

## **Considerations Regarding Application of Permanganate for Remedies in Tennessee**

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### **Introduction:**

In Tennessee the Drycleaner Environmental Response Program (DCERP) is the regulating authority over the cleanup of drycleaning facilities. Participation in the environmental restoration side of DCERP is voluntary, but advantages to applicants include liability protection and limits on applicant cost. Since DCERP's inception in 1996, the program has successfully investigated or is in the process of completing investigation at more than 75 sites. Many of our more mature sites are in the process of remediation using a variety of technologies. This paper presents our experience using In-situ Chemical Oxidation as a remediation technology.

Generally, in Tennessee an impacted soil source is usually required to be addressed prior to remediating groundwater. Following any soil remediation, ground water (saturated zone) interim actions are considered. Chemical Oxidation is a proven remediation method that is often used to address chlorinated solvent-impacted ground water. Through the oxidation actions electrons are transferred from an atom, ion or compound to destroy organic contaminants. This technology has been employed at several DCERP sites in all three of the state's grand geologic regions to inject oxidant, typically a solution of sodium permanganate, into the subsurface. The delivery technique commonly employed for remediation is in-situ (in-place) chemical oxidation. This process will remediate organic contaminants that are present in ground water, contaminants that are sorbed onto aquifer materials, or even free phase product. In this paper we will share our experiences with injection applications. The information should not be regarded as complete. We provide this as a starting point and suggest you conduct additional research into the delivery methods, cost, equipment, chemical handling and health and safety etc. that are appropriate for your region.

### **Overview:**

DCERP clean-up efforts in Tennessee currently uses a phased approach and initially involve identifying the source zone and impacted media and conducting appropriate interim remediation activity. In simplistic terms, this means completing the site characterization/investigation to collect the information necessary to support source zone remediation. When the characterization is complete, site geology, soil type, soil material and hydraulic properties will have been determined, ground water depth, flow direction and gradient will be known and analytical parameter concentration ranges will be known. Aside from soil and ground water constituent concentrations, other useful parameters include soil oxidant demand, total organic carbon and biological census determinations. As the details specific to the site become known and the site characterization is completed, the site remediation can be evaluated and planned. One key to the process is identifying the location and extent of mass source areas in both the vadose and saturated zones and in determining the extent of ground water impacts. The extent that source areas are identified and defined will dictate the success of future remedial site action to facilitate the clean up.

## Tennessee Geology

Besides the general difficulty of cleaning up spilled PCE, site remediation in Tennessee is challenging because of the state's complex geology. Depending on locale several geologic environments may be encountered. Some common Tennessee situations are summarized below.

Middle Tennessee geological conditions commonly include low permeability clay and silt overlying Paleozoic age carbonate bedrock. In areas where karst is highly developed the geology may exhibit pinnacle and cutter features. With pinnacle and cutter geology, the subsurface bedrock topography may vary considerably over short horizontal distances. For example, limited thickness soil and rock fragment intervals will overlie shallow depth bedrock pinnacles in some areas, while in other areas thicker soil intervals are encountered, soils will contain increasing size and number of rock pieces with increasing depth. These thicker soils likely represent collapse features. Rock floaters (boulders surrounded by soil matrix) may also be encountered while drilling and may hinder and confuse the site interpretation if these erratic are assumed to represent the top-of-bedrock. These variations in site geology will probably impact contaminant distribution and will also make remediation more difficult. The location of the water table will also impact site contamination distribution. In Tennessee, karst regimes may have dry/unsaturated soils that overlie rock, ground water may be encountered at the soil/bedrock interface or the surficial water table may be present in soil and be feet or tens of feet thick. In karst limestone bedrock areas where soils are dry, if first ground water is encountered in bedrock, ground water movement will likely be associated with solution voids, cavities and fractures. Limestone and karst is not limited to middle Tennessee, but may be also found throughout east Tennessee.

In the western third of Tennessee, significant thicknesses of Mesozoic and Cenozoic age sediments that were deposited in a structurally active embayment are present. This deposition event produced sediments that are hundreds of feet or more thick. These materials are interbedded marine-origin sands and gravels and associated fine-grained sediments. Terrestrial origin sands may also be represented in these sediments. Experience shows that near-surface and surface deposits are typically fine-grained, low permeability aeolian origin inter-bedded silts and clays or fluvial origin materials. The embayment materials grade from silts, clays, and silty sandy clays to sands and gravel units that represent the drinking water supply source for this area. Around Memphis the water-bearing units that are employed as a water resource are encountered at depths of 200 to 300 feet or greater below land surface. In the Memphis area clay aquitard sequences typically cap and protect the underlying water-bearing sands. In some areas (called windows) the clay cover is not present or is only thin which results in the aquifer unit potentially being unprotected. In areas to the east away from Memphis region, the sediments that overlie the water-bearing sands are thinner or absent. For example around Jackson the upper portion of the top of the first water bearing sand is shallow (10-15 feet below grade) and water wells in this area are commonly completed to depths of 150 feet. In west Tennessee, surficial ground water is usually first encountered anywhere from between 10 and 35 feet (shallow) below land surface to depths of between 60 and 100 feet (deeper) below land surface. This surficial ground water is commonly not employed as drinking water, and typically only deeper aquifer units (greater than 200 to 300-foot depth) are used as a water resource. At some west Tennessee

locations, a water-bearing interval may be encountered at shallow depth (from approximately 5 to 20 feet) prior to encountering the upper regional aquifer zone. These water intervals are interpreted to be perched water and are commonly associated with an underlying low permeability unit or some manmade structure such as a utility line or a building foundation. Typically these perched zones have a limited on-site aerial extent or may only be present seasonally.

East Tennessee geology consists predominately of Precambrian, Cambrian, and Ordovician folded and faulted igneous, metamorphic and sedimentary bedrock sequences. Historical orogenic mountain building resulted in rock uplift and movement. Through weathering and erosion a thin to thick mantle of soil developed on these under-lying rock units. In this region of Tennessee, we may encounter from 5 feet up to 75 feet or more of soil overlying the local bedrock. Soils are commonly low permeability clays and silts mixed with variable proportions of the underlying rock type. Depending on location, these soils may yield limited amounts of ground water, but typically are not used as a drinking water source. Water yield commonly is sufficient for sampling purposes. If the overlying soils are dry, ground water may be encountered at the soil bedrock interface or in rock. Bedrock yield is difficult to predict and is site-specific. In some areas, wells may produce a sufficient yield to be used as a supply source, but commonly well yield will not be sustainable to allow use as a water supply. Higher yield bedrock wells are often associated with water bearing fractures that may produce sufficient water quality and quantity to be locally used as a water supply.

#### Site Soil Considerations

Based on experience, it is first beneficial to address soil impacts as these may represent a source mass. Any identified source mass that is untreated has the potential to leach and contaminate ground water. Until these chronic problems are addressed, impacted groundwater will continue to limit site remediation. For this reason in Tennessee when we have known impacts to both soil and ground water media we usually manage these problems as separate remediation efforts that we describe as Interim Actions. Based on the soil mass accessibility, the primary soil interim action usually involves excavating and removing the mass. Depending on the site characteristics, open soil excavation pits are often completed with infiltration galleries prior to backfill for use in future site remediation. Although there is some cost associated with the gallery, when the excavation pit is open, we feel that these costs are justified compared to the relatively higher cost or time and site disruption that would be required to put the gallery in at a later date. Injection galleries can be very simple devices that generally are very inexpensive in terms of raw materials.

#### Related Considerations

Given that many sites requiring remediation are still operating as drycleaners or other businesses and that source zones are often located within the floor plan of the existing building, it must first be determined the extent to which any indoor drilling or excavation will be tolerated by the property owner and/or the tenant and structural constraints. This and other site constraints such as nearby underground utilities, geologic and hydrologic conditions and the presence of other contaminants will all factor into the best method for implementing chemical oxidation. However,

it has been shown that without properly identifying and remediating the source area, in-situ chemical oxidation may initially lower contaminant concentrations, but they will eventually rebound once the permanganate has dissipated. Since multiple source areas are potentially located within the structure, often in the vicinity of the dry cleaning machines, we have utilized varying injection delivery methods.

#### In-Situ Chemical Oxidation:

At the typical DCERP site, a permanganate solution will be introduced to ground water through one or more delivery methods, including permanent wells/injection points, infiltration galleries, or direct push boreholes. When an oxidant like permanganate is used for site remediation, the remediation success will be dependent on our ability to deliver the oxidant so that it contacts the target contaminant. For this reason, it is critical to first identify the source area on the subject property with a high level of confidence. While it may be more costly during the investigation phase to extensively investigate potential source areas, it is far more costly to implement a remedial plan that is based upon incorrect source area data.

Oxidants work by overcoming both the naturally occurring organic matter that is associated with the remediation target and by oxidizing the contaminant. This means that the oxidant is non-selective and will react not only with the contaminant, but also with soil materials that is readily oxidized. The oxidant is also non-selective regarding the contaminant. Not only dry clean solvents like PCE will be consumed, but other carbon constituents have an affinity for oxidation. Therefore, we need to know in advance if other constituents are present on-site, otherwise treatment using permanganate may not have the anticipated results. As the oxidant mixes with and encounters the contaminant, the contaminant breaks down into intermediate products plus carbon dioxide and water. For this reason, it is important to first sample and to analyze representative soils within the treatment zone for Natural Oxygen Demand (NOD) to determine whether oxidation using permanganate is a viable and cost effective means of remediation for a given site. We predominately use sodium permanganate ( $\text{NaMnO}_4$ , liquid) and less often potassium permanganate ( $\text{KMnO}_4$ , solid). Liquid sodium permanganate is a 40% concentration product while solid potassium permanganate is a 100% concentration product. Liquid permanganate is typically diluted to 10% or less while solid permanganate is diluted to 2 to 4% prior to injection. Research by Carus Chemical indicates that  $\text{KMnO}_4$  has fewer radiation concerns than grocery store salt substitutes (potassium chloride).

While the use of sodium permanganate typically involves greater care due to the higher safety risks posed by the chemical, it is also easier to mix with water and inject into the subsurface. Sodium permanganate is heavier than water, diluted to 10% solution it has a specific gravity of approximately 1.1 and PCE has a specific gravity of 1.6, and therefore it is logical to assume that when it is injected into the source zone, the permanganate should eventually migrate along the same path as the contamination.

#### Injection Methods

With regard to the injection methods, we have employed permanent wells/injection points, infiltration galleries, and direct push boreholes. In some cases, it may be applicable to utilize more than one method for a given site.

Based upon our experience, the direct push injection method has been shown to be relatively difficult due to the high density of the local soils. Fluids under pressure will always follow the path of least resistance, and in dense clays using direct push, this path may be the joints between the drilling rods or the borehole itself (i.e. permanganate rising up to the surface). If injecting at relatively high pressures, this can lead to significant site safety issues in addition to increasing the likelihood of staining the surrounding pavement, structures, and/or vehicles with permanganate. When installing permanent injection wells, the screened portion of any injection well should be carefully selected to maximize the injection interval, and extra attention should be paid to properly sealing the wells above the screened interval.

Injection galleries can be constructed with standard well materials, such as 2" screened PVC pipe and are generally more cost effective than drilling injection wells unless significant re-paving is involved. Care should be taken when backfilling around any screened pipe, as slotted screen is more fragile than standard pipe. One should also consider the addition of multiple inlets to a gallery in the event that the primary injection inlet becomes clogged or damaged. System installers should consider using hydrated grout or bentonite powder to seal the upper portions of injection wells or galleries to reduce the possibility of breakthrough during the injection activities. Another means of reducing spills is by using quick-connect fittings for the injection lines and well/gallery connections. Even when injecting at less than 50 psi, consultants have witnessed permanganate surfacing as purple solution leaking from cracks in asphalt, along the edges of concrete man-way pads, from previously abandoned boreholes, and other pathways. Breakthroughs have been observed by TVG personnel as far as 15' laterally from the injection location. For this reason, it is advisable to always use at least two personnel for injection activities: one to observe the injection area and one to operate the injection equipment.

