Combined Technologies for *In Situ* Stabilization / Isolation of Mercury Contamination in Remