Successful Denitrification Using Food-Grade Lecithin

Group 1

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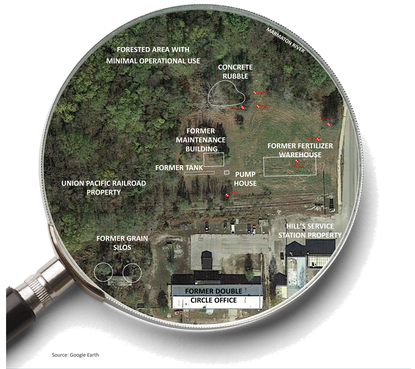
BACKGROUND

THE SITE



Source: Google Earth

- Former railroad maintenance yard
- Property leased to fertilizer distribution company that warehoused fertilizer on-site
- Two plumes of nitrate and low concentrations of ammonia caused by site flood event
- Geology is silty clay with sand stringers
- Groundwater is at 25 ft. bgs
- Site is in the Kansas Department of Health & the Environment (KDHE) Voluntary Cleanup Program (VCP)
- Average concentration of nitrate + ammonia (16.8 mg/L) exceeds the KDHE standard of 10 mg/L
- Long-term monitoring and groundwater extraction were considered
- Site received injection permit for bioremediation amendment

FOCUSED TREATMENT AREA

MW-2	Ammonia	Nitrate	TPH-DRO
	mg/L	mg/L	mg/L
08/11/09	1.67	6.88	0.12
01/19/10	0.608	<0.61	<0.0853
07/29/10	0.62	12.5	0.0482
01/20/11	0.111	32.2	0.0413
01/26/12	0.252	55.3	<0.0485
07/18/12	0.25	26.4	0.0306
07/17/13	0.07	45.2	0.12
01/22/14	0.390	33.3	<0.0962
09/29/14	<0.1	19.7	NA
03/11/15	0.031 J	18.7	NA

MW-1	Ammonia	Nitrate	TPH-DRO
	mg/L	mg/L	mg/L
10/16/09	0.823	<0.10	0.0539
01/19/10	0.574	<0.100	<0.0971
07/29/10	0.337	0.282	0.298
01/20/11	<0.1	0.0320	0.0390
07/26/11	0.238	<0.100	<0.0980
01/26/12	0.141	155	0.042
07/18/12	0.304	0.0330 J	0.0374 J
07/17/13	<0.10	0.061	<0.0935
01/22/14	0.367 B	0.05 J	0.225
09/29/14	<0.1	0.17	NA
03/11/15	<0.10	0.23	NA

MW-3	Ammonia	Nitrate	TPH-DRO
	mg/L	mg/L	mg/L
08/11/09	2.59	111	0.0416
09/04/09	3.04	54.7	0.0748
09/11/09	2.82 / 2.77	96.7 / 145	0.0322 / 0.0470
10/16/09	2.65	85.9	0.0509
01/19/10	2.30	106 J	< 0.0952
07/29/10	1.84 / 1.56	136 / 135	0.0451 J,B / 0.05111,B
01/20/11	0.377 / 0.566	111 / 155	0.0763 J,B / 0.0552 J,B
07/26/11	0.383 / 0.393	204 / 211 H2	0.0379 J,B / 0.05181,B
01/26/12	0.975 / 0.884	128 H2 / 115 H2	0.0762 QB,J / <0.0472
07/18/12	0.390 / 0.723	142 / 185	0.0448 J / 0.0393 J
07/17/13	<0.1 / 0.194	114 / 116	<0.0935 / <0.1
01/23/14	1.67 B / 1.25 B	156 / 163	0.0948 J / <0.0962
09/29/14	<0.1 / <0.1	149 / 150	NA
03/11/15	0.45 / 0.57	300 / 275	NA
10/06/16	2.5 / 2.0	284 / 312	NA
02/28/17	1.8 / 1.3	<0.10 / <0.10	NA
05/25/17	0.23 / 0.13	<0.10 / 0.053J	NA
08/29/17	1.5 / 1.3	<0.10 / <0.10	NA
11/28/17	2.0 / 2.0	<0.10 / <0.10	NA

