

# Underground Tank Technology Update

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*UTTU's* home page, <http://epdwww.engr.wisc.edu/uttu/>, contains an alphabetical and topical list of every article that has appeared in *UTTU* since 1987.



## BTEX biofiltration

Matteau and Ramsay (1997) recently investigated high-temperature biofiltration of toluene in an active compost in the laboratory.

### Materials and methods

Using a 6-liter reactor (a glass column), researchers created a biodegradation microcosm by

- generating off-gases by bubbling a portion of air through the toluene
- sparging the remaining air through water for humidification
- limiting heat loss during composting by using an external heat exchanger consisting of plastic tubing connected to a recirculating water bath
- keeping temperatures between 45° and 55° by daily addition of substrates (SCT) or by an external heating system (EBT)

The original compost material consisted of a blend of maple leaves and Rabbit Chow (Ralston Purina).

To this compost, researchers

- adjusted the carbon to nitrogen ratio to 19 (w/w)
- added calcium carbonate (70 g/kg dw) as a pH buffer
- adjusted initial water content to between 55 and 60 percent (w/w)
- added an inoculum (85 g wet/kg dw), a compost previously used for toluene biofiltration

Researchers manually mixed the compost every 24 hours. They measured pH and analyzed water content and ash content before and after addition of fresh substrate. In addition, mineralization experiments were conducted with <sup>14</sup>C-ring-labelled toluene and benzene. Researchers measured toluene concentration using a gas chromatograph and flame ionization detector.

### Results

Researchers added fresh organic substrates daily which "provided enough energy due to microbial activity to maintain the temperature above 45°C. Based on mass balances, 7 percent of dry weight was degraded daily. The average solids residence time was 6.7 days, and gas residence time was 100 seconds. Water content was relatively constant at 62 ±3 percent (w/w). A 3-day period was necessary to obtain maximum temperature and high degradation rates. Toluene was degraded during this extended thermophilic phase at a mean biodegradation rate of 105 ±15 g toluene/m<sup>3</sup>/h. A maximum biodegradation rate of 120 ±17 g toluene/m<sup>3</sup>/h at an inlet concentration of 5.09 ±0.64 g/m<sup>3</sup> was measured at day 4."

To ascertain if addition of organic substrate affected biofiltration rates, researchers performed extended batch thermophilic composting where temperature was maintained at 50°C by external heating. During this time

- almost 50 percent of the dry weight of the filter bed degraded
- water content decreased from 60 to 53 percent during the 15-day period

"Although the mean biodegradation rate (72 ±14 g toluene/m<sup>3</sup>/h) was lower than in SCT biofiltration (semi-continuous thermophilic composting), the maximum degradation rate (94 ±16 g toluene/m<sup>3</sup>/h) was not significantly different from the SCT maximum rate. EBT (extended batch thermophilic composting) degradation rates increased rapidly after mixing. The mixing distributed water content and eliminated bed channeling. Although maximum degradation rates were similar in both conditions, addition of fresh substrate could be used to maintain a constant height in the filter bed without decreasing biofiltration rates."

### Thermophilic mineralization

Matteau and Ramsay conducted studies with radio-labelled toluene and benzene to prove complete mineralization of these compounds to CO<sub>2</sub> and H<sub>2</sub>O. These studies indicated the following:

- after 9 hours, 41.6 percent and 48.4 percent of the initial added toluene and benzene had been recovered as <sup>14</sup>CO<sub>2</sub>
- toluene and benzene mineralization rates were very similar

Matteau and Ramsay maintain that "a direct relation between these data and degradation rates in a reactor cannot be used for scale-up calculations. Mass transfer limitation and incorporation of carbon into biomass can lead to an underestimation of the biodegradation rate in the microcosm. It has been reported that 15 to 40 percent of toluene transformed in groundwater microcosm was incorporated into biomass."

### Conclusion

Researchers conclude that "extending the thermophilic phase of composting using either semi-continuous or extended batch biofiltration technologies helps to maintain high biodegradation rates for toluene. Thermophilic biofiltration is feasible for BTEX-contaminated gases; BTEX biofiltration may be successfully coupled to composting processes."

### Reference

Matteau, Y. and B. Ramsay, "Biofiltration of BTEX Under Thermophilic Conditions," 1997, in *In-Situ and On-Site Bioremediation*, Vol. 5, Battelle Press, 614-424-6393; press@battelle.org.

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UTTU thanks Yanick Matteau for his help on this article.



## Predicting contaminant migration using assimilative capacity, Peclet and Damkoler numbers

Scientists can use computational models to assess the likelihood of a plume reaching a sensitive receptor. In turn, such predictions can help a remediator determine how to apply intrinsic bioremediation at a given site. The predictive models rely on the site assimilative capacity and fate and transport ideas/theories (Cho, Wilson and Weaver, 1997).

### The importance of assimilative capacity in intrinsic bioremediation

Microorganisms catalyze the transfer of electrons from electron donors to electron acceptors to obtain energy for cell production and maintenance. The electron donors are oxidized (oxygen added) while the electron acceptors are reduced. Electron donors at a site are

- indigenous carbon, carbon found within the aquifer, soil or rock material
- fuel hydrocarbons, which can be completely degraded if used as the primary electron donor

Electron acceptors include

- oxygen
- nitrate
- ferric iron
- sulfate
- carbon dioxide

Dissolved oxygen (DO) is used as the first prime electron acceptor; after that, biodegradation becomes anaerobic and the order of preference is nitrate, ferric iron, sulfate and carbon dioxide. Anaerobic biodegradation can occur by denitrification, sulfate reduction, ferric iron reduction or methanogenesis. The process will depend on

- type of electron acceptor present
- pH
- redox potential

Under favorable environmental conditions, manganese reduction could dominate. Typically, anaerobic degradation of BTEX is associated with

- fatty acid accumulation
- methane production
- iron solubilization
- nitrate and sulfate reduction

The dominating processes will depend on environmental conditions and microbial competition. Remediators can determine the assimilative capacity of a site, using stoichiometric relationships of identifying species. For instance they would measure the difference in oxygen, nitrate and sulfate concentrations within and outside of the hydrocarbon plume and the concentrations of ferrous iron and methane within the plume and combine these data to determine assimilative capacity.

