



*Use of Remox SR+ Cylinders in Treatment for
Chlorinated Solvents in Groundwater*



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Slow Release Oxidants: Use of Remox SR+ Cylinders in Treatment for Chlorinated Solvents in Groundwater

SMART Remediation – February 15, 2018

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Outline

- Chlorinated Solvents ... Remediation
- Decision Criteria
- Technology Development
- Field Installation
- Case Studies/Examples
- Summary



Chlorinated Solvents ... Remediation

- We all know:
- Difficult
- Persistent
- Geology and Hydrogeology issues
- Breakdown is more toxic than original

- Costly ...



Decision Criteria

- Ease of Application – Difficult location/situation
- Known Technology – want to be sure it works

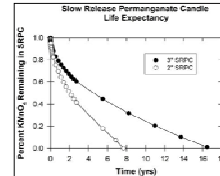
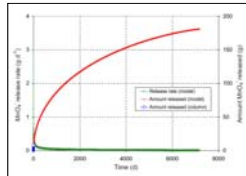
- Low Operation & Maintenance
- Overall Cost

- Remtech 2012 ... RemOx SR Presentation



Technology Development – Sustained-Release (SR+) Oxidants

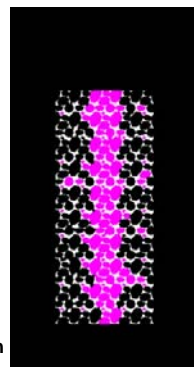
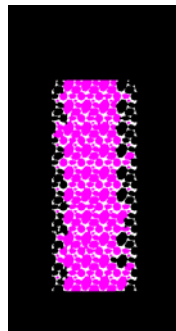
- Promising slow-release permanganate and persulfate modeling, lab, pilot-scale field studies (e.g., Ohio State University, Clemson, University of Nebraska, Colorado School of Mines)



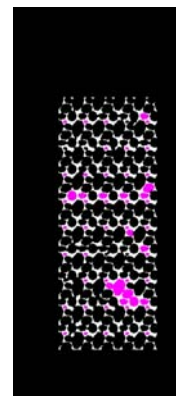
- Variety of reactive materials are possible
 - Oxidants, bio-amendments, oxygen release compounds, activators, chelating agents



Oxidant Release from Wax



- This is why we see an initial spike of permanganate in early time...
- And a significantly slower and lower release of permanganate at later times



- Newly created void spaces expose permanganate solids for dissolution and diffusion
- Process occurs radially from the exterior of the cylinder to the inner core



Technology Development: SR+ Oxidants

- Sustained-release permanganate is a KMnO_4 -based product dispersed in a solid paraffin wax matrix (~80% w/w) RemOx® SR ISCO Reagent



- Sustained-release persulfate is a $\text{Na}_2\text{S}_2\text{O}_8$ -based product dispersed in a solid paraffin wax matrix (~80% w/w)



SR+ Technology - Versatility in Form

- Solid product formed as cylinder, chipped for trench/barrier applications or small pellets/pastilles for hydro-fracturing into low permeability media:

- 1.35 or 2.5 inch diameter
- 18 inches long
- DPT emplacement, well installation, hydro-fracturing