Regardless of the injection method, permanganate stains and spills are inevitable and should be neutralized and properly diluted in order to insure a safe working environment. Neutralizing solution should only be applied to the diluted permanganate. Should a spill of 40% solution occur, it should first be diluted before neutralizing to prevent an exothermic reaction. When transferring and handling the 40% permanganate solution, extra care needs to be taken, as the solution can cause spontaneous combustion of some materials such as cotton clothing, paper products, and other organic materials, in addition to the dermal and other health risks identified on the material safety data sheet.

Permanganate Neutralizing Solutions: Guidance from Carus Chemical Co:

The following information was obtained from Carus Chemical Company and is used with their permission. RemOx® S Reagent (potassium permanganate –  $\text{KMnO}_4$ ) and RemOx® L Reagent (40% sodium permanganate –  $\text{NaMnO}_4$ ) are commonly used for the in situ chemical oxidation of chlorinated solvents such as PCE, TCE, and their daughter products. Both permanganates are strong oxidizers and require careful handling. During the course of the application of permanganate, there is the chance that the neutralization and/or disposal of excess permanganate

may be required. Regardless of whether the need is for the clean up and removal of a small spill, the neutralization of excess permanganate solution from equipment, the rinse water produced when cleaning buckets and drums, or any other activity where excess permanganate may cause a concern, following a few simple rules will ensure that the process will be safe and easy.

If neutralization is required because of a spill, and the spill is dry potassium permanganate, it can be swept or shoveled up and transferred to a clean, metal container. Dilute the product with water, and mix the solution until all the crystals are dissolved prior to neutralization. If the spill is a liquid potassium permanganate solution, contain the liquid by diking or collecting and neutralize.

If the spill is sodium permanganate, the first step is to contain or collect the spill. Prior to any neutralization, sodium permanganate **MUST BE DILUTED** with water to a concentration of 6% or less. Once the product has been diluted, it can be safely neutralized.

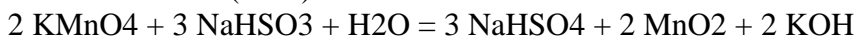
There are a number of different chemicals that will neutralize permanganate solutions. Below are some of the commonly used chemicals, their reactions with permanganate and the stoichiometric requirements.

Sodium thiosulfate



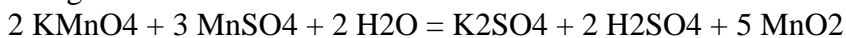
Weight Ratio: 0.375 parts  $\text{Na}_2\text{S}_2\text{O}_3$  : 1 part  $\text{KMnO}_4$

Sodium bisulfite (meta)



Weight Ratio: 1 part  $\text{NaHSO}_3$ : 1 part  $\text{KMnO}_4$

Manganous sulfate



Weight Ratio: 1.43 parts  $\text{MnSO}_4$  : 1 part  $\text{KMnO}_4$

Hydrogen peroxide



Weight Ratio: 0.43 part  $\text{H}_2\text{O}_2$ : 1 part  $\text{KMnO}_4$

Note: at pH <9

In addition to the above, permanganate solutions can be neutralized using products readily available for purchase locally. These include the following:

**Cleaning/Neutralizing Solution:** This solution consists of products that can be purchased from a local food or drug store. This solution is especially effective for removal of brown stains on skin; however, it has also been used, in some cases, as a neutralization solution for small spills. It would not be economical for anything but the smallest volumes of dilute permanganate.

30 parts water

40 parts white vinegar

30 parts 3% hydrogen peroxide

Sugar: White sugar is also readily available and can be used to neutralize permanganate solution. The reaction of permanganate and sugar is relatively slow, taking about 30 minutes for a complete reaction. The by-product of the reaction is typically a gelatinous residue.

Sugar (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>) Weight Ratio: 8.8 parts sugar: 1 part KMnO<sub>4</sub>

- Never use any of these solutions on sensitive tissues such as eyes, mucous membranes, open wounds, etc.
- Do not add directly to concentrated permanganate solutions.
- Dilute the permanganate solution to less than 6% before using any of these solutions.

