REGENESIS®

9 REASONS

To Consider *In Situ* Chemical Oxidation to Treat Your Site

Why *In Situ* Chemical Oxidation?

In situ Chemical Oxidation (ISCO) is a cost-effective technology that involves delivering chemical oxidants into the subsurface soil and groundwater to destroy organic contaminants. There are a variety of chemical oxidants that will have varying levels of effectiveness depending on the target contaminant, soil conditions, hydrogeology, and remedial goals, but if used intelligently and selectively, they can be a very budget-friendly remediation tool to achieve positive results.

9 Reasons to Consider *In Situ* Chemical Oxidation to Treat Your Site

ISCO is Widely Accepted by the Regulatory Community

#1

> *"... A chemical oxidant approach can reduce a lengthy approvals process..."*

ISCO is a Widely Recognized and Effective Approach

Starting with Fenton's Reagent in the 1980s, chemical oxidation has been used in environmental cleanups for almost four decades and has been implemented on thousands of sites worldwide. In the United States, it is a familiar technology to both state and federal regulatory bodies.

Over the years, chemical oxidation has been selected for use on Superfund sites, a federal government program operating under the authority of the United States Environmental Protection Agency (USEPA). Technologies used on these sites are thoroughly assessed under the USEPA Superfund Innovative Technology Evaluation (SITE) program. This assessment includes literature reviews, treatability studies, and in-field pilot tests. Technologies approved for Superfund use are more likely to be approved for use by other US regulatory bodies.

The technology is also familiar to Canadian regulatory authorities. In the province of Ontario, chemical oxidants have received Environmental Compliance Approval (ECA). Under the ECA program, chemical oxidants can be used on any site given sufficient notice, eliminating the need to submit site-specific approvals for each project therby expediting the remediation process.

Because of its widespread use and regulatory familiarity, the decision to use a chemical oxidant approach can reduce a lengthy approvals process which can be particularly important if project timelines are short.

#2 An ISCO Approach Can Be Implemented Quickly

> *As a rule, chemical oxidants require very little time to prepare for delivery, and thus can reduce contractor time on site, minimize disruptions, and result in cost savings.*

A Quicker Implementation Process

When it comes to any remediation project, time is money. One of the advantages of chemical oxidation is that preparation of the oxidant for subsurface delivery is a relatively simple procedure that typically involves the addition of water and an activator. In some rare cases where site access is extremely limited, the oxidant can even be shipped as a solution, eliminating the mixing step and allowing application to begin immediately.

Some oxidant options such as PersulfOx®, an ISCO reagent by REGENESIS®, streamline the process even further by providing an oxidant already mixed with a solid-state catalyst so the only step required is the addition of water.

Keep in mind:

- If the chemical oxidant is being used in a recirculation system or being injected into pre-installed trenches or permanent wells, then only the pump setup and mixing of the oxidant solution is required.
- The time required to complete direct-push injections will depend on the soil conditions, the injection depth, and contractor experience but, in general, it is a relatively quick process.
- The quicker the implementation process, the fewer disruptions to site operations which would be beneficial for a variety of reasons, such as reducing costs.

ISCO Remediation Approaches Can Cost Less #3

A Cost-Effective Approach

When it comes to reducing contaminant mass, ISCO is one of the most cost-effective technologies currently available. Even when replacing an existing pump and treat system, ISCO can result in significant savings. In addition to the savings on contractor costs, ISCO can be less expensive than other technologies.

When comparing ISCO to physical approaches, ISCO can be much cheaper than excavation and disposal and avoids the capital cost of building and installing a mechanical extraction system. It also obviates the costs associated with operation and maintenance.

> *"When comparing ISCO to physical approaches, ISCO can be much cheaper..."*

ISCO can also provide cost-savings when used in conjunction with biological treatment systems such as enhanced bioremediation or monitored natural attenuation. Including ISCO in an approach can lead to site closure being achieved faster, potentially eliminating months to years of monitoring costs.

> *An ISCO approach at an former industrial paint manufacturing site saved $100,000...*

CASE STUDY: Former Industrial Paint Facility Treated with ISCO

At a former industrial paint facility in Tempe, Arizona impacted with high concentrations (~50 ppm) of BTEX compounds in the groundwater, ISCO was used to replace a recirculation well system that was underperforming due to its limited radius of influence.