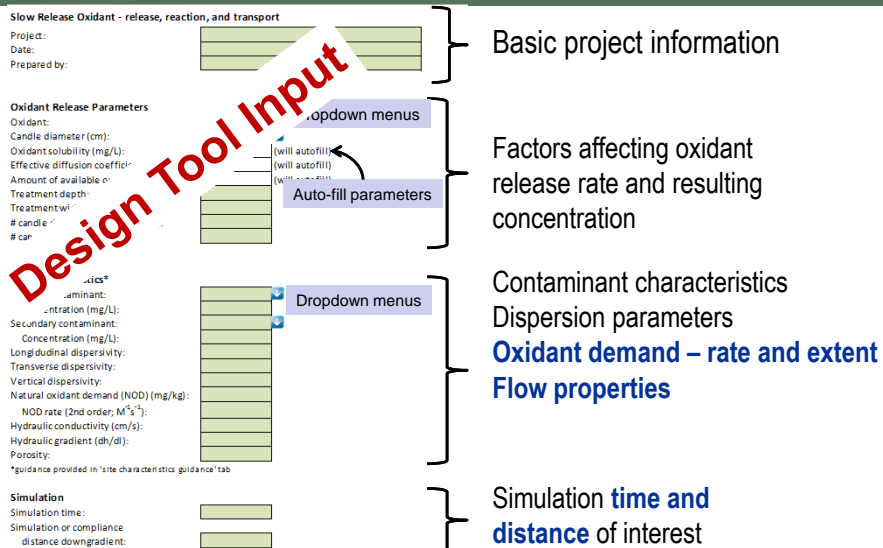


SR+ Technology: Versatility in Application

- Current Emplacement Methods:
 - Direct push technology
 - Holders in existing wells
 - Hydro-fracturing being investigated

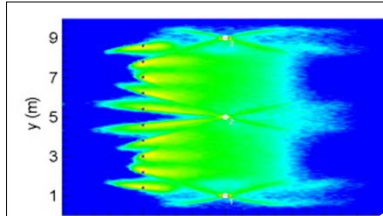


Approach – SR+ Design Tool

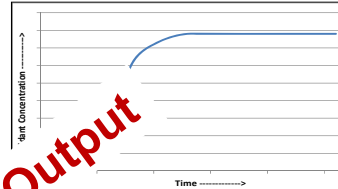


Approach – SR+ Design Tool

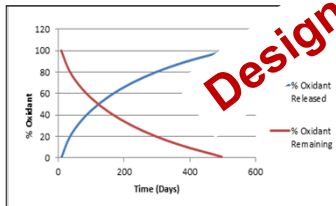
Oxidant concentrations vs. distance at a given time



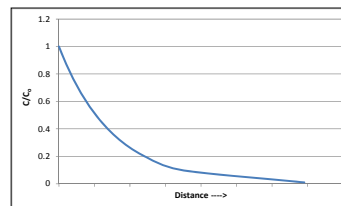
Oxidant concentrations at a given point over time



Oxidant release from cylinder



Contaminant concentrations vs. distance at a given time



Design Tool Output



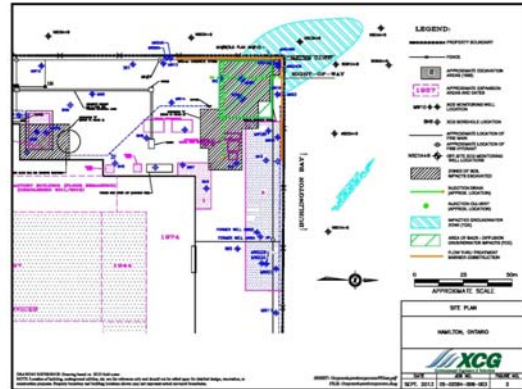
Case Study #1 – Historical Manufacturer

- Historical Industrial Site in Hamilton, Ontario
- Developed circa 1925
- Close to the Harbour
- Geology is fill over silty-clay down to clay material
- Historical use of chlorinated solvents
 - **PCE**, **TCE** → **c-DCE** and **VC** in groundwater
- Difficult Remediation – Complicated Ownership



