Remediation of Leaking Underground Storage Tank Sites in Iowa

August 2014 - UST Section, IDNR

Injection Remediation Technologies

Since 1988, DNR records indicate 984 leaking underground storage tank (LUST) sites have undergone some type of active remediation in Iowa. Remediation was triggered by emergency conditions, free phase petroleum, and/or high risk conditions as determined by risk-based corrective action (RBCA).

This report will focus on remediation technologies specific to injection of chemicals. Materials injected may include **slurry, solids, or liquids for in-situ chemical oxidation (ISCO), washing (surfactants), bioremediation, or sequestration.** Some injectates are for the purpose of promoting bioremediation of the contaminants; other compounds are injected to chemically break down the contaminant compounds and then enhance bioremediation of the remaining contamination. The types or trade products of injection technologies are further described in Table 1.

Table 1: Chemical Injection Technologies

Injection Technology	Technology Description
BIOX^{tm}	Proprietary mixture of chemicals based upon hydrogen peroxide, a strong oxidizer. In concentrated form, the hydrogen peroxide chemically destroys the contaminant hydrocarbons and then provides oxygen for the in-situ bacteria to consume the hydrocarbons and leave carbon dioxide as a waste product.
Bos 200^{tm}	Trade name for injection of granular activated carbon (GAC) and compounds as a slurry. The carbon serves to adsorb contaminants in the groundwater and reportedly promotes bioremediation. Also known as a 'trap and treat' technology.
ORC^{tm}	Oxygen releasing compound (ORC^{tm}) is a solid material which slowly releases oxygen into groundwater to promote bioremediation. It can be injected as a slurry, left in backfill of excavations, or dropped into monitoring wells as a solid.
Persulfate	Calcium or sodium persulfate are other ISCO compounds which may be injected for contaminant breakdown; these can then leave behind sulfate to provide an electron acceptor for bioremediation. Sometimes a compound of sulfate such as Epsom Salts is injected to promote bioremediation.
PlumeStop^{tm}	Trade name for injection of granular activated carbon (GAC) as a slurry. The carbon serves to adsorb contaminants in the groundwater and reportedly promotes bioremediation. Also known as a 'trap and treat' technology.
Regenox^{tm}	Trade name for another oxidant which uses a sodium percarbonate compound in combination with catalysts and with other chemicals.
Surfactants	Soap-like compounds which help "wash" contaminants from soil particles so the contaminants can be captured by a remediation system.

Chemical injections have been used at approximately 65 Iowa LUST sites. A subset of these sites is presented in Table 2. The table includes information on the site location, general geology, remediation methods used including identification of injection technologies, status/risk of site, and general comments on results of the injections. Results of the injections and "success" or "failure" can be very difficult to quantify due to lack of data and extreme variations between sites.

Lessons learned from use of injections in Iowa:

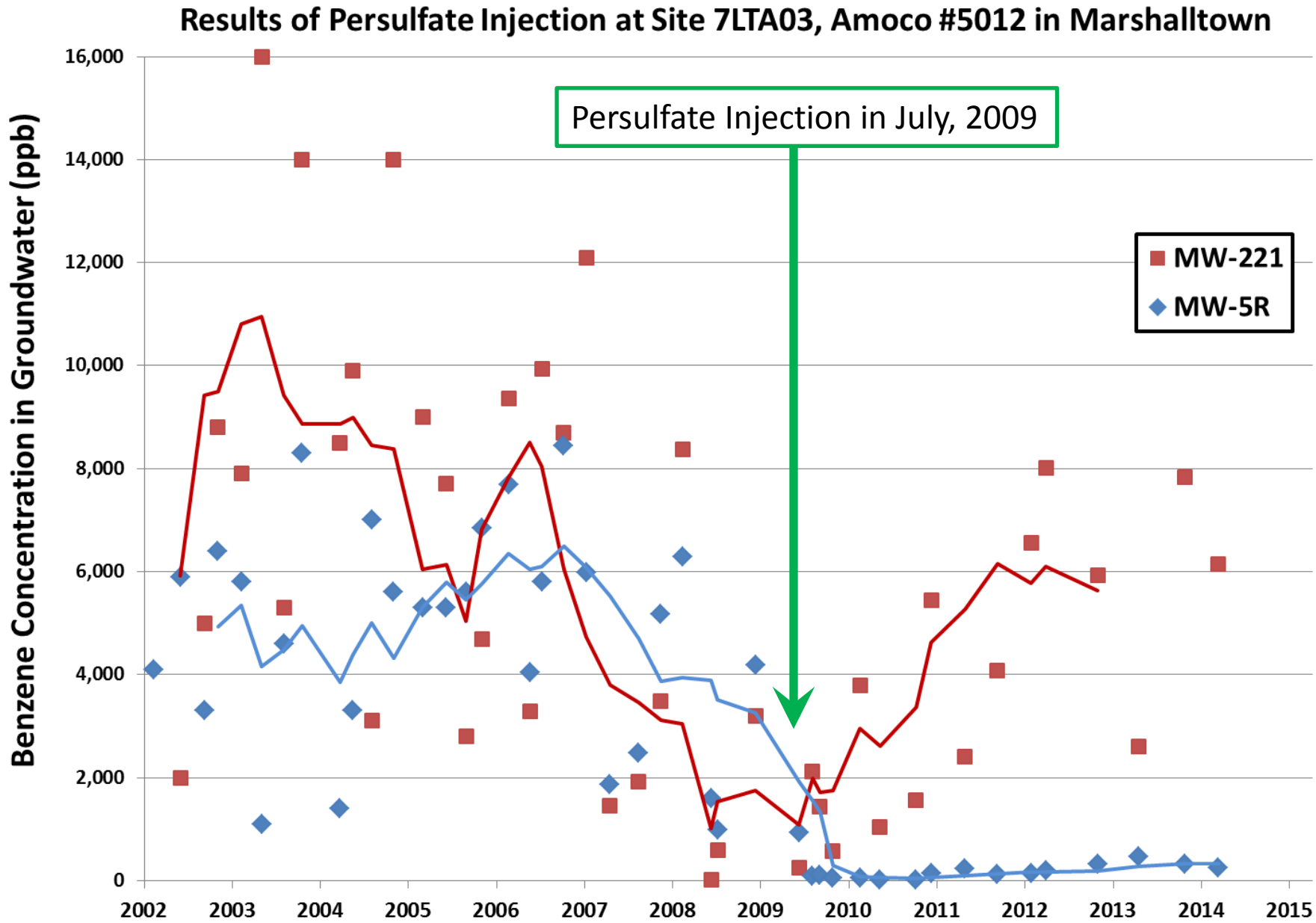
- Clay soils may not allow sufficient fluid to be injected. Sometimes the injectate returns to the surface around injection tools (daylights).
- At sites with both clay and sand layers, the injectate appears to preferentially flow into the sand layers and miss the clay layers. Fractured clay can also provide preferential pathways.
- Sufficient vertical and horizontal definition of contamination generally leads to better planning and consequently, more desirable results when using injection technologies.
- Injections are often used with a series of other treatment technology approaches to target specific areas of contamination or free product after other methods of remediation have been used to treat additional (possibly larger) volumes of contamination.
- Injections have often been used as the final step in moving a site toward closure by successfully targeting small areas of remnant contamination.
- When using injection technology to treat a plume or site (as opposed to a specific well or wells), injections made in a grid-like pattern with sufficient density, and with respect to subsurface geology, are most likely to succeed.
- In Iowa, Bos 200 (GAC) has not been used at a sufficient number of sites to draw conclusions on its effectiveness.
- Sometimes injection of chemicals flushes or releases petroleum contaminants sorbed to soil particles. This can cause a localized, temporary increase in the concentration of petroleum hydrocarbons dissolved in groundwater.

A study of the use of ISCO at sites in Colorado was completed in 2007. From *Petroleum Hydrocarbon Remediation by In-Situ Chemical Oxidation at Colorado Sites*, Colorado Department of Labor and Employment, Division of Oil and Public Safety, June 14, 2007, the study concludes:

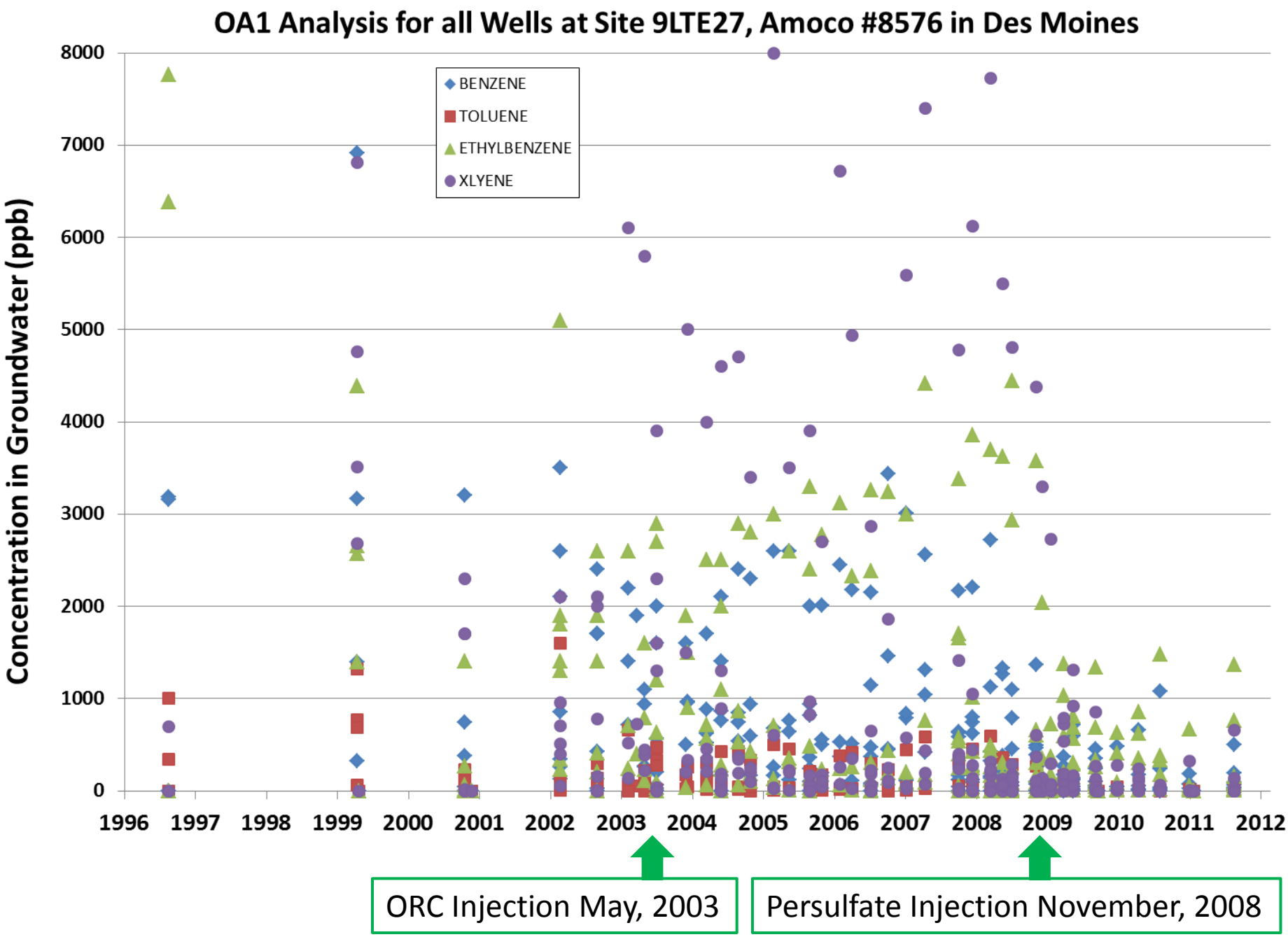
> *"The results of this Colorado study suggest that the lack of success, at least at 15 of the 20 sites selected, was due to incomplete or insufficient site characterization and/or pilot testing leading to insufficient oxidant delivery volumes and concentrations, determination of the effective radius of influence, or determination of vertical intervals to be treated. Therefore, the ISCO technology may have been appropriate in each case although the inadequate preparation for and implementation of the technology was the reason for the failure of ISCO at the site."*

An evaluation of the all the technologies used at high risk LUST sites shows that approximately one quarter of the sites require multiple and/or sequential technologies to clean up the site. Some sites have needed as many as five different remediation events. However, this is not to say that individual remediation events necessarily failed or were inadequate. Different areas of the site or specific plumes of contamination may have been targeted by different remediation events.