MW-4	Ammonia	Nitrate	TPH-DRO
	mg/L	mg/L	mg/L
08/11/09	2.69	7.89	0.0396
09/04/09	2.24 / 2.64	0.46 / <0.1	0.124 / 0.0696
09/11/09	2.63	0.0730	0.0501
01/19/10	1.96	6.11 J	< 0.0952
07/29/10	1.22	7.44	0.0621 J,B
01/20/11	0.977	8.24	0.03791 J,B
07/26/11	1.42	18.2 H2	0.04731 J,B
01/26/12	0.711	42.8 H2	<0.0476
07/18/12	0.583	26.6	<0.050
07/17/13	<0.1	12.7	<0.0935
01/22/14	0.434 B	27.8	<0.0962
09/29/14	<0.1	24.2	NA
03/11/15	0.36	25.7	NA
10/06/16	<0.10	35.7	NA
02/28/17	0.053 J	<0.10	NA
05/25/17	<0.10	<0.10	NA
08/29/17	0.37	<0.10	NA
11/28/17	0.91	<0.10	NA

MW-5	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/16/09	0.823	<0.10	0.0539	NA
01/19/10	0.574	< 0.100 UJ	< 0.0971	NA
07/29/10	0.337	0.282	0.298 B	NA
01/20/11	< 0.1	0.0320 J	0.0390 J,B	NA
07/26/11	0.238	< 0.100 H2	< 0.0980	NA
01/26/12	0.141	155 H2	0.042 QJ,QP	NA
07/18/12	0.304	0.0330 J	0.0374 J	<0.10
07/17/13	<0.10	0.061	<0.0935	<0.10
01/22/14	0.367 B	0.05 J	0.225	<0.10
09/29/14	<0.1	0.17	NA	<0.10
03/11/15	<0.10	0.23	NA	<0.10
10/06/16	<0.10	<0.10	NA	<0.10
02/28/17	0.20	<0.10	NA	<0.10
05/25/17	<0.10	<0.10	NA	<0.10
08/29/17	0.48	<0.10	NA	<0.10
11/28/17	0.16	<0.10	NA	<0.10

MW-6	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/06/16	2.5	0.19	NA	0.011 J
02/28/17	2.5	<0.10	NA	<0.10
05/25/17	4.1	<0.10	NA	<0.10
08/29/17	3.2	<0.10	NA	0.034 J
11/28/17	3.9	<0.10	NA	<0.10

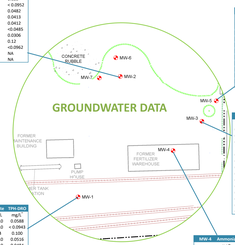
MW-7	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/06/16	2.4	13.3	NA	<0.50
02/28/17	2.5	<0.10	NA	<0.10
05/25/17	2.3	<0.10	NA	<0.10
08/29/17	2.5	<0.10	NA	<0.10
11/28/17	2.8	<0.10	NA	0.033 J

MR-2	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/06/16	<0.10	0.29	NA	<0.10
02/28/17	0.021 J	<0.10	NA	<0.10
05/25/17	<0.10	0.46	NA	<0.10
08/29/17	<0.10	0.20	NA	<0.10
11/28/17	<0.10	<0.10	NA	<0.10

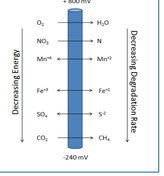
MR-35	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/06/16	<0.10	0.32	NA	<0.10
02/28/17	0.028 J	<0.10	NA	<0.10
05/25/17	<0.10	0.42	NA	<0.10
08/29/17	<0.10	0.15	NA	0.036 J
11/28/17	<0.10	<0.10	NA	<0.10

MR-4	Ammonia	Nitrate	TPH-DRO	Nitrite
	mg/L	mg/L	mg/L	mg/L
10/06/16	<0.10	0.28	NA	<0.10
02/28/17	0.044J	<0.10	NA	<0.10
05/25/17	<0.10	0.42	NA	<0.10
08/29/17	<0.10	0.19	NA	<0.10
11/28/17	<0.10	<0.10	NA	0.039 J

GROUNDWATER DATA



UTILIZING MOLECULAR BIOLOGICAL TOOLS AND GEOCHEMISTRY



CENSUS qPCR ANALYSIS

MICROBIAL INSIGHTS, INC.