### Fate and transport: Peclet and Damkoler numbers

Once remediators estimate a site's assimilative capacity, they can use other data to determine the effect of dilution, dispersion, sorption and hydrolysis on plume migration. The remediator can determine the Peclet number, which is the ratio of diffusive to convective transport. When groundwater flow is low, the number depends on molecular diffusion and tortuosity. "As the velocity increases, the dispersion largely becomes a function of velocity. The Peclet number becomes merely a ratio of dispersivity and the characteristic length" (Cho, Wilson and Weaver, 1997).

The Damkoler number is the ratio of convection to biological degradation. Researchers found that to effectively control a plume expansion, this number would have to be larger than 1 at a given site.

### Application

Researchers investigated one fuel spill site in New York and one in North Carolina. For each site they estimated assimilative capacities, Peclet and Damkoler numbers. They were then able to determine that the New York site required active remediation in addition to natural attenuation, to prevent receptors from being impacted. Using assimilative capacities alone, while ignoring high groundwater flow rates and slow biodegradation rates (Peclet and Damkoler numbers), led to an erroneous conclusion: that is, that the New York site did not require any active remediation.

### Reference

Cho, J.S., Wilson, J.T. and J.W. Weaver, "Criteria for Selection of Intrinsic Bioremediation for Petroleum Hydrocarbon Plumes," 1997, paper from *In-Situ and On-Site Bioremediation*, Vol. 1, Battelle Press, 614-424-6393; press@battelle.org.



## Guidelines for using Fenton's reagent at remedial sites

An innovative technology used to remediate dissolved gasoline constituents in groundwater involves the injection of Fenton's reagent, or hydrogen peroxide/catalyst (*Niedergang, 1997*). Fenton's reagent can oxidize organic compounds into basically harmless substances. In 1997 a sewer and home exploded in the vicinity of a Wisconsin LUST site using this technology. Vapors from the site may have migrated along the sewer line to the house. To prevent future problems, regulators in Wisconsin and Florida developed guidelines for using product reagent. These guidelines are summarized below (*Giesfeldt, 1997*).

The Wisconsin Department of Natural Resources recommends that a thorough site characterization be undertaken to understand the site's hydrogeology and geology (*Giesfeldt, 1997*). The technology should **not** be used in the following situations:

- where measurable free-product or non-aqueous liquids (NAPLs) exist; once these substances are removed, it may be appropriate to use Fenton's reagent; one exception is sites with deep or contained groundwater where free-product is not floating on the groundwater and where vapor migration pathways do not exist, or where the contaminant vapor pressure is low enough not to present a vapor migration risk
- sites with a history of prior contaminant vapor migration to utility trenches, sewers, buildings or other anthropogenic features unless migration is completely controlled
- where the reaction could cause contaminant vapor migration, unless appropriate measures are taken to prevent or control migration; such measures would include:
  - efforts to identify all nearby buildings, USTs, piping and utilities, sewers, permeable soil zones and other anthropogenic or natural features that could act as vapor migration pathways; local governments, "digger's hotline" and utility companies should be contacted; unmapped and old features could be located using remote sensing techniques such as ground-penetrating radar
  - monitoring and control of all potential vapor migration pathways; this may involve using gas probes and combustible gas meters; pressure monitoring can provide useful information, since positive soil gas pressure can be an indicator of vapor migration; temperature monitoring of the subsurface may be advisable when injecting high concentrations of Fenton's reagent under pressure; soil vapor extraction systems are the preferred method to control migration in soil and utility trenches; other methods may be required for vapor control through pipes and sewers,

such as forced air venting; some sites may require excavation

- notification of nearby occupants and evaluation and/or monitoring of nearby buildings

Furthermore, workers should establish exclusion zones around the treated area. Safety measures should include the control of possible ignition sources such as switches, motors and electrical equipment and the use of intrinsically safe equipment and tools (*Giesfeldt, 1997*).

### Injection concerns

Injection of any material, under high enough pressures, can cause fracturing in the subsurface. Wisconsin DNR developed guidelines a few years ago pertaining to injection of "remedial materials". A portion of this guideline is reprinted below (*Didier and others, 1996*).

Prior to approval, any proposal that calls for the use of a remedial infiltration system or injection well shall be reviewed to ensure the following:

- infiltration systems and injection wells are designed to operate effectively
- the infiltration or injection of a substance or a remedial material is required as part of a remedial treatment scheme and that the substance or remedial material introduced will not increase the severity of the existing contamination or permanently impair future use of the affected soil or groundwater
- the type, concentration and/or volume of the infiltrated or injected substance or remedial material is limited to the extent necessary for restoration of the contaminated soil, aquifer or groundwater
- any by-product formed as a result of remediation processes will either be recaptured or further degraded to a point where it does not constitute further risk to either human health or the environment
- environmental contaminants and all infiltrated or injected substances and remedial materials shall be controlled such that cleanup of the contaminated media is achieved and the boundaries of the impacted area are not significantly expanded during, or as a result of, the proposed remedial action
- maximum limits on soil concentration and/or water quality are established for any infiltrated or injected substances or remedial materials that are not covered under a Wisconsin Pollutant Discharge Elimination System (WPDES) permit
- monitoring of remedial activities will be sufficient to verify the performance of the infiltration or injection devices, and the effectiveness of all required contaminant containment measures

Didier and others (*1997*) also emphasize that injections of a substance or remedial material through a well or drillhole solely for the purpose of waste disposal are prohibited. In addition, this guidance also addresses specific requirements for groundwater protection and water supply protection.

### Florida's guidelines

The Florida Department of Environmental Protection (Sole, 1997) also recently issued guidelines that are consistent with Wisconsin's. In addition, because of its warmer climate, Florida DEP has considered volatility concerns. Excerpts from its guidelines follow.

Because petroleum hydrocarbon volatility is temperature sensitive, a significant change in both concentration and distribution of flammable vapors could develop when remediators use an in-situ chemical oxidation method. This dynamic environment is less predictable than the usual cleanup situation, which relies on techniques that do not significantly change the equilibrium of the hydrocarbons' vapor, liquid, and adsorbed phases. The drawback, however, is that more oversight may be needed to maintain control of a remedial situation using Fenton's reagent (Sole, 1997).