REGENESIS injected 10,028 pounds of PersulfOx at a 12% solution in two applications and achieved a 95% reduction of target contaminant concentrations, reaching site goals.

The overall ISCO injection treatment cost $40,000 which was a small fraction of the recirculation system cost and equal to four months of operational expenses, representing a total cost savings of $100,000.

When it comes to overall cost, an ISCO approach can be very competitive compared with other technologies and should be considered a viable option as part of any remedial design strategy.

ISCO Solutions Can Be Applied in a Variety of Ways #4

> *"This approach allows for quite a bit of flexibility when it comes to..."*

ISCO Approaches Range From Direct-Push to Excavation

There are many different ways that chemical oxidants can be introduced into the subsurface. The most common method is injection, either via permanent injection wells or temporary direct-push holes. With direct-push, an injection rod is hydraulically pushed into the subsurface so that the oxidant can be delivered at the desired depth. This approach allows quite a bit of flexibility when it comes to injection spacing, oxidant volume per point, and injection depths. Direct-push injection also produces no drill cuttings, causing less disturbance to the natural formation, and increasing overall speed. With some of the smaller direct-push rigs, injection points can be done indoors to treat contaminants underneath buildings.

Oxidants have also been proven to be effective in recirculation systems in which the reagent is injected into upgradient wells while groundwater is extracted from a downgradient location. Extracted groundwater can be amended with oxidant and re-injected into the impacted zone.

In situations where there are subsurface obstructions or a thin saturated zone, recirculation systems can utilize horizontal wells. Recirculation systems allow for greater control of oxidant and contaminant migration and higher volumes of injectable oxidant because the simultaneous downgradient extraction frees up pore space.

Treatment walls consisting of trenches filled with aggregate and a piping network for oxidant delivery have been successfully used in the past. These walls can be placed at the property boundary to prevent off-site migration or at various intervals along the length of the plume. The applicability of this approach will depend on the hydraulic velocity and contaminant concentrations.

On sites where there is significant contaminant mass, but not free product, chemical oxidants can be mixed into the soil to achieve contaminant reduction. The most common type of soil mixing used for ISCO is large-diameter single-auger soil mixing but mixing can also be achieved either using excavator buckets or rotary tools. Because mixing increases the chances of contact between oxidant and contaminant, this approach can be very effective. Additionally, for remote sites where there is a significant distance from the nearest suitable landfill, transport and disposal fees can be exorbitant, so soil-mixing can be a much less expensive approach for treating impacted soils.

The variety of ways in which a chemical oxidant can be delivered means that an application can be tailored to the requirements of a site to maximize its efficacy while minimizing costs.

#5 ISCO Remediation Approaches Can Be Effectively Combined with Other Methods

> *Chemical oxidants can be a very cost-effective way to reduce the mass...*

A Combined Remedy Approach is an Effective Recipe for Success

While ISCO is effective on its own, it can be enhanced by and also enhance the effectiveness of other technologies. Surfactants can increase the effectiveness of chemical oxidants by desorbing contaminants from soil into the aqueous phase, thus making them more available for oxidation, and thereby increasing the efficacy of the treatment, as long as the additional carbon load of the surfactant is accounted for.

In some cases, the chemical oxidant can increase contaminant availability by acting as a surfactant itself. For example, PetroCleanze™, a custom formulation of the widely-used RegenOx® (an oxidant technology based on sodium percarbonate), can increase the desorption rates of hydrocarbons bound in saturated soil by creating detergent-like molecules *in situ*. This avoids the additional carbon loading that can be problematic with standard surfactant-based technologies while still increasing the efficiency of enhanced recovery techniques such as dual-phase vacuum extraction (DPVE) or pump and treat systems.

Mechanical removal systems such as dual-phase or multi-phase extraction can be augmented and sometimes replaced by chemical oxidation. For example, a luxury residence redevelopment project was successfully completed using a DPVE system enhanced with RegenOx. The DPVE system was initiated to remove the existing free product before a temporary shutdown period during which RegenOx was injected to achieve desorption and partial chemical oxidation of the residual hydrocarbons. Adding the RegenOx sped up the process and allowed the project to remain on schedule.