CENSUS

10515 Research Dr., Knoxville, TN 37932
Tel.: (865) 573-8188 Fax.: (865) 573-8133

Client: Antea Group
Project: Double Circle Farm Supply

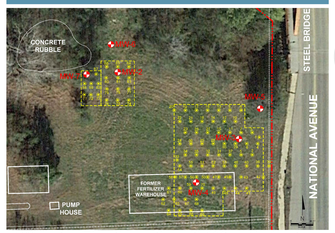
MI Project Number: 1206J
Date Received: 10/31/2014

Sample Information

Client Sample ID:		MW-2	MW-3	MW-4
Sample Date		10/30/2014	10/30/2014	10/30/2014
Units		cells/bead	cells/bead	cells/bead
Analyte		16S	16S	16S
Functional Genes				
Denitrifying Bacteria	narK	1.42E+04	1.74E+04	1.10E+04
Denitrifying Bacteria	narG	1.02E+04	2.92E+03	2.08E+04
Phylogenetic Group				
Total Eubacteria	EBAC	4.20E+08	3.42E+08	4.68E+08
Ammonia Oxidizing Bacteria	AOB	2.18E+04	8.34E+04	2.07E+04

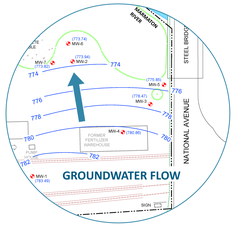
Legend:
NA = Not Analyzed NS = Not Sampled J = Estimated gene copies below PQL but above LQL I = Inhibited
< = Result not detected

INJECTION LAYOUT



- 89 direct push injection locations with 10 ft. spacing in between
- Target vertical interval in the saturated zone = 40 – 50 ft. bgs
- Top down injection technique used
- Injection parameter goals - ≤10 gallons per minute (gpm)/ ≤30 pounds per square inch (psi)
- 60 gallons of amendment solution per location

GROUNDWATER FLOW



- Bioremediation and phytoremediation are common technologies for treating nitrate in groundwater
- Denitrifying bacteria and some aerobic bacteria can utilize nitrate
- Rapid utilization of nitrate occurs when dissolved oxygen is nearly depleted
- Many states defer to treatment standards for nitrate used by Midwestern states

APPROACH

DENITRIFICATION PROCESS

A food-grade lecithin amendment is injected to provide electron donor to enhance the denitrification process

The lecithin amendment is a combination of hydrophilic and hydrophobic phospholipids, fatty acids, complex carbohydrates, and simple sugars and also provides traces of nitrogen and phosphorous nutrients

Through biodegradation of the amendment, hydrogen is released and utilized by the subsurface bacteria to reduce the nitrate

The denitrification process proceeds through steps to nitrite, nitric oxide, nitrous oxide, and ultimately, nitrogen gas. Nitrite is often the only detectable intermediate

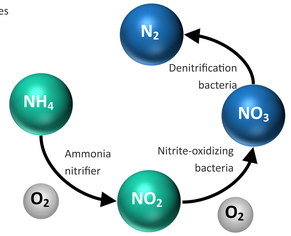
REMEDIATION CONCEPT

The treatment solution is Emulsified Lecithin Substrate (ELS). ELS is a lecithin-based micro-emulsion composed of complex organic carbon used to enhance anaerobic bioremediation

The ELS is delivered as an easy to handle 25% liquid emulsion that is cold water soluble of on-site mixing to the desired dilution amount

The ELS solution was designed based upon stoichiometric demand calculations. The ELS solution is mixed to a 10-percent solution for injection.

The total injection volume per point = 57 gallons of treatment solution (~6 gallons per vertical foot of treatment zone). Total treatment volume for the project = 4,527 gallons



Reaction route of conventional nitrification and denitrification

ELS® AMENDMENT FROM PEROXYCHEM

RESULTS

INJECTION METRICS

- 85 out of 89 direct push injection locations received the prescribed volume of amendment solution
- Top down injection technique used for all but 10 direct push injection locations, which were completed using a bottom up technique
- Injection parameters – 6-7 gpm met the goal of ≤10 gpm/ 50 psi was higher than the goal of ≤30 psi for injection pressure

SECONDARY PARAMETERS

- pH remained neutral during injection averaging 7.12 standard units, ideal for denitrification
- Conductivity increased from average of 1.172 milli-siemens to 2.875 milli-siemens, indicating amendment dose response at the performance monitoring wells
- Dissolved oxygen ranged from 0.5 – 1.2 mg/L , ideal for denitrification
- Oxidation-reduction potential ranged from -50 millivolts to 50 millivolts, ideal for denitrification

INJECTION STANDARDS MET!