Tennessee experience and lessons

In Tennessee we have introduced permanganate into the subsurface via several methods including 1 and 2-inch diameter permanent wells, probe borings, and gallery piping. By conducting numerous injections at multiple sites, we have gained experience and advanced our technical knowledge and understanding of this type of activity. Some of the many considerations that have been learned from our injection experience include:

Technology cost savings

By employing permanganate oxidation for saturated zone remediation we avoid installing complicated infrastructure and high dollar cost capital equipment. Compared to other remediation alternatives, permanganate is relatively inexpensive and we anticipate will have a reduced remediation time of operation. However, one consideration is that we plan to conduct as many as three injection events at a site to achieve our goals. Three injections may not be required at every site, but as a budget consideration it may be helpful to plan for multiple injections. Aside from cheaper start-up costs, oxidation using permanganate may be more economical due to reduced long-term O&M requirements and related monitoring costs.

Injection wells:

Permanganate remediation works through contacting the impacted media so it is important to consider the injection application method. If using direct push technology or similar drilling equipment, the installation of permanent or temporary 1" injection wells may be a more effective means of delivering the permanganate solution into the subsurface. We prefer to install a greater number of smaller diameter wells instead of fewer larger diameter wells in order to increase the area of influence of the injected material. Therefore, if the costs for installing ten 1" wells, six 2" wells, or four 4" wells are equal, it would be advisable to consider installing the one inch wells to obtain a larger permanganate distribution. More wells should benefit the injection product distribution. Again, it is critical to install any such wells as close to the source area as possible, even if it means drilling inside operating drycleaner buildings. In some cases, underground injection lines have been routed from inside the building to an outdoor area so that injection events do not disturb the ongoing drycleaner operations.

At sites planned for multiple injection phases, we prefer to use small diameter permanent injection points as a cost saving measure. Through conducting injections through permanent points we are able to make multiple injections without incurring additional drilling cost. This will be true until site conditions and monitoring show that subsequent injections would benefit from moving the injection points to address other areas that have not been remediated.

In situations where drilling into bedrock is necessary the drilling cost will be a major project influence. In situations where we have installed wells for bedrock/top-of-rock remedial injection purposes we have installed 2-inch wells. For bedrock applications we use minimum 2-inch wells, as wells of this size will be more durable over longer-term remediation efforts than smaller sized wells, as bedrock wells will typically be subject to multiple injections. Wells completed into bedrock must also be connected to the aquifer requiring treatment. For this reason be aware that unless a proposed injection well intersects a water-bearing void or fracture that the well may be a dead end and not useful for injections.

It has been suggested that injections performed using non-permanent probe points are better than the injections conducted through permanent wells. One advantage of using non-permanent points is flexibility; single borings can efficiently inject specific target intervals or multiple intervals using the same boring, whereas permanent wells cannot.

Another possible advantage of non-permanent borings is that these boring locations are not fixed. If a site is undergoing repeat multiple injections the injection target or target zone can be moved between injection events to accommodate changes in plume configuration or project objective. If the target changed or moved between injection events with the use of permanent wells, it is possible that additional site drilling would be required to add permanent injection points to address the new or modified remedial target. Finally, at the remediation completion there will be a project cost associated with well point abandonment. The disadvantage to non-permanent temporary points is the health and safety hazard associated with a spill resulting from a weak seal.

#### Horizontal Galleries:

An additional permanganate application mechanism is through horizontal gallery piping that has been installed in either a trench or in an excavation that was completed to address near surface media impacts. Infiltration galleries are often used to address both ground water and residual soil impacts at locations where ground water depth is shallow. Consideration for an infiltration gallery appears to be most useful to address small limited extent shallow depth plumes. In DCERP we typically install gallery infrastructure under building floors in conjunction with source mass removal actions. In this situation DCERP takes advantage of the floor being open to install the gallery plumbing for future anticipated remediation. The remedial solution may be applied under pressure using a pump or delivered by gravity flow. Advantages in this situation are that we are able to minimize the disturbance to the business operation and that we can make multiple injection applications using the galley. A disadvantage is that the gallery will only be able to influence a limited area, so if site impacts are widespread an alternative mechanism will need to be employed to supplement the remediation. Such installations are thought to be



particularly effective in areas with above average groundwater flow, as the natural conditions effectively disperse the permanganate, rather than relying solely upon pump pressure and gravity.

