Permeable Reactive Barrier Treatment for Groundwater Exiting a NAPL Contaminated Area

Donald Pope| IPEC 2015 Conference

Water Energy & Resources Environment Property & Buildings Transportation

Agenda

- Site Description
- Description of Non-aqueous phase liquid (NAPL)
- Description of Permeable Reactive Barriers
- Laboratory Treatability Study Design
- Laboratory Treatability Study Results
- Recommendations
- Conclusion

Site Description

- Site is located in Michigan
- Water treatment property
- Groundwater contains Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs) above the Michigan Department of Environmental Quality (MDEQ) generic clean up criteria
  - Highest concentrations include: benzene, toluene, ethylbenzene, and xylenes (BTEX compounds)
  - Naphthalene, trimethylbenzene, trichloroethylene (TCE), and cis-1,2-dichloroethylene (cis-1,d-DCE)
- Groundwater is migrating off-Site at locations that cover approximately 2,500 linear feet along the Sites western property boundary

Remedial Option under Consideration

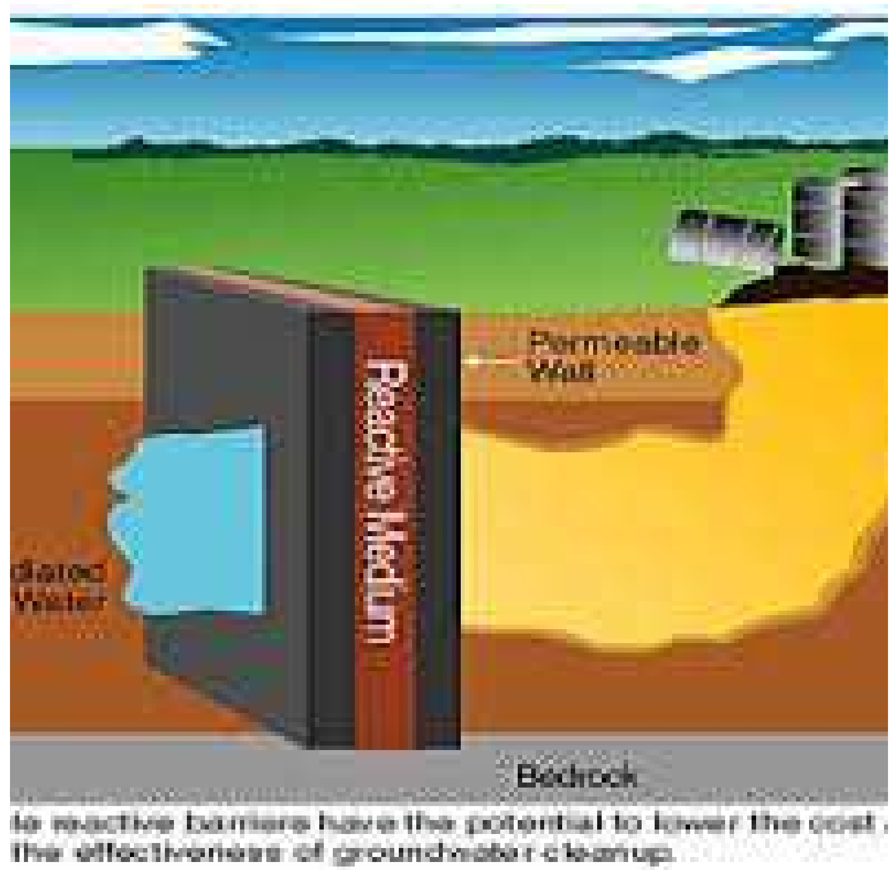
- A bentonite slurry wall constructed along the western property boundary
- The insertion of a funnel and gate permeable reactive barrier (PRB) system into a slurry wall to treat impacted groundwater in-situ as it leaves the Site

Laboratory Study

- A bench-scale treatability study was performed to assess the potential technologies for their ability to remove the VOCs, SVOCs, and inorganics from the groundwater as it flows through the gate
- The in-situ remedial technologies evaluated in the treatability study for the gate system included enhanced biodegradation, ozone sparging, and adsorption

Description of Permeable Reactive Barriers (PRB)