Remedial efforts using petroleum/flammable solvents must consider potential fire and explosion hazards. Such efforts must also ensure that appropriate equipment is on site and that appropriate operating procedures are followed. With this in mind, Florida's DEP remedial action plan checklist reminds practitioners to consider the following:

- migration via underground conduits and utilities
- lower explosive level (LEL)
- National Electrical Code practices intended to minimize ignition from electrical devices
- explosion-proof motors
- spark-resistant material for construction of vapor blower housings and impellers
- prevention of furnace explosions with respect to thermal oxidizers

Other general considerations at these sites involve the following:

- the potential for subsurface vapor migration, either through pathways in the aquifer and soil or via anthropogenic conduits, and migration destination
- the presence of free-product in the subsurface, either in underground utilities, or in the form of non-aqueous phase liquids, which could be volatilized by heat from an exothermic chemical reaction; vapor concentrations might then exceed the lower explosive level
- the presence of UST and pipelines that may be near the source of heat generated by chemical oxidation reactions: measures should be taken to prevent structures from exposure to excessive amounts of heat
- identification and control of possible ignition sources (electrical equipment, devices and switches, vehicle exhaust sparks, mechanical sources of sparks, etc.) at potential vapor migration pathway destinations
- vapor concentration monitoring for comparison with lower explosive levels, at the site and/or in conduits and other potential pathways during operation of the chemical oxidation system

- identification of the chemical reactants involved and the amount of heat liberated by these reactions
- monitoring of aquifer and/or vadose temperature during treatment
- identification of the maximum temperature that may be tolerated before shutting down the operation
- control of reactant concentrations and/or quantities as a means of controlling temperature
- the possibility of using a vacuum extraction system to collect vapors at sites where significant volatilization is anticipated
- safety of workers who handle the chemicals

### References

Didier, P., Kopecky, M.J., Krill, B. and B. Baker, "Policy on the Approval of Infiltration Systems and Injection Wells for Soil, Groundwater or Aquifer Remediation," May 7, 1996, Wisconsin DNR Memorandum.

Giesfeldt, M.F., "Repeal of Temporary Suspension on Approval of and General Interim Guidance for the Use of Hydrogen Peroxide/Catalyst Injection (aka Fenton's Reagent)", December 1, 1997, Wisconsin DNR Memorandum.

Niedergang, N.R., "Hydrogen Peroxide/Catalyst Injection," Letter to Mark Giesfeldt, October 27, 1997; U.S. EPA Region 5, 77 West Jackson Boulevard, Chicago, Illinois 60604-3590.

Sole, M., "In-situ Chemical Oxidation Safety Advisory," October 9, 1997; Florida Department of Environmental Protection Memorandum.

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*To order WDNR's "Repeal of Temporary Suspension on Approval of and General Interim Guidance for the Use of Hydrogen Peroxide/Catalyst Injection" (RR-583), write Public Information Requests, Bureau for Remediation and Redevelopment—RR/3, Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.*

*UTTU thanks Gary Edelstein, WDNR, edelsg@dnr.state.wi.us, for his help on this article.*



# Inspector's guide for impressed-current CP systems: checklist, part 1

By Dr. James Myers

The components for an impressed-current cathodic-protection (CP) system used to mitigate corrosion must be properly specified and detailed on engineering drawings. The specified components must be installed according to specifications and engineering drawings. The following checklist will assist the CP system inspector.

## Electrical continuity

If the structure to be cathodically protected is not electrically continuous, the entire structure will not receive protective current. To ensure electrical continuity, the installer may need to install metallic bonds, such as a continuity bond between each joint on bell-and-spigot ductile-iron waterlines. Figure 1 shows a typical method for achieving electrical continuity at a high-resistance/insulated joint. With regard to the structure's continuity, the inspector should record answers to the following questions:

1. Were any electrical-continuity bonds included in the specifications?  
 Yes     No  
*If "no," you may proceed to the next section on electrical isolation.*
2. If electrical-continuity bonds were required, were they installed at each location identified in the specifications?  
 Yes     No

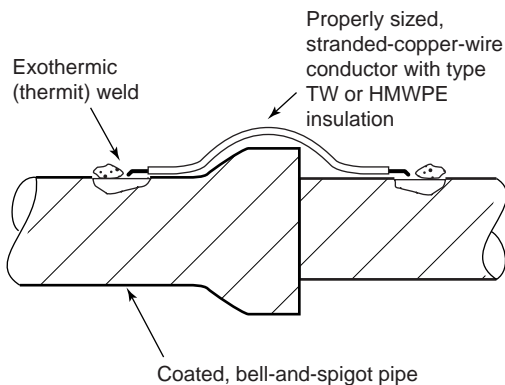


Figure 1. Schematic shows concept for obtaining electrical continuity at a high resistance/insulated connection (from Myers, 1996).

3. Were tests conducted to ensure that the metallic bonds were providing the required electrical continuity?  
 Yes     No
4. Was the required electrical continuity achieved by the metallic bonds?  
 Yes     No
5. Did the copper conductor for the electrical-continuity bonds have the specific number of strands?  
 Yes     No  
 Number of strands \_\_\_\_\_
6. Diameter of the copper conductor \_\_\_\_\_  
 Diameter of each strand \_\_\_\_\_  
 Conductor size (use Table 1) \_\_\_\_\_
7. Did the copper conductor have the size specified?  
 Yes     No
8. What was the type and thickness of the insulation for the copper conductor used to make the electrical-continuity bonds? Table 2 includes information on cables that are often used during the installation of a CP system.  
 Insulation type \_\_\_\_\_ Insulation thickness \_\_\_\_\_
9. Did the insulation type and thickness for the electrical-continuity bonds satisfy specification requirements?  
 Yes     No
10. Did each electrical-continuity bond have the required slack over its length to ensure that it would not be broken during backfilling or other movement?  
 Yes     No

Conductor size AWG/MCM	Diameter, solid conductor, inch <sup>(1)</sup>	Diameter, stranded conductor, inch <sup>(1)</sup>
350 <sup>(2)</sup>	—	0.681
300 <sup>(2)</sup>	—	0.630
250 <sup>(2)</sup>	—	0.575
4/0	0.460	0.528
3/0	0.4096	0.470
2/0	0.3648	0.418
0	0.3249	0.373
1	0.2893	0.332
2	0.2576	0.292
3	0.2294	0.260
4	0.2043	0.232
6	0.1620	0.184
8	0.1285	0.146
10	0.1019	0.116
12	0.0808	0.092
14	0.0641	0.073

(1) Without insulation (2) Thousands of circular mils (MCM)

Table 1. Diameters for copper conductors (from Myers, 1996).

