:

If e donor < 0.6%, denitrification rate < 14 mg N/L/yr (1 mM/yr) If e donor > 0.6%, denitrification rate > 14 mg N/L/yr (1 mM/yr)

Conclusions:

- Nitrate vulnerability assessment tools need to consider the fundamental requirement for groundwater denitrification: supply of e⁻ donors.
 - Denitrification rates are fastest with edonor concentrations > 0.6%.



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 - Denitrification rates are fastest with edonor concentrations > 0.6%.
 - ND has at least two "super-denitrifying" aquifers.
 - **MN**?
 - **IA?**



Acknowledgments:

- Luverne Municipal Utilities
- MN Dept. of Agriculture
- MN Dept. of Health
- MN Pollution Control Agency
- ND Dept. of Health
- ND Rural Water Users Systems Association
- NDSU
- ND State Water Commission (Bill Schuh)
- ND Water Resources Research Institute
- UND
- US EPA Section 319 funding
- USGS
- Private land owners
- Graduate students (Schlag, Kammer, Warne, Skubinna, Spencer, Tesfay, Klapperich, Mahargan, Christenson, Krieger)





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