- Passive treatment that relies on groundwater flow to bring contaminants to reactive media
- Permanent structure which intercepts and treats impacted groundwater
- Physical, chemical, and/or biological processes can be used as removal mechanisms for contaminants
- Con consist of a trench or rows of injection wells
- Various reactive media can be used for PRBs

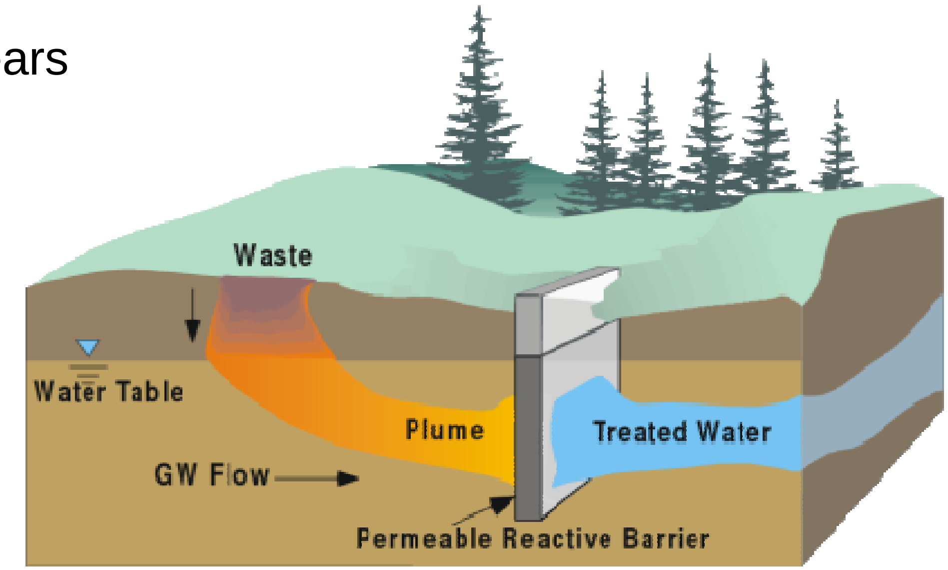


Description of Permeable Reactive Barriers (PRB)

- Commonly used trench reactive media include:
  - Zero Valent Iron (ZVI)
  - Zeolites
  - Granular Activated Carbon (GAC)
  - Organic Media
  - Proprietary Substrates such as EHC
  - Chemical Oxidation agents
  - Chemical Reducing Agents
  - Emulsified Zero Valent Iron (EZVI)
  - Ozone Sparging

Advantages of PRBs

- Passive, no energy input
- No aboveground structures
- Limited maintenance
- Low O&M costs
- Contaminant concentrations are rapidly reduced upon contact with the media
- Long lifetime, 10 to 20+ years