Very high contaminant concentrations can be toxic to microbes therby hampering biological remediation or simply require more time than the project timeline will allow. Chemical oxidants can be a very cost-effective way to reduce the mass, paving the way for bioremediation (i.e. oxygen release compounds, hydrogen release compounds, or monitored natural attenuation) to take the site to completion. Chemical oxidants are very often combined with bioremediation technologies and, in the right combinations, can be applied simultaneously.

> *This remedial approach was chosen as the most technically-feasible and cost-effective strategy*

CASE STUDY: FDEP Uses Combined Remedy to Effectively Address Petroleum Hydrocarbon Plume

In Taylor County, Florida, a project overseen by the Florida Department of Environmental Protection (FDEP) used a combined-remedy approach that employed PlumeStop, RegenOx, and ORC-Advanced to sorb, degrade, and destroy the existing petroleum hydrocarbon plume. This remedial approach was chosen as the most technically-feasible and cost-effective strategy in a competitive bid scenario. Thus far, all remedial milestones have been achieved within their allotted timelines.

#6 ISCO Can Treat a Wide Range of Contaminants

"Chemical oxidants are effective on a wide variety of contaminants ranging from..."

When Treating Mixed Plumes Consider ISCO to treat contaminants simultaneously

Chemical oxidants are effective on a wide variety of contaminants ranging from petroleum hydrocarbons such as BTEX (benzene, toluene, ethylbenzene, and xylene) compounds, diesel, oil, and methyl tert-butyl ether (MTBE) to chlorinated compounds such as perchloroethylene (PCE), trichloroethylene (TCE), trichloroethane (TCA), and carbon tetrachloride. In cases where there are mixed plumes of contaminants, chemical oxidants can be used to treat all of them simultaneously.

Just as there are a variety of contaminants, there are also a variety of oxidants and activation methods that can be employed to treat them. The key is to ensure that the selection process narrows down the oxidant and activation method that best suits the target contaminants.

Persulfate has traditionally been activated in a variety of ways such as high-pH, hydrogen peroxide, heat, or chelated iron. These activators generate different species of radicals with varying oxidizing potentials and stability. For example, the sulfate radical is more stable than the hydroxyl radical which means it has a larger radius of influence since it has more time to transport through the subsurface.

Each of these activation methods will have advantages and disadvantages depending on the nature of the target contaminant. Iron activation is not recommended for the destruction of gasoline and diesel range organics, trichloroethane (TCA), dichloroethane (DCA), or vinyl chloride. However, it is known to be effective on MTBE, tert-butyl alcohol (TBA), and BTEX. For gasoline and diesel range organics, peroxide or alkaline activation would be preferable.

Recent developments have resulted in the availability of new tools for environmental site professionals, giving them even more options when devising remedial strategies.

PersulfOx is a persulfate-based oxidant product that is activated by a novel silica-based heterogeneous catalyst which generates sulfate radicals and other oxidizing species. Similar to alkaline and peroxide activation, it is effective at treating aliphatic hydrocarbons, BTEX, chlorinated ethenes and ethanes, and oxygenates but without the need for a separate activator requiring an extra mixing step and eliminating the need for the additional safety precautions necessary when dealing with caustics and strong oxidants.

Also, because the PersulfOx catalyst is persistent in the subsurface it can continue to activate persulfate over many oxidation cycles. In contrast, alkaline activation can be limited by high buffering capacity in soils and depletion of the hydroxide activator which makes it difficult to maintain the pH conditions necessary for contaminant oxidation.

Using a similar catalyst as PersulfOx, RegenOx can treat BTEX, petroleum hydrocarbons, chlorinated solvents, PAHs, energetics, and a wide range of aromatics.

While the underlying principles of oxidant usage are the same, there is a wide selection of specific oxidants and activators that can be used in remediation strategies to treat a diverse range of contaminants.