The results of this investigation indicate the question is not whether these chemicals can work to degrade the contamination and/or promote biodegradation, but rather how to inject sufficient quantities of the compounds to the exact location(s) of the contamination so the targeted hydrocarbons can be degraded.



Note: Monitoring Well 5R is near an injection point. Monitoring Well 221 is distant from an injection point. Trend lines are weighted averages (3rd order). Injection was only performed near wells with free product.


OA1 Analysis for all Wells at Site 9LTE27, Amoco #8576 in Des Moines
Concentration in Groundwater (ppb)
8000
7000
6000
5000
4000
3000
2000
1000
0
BENZENE
TOLUENE
ETHYLBENZENE
XLYENE
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
ORC Injection May, 2003
Persulfate Injection November, 2008

Sub-surface Chemical Injection Technologies at Selected Sites in Iowa

LUST#	Site	City	General Geology	Remediation Sequence	Free Product?	Injection Type	Injection Date(s)	Site Classification (Aug 2014)	Comments/Results of Injectionion
7LTA03	Former Amoco #5012	Marshalltown	Alluvial clay layers over sand	P&T 89-97; HVE 02-08; Persulfate 7/15/09	1989-2011	Persulfate	7/15/2009	NAR 8/11/14	Overall decrease in groundwater with rebound at wells not near injection (only injected around wells w/LNAPL).
7LTA42	Stuart BP Amoco	Stuart	Till, mostly clays	HVE 03-05; SO4 BIOX 05; Persulfate 2008	2000	Persulfate	9/15/2008	NAR 7/8/10	Second injection more effective. No rebound.
7LTB93	Amoco #5299	Coralville	Clay and silts over sand layers	OE 2000; HVE 03-07; OE 2010; Persulfate 9/15/06	1992-2009	Persulfate	9/15/2006	HR	7/2014: received reclass recom to NAR. Steady decline after persulfate injection; other techs used also.
7LTC47	Deli-Mart #6	Coralville	Alluvial clay layers over sand	ORC 2001; ART 04-06; 7 Persulfate 2008/2010	1989-2000	Persulfate	11/08 to 10/10	NAR 2014	Concentrations steady after injection. No clear result. Small data set.
7LTD14	Casey's	Glidden	Till	One BIOX injection 2007	No	BIOX	3/12/2007	NAR 2009	All wells fell below SSTLs after injection, but only a small data set.
7LTE90	Fast Avenue One Stop	Muscatine	Silts, clay, and sands	One Persulfate 2009	1999-2004	Persulfate	2009	NAR 2013	Dramatic decrease in groundwater after injection. Good example of trouble wells being treated.
7LTF44	Kitt Plumbing	Carroll	Organic silt/clay over till	OE 03; BIOX 2/8 thru 2/17/05	2005-2006	BIOX	2005	NAR 2007	Concentrations declining but fluctuating at time of injection. Stayed below SSTLs long enough for NAR.
7LTN05	Midway Oil	Indianola	Lean clay	Bos 200, 2012	No	Bos 200	2012	HR	Reduced concentrations, but still one hot area.
7LTN73	Home Oil	Agency	Silty clay, blocky clay	BIOX 2009	2004-2014	BIOX	2009	HR	Shows declining trend after injection, but concentrations still very high.
7LTO81	Capitol DX	Des Moines	alluvial clay layers over sand	BIOX 9/19/06 to 9/28/06	No	BIOX	9/06-9/06	NAR 2008	Injection for soils in small area; successful
7LTR08	Casey's	Tipton	Mostly clay w/occ. sand and gravel	OE 05; BIOX 2006 & 2007	1999-2008	BIOX	9/06 & 4/07	NAR 2010	Notable decrease in GW concentration after injection.
7LTU82	Best Food Mart	Des Moines	Clay layers over sand layer	OE 07; BIOX 2013	2002-2013	BIOX	2013	HR	2007 OE had dramatic results. Concentrations steady after injection.
7LTY16	Data Gas	AMES	Thick sand on top of clay	ORC 2000		ORC	2000	NAR 2007	GW concentrations decreased significantly
8LTA41	Hawkeye Truck Stop	Coralville	Clay with sand underneath	Persulfate 2010, planned for 2014, not done yet	1999-2014	Persulfate	2010, 2014?	Unk	First injeciton reduced FP. Second injection planned for 2014 at FP wells.