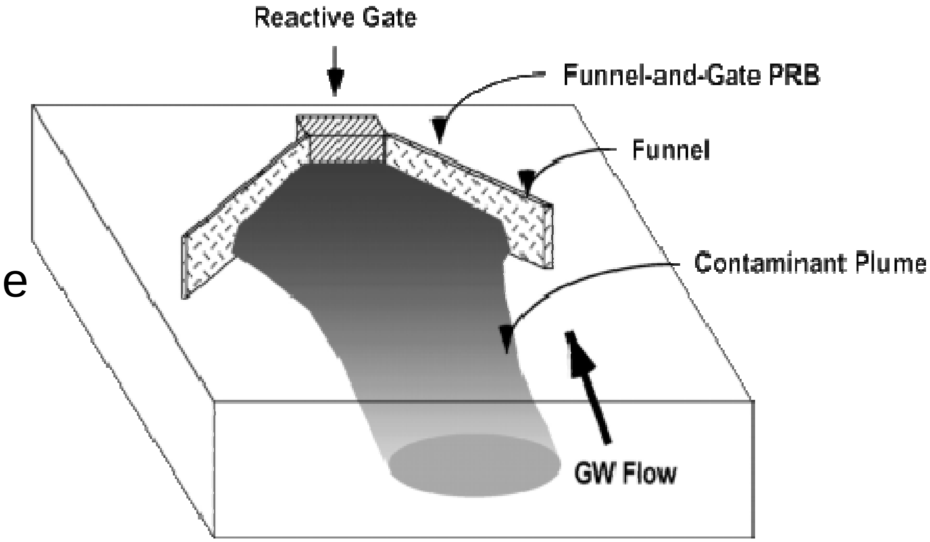


Disadvantages of PRBs

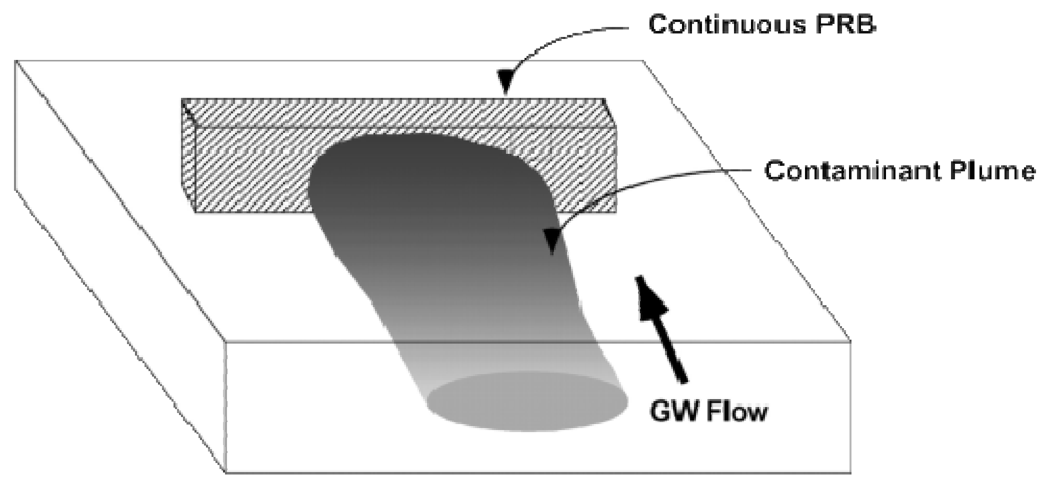
- DNAPL not treated effectively
- Dissolved metal species may interfere with PRB longevity (clogging)
- Detailed understanding of hydraulic flow characteristics (overtopping)
- Installation can be expensive and complex (deep plumes)
- May need to be maintained indefinitely if source is not removed

Types PRBs

- Funnel and Gate
  - Impermeable walls guide the groundwater to reactive media



- Continuous Trench
  - Treatment media extends across width and depth of plume



Treatability Study Objectives

- Determine the empty bed contact time (EBCT) for a GAC only column
- Determine whether pre-treatment with manganese green sand would enhance the performance of the GAC columns
- Determine the GAC change out frequency
- Determine the effect of sparge rates that can be achieved in a waster water treatment place setting on the residence times for aerobic treatment or ozone treatment
- Determine the optimum technology or combination of technologies for groundwater treatment

Initial Groundwater Characterization

Parameters	Units	GW-001
1,2,4-Trimethlybenzene	µg/L	434
Benzene	µg/L	103,000
Ethylbenzene	µg/L	7,800
Naphthalene	µg/L	5,780
Toluene	µg/L	19,600
m/p-Xylenes	µg/L	1,100
O-Xylenes	µg/L	938

Treatability Study Design

- GAC Test Set Up:
  - 3 Columns were set up as follows:
    - Column 1: Groundwater pumped in at a flow rate of 1.25 mL/min
    - Column 2: Groundwater pumped in at a flow rate of 2.5 mL/min
    - Column 3: Groundwater pumped in at a flow rate of 5 mL/min
  - Effluent samples from the columns were analyzed for VOC after 1 hour of operation and then every 24 hours thereafter until breakthrough was observed

Treatability Study Design

Column 1: Flow
1.25 mL/min

Column 2: Flow
2.5 mL/min

Column 3: 5 mL/min

Treatability Study Design

- Biodegradation Test Set Up:
  - Testing was performed to determine the parameters for biological treatment
  - Two identical glass columns were run as follows:
    - Column 1: Sand only (Control)
    - Column 2: Sand, air, and nutrients
  - Site groundwater pumped using a multi-channel pump into the bottom of each of the columns at a rate that would give a hydraulic retention time (HRT) of 2.5 hours
  - Air was sparged into each column at 10mL/min
  - The water from the tops of the columns was collected after 24 hours and analyzed for VOC
  - The flow rates were slowed to increase the HRT to increase the removal of the VOC present in the groundwater