### Product surfacing

An additional injection consideration known as surfacing may occur while the injection is being conducted. Surfacing occurs when the pressured fluid that has been injected into the subsurface migrates or leaks back to the surface. Surfacing may occur through the annular space of an injection point, through cracks and joints in asphalt or concrete surface cover or onto bare surfaces. Surfacing is site specific and is difficult to predict in advance. Typically, injection activity is conducted to facilitate introducing as much product as possible into the subsurface. Especially with shallow injections when the available void space becomes filled there is an increased likelihood for surfacing. On agency projects when surfacing has been observed, it is usually associated with seams that are present between curbing and asphalt/concrete pavement and at shallow injections that migrate to bare uncovered surfaces. When this situation occurs, field crews should be prepared to stop the active injection and be ready to neutralize any surface spills. At sites where permanent injection points are used, care should be taken to provide adequate surface seals to mitigate the potential for surfacing problems. Extra care should be taken for injections that are planned for inside buildings. In addition to health and safety considerations if surfacing occurs inside a building structure we may also have some concerns about pressure impacts to the building foundation and to utility line conducts.

Underground utility lines are typically present at every site. Although we are not aware of adverse effects to buried lines due to exposure to permanganate, reasonable care should be taken to minimize permanganate/line contact. Utility lines and trenches are often located at elevations that are higher than remediation targets; this usually prevents line/permanganate interaction. Also dilute permanganate solutions (10% or less) are not persistent long-term in the environment but will degrade over time; if line exposure was a project concern the potential impact should be minimized due to product degradation.

### Mixing and pumping considerations and connections:

To accomplish transfer of the permanganate solution from the drum to the mixing tank, we suggest employing a chemical resistant drum pump. Early experience identified the cause of accidental spills was the result of the difficulties in mixing and diluting the 40% sodium permanganate solution. Through use of a drum pump and a large capacity translucent mixing tank, the dilution procedure may be accomplished in a completely sealed system, and is thus far safer and more efficient in terms of time and effort expended.

After mixing, the permanganate will be pumped (injected) into the subsurface via hoses and fittings. Quick connect fittings are used on permanent wells to attach the product distribution hose to the pump. The distribution hose will be 1 to 2-inch diameter chemical resistant pressure rated hose. The wellhead quick connect attachments will have shut-off valves. Due to the corrosive effect of the permanganate on the quick connect fittings; these fittings should not be permanently attached to individual wells. These components will deteriorate and rapidly rust if

left in the field attached to the well. Typically, an initial expense outlay for a set of 3 to 4 wellhead fittings will be necessary (generally \$25-\$35/each). If these components are cleaned with neutralizing solution to prevent rust after use and properly stored, this group of fittings should last for several years and not require frequent replacement.

DCERP contractors have used both Geoprobe® and Wanner pumps to perform permanganate injections. The Geoprobe® pump is gasoline powered while the Wanner is an electric motor pump. Both pumps are positive displacement capable of pumping permanganate. The Geoprobe® is capable of high pressure (up to 650 psi). Injections using Geoprobe® equipment will have greater success if you employ the use of these accessories: a grout pressure assembly and a pressure activated injection probe (backflow preventer). The injection probe tool will minimize permanganate spillage when injections are conducted through probe borings rather than through permanent well points. Another consideration is the spills from leaks at the rod joints. Care must be used when employing rod connections that are sealed with O-rings. Our experience has been that these seals may leak and potentially spill the pressurized fluid as the rods are removed from the borehole. Consultants in Middle Tennessee prefer the pressure and pump speed control associated with the electric pump. When outfitted with an integrated bypass valve, the valve will relieve line pressure when a pre-set pressure is exceeded. In the situation when surfacing occurs then the pump can be turned down until the ideal flow rate is determined. Typically the electric driven pump injection pressures range from 10 to 60 psi. For higher pressure situations (greater than 100 psi or more) conducted into permanent injection points there may also be a concern that the well casing and screen interval could be damaged. To minimize the possibility of this occurrence injection should be conducted at lower pressures.