8LTA58	Russ's Amoco	Iowa City	Alluvial clay layers over sand	OE 04; SVE 06-09; 3 BIOX events;	2001-now	BIOX	2010, '11, '12	HR	Overall decline in concentrations, but effect of injections is unclear.
8LTC23	Benco Inc	Council Bluffs	Alluvial soil (silt/clay fine sand)	ORC/Regenesis 2003	No	ORC	2003	NAR 2008	Low levels before treatment. Likely a combination of natural attenuation and injection that reduced concentrations.
8LTE15	Country Store	Bedford	Till, mostly clays	SVE 06-09; BIOX 11/15/10 to 11/20/10	No	BIOX	11/2010	HR	Increase in concentrations after injection. Result of disturbing the subsurface?
8LTF64	Former Vista	Fort Dodge	Silty clay w/occ. fine sand seams	P&T 1991; OE and ORC 2004; Persulfate Injections 2009	No	Persulfate	2004, 2009	NAR 2010	Mainly treated for soil contamination. Not enough resolution in data for a conclusion on efficacy.
8LTJ93	Wold's Petro Stop	De Witt	Silty clay	Biox 2012	No	BIOX	2012	HR	Limited sampling after injection appears to show benefit to GW and soil. NAR applied for in 2014.
8LTS41	Former Kum & Go #194	Des Moines	Mostly silts and clays	BIOX 8/15/07-9/15/07	2006-2001	BIOX	2007	NAR 2011	Large plume, large quantity of BIOX injected
8LTU49	Jet Gas	Montrose	Clay with sand underneath	OE 2003; OE 2005; BIOX 2007, BIOX 2009		BIOX	2003, '07, '09	NAR/Free Product	Sharp decrease in high benzene concentrations after second injection. Done only in areas of high soil contamination.
9LTC15	Mahaska Farm SVC	Moravia	Clay w/some silt and fine sand	BIOX 2008	2006-2009	BIOX	2008	HR	Already declining before injection, no rebound, hard to assess exact impact. Done mainly for soils.
9LTE27	Amoco #8576	Des Moines	Clay and silt with some thin sand layers	ORC 2003; Persulfate 2008	No	Persulfate	2008	NAR 2011	Persulfate injection was effective and led to NAR. Injected as many places as possible in grid pattern.
9LTH73	Scott County	Davenport	Clay w/sand layers	ORC 10/17/2002	2000-2005	ORC	2002	NAR 2006	Steadily declining trend is likely the result of natural attenuation. Injection signature apparent, but small.
9LTI29	Vogt Trucking	Charter Oak	Loess (silt)	ORC 4/25/2003	No	ORC	2003	NAR 2008	ORC likely had a positive impact on GW concentration, but not enough data to confirm.
9LTI98	K F Hoelscher	Popejoy	Till, mostly dense clay	OE 06; AS (iSOC) 2006-10; BIOX 3/30/11 to 4/2/11	No	BIOX	2011	HR	Both technologies produced notable decreases in GW concentration.
9LTJ06	Fm B&C Service	Lockridge	Mostly silts and clays	BIOX 4/12/10 & 12/15/10; Bos 200 4/8/14	No	BIOX	2010	HR	Concentrations have remained steady since BIOX. No sampling since Bos 200 injection.
9LTJ35	Former Amoco #7422	Cedar Rapids	Clay and silt over sand layer at 15-20 ft.	Persulfate 2007; 3 injections Sulfate 2011-12	No	Persulfate	2007	NAR 2014	Spike after 2007 injections, but dramatic reduction afterwards. Site below SSTLs post 2011/12 injections.
9LTM48	Fm Air Force Radar Station	Waverly	Till: clay, silts, some sand	Persulfate 2012	No	Persulfate	2012	HR	GW Concentrations decreased, but not to SSTL
9LTM88	City of Jefferson	Jefferson	Till, clay, silty clay	BIOX 2012	2012-2014	BIOX	2012	HR	Some reduction apparent, but not enough data yet to confirm efficacy.

This is not a complete list of injection sites in Iowa and includes only sites with history or data sufficient for general conclusions on the use of chemical injections at that location. Some sites are included to show the effect of multiple technologies in a treatment "train".