Treatability Study Design

Air Sparge Flow Meter

Air Sparger

Vent

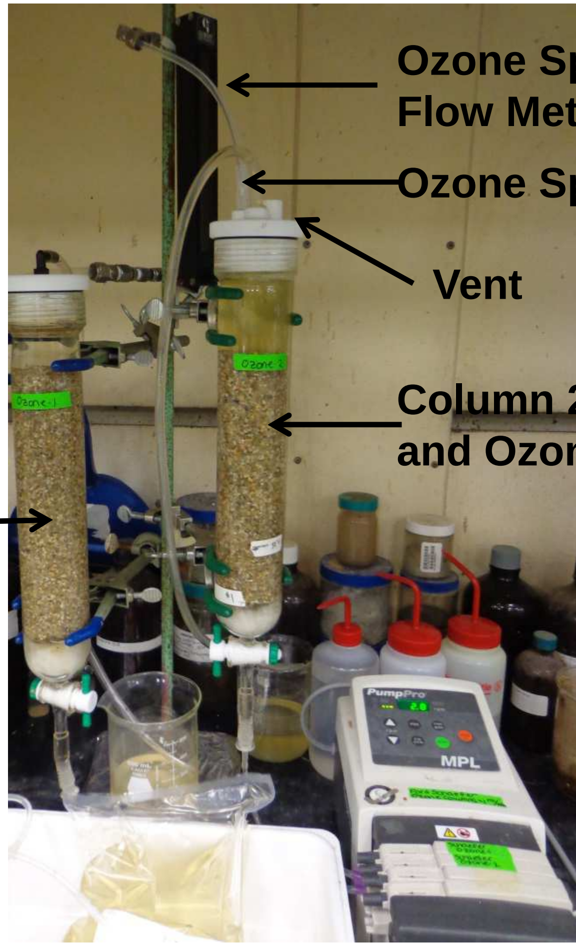
Column 1: Sand Only (Control)

Column 2: Sand and Air

Treatability Study Design

- Ozone Test Set Up:
  - Two identical columns were run as follows:
    - Column 1: Sand only (Control)
    - Column 2: Sand and ozone sparger
  - Ozone was sparged into column 2 at 20 mL/min
  - Site groundwater pumped into the bottom of each of the columns at a rate that would give a HRT of 5 hours
  - Groundwater was collected after 5 hours of operation
  - The flow rate of the columns were decreased to increase the HRT to increase the VOC removal
  - The ozone sparge rate was increased to increase the VOC removal

Treatability Study Design



Ozone Sparge Flow Meter

Ozone Sparger

Vent

Column 2: Sand and Ozone

Column 1: Sand Only (Control)

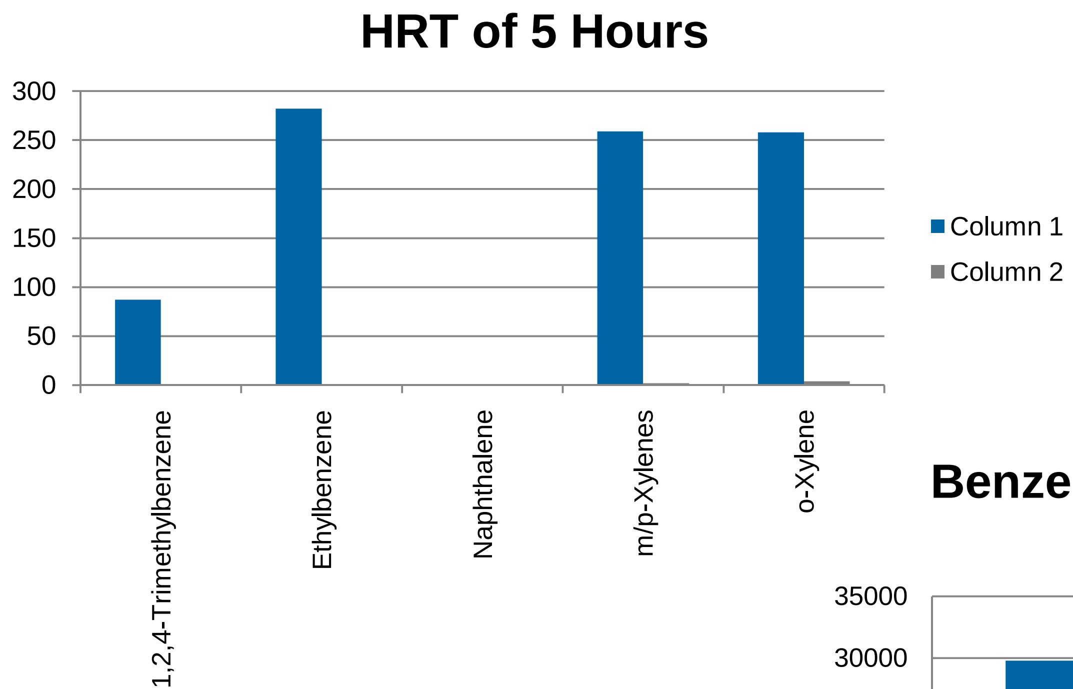
Ozone Generator Used to Produce Ozone

GAC Test Results

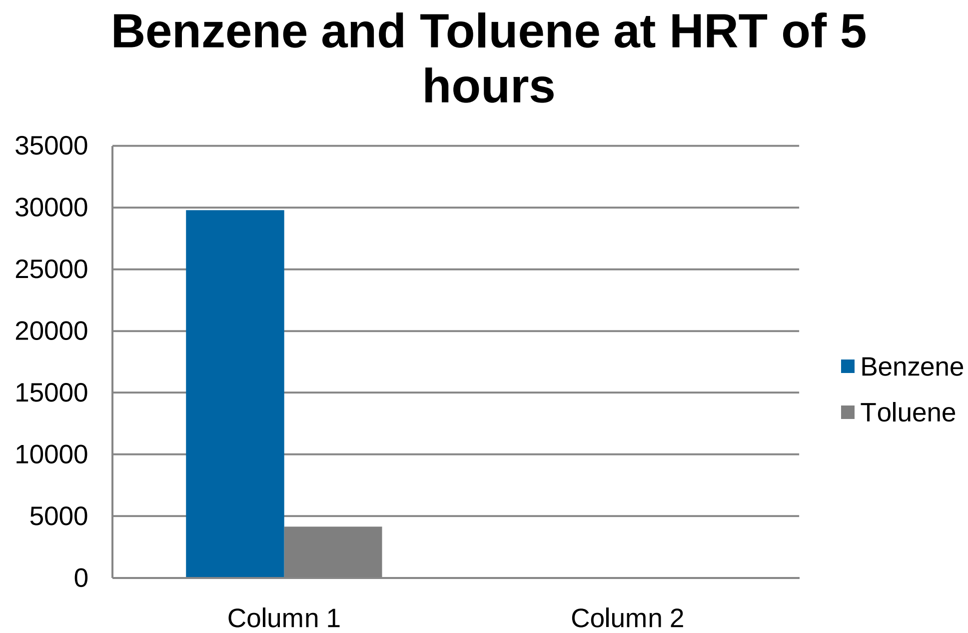
Parameters	Column 1	Column 2	Column 3
Flow Rate	1.25 mL min^{-1}	2.5 mL min^{-1}	5 mL min^{-1}
EBCT	38.4 min	19.2 min	9.6 min
Volume at Breakthrough	33.4 L	32.4 L	14.8 L
Benzene Loading Rate	0.28 g benzene/g carbon	0.27 g benzene/g carbon	0.12 g benzene/g carbon

- An EBCT of 9.6 minutes is sufficient to treat the water
- A lower loading of benzene was achieved which would require more change outs of the carbon
- An EBCT of 19.2 minutes would reduce the change out frequency
- At an EBCT of 19.2 minutes 1,000 pounds of carbon would treat approximately 324,000 gallons of water prior to becoming saturated

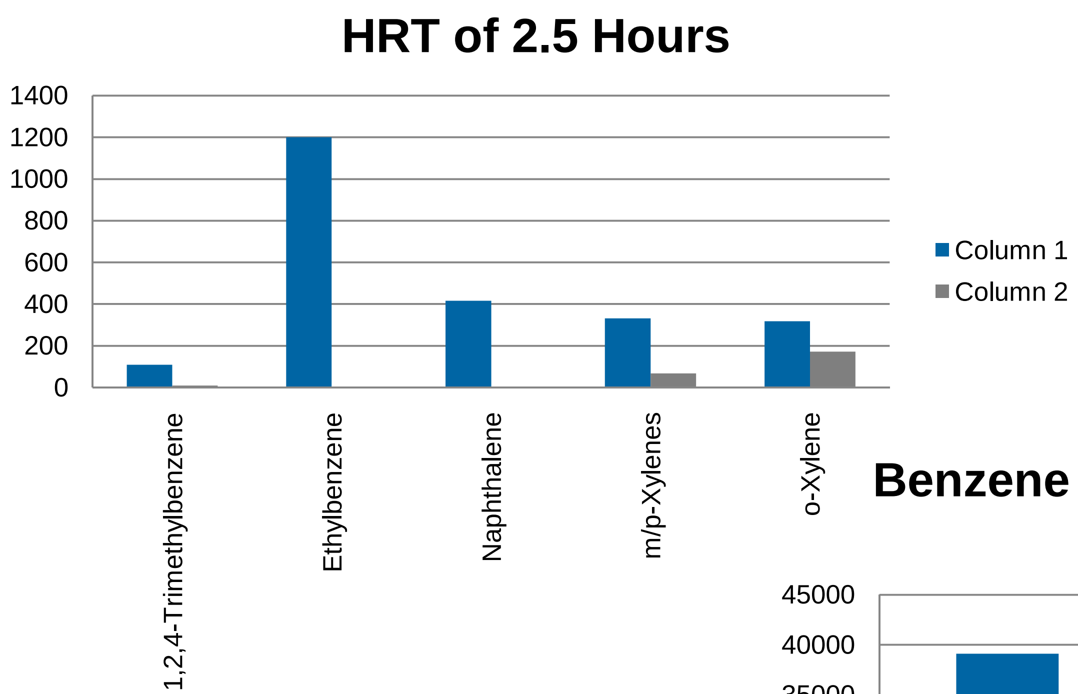
Biodegradation Test Results



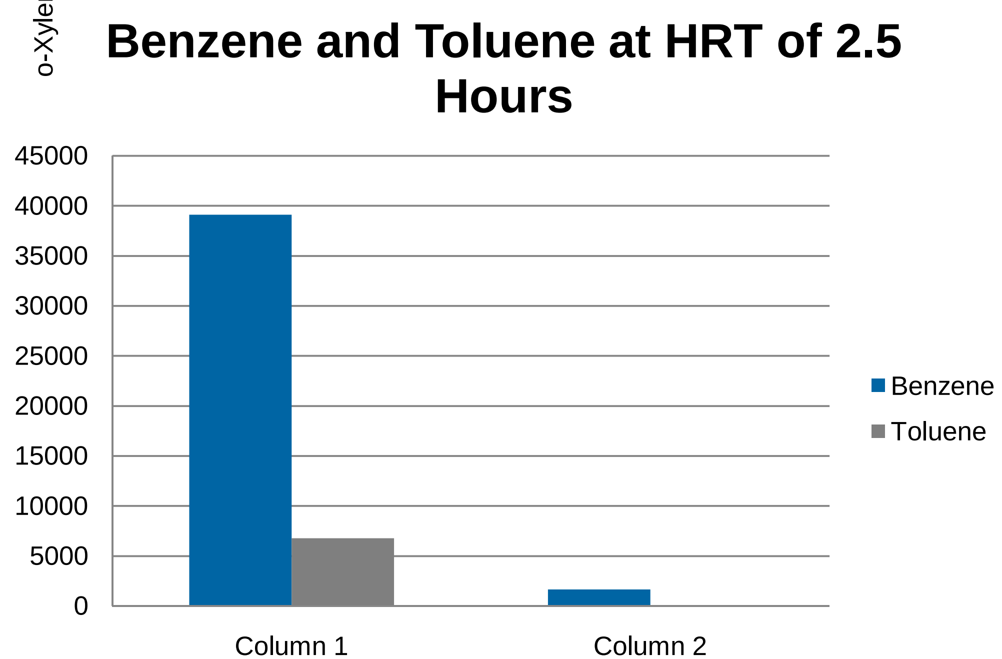
Over 90 percent removal of all VOCs was observed at an HRT of 5 hours comparing Column 1 (control) to Column 2



Biodegradation Test Results



Satisfactory removal of VOC was obtained once the microbial population has been established in the columns



Greater than 80 percent removal of all VOCs compared column 1 (control) to column 2 except for xylenes which showed greater than 50 percent removal

Ozone Test Results

	HRT of 5 hours 20 mL/min Ozone	HRT of 7 hours 20 mL/min Ozone	HRT of 7 hours 30 mL/min Ozone	HRT of 7 hours 40 mL/min Ozone
% Removal of 1,2,4-Trimethlybenzene	55.1%	0.00%	83.7%	51.4%
% Removal of Benzene	54.0%	88.5%	83.3%	89.5%
% Removal of Ethylbenzene	47.9%	87.0%	76.2%	37.5%
% Removal of Naphthalene	<1%	<1%	96.0%	<1%
% Removal of Toluene	52.6%	90.1%	86.0%	91.8%
% Removal of m/p-Xylenes	48.0%	88.4%	86.8%	91.3%
% Removal of O-Xylenes	43.1%	88.6%	80.5%	86.6%

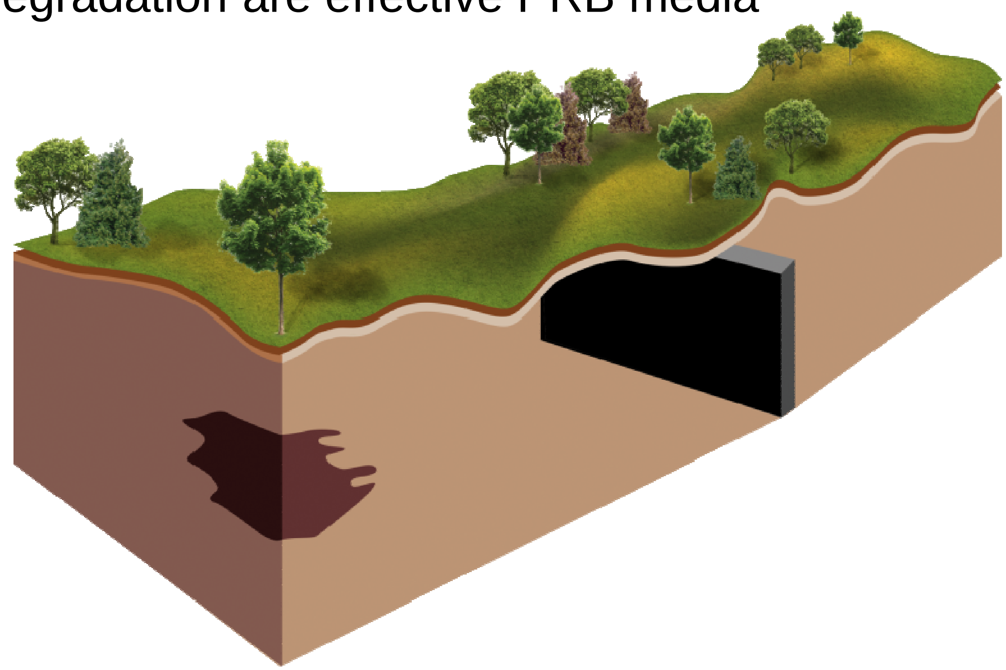
Although significant removal of VOC was observed at an ozone sparge rate of 30mL/min and 40mL/min, the VOC concentrations remained elevated. The testing was discontinued since satisfactory removal of VOC was unlikely to occur.

Recommendations

- GAC Tests:
  – EBCT to 19.2 mins
  – Change out approximately every 324,000 gallons
- Biodegradation Tests:
  – The addition of nutrients to the groundwater and the provision of air to the biologically active filter
  – The addition of a microbial inoculum is required since the groundwater contained the bacteria necessary for the treatment of the water
  – HRT of 2.5 hours
- Ozone Tests:
  – Ozone sparging would not treat the VOC in the groundwater within a practical time period, therefore, this technology is not recommended

Conclusion

- Permeable Reactive Barriers are effective technologies for the treatment of groundwater before migrating off-Site
- Many different media are available for use in PRB and the selection of the medium depends on the contaminant(s) and site characteristics
- PRB can be installed using trenches or injection wells
- GAC and biodegradation are effective PRB media



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