We have learned from experience that the Wanner pump is sensitive to electrical power variations. The pump should only be operated using a “clean source” electrical power supply. Clean electric power is not subject to the voltage fluctuations that may result in power spikes. If the pump is not operated using clean electric power we risk burning out the pump’s electrical components. This means that the pump should ideally be powered by a regular, domestic plug in-the-wall power source. If an on-site wall plug is not available, a generator will probably be required as an electrical power source. Any generator that is used to operate the pump must be a certified clean electrical power generator. Clean electric generators are slightly more expensive to rent than regular generators, but are necessary to power sensitive electric equipment. The small cost of the added equipment expense of obtaining a clean electrical power generator is more than justified compared to the potential cost for equipment repair and project down-time.

### Observational and Analytical Sampling Considerations

After injection we use observational monitoring followed by laboratory analytical testing at a prescribed interval to track progress. The observational monitoring allows us to track the action of the permanganate as the color changes from purple through to clear. Our observations to date have not identified any fouling of injection points from this remedy method. Either relative color determination or color chip color comparisons can be used to evaluate color changes. The analytical allows us to document contaminant concentration reduction over time. We generally conduct fixed based analytical sampling quarterly. When we encounter a well that still has purple color we use a Carus Chemical procedure to quench the media. The sample may still be collected

and the following procedure should be used. This procedure is reproduced here with the permission of Carus Chemical Company.

Prior to going to the field, make up a solution of sodium thiosulfate in water by adding 20 g to 100 mL of water. Put in a dropper bottle.

A soil sample is placed into a pre-cleaned 40-mL VOC vial pre-charged with 2-5 mLs of sodium thiosulfate solution. The vial shall be capped, inverted or mixed gently, and the color of the resulting solution/soil (test specimen) checked. If the sample turns brown, tan, or colorless the permanganate has been completely reduced.

An aliquot of the groundwater shall be decanted into a pre-cleaned 40-mL VOC vial, pre-charged with one drop of sodium thiosulfate solution. The vial shall be capped, inverted gently, and the color of the resulting solution (test specimen) checked. Solids generated from this reaction need time to settle to accurately determine the color of the sample. If the sample turns brown, tan, or colorless the permanganate has been completely reduced. If the color of the samples is not clear, then add additional sodium thiosulfate, recap, and invert gently. Continue adding drops of sodium thiosulfate until the color of the test specimen is clear then add an extra drop of sodium thiosulfate. Note the total amount of sodium thiosulfate added and discard this test specimen.

Pre-preserve two 40-ml VOC vials per sample with the total amount of sodium thiosulfate required for the test vial, and fill each with aliquots of the soil or groundwater, cap, and invert/mix gently. Hydrochloric acid shall not be added – note this on Chain of Custody (COC).

Use of this procedure decreases the sample holding time from 14 days to 7-days –this must be so noted on the sample Chain of Custody (COC) and the laboratory notified. Prior to submitting quenched samples for laboratory testing, the receiving laboratory must be contacted and notified to ensure that the laboratory instrumentation is not inadvertently damaged.

We hope that sharing our experience is helpful and remind you that our experience is a starting point and we suggest you conduct additional research into the delivery methods, cost, equipment, chemical handling, health and safety etc.

The Tennessee DCEERP program is also a member of the State Coalition for the Remediation of Drycleaner sites (SCRD). SCR D provides a forum for states to share programmatic, technical, and environmental information to improve the remediation of drycleaner sites. The SCR D web site resources may be accessed at [www.drycleancoalition.org](http://www.drycleancoalition.org). In addition, through the Interstate Technology and Regulatory Council (ITRC) at [www.ITRCWEB.org](http://www.ITRCWEB.org) a guidance document on Technical and Regulatory Guidance for In-Situ Chemical Oxidation of Contaminated Soil and Groundwater is available which has a comprehensive discussion on various chemical oxidants and their uses.