ISCO Is a Safe and Effective Approach #7

> *RegenOx is effective at destroying petroleum hydrocarbons but is actually relatively safe to handle in the field compared to other oxidants.*

ISCO Applications Avoid Producing Harmful Daughter Products Present in Alternative Remedial Approaches

Of course, chemical oxidants can be beneficial to human health simply due to their ability to destroy harmful environmental contaminants, but as an added benefit, they can be safer than other remedial approaches as well.

With biological degradation, chemicals are broken down stepwise and can often lead to intermediary contaminants which are sometimes more harmful than their parent compounds. Daughter products such as vinyl chloride are carcinogenic and can pose a health hazard, especially in situations where humans might be exposed via vapor intrusion pathways into an occupied space.

By contrast, instead of gradually transforming contaminants into harmless constituents, chemical oxidants abiotically destroy contaminants upon contact, bypassing those intermediate steps. By avoiding the creation of those potentially harmful daughter products, the use of chemical oxidants can eliminate those health concerns and obviate the need for an expensive vapor intrusion mitigation system.

While most oxidants can be dangerous to handle, there are options available which can mitigate some of those hazards. For example, RegenOx is effective at destroying petroleum hydrocarbons but is actually relatively safe to handle in the field compared to other oxidants. On the other hand, permanganate, often used for treating chlorinated solvents, is a highly-reactive material and if contacted with clothing or paper products can result in fire. Persulfate activated by peroxide or high-pH will require the handling of strong oxidants and caustics which can also be dangerous.

Many oxidants cannot be used near buildings because they can corrode and weaken the underlying infrastructure leading to structural instability. Non-corrosive and generating minimal heat and pressure, RegenOx is compatible with underground infrastructure such as tanks, piping, and foundation which means it can be used to treat contaminants beneath a building and mitigate the risks of exposure to its occupants.

When used properly, chemical oxidants can do their part, along with other remediation technologies, to make the environment a safer place for everyone.

8 Applicable to a Range of Subsurface Conditions

> *Chemical oxidants can be very effective in a wide range of soils...*

Effective in a Wide Variety of Subsurface Conditions Including Tight Clays

Whether the soil is a flowing sand or a tight clay, oxidants can be very effective when applied correctly. Each site comes with its own set of unique challenges that must be considered when designing a remedial approach. One of the parameters with the greatest design impact is soil type. Chemical oxidants can be very effective in a wide range of soils provided they can achieve sufficient contact with the contaminants. The characteristics of the impacted soil will affect injection spacing, injection pressures, injection method, and even the selection of remedial technology.

While a loose sand aquifer poses fewer obstacles, allowing for easier injection of oxidant into the impacted zones, it must also be considered that the contaminant will be moving relatively quickly. Any design must therefore account for the residence time of target contaminants within the treatment areas where oxidant has been injected. With higher hydraulic conductivity soils such as sand, injection spacing can be further apart as each point can achieve a higher radius of influence.

A very tight clay, on the other hand, will have far lower permeability and will not readily allow for dispersion, advection, or diffusion, and as such will make it more difficult to achieve contact between oxidant and contaminant. This does not mean that oxidants will be ineffective, but it does mean that the design and application must take this into account with tighter injection spacing and appropriate injection pressures.

For clays and other tight soils, soil fracturing might be necessary to create pathways to transmit the oxidant.

As an example of oxidants being effective in tight clays, PersulfOx was applied at a former paint manufacturing facility in Northern California where soil and groundwater was impacted with Methyl isobutyl ketone (MIBK) and BTEX. The impacted soil was comprised of clay with sand stringers and presented challenging geologic conditions. Using a specially-designed injection trailer and manifold to inject into four points at once, an experienced contractor (REGENESIS Remediation Services) was able to inject 29,644 pounds of PersulfOx through 58 direct push points in just two applications.

Chemical oxidants can also be effective in bedrock. At a trailer park in Eastern Ontario, two tanks released heating oil into the underlying unconsolidated and fractured rock. Approximately 12,000 pounds of RegenOx was delivered to the impacted areas which resulted in the groundwater being treated to drinking water quality within 15 months without any interruption or displacement to surrounding tenants.

While different soil types can present obstacles to efficient remediation, they can be overcome with proper remedial design and the selection of an experienced contractor to achieve excellent results.