Insulation type	Conductor size (AWG/MCM)	Insulation thickness (in inches)
Thermoplastic waterproof (TW)	10-14	0.030
	8	0.045
	6-2	0.060
	1-4/0	0.080
High molecular weight Polyethylene (HMWPE)	213-500 <sup>(1)</sup>	0.095
	2-8	0.110
	1-4/0	0.125
Dual	250 <sup>(1)</sup>	0.155
	ECTFE <sup>(2)</sup> or PVF <sup>(3)</sup> (primary)	
HMWPE (secondary)		0.065

(1) Thousands of circular mils (MCM) (2) Ethylene monochlorotrifluoroethylene (3) Polyvinylidene fluoride  
 Note: For dual insulation, the primary is the inner insulation; secondary is the outer insulation.

Table 2. Insulation thicknesses for stranded and solid copper conductors (from Myers, 1996).

11. How were the copper conductors for the electrical-continuity bonds attached to the structure?
  - Exothermically welded
  - Welded
  - Brazed
  - Other, identify \_\_\_\_\_
12. If the copper conductors for the electrical-continuity bonds were exothermically welded to the structure, what were the mold-part and weld-metal-part numbers?
 

\_\_\_\_\_
13. Were these numbers used to make the exothermic welds for the continuity bonds on the structure in accordance with the manufacturer's recommendations?
  - Yes
  - No
14. Was each copper-conductor connection on the electrical-continuity bonds tested to ensure that it had the required integrity?
  - Yes
  - No
15. Were the electrical-continuity bond connections on the structure made in accordance with the specifications?
  - Yes
  - No
16. Where copper conductors for electrical-continuity bonds were attached to the structure, what material(s)/coating(s) were applied to the exposed metal?
 

\_\_\_\_\_

\_\_\_\_\_
17. Where copper conductors for electrical-continuity bonds were attached to the structure, did the coatings(s)/material(s) applied to the exposed metal satisfy specification requirements?
  - Yes
  - No

18. Was a non-metallic weld cap (backfill shield) installed at each location where a copper conductor for an electrical-continuity bond was attached to the structure?
  - Yes
  - No
19. Was a non-metallic weld cap required to be installed at each location where a copper conductor for an electrical-continuity bond was attached to the structure?
  - Yes
  - No
20. Did the coating repair at the locations of the copper-conductor attachments to the structure satisfy the requirements of the specifications and/or engineering drawings?
  - Yes
  - No

**Electrical isolation**

The structure to be cathodically protected must be electrically isolated from other underground or submerged metallic structures that might exist in the general area. Otherwise, the shorted structure(s) will receive some of the protective current and the intended structure may not be adequately protected by the impressed current. For example, shorted flanges often allow underground gas and water lines to become electrically continuous with the casings/conduits on underground heat-distribution systems, which adversely affects the CP of the casings/conduits.

With regard to electrical isolation, the inspector should answer the following questions:

1. Was any electrical isolation of the structure to be cathodically protected required by the specifications and/or engineering drawings?
  - Yes
  - No

*If the answer is "no", skip the remainder of this section and proceed to the next section on stray current corrosion.*
2. If electrical isolation was required, was the specified device installed at each of the locations identified in the specifications and/or engineering drawings?
  - Yes
  - No
3. Was a test(s) conducted to ensure that electrical isolation had been achieved at each of the designated locations?
  - Yes
  - No
4. If a test(s) was conducted to ensure that electrical isolation had been achieved at each of the designated locations, list the test(s) and the test results.
 

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_
5. Was the required electrical isolation achieved at each of the locations identified by the specifications?
  - Yes
  - No

## Stray-current corrosion

Stray-current corrosion (sometimes referred to as cathodic interference or "electrolysis") due to the flow of impressed currents through soil/water should be a concern when other (i.e. "foreign") underground metallic structures exist in the vicinity of the structure to be cathodically protected and/or its associated anode bed(s). For example, if a "foreign" underground structure exists between a cathodically protected structure and its associated anode bed(s), the "foreign" structure can be expected to receive (i.e., pick-up) current at some locations and discharge this current at other locations. This must be avoided because corrosion (often at an unacceptably high rate) will almost always occur at those locations on the "foreign" structure where current is discharged.

With regard to stray-current corrosion, the inspector should record answers to the following questions:

1. Did the specifications identify any concerns regarding the stray-current corrosion of other (i.e., "foreign") underground structures in the vicinity of the structure to be cathodically protected or its associated anode bed(s)?

Yes    No

2. What "foreign" structures identified in the specifications might be adversely affected by the cathodic protection system?

\_\_\_\_\_

\_\_\_\_\_

3. Had provisions been made in the specifications for the mitigation of stray-current corrosion on the "foreign" structures identified?

\_\_\_\_\_

\_\_\_\_\_

4. Was there reason to believe that underground structures, not identified in the specifications and which might be adversely affected by a stray-current corrosion, could exist in the vicinity of the structure to be cathodically protected and its associated anode bed(s)?

Yes    No   Other "foreign" structures \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

5. Was the individual/agency/organization responsible for the cathodic protection design and its installation advised regarding the existence of these other "foreign" structures that might be adversely affected by stray-current corrosion resulting from the installation of the CP system?

Yes    No

## Reference

Myers, J., "Acceptable criteria for impressed-current-type, cathodic protection systems: an inspector's guide/checklist for components and their installation," 1996, J. Myers, 4198 Merlyn Drive, Franklin, OH 45005.



# 1998 national RNA survey spreadsheet

by Mike Martinson

The data on the following pages were collected and compiled in January and February 1998 during a survey on remediation by natural attenuation. Some of the results were reported in *UTTU's* May/June 1998 newsletter in the article "1998 national RNA survey."

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## KEY to spreadsheet abbreviations

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alt	alternate
conc	concentrations
consec	consecutive
CAP	corrective action plan
dec	decreasing
dn	down
dpd	depends
dvlp	developing
eval	evaluation
GW	groundwater
GW-D	groundwater suitable for drinking
guid	guidance
HAL	health advisory limit
HRL	health risk limits
inst	institutional
max	maximum
mdl	model
mon	monitoring
NR	not regulated
NS	no specifics
pl	planning
plm	plume
POC	point of compliance
pos	possible
pro	proposed
qtrs	quarters(ly)
RAP	remedial action plan
RBCA	risk-based corrective action
r/e asmt	risk/exposure assessment
ss	site-specific
srce	source
std(s)	standard(s)
SSTL	site-specific target levels
thrsh	threshold
TEHC	total extractable hydrocarbons
vel	velocity

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*UTTU thanks Dr. Myers for sending us this article.*

State	Acceptable cleanup remedy		Contingency plan	State established			Type of cleanup levels	
	W/other tech	Sole	Before RNA	Statutes	Regs	Guidance	Generic	Site-specific
AL	y	y	n	n	n	y	y	y
AK	y	y	n	n	n	n	y; pro	y; pro
AZ	y	y	n	n	n	n	y; GW	n; GW
AR	y	y	n	n	n	n	y	y
CA	y	y; ss	n	n	n	n		y
CO	y	y	n	n	n	n	y	y
CT	y	y; ss	y	n	y	n	y	y
DE	y	y	n	n	y	y	y	y
DC	y	n	y	n	n	n	n	y
FL	y	y	n	y	y	pos	y	y
GA	y	y	n	n	y	y	y; thrsh values	y; alt thrsh/alt conc
HI	y; ss	y; ss	y; w/mon only	n	n	dvlp	y; default	y; soil, not GW
ID	y	y	y; in CAP	n	n	y	y	y
IL	y	n	y	n	n	y	y	y
IN	y	y	y; CAP no detailed	n	n	n	y	y; low-level/contained
IA	y	y	n	y	y	y	y	y
KS	y	n	y	In '98-'99	n	n	y	y
KY	y	y	y	n	y	y	n	y
LA	y	y	n	n	n	pl	n-current; y-w/RBCA	y
ME	y	y	n	n	n	n	y	y
MD	y	y	n	n	n	n	n	y
MA	y	y	n	n	n	pl	y; Tier I	y; Tiers II/III
MI	y	y	ss	n	n	y	y	y
MN	y	y	n	y	n	y	y	y
MS	y	y	y	n	n	pl	y	y; w/RBCA
MO	y	n	y	n	n	n	y	y
MT	y	y	n	n	n	n	n	y
NE	y	y	n	n	n	pl	y	pos
NV	y	y	y; afterward	n	n	n	y	y; ss
NH	y	y	y; afterward	n	pl	y	y	n
NJ	y	y	n	n	y	y	y	n; w/inst controls
NM	y	y; not always	y	n	n	n	y; numeric	soil only; GW driver
NY	y	n	n	n	n	pl	n; GW stds	n; r/e assmt
NC	y	y	n	y	y	y	y	y
ND	y	y	n	n	n	n	n	y
OH	y	y	n; re-propose alt	n	n	pl	y	y
OK	y	y	n; not typical	n	n	pos in '98	y; re: action levels	y
OR	y	y; mon=NA	n	n	n	pl	y	y
PA	y	y	n; in CAP	n	n	n	y	y
RI	y	y	n	n	n	n	y; GW-D	y; GW-D
SC	y	y	n	n	y	y	y; Tier I RBSL	y; Tier II SSTLs
SD	y	n	n	n	n	pl	y	y
TN	y	y	n	n	y	y	y	y
TX	y	y	n	n	n	y	y	y
UT	y	y	y	n	n	pl	y	y; ss; Tier II in '98
VT	y	y	n	n	n	y	y	y
VA	y	y	n	n	n	n	n	y
WA	y	y	ss	n	n	pos in '98	y	y
WV	y; post-rem	n	n	n	n	n	y	y
WI	y	y	n	n	y	y	y	y; soil
WY	y	n; ss pos	y; in RAP	n	n	pl	y	y

State	Natural attenuation requirements				
	Site char.	Source control needed	Free-phase removal	Risk assessment needed	Monitoring needed
AL	y	y	y	y	y
AK	y	y	y	y when target level modified	y
AZ	y	y	y	y; less formal	y
AR	y	y	y	y	y
CA	y	y	y		
CO	y	y	y	ss	y
CT	y	y	y	ss	y
DE	y	y	y	n	y
DC	y	y	y	y	y
FL	y	y	y	ss	y
GA	y	n always preferred	y	y	y
HI	y		y	ss	y
ID	y	y	y	y	y
IL	y	y	y	y	y
IN	y	y; where practical	y; where practical	n; informal-new RBCA	y
IA	y	y; dpd on srce mon	y	y	y
KS	y	y	y	not yet; eval exps pthwys	y
KY	y	y	y	optional	y
LA	y	y	y	n; new RBCA has RA	y
ME	y	y	y	n	y
MD	y	ss	y	within existing program	y
MA	y	y	y; <0.5 inch	y	y
MI	y	y	y	y	y
MN	y	ss	y	y	y
MS	y	y	y	y	y
MO	y	y	y	y; MDNR-type	y
MT	y	y	y	not typically	y
NE	y	n	y	dvlp	y
NV	y	y	y	built into stds	y
NH	y	y	y	y; soil only	y
NJ	y	y	y	n; ss	y
NM	y	y	y	n; F&T to receptors	y
NY	y	y	y	y; pos rem prior to RA	y
NC	y	y	y	y	y
ND	y	y	y	n; not formal	y
OH	y	y	y	sometimes	y
OK	y	y	y; water elev. eval	y	y
OR	y; rules	y; rules	y; rules	In '96 interim RBCA guid	y; mon guid
PA	y	y	y; POC<0.01ft meet stds	ss; RA need	y
RI	y	y	y	y; informal	y
SC	y	y	y	y	y
SD	y	y	y	y	y
TN	y	y	y	y	y
TX	y	n; preferred	y; ss	RBCA	y
UT	y	y	y	sometimes	sometimes
VT	y	y; not always	y	n; sometimes	y
VA	y	address soil saturation	y; technically feasible	y	n risk/closed; n mon
WA	y	y	y	n; informal	y
WV	y	y	y	y	y
WI	y	y	y	receptor risk eval	y
WY	y	y	y	y	y

State	Natural attenuation monitoring				
	Min# mon pts	# Pts.	Locations	Duration	Frequency: events/yr
AL	y	3	up/plm/dn	1.25 yrs (min); ss	1-4 /yr
AK	n	ss	ss	ss	1-4 /yr; cleanup goals
AZ	y	3	srce & 2 dn	<stds; ss	ss by CAP; 2-4 /yr -> 1 /yr
AR	n		plm/dn	establish trend; 2 yrs guid	Varies; 4 /yr (typ)
CA	n	ss		ss	ss
CO	y	> 2	up/dn	1 yr (min)	4 /yr
CT	n			to cleanup levels	Varies; ss
DE	n		ss	1 yr min.	4 /yr
DC	n	ss	ss	ss	2-4 /yr
FL	y	2	srce/dn	to MCLs or NFA w/restrictions	4 /yr, then variable
GA	n	ss	srce/dn-centerline/mdpt	4 consec qtrs; ss	4 /yr for about 2 yrs
HI	ss	ss	ss	2yr post-rem maintain<action levels	prefer 2-4 /year
ID	n	ss	ss	ss	ss
IL	y	4	1 up/3 dn	no set period	4 /yr
IN	ss	4 min; ss	2 srce/2 permtr min	7 yrs qtrly/3 yrs w/degradation eval	4 /yr
IA	y	3	srce/plm/POC	not specified; until <goal	1 /yr
KS	ss	ss	plm/dn	to <KS action levels	4 /yr for 2 yrs
KY	ss	ss	ss	4 consc clean qtrs	4 /yr
LA	y	ss	ss	4 consc qtrs<ss levels	4 /yr
ME	n	ss	ss	ss	ss
MD	ss	ss	ss	ss	ss
MA	n	ss	n	1 yr mon guid	4 /yr guid
MI	n	ss	plm	4 qtrs, then establish trend	2-4 /yr
MN	n	ss	ss	6 qtrs min<HRLs/plm <200ft	4 /yr initially; ss
MS	y	5	plm/up/dn/defining	1 yr min	3 /yr typically
MO	n		ss	1-5 yrs	1-4 /yr
MT	ss	ss	plm/up/outside	1 yr min/2-3 preferred	1-4 /yr
NE	n	ss		ss	ss; 2-4 /yr
NV	n	ss	ss	ss; GW 1 yr post-closure mon	ss/12 /yr max
NH	n	ss	ss	<goal for 2 qtrs/dec trend	2 /yr
NJ	y	3	ss	ss	ss
NM	n	ss	ss	to<GW stds or alt std	1-4 /yr
NY	n	ss	plm centerline	ss; plm shrink/diminish	2-4 /yr/GW vel depend
NC	ss	ss	ss	to <GW stds	1-4 /yr; ss based on risk
ND	y	3	property boundaries	2 yrs min	2-4 /yr
OH	y	3	plm/up/dn	1 yr min	ss
OK	y	ss	plm/dn; ss	ss	4/yr; O&M pos; monthly
OR	y	3	up/dn/extent	1 yr min.	4 /yr; then ss
PA	n	ss	ss	2 yrs min<std/ss/post-rem mon	4 /yr/post-rem ss
RI	n	3 typ?	plm/pl-edge/dn	ss; generally 1 yr min	2-4 /yr
SC	n	ss		2 yr max	ss
SD	y	3	1 dn min	1 yr min	4 /yr
TN	y	4	srce/up/dn	low-2 yrs/high>2 yrs	2 /yr
TX	n	ss	mon plm extent	stable/declining plm<SSTLs	4 /yr
UT	n	ss	ss	ss; Proj. manager's call	4 /yr
VT	n	4; ss	general 1 up/3 dn	to<GW stds	4 to 2 to 1 /yr
VA	n	ss	ss	1 yr usually	4 /yr
WA	n	ss	ss	<cleanup objectives	ss
WV	n	ss	ss	ss	4 /yr
WI	n	ss	ss; plm/up/dn	flexible	2-4 /yr
WY	y	6	plm/up/dn	<stds	4 /yr