ID	Collection Date	Analysis			
		Ammonia	Nitrate	TPH-DRO	Nitrite
		mg/L	mg/L	mg/L	mg/L
MW-1	08/11/09	3.5	< 0.10	0.0588	NA
	01/19/10	2.91	< 0.10 UJ	< 0.0943	NA
	07/29/10	0.707	1.94	0.100 J,B	NA
	01/20/11	2.48	< 0.10	0.0516 J,B	NA
	07/26/11	2.75	< 0.10	0.0484 J,B	NA
	01/26/12	1.95	0.744	0.0777 QJ,J	NA
	07/18/12	1.68	1.14	0.0344 J	<0.10
	07/17/13	1.70	0.104	<0.0935	<0.10
	01/22/14	1.36 B	0.387	<0.10	<0.10
	09/29/14	0.86	0.35	NA	<0.10
	03/11/15	1.20	<0.10	NA	<0.10
	10/06/16	1.6	0.84	NA	<0.10
	02/28/17	0.21	<0.10	NA	<0.10
	05/25/17	2.1	<0.10	NA	<0.10
	08/29/17	2.2	<0.10	NA	<0.10
	11/28/17	2.1	<0.10	NA	<0.10
MW-2	08/11/09	1.67	6.88	0.123	NA
	01/19/10	0.608	49.0 J	< 0.0952	NA
	07/29/10	0.62	12.5	0.0482 J,B	NA
	01/20/11	0.111	32.2	0.0413 J,B	NA
	07/26/11	0.404	21.8 H2	0.0412 J,B	NA
	01/26/12	0.252	55.3 H2	<0.0485	NA
	07/18/12	0.25	26.4	0.0306 J	<0.10
	07/17/13	0.07	45.2	0.12	0.428
	01/22/14	0.390 B	33.3	<0.0962	0.428
	09/29/14	<0.1	19.7	NA	<1
	03/11/15	0.031 J	18.7	NA	<1
	10/06/16	<0.10	50.9	NA	<2
	02/28/17	0.70	0.88	NA	1.7
	05/25/17	0.52	<0.10	NA	<0.10
	08/29/17	1.2	<0.10	NA	<0.10
	11/28/17	0.77	<0.10	NA	<0.10

ID	Collection Date	Analysis			
		Ammonia	Nitrate	TPH-DRO	Nitrite
		mg/L	mg/L	mg/L	mg/L
MW-3	08/11/09	2.59	111	0.0416	NA
	09/04/09	3.04	54.7	0.0748	NA
	09/11/09	2.82 / 2.77	96.7 / 145	0.0322 / 0.0470	NA
	10/16/09	2.65	85.9	0.0509	NA
	01/19/10	2.30	106 J	< 0.0952	NA
	07/29/10	1.84 / 1.56	136 / 135	0.0451 J,B / 0.05111,B	NA
	01/20/11	0.377 / 0.566	111 / 155	0.0763 J,B / 0.0552 J,B	NA
	07/26/11	0.383 / 0.393	204 / 211 H2	0.0379 J,B / 0.05181,B	NA
	01/26/12	0.975 / 0.884	128 H2 / 115 H2	0.0762 QB,J / <0.0472	NA
	07/18/12	0.390 / 0.723	142 / 185	0.0448 J / 0.0393 J	0.063 / 0.353
	07/17/13	<0.1 / 0.194	114 / 116	<0.0935 / <0.1	<0.1 / <0.1
	01/23/14	1.67 B / 1.25 B	156 / 163	0.0948 J / <0.0962	<0.1 / <0.1
	09/29/14	<0.1 / <0.1	149 / 150	NA	<5 / <5
	03/11/15	0.45 / 0.57	300 / 275	NA	<10 / <10
	10/06/16	2.5 / 2.0	284 / 312	NA	<10 / <10
	02/28/17	1.8 / 1.3	<0.10 / <0.10	NA	0.13 / 0.072 J
	05/25/17	0.23 / 0.13	<0.10 / 0.053J	NA	<0.10 / <0.10
	08/29/17	1.5 / 1.3	<0.10 / <0.10	NA	<0.10 / <0.10
	11/28/17	2.0 / 2.0	<0.10 / <0.10	NA	<0.10 / 0.067 J
MW-4	08/11/09	2.69	7.89	0.0396	NA
	09/04/09	2.24 / 2.64	0.46 / <0.1	0.124 / 0.0696	NA
	09/11/09	2.63	0.0730	0.0501	NA
	01/19/10	1.96	6.11 J	< 0.0952	NA
	07/29/10	1.22	7.44	0.0621 J,B	NA
	01/20/11	0.977	8.24	0.03791 J,B	NA
	07/26/11	1.42	18.2 H2	0.04731 J,B	NA
	01/26/12	0.711	42.8 H2	<0.0476	NA
	07/18/12	0.583	26.6	<0.050	0.124
	07/17/13	<0.1	12.7	<0.0935	<0.1
	01/22/14	0.434 B	27.8	<0.0962	<0.1
	09/29/14	<0.1	24.2	NA	<1
	03/11/15	0.36	25.7	NA	<1
	10/06/16	<0.10	35.7	NA	<0.10
	02/28/17	0.053 J	<0.10	NA	0.94
	05/25/17	<0.10	<0.10	NA	<0.10
	08/29/17	0.37	<0.10	NA	<0.10
	11/28/17	0.91	<0.10	NA	<0.10