ISCO Is Scientifically Proven To Achieve Rapid Results #9

> *"TBA Concentrations were reduced from >14,000 ppm to 2,100 ppm in 3 weeks."*

Kinetics Behind Chemical Oxidation Are Quite Rapid And Will Destroy Contaminants Almost Instantly Upon Contact

With proper project design, positive results can be achieved much quicker than with other remediation methods. Physical extraction systems can be limited to a radius of influence based on installation restrictions whereas, with the flexibility of direct-push injection, chemical oxidants can more accurately target contaminants leading to faster results.

Even compared to other chemical oxidants and activation methods, improvements can be made to speed things up.

On a manufacturing facility in New Jersey, groundwater impacted with TBA was previously treated with alkaline-activated persulfate which did not meet performance goals. It was found that the pH was not below the range required for persulfate activation due to the buffering capacity of the aquifer. The amount of sodium hydroxide required to raise the pH to sufficient levels raised concerns of impacting nearby storm sewers.

The consultant decided to switch to PersulfOx, utilized a treatment approach of six injection points spaced 15-feet apart, and injected > 1,800 pounds of oxidant into a sandy aquifer across a 5-foot thickness. TBA concentrations were reduced from > 14,000 ppm to 2,100 ppm within only 3 weeks.

CASE STUDY: Dry Cleaning Site Treated With Combined Remedy Approach

On another site in West Allis, Wisconsin, an industrial dry cleaning plant had accidentally released PCE into the groundwater creating a 4,500 square foot contaminant plume. To address this, the consultant devised an *in situ*, combined remedies approach which included PlumeStop, RegenOx, HRC, and BioDechlor INOCULUM (BDI Plus).

The ISCO portion of the program was designed to treat a total of 140 tons of PCE-impacted clay soil with initial concentrations of 169 ppm and a remedial goal of less than 14 ppm. PlumeStop was used to address PCE impacts in the deeper portion of the plume approximately 80 to 95 feet below ground surface and co-applied with HRC and BDI Plus.

This combined approach rapidly reduced contaminant concentrations and achieved remediation goals in just 30 days post-application. As a result, the client has submitted for site closure.

The less time it takes to achieve site closure, the less money the client has to spend on monitoring, additional remediation, and other project costs and the faster they can complete their property transactions or begin redevelopment.

Either on its own or in a combined remedy approach, chemical oxidation can be a very effective tool for the rapid reduction of contaminant mass.

Solutions Provided in This eBook Include:

PLUME STOP® Liquid Activated Carbon

PlumeStop® Liquid Activated Carbon™ is a break-through groundwater remediation technology that reduces dissolved phase contaminant plumes in days. It is composed of extremely fine particles of activated carbon (1-2µm) suspended in water through a proprietary dispersion chemistry that allows the technology to flow into the subsurface at low pressure and achieve consistent, reliable distribution – a capability unlike any other form of activated carbon used for groundwater remediation today.

PETRO CLEANZE™ Enhanced Desorption

PetroCleanze™ is a customized formulation of the widely used RegenOx *in situ* chemical oxidation (ISCO) technology. This two-part reagent contains purposefully enhanced, detergent-like properties which significantly increase the desorption rates of hydrocarbons bound in saturated soils.

HRC® HYDROGEN RELEASE COMPOUND

Hydrogen Release Compound (HRC®) are a range of electron donors with varying release profiles to suit project specific needs. Each technology provides controlled-release lactic acid to promote reducing conditions and optimize the anaerobic enhanced reductive dechlorination process.

BDI® PLUS BIO-DECHLOR INOCULUM

Bio-Dechlor INOCULUM® PLUS is an enriched natural microbial consortium containing species of *Dehalococcoides sp.* (DHC). This microbial consortium has since been enriched to increase its ability to rapidly dechlorinate contaminants during in situ bioremediation processes.

REGEN Ox®

RegenOx® is an injectable, two-part ISCO reagent that combines a solid sodium percarbonate based alkaline oxidant (Part A), with a liquid mixture of sodium silicates, silica gel and ferrous sulfate (Part B), resulting in a powerful contaminant destroying technology.

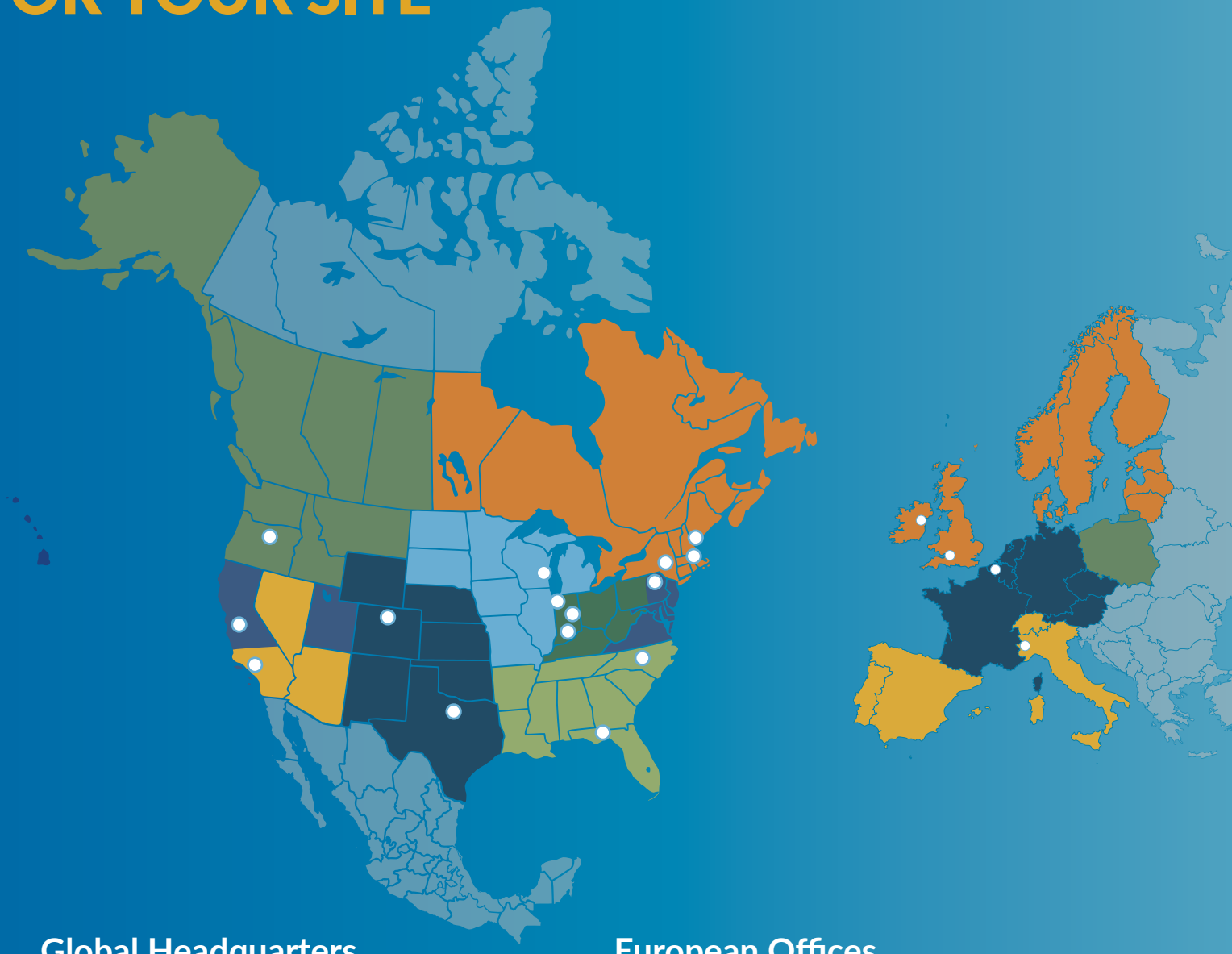
PERSULF Ox®

PersulfOx is an advanced *in situ* chemical oxidation (ISCO) reagent that destroys organic contaminants found in groundwater and soil through abiotic chemical oxidation reactions. It contains a built-in catalyst that remains active through the entire lifespan of the persulfate oxidation reaction.

REGENESIS®

WE'RE READY TO HELP YOU

FIND THE RIGHT SOLUTION FOR YOUR SITE



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