State	Natural attenuation an acceptable remedy				MTBE enforcement in GW [ $\mu\text{g/L}$ ]
	Gasoline/BTEX	Diesel/PAHs	Fuel additives	MTBE	
AL	y	y	y	MTBE; ss	(20-40) <sup>(a)</sup>
AK	y	y	n	MTBE; not present	no chg in '98
AZ	y	y	y	MTBE; new sites mon/not enforced	EPA-driver <sup>(b)</sup>
AR	y	y		ss; EPA as guide	ss
CA	y	ss		ss	35/15
CO	y	y	pos	MTBE; ss	ss
CT	y	y	y	ss	100
DE	y	y	n		(30) <sup>(a)</sup>
DC	y; ss	y; ss	y	MTBE; no experience	NR
FL	y	y	y	y	35/350
GA	y	y	NR	MTBE; ss	EPA-driver <sup>(b)</sup>
HI	y	y	NR	MTBE; no NA policy	(20-40) <sup>(a)</sup>
ID	y	y	n/ss	MTBE; ss	RBSL-52
IL	y	n	n	MTBE; not evaluated	230
IN	y	y	y	MTBE; ss risk eval	EPA-driver <sup>(b)</sup>
IA	y	TEHC	y	NR	NR
KS	y	y		guid MTBE goal; ss	20
KY	y	y	NR	NR	NR
LA	y	y; w/RBCA	n	MTBE; testing since 7/97	NR
ME	y	y	no ref	MTBE; ss	25/50
MD	y	y	y	MTBE; ss	50; ss
MA	y	y	y; ss	MTBE; ss	70/50,000
MI	y	ss	n	MTBE; ss	240 (under eval-'98)
MN	y	y; ss w/PAHs	no ref	MTBE; NR	NR
MS	y	y	not sampled	MTBE; probably not	EPA-driver <sup>(b)</sup>
MO	y	y	y	y; MTBE	40/400
MT	y	y	y	MTBE; ss	(20-40) <sup>(a)</sup>
NE	y	y	NR	MTBE regs w/RBCA	projected for '99
NV	y	y	no ref	MTBE; ss; not smpl	EPA-driver <sup>(b)</sup>
NH	y	y	y	MTBE; ss	700
NJ	y; ss	y; ss w/PAHs		MTBE; ss	70
NM	y	y; ss	y	MTBE; maybe yes/no/ss	100; ss
NY	ss	ss	n	MTBE; probably not viable option	50
NC	y	y	y	If MTBE risk OK; w/ 70% sites	70; since 1/98
ND	y	y	n	MTBE; NR	no change in '98
OH	y	y	not tested	MTBE; NR	pos in '98
OK	y	y	y	MTBE; ss	likely in '98
OR	y	y	y	MTBE; risk in RBCA guid	180; since '96
PA	y	y		MTBE; ss	20 (HAL)
RI	y	y	y	MTBE; NA ok	GW-D, 40
SC	y	y	n	MTBE; NA ok	40
SD	y	y	y	MTBE; nothing formal	pos in '98
TN	y	y		Include in total HC analysis	NR
TX	y	y	smpl then dn	MTBE; ss	EPA-driver <sup>(b)</sup>
UT	y	y	y	MTBE; ss	200/Tier I
VT	y	y	y	MTBE; yes	40
VA	y	y	y	MTBE; no effective treatment	ss
WA	y; pos	y; pos		MTBE; can be	(20) <sup>(a)</sup>
WV	n	n	n	MTBE; NR	no change pl
WI	y	y; ss	y	MTBE; reduce GW conc/mass-dilute	60/12
WY	y	y	y	MTBE; pos	200

(a) possible MTBE '98 regulations value/range in parenthesis

(b) EPA health advisory/MCL driving state regulation enactment

State	Natural attenuation evidence required				
	Plm (stable or shrinking)	Decreasing concentrations	Geochemical indicators	List geochemical indicators	Other parameters
AL	y	y	y	DO, redox, Fe <sup>2+</sup> , NO <sub>3</sub> , SO <sub>4</sub>	pH, temp, conductivity, CH <sub>4</sub> , CO <sub>2</sub>
AK	y	y	y	DO, Fe, SO <sub>4</sub>	conductivity
AZ	y	y	y	Chevron '95 Intrinsic Bio approach	NS
AR	y	y	ss	NS	NS
CA	y	y	ss	NS	NS
CO	y	y	n	NS	NS
CT	y	y	y	NS	
DE	y	y	n	NS	mdl; BioplM/Bioscreen
DC	y	y	y	NS	NS
FL	y	y	ss	potential parameter & F&T models	
GA	y; models	n; consistent w/predict	n	NS; validate model inputs	assist w/mdl predictions
HI	no NA policy	no NA policy	ss	ss	
ID	y	y	n	NR	NS
IL	y	y	y	DO	NS
IN	y	y	n	Direct eval degradation rates	NS
IA	y	y	n	NS	NS
KS	y; not always	y; not always	coming w/new RBCA	DO, redox, NO <sub>3</sub> , TOC	NS
KY	y	y	y	DO, et al – guid pp. 41-56	In guid
LA	y	y	n	NS	NS
ME	y	y	y	DO, redox, NO <sub>3</sub> , Fe, CH <sub>4</sub> , alkalinity	well purge: conductivity, pH, temp
MD	y	y	ss; RBCA guid address	NS	NS
MA	y	y	n	NS; guid in '98	ss; guidance for well purge
MI	y	y	not always	DO, redox, etc	conductivity, pH, etc
MN	y	y	y	DO, NO <sub>3</sub> , Fe, SO <sub>4</sub> , H <sub>2</sub> S, HS	temp, pH
MS	y	y	considering	NS	NS
MO	y	y	n	NS	NS
MT	y	y	y; ss	NS	NS
NE	No formal method		NS		
NV	y	y	y	NS	NS
NH	y	y	y; under policy	interim: Fe, Mn, NO <sub>3</sub> , SO <sub>4</sub> , DO	pH, alkalinity
NJ	y; NFA when plm decr	y	y	DO, microbes #s, degrad. products	
NM	y	y; pos	y; generally require	DO, redox, NO <sub>3</sub> , SO <sub>4</sub> , Fe, CH <sub>4</sub> , TDS	cond, alkalinity, trimethylbenzene
NY	y	y	n; ss	NS	NS
NC	preferred; mdl Bioscreen	preferred; models	y; initial demo enough	DO, NO <sub>3</sub> , Fe, SO <sub>4</sub>	ss; well purge use
ND	y	y	n	NS	NS
OH	y	y	y; ss	DO, etc; ss	pH, etc; ss
OK	y	y	n; ss	NS	NS
OR	y	y	n	dvlp in '98	
PA	y;<inc trend for std	n; n inc>std@ F&T mdl	n	ss	ss
RI	y	y	n; overkill	DO for active biodegradation?	NS
SC	y	y	y; required	DO, NO <sub>3</sub> , SO <sub>4</sub> , ss	routine well purge
SD	y	y	n	NS; maybe DO for '98	NS
TN	y	n	n	NS	NS
TX	y	y	y	DO, redox, SO <sub>4</sub> , NO <sub>3</sub> , Fe	NS
UT	y	y	n	NS; ss	NS
VT	y	y	y	DO, CH <sub>4</sub> , SO <sub>4</sub> , Fe, chromatograms	NS
VA	y	y	not statutorily; ss	NS	NS
WA	shrink	Y	y	NS; ss	
WV	y; possibility	y; pos	n	NS	NS
WI	y; shrink for closure	y; projection to regs	y	DO, NO <sub>3</sub> , Fe <sup>2+</sup> , SO <sub>4</sub>	NS
WY	y	y	y	ss	NA feasibility/testing microbes present

UTTU thanks Mike Martinson, Delta Environmental Inc., for contributing this spreadsheet. Contact him at 612-697-5156. emikema@deltaenv.com.