ID	Collection Date	Analysis			
		Ammonia	Nitrate	TPH-DRO	Nitrite
		mg/L	mg/L	mg/L	mg/L
MW-5	10/16/09	0.823	<0.10	0.0539	NA
	01/19/10	0.574	< 0.100 UJ	< 0.0971	NA
	07/29/10	0.337	0.282	0.298 B	NA
	01/20/11	< 0.1	0.0320 J	0.0390 J,B	NA
	07/26/11	0.238	< 0.100 H2	< 0.0980	NA
	01/26/12	0.141	155 H2	0.042 QJ,QP	NA
	07/18/12	0.304	0.0330 J	0.0374 J	<0.10
	07/17/13	<0.10	0.061	<0.0935	<0.10
	01/22/14	0.367 B	0.05 J	0.225	<0.10
	09/29/14	<0.1	0.17	NA	<0.10
	03/11/15	<0.10	0.23	NA	<0.10
	10/06/16	<0.10	<0.10	NA	<0.10
	02/28/17	0.20	<0.10	NA	<0.10
	05/25/17	<0.10	<0.10	NA	<0.10
	08/29/17	0.48	<0.10	NA	<0.10
	11/28/17	0.16	<0.10	NA	<0.10
MW-6	10/06/16	2.5	0.19	NA	0.011 J
	02/28/17	2.5	<0.10	NA	<0.10
	05/25/17	4.1	<0.10	NA	<0.10
	08/29/17	3.2	<0.10	NA	0.034 J
	11/28/17	3.9	<0.10	NA	<0.10
MW-7	10/06/16	2.4	13.3	NA	<0.50
	02/28/17	2.5	<0.10	NA	<0.10
	05/25/17	2.3	<0.10	NA	<0.10
	08/29/17	2.5	<0.10	NA	<0.10
	11/28/17	2.8	<0.10	NA	0.033 J
MR-2	10/06/16	<0.10	0.29	NA	<0.10
	02/28/17	0.021 J	<0.10	NA	<0.10
	05/25/17	<0.10	0.46	NA	<0.10
	08/29/17	<0.10	0.20	NA	<0.10
	11/28/17	<0.10	<0.10	NA	<0.10
MR-35	10/06/16	<0.10	0.32	NA	<0.10
	02/28/17	0.028 J	<0.10	NA	<0.10
	05/25/17	<0.10	0.42	NA	<0.10
	08/29/17	<0.10	0.15	NA	0.036 J
	11/28/17	<0.10	<0.10	NA	<0.10
MR-4	10/06/16	<0.10	0.28	NA	<0.10
	02/28/17	0.044J	<0.10	NA	<0.10
	05/25/17	<0.10	0.42	NA	<0.10
	08/29/17	<0.10	0.19	NA	<0.10
	11/28/17	<0.10	<0.10	NA	0.039 J

Acknowledgements:
Addie Mette, Antea Group
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