Case Study #1 – Historical Manufacturer

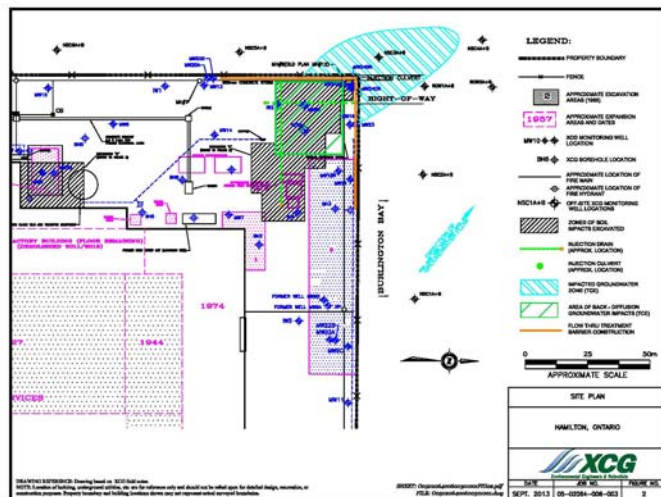
- Off-site Groundwater Impacts ...
 - Higher concentrations
 - Near saturation levels
- Remediation Stages ... excavation of soil impacts
- **Back-Diffusion** of impacted groundwater following excavation and hydraulic re-equilibration



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Case Study #1 – Historical Manufacturer

- First Site Application in Canada - December 2012
- Installed 476 cylinders in 119 direct-push boreholes over 8 days
- Straight-forward installation – health and safety



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Case Study #1 - Field Installation



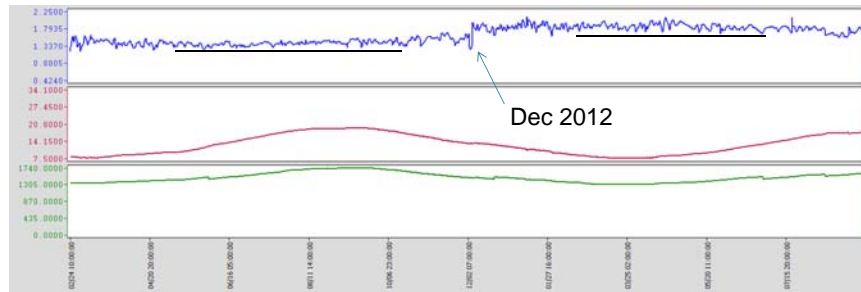
Case Study #1 - Monitoring Effectiveness

- Installed ... now what?
- Client needs assurance that effective
- Monitoring indicators in groundwater – electrical conductivity, ORP, oxidant
- Eventual cVOCs concentration decrease



Monitoring Effectiveness

- Location MW20B – observed an almost immediate increase in electrical conductivity (distance ~ 5m)



Monitoring Effectiveness

- Down-gradient (off-site) monitoring locations have shown increases in electrical conductivity and increasing trend with time:
 - Location NSC5A (avg. of 0.32 up to 4.44 mS/cm)
 - Location NSC5B (avg. of 0.87 up to 2.21 mS/cm)
 - Location NSC3A (avg. of 1.94 up to 3.11 mS/cm)
 - Location ROW1B (avg. of 3.34 up to 4.53 mS/cm)
- Hydraulic conductivity is low ... 1.27×10^{-5} m/s



Monitoring Effectiveness

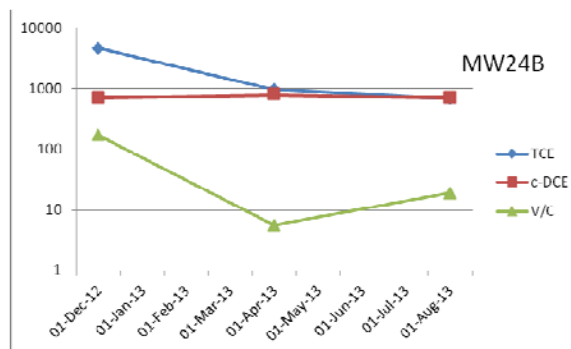
- Impacts of TCE ... c-DCE and vinyl chloride:
 - MW24B
 - MW24C
- Slight increases in electrical conductivity observed



Monitoring Effectiveness

MW24B installed at 5.5 metres below ground surface, located approximately 1.5 metres from barrier

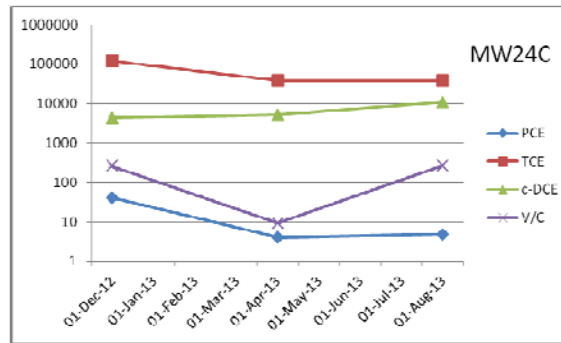
MW24B	06-Dec-12	15-Apr-13	12-Aug-13
c-DCE	710	790	720
PCE	0	0	0
TCE	4600	950	700
V/C	170	5.6	19



Monitoring Effectiveness

MW24C installed at 10 metres below ground surface, located approximately 1.5 metres from barrier

MW24C	06-Dec-12	15-Apr-13	12-Aug-13
c-DCE	4400	5100	11000
PCE	41	4	4.9
TCE	120000	39000	38000
V/C	260	9.2	270

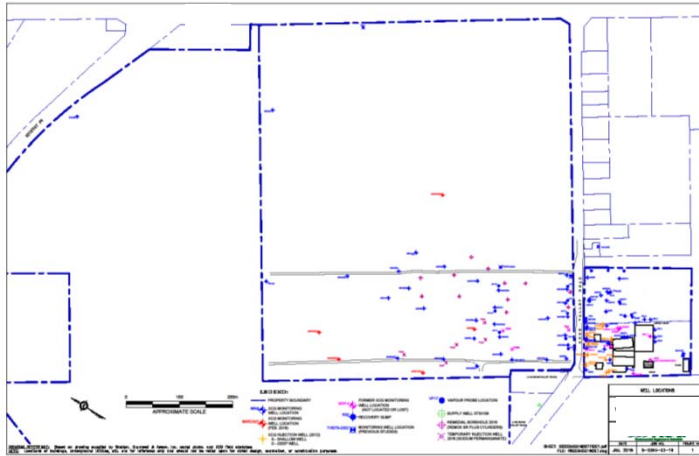


Case Study #2 – Liquid Industrial Waste Facility

- Long History of Site –
 - Former Lagoons Leak ('78); Warehouse Fire ('03)
- Large Plume of mixed chlorinated VOCs extends off-site
- Deep sand to silt aquifer ... (contaminants at depths of 12 to 15 m)
- Working through a strategic remediation process



Case Study #2 – Liquid Industrial Waste Facility



- Working to reduce contaminants concentrations
- Combined Remedies
- Use of Remox SR+ and Liquid Sodium Permanganate

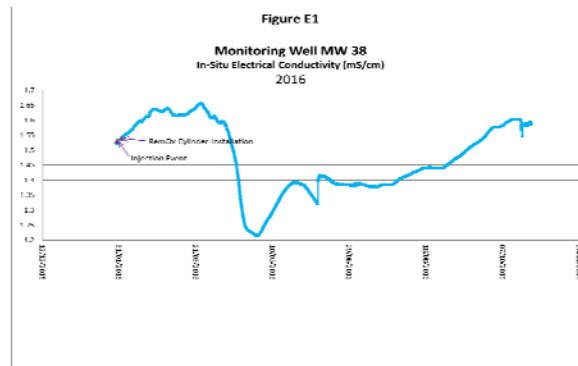
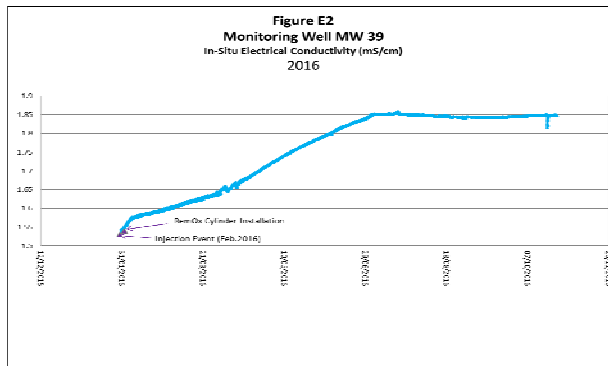


Case Study #2 – Liquid Industrial Waste Facility

- Plume core use liquid permanganate injected direct by gravity
- Plume fringes use Remox SR+
 - (stacked 3 cylinders per borehole at 12 locations)
- January/February 2016 installation



Case Study #2 – Liquid Industrial Waste Facility



- One indicator of EC shows increase, dispersing of oxidant



Case Study #2 – Liquid Industrial Waste Facility

Also **ORP** changes ...

- prior to installation observed ranges **9 to 48 mV**
- Following installation increased to ranges of **111 to 158 mV**
- Concentration decreases of all cVOCs
 - **PCE** from **17 µg/L** to **2 µg/L**
 - **TCE** from **15 µg/L** to **2.4 µg/L**
 - No VC !!!

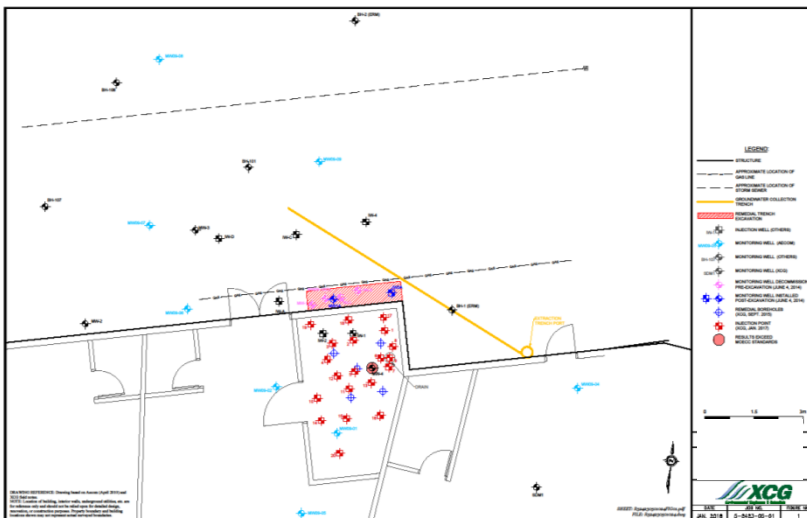


Case Study #3 – Dry-cleaner

- Typical scenario – dry-cleaner in a neighbourhood strip mall
- Some below building, some outside bldg. footprint
- Client and tenant relations are always paramount
- Desire to meet Generic Standards (versus use of Risk Assessment)
- XCG working through the remediation since 2013
- Combined Remedies – hydraulic control, strategic excavation, injections



Case Study #3 – Dry-cleaner



One persistent well with TCE marginally above Table 3 Standard of 17 µg/L

Limited opportunity for injections ... tenant disruption



Case Study #3 – Dry-cleaner

- Placement of Remox SR+ cylinders in Boreholes



5 boreholes with 2 cylinders each; depth of 2.5 m



Case Study #3 – Dry-cleaner

- Monitor the Results ... wells within 2 to 3 metres of cylinders
- **ORP** ... natural historic ranged from **79 to 97 mV**
- Within 3 months following installation ranged from **154 to 202 mV**
- **EC** ... natural historic ranged from **0.36 to 0.90 mS/cm**
- Within 3 months following installation ranged from **4.22 to 7.97 mS/cm**



Case Study #3 – Dry-cleaner

- TCE before Installation ... 37 µg/L
- Within 6 months ... 19 µg/L

MOECC
Table 3 Standard
for TCE
is 17 µg/L

- Working on site Closure ...
 - 4 Quarterly events
 - Record of Site Condition



Summary

- New twist on a known technology – KMnO_4 & NaS_2O_8
- Application ease for difficult locations/situations
- See instant results (↑ ORP and electrical conductivity)
 - Clients are pleased with Cost/Benefit
 - Sustained Release
- Technology fits well as an option for overall remediation plans and combined remedies



Closing

- Questions?
- Thank you for Attending!
- Consider yourself SMARTer!

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