## Information sources

### Publications

New publications from CRC Press include

*Groundwater Geochemistry: Fundamentals and Applications to Contamination*

*Quantitative Solutions in Hydrogeology and Groundwater Modeling*

*Practical Environmental Bioremediation: The Field Guide Natural Attenuation*

For more information call CRC Press at 800-272-7737, fax them at 800-374-3401, visit their website at <http://www.crcpress.com> or e-mail them at [orders@crcpress.com](mailto:orders@crcpress.com).

For the 1998 ASTM publications catalog, call 610-832-9585, fax 610-832-9555, e-mail [service@astm.org](mailto:service@astm.org) or visit the website <http://www.astm.org>.

### Websites

<http://www.agu.org>: American Geophysical Union homepage

<http://www.geoafrica.co.za>: GeoAfrica Earth Science Resource Directory

<http://www.fws.gov/>: U.S. Fish and Wildlife Service

<http://eos.ubc.ca/>: University of British Columbia Department of Earth and Ocean Sciences

<http://www.dsa.unipr.it/phytonet/>: phytoremediation electronic newsgroup network

<http://www.wef.org>: Water Environment Federation

<http://www.scisoftware.com>: information on QuickLog, QuickCross, Fence, QuickSoil, WinLog and EQWin Geology; for a free catalog, e-mail: [tech@gwsoftware.com](mailto:tech@gwsoftware.com)

<http://www.wvpointstar.com>: descriptions of statistical analysis software including graphs, parametric methods, non-parametric methods and distribution testing; also call 513-755-7624

<http://www.science.uottawa.ca/~eih/>: site for book, "Environmental Isotopes in Hydrogeology"

<http://www.respirometer.com>: information on an on-line waste water respirometer

<http://www.gbatech.com>: information on Well Logger, a computer application for drafting soil boring logs and well construction diagrams

<http://www.ibmcpug.co.uk/~bedrock/gsd/>: boring logs listings

<http://www.scisoftware.com>: general information on software

<http://www.rtdf.org>: Remediation Technology Development Forum homepage

<http://www.frtr.gov>: federal remediation technologies roundtable homepage

<http://www.gwrtac.org>: information on costs and treatments of contaminated groundwater

<http://www.remedial.com>: remedial information management system that contains a database of over 800 remedial technologies

<http://www.elmengineering.com>: fingerprinting information

<http://alpha.wcoil.com:80/~waterdig/index.html>: contains information on "iron bacteria" and other forms of biofouling phenomena

<http://wwwhost.cc.utexas.edu/ftp/pub/grg/gcraft/notes/gps/gps.html>: information on GPS, ground positioning system

<http://water.usgs.gov/>: for general information on water

<http://www.ngs.noaa.gov/>: for datum and benchmark data

<http://water.usgs.gov/software/> (also <http://h2o.usgs.gov/software/>): offer electronic retrieval of SUTRA-GUI, U.S.G.S. code for saturated or unsaturated groundwater flow and solute or energy transport, MODFLOW and PHREEQC, the latter which can calculate activity coefficients

<http://www.osha.igs.net/~gaea>: contains POLLUTEv6 and MIGRATEv9, which can model contaminant transport through fractured soils and rock

<http://www.mindspring.com/~rbwinston/rbwinsto.htm>: for groundwater modeling programs (search for "pump" for pump test programs)

<http://www.mindspring.com/~rbwinston/modhelp.htm>: for MODFLOW help

<http://ourworld.compuserve.com/homepages/terradat> contains case studies related to geophysical methods in groundwater contamination

<http://www.ozemail.com.au/~wcomp/>: contains PEST, which interfaces with existing computer models and "takes control" of the model

<http://www.RGSL-geosciences.com>: contains topics related to geophysics

<http://www.env-sol.com>: for information on U.S. code of federal regulations

<http://www.kencon.com>: for a free evaluation of the RBSSL Power Tool Kit

<http://www.amtec.com>: for a free evaluation of Tecplot 7

<http://www.regenesis.com>: for information on oxygen release compound, ORC

http://www.job-sites.com/she/shejobs.htm: for the Safety, Health and Environmental Job-site

http://clu-in.com: for subscribing to TechDirect

http://clu-in.com/techpubs.htm: to view the report, "Phytoremediation of TCE in Groundwater Using Populus"

http://www.epa.gov.swerust1/mtbe/mtbepubs.htm: for MTBE fact sheets, or call 800-490-9198

http://www.westgov.org/itrc/: for the report, "Multi-State Evaluation of the Site Characterization and Analysis Penetrometer System"

The Chemical Information Online System contains databases on chemicals; in particular, two databases are:

- Biodegradation of substances in the environment
- Biodegradation literature references

For more information, contact Mary Ann Hoffman, 800-247-8737 or e-mail her at cissupport@oxmol.com.

To subscribe to HYDROLOGY, send email to majordomo@eng.monash.edu.au with the text message: SUBSCRIBE HYDROLOGY or UNSUBSCRIBE HYDROLOGY

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For a free trial subscription to the Daily Regulatory Reporter, send a request to jrboyer@dakotacg.com.

To join the following sci.geo newsgroups, go to the directory of listservs located on the Groundwater.com web site, http://www.groundwater.com/lists.html.

- sci.geo.fluids
- sci.geo.geology
- sci.geo.rivers+lakes
- sci.geo.satellite-nav

To join a forum on contaminated land, send an e-mail to MAILBASE@MAILBASE.AC.UK and use the message: subscribe focol First\_Name Surname

**UTTU obtained many of these sites and other information from the Groundwater Mailing List (http://groundwater.com) and Bioremediation Discussion Group (http://biogroup.gzea.com).**

**UTTU thanks the moderators from these groups — Ken Bannister of Groundwater.com and Richard Schaffner of the Biogroup — for allowing us to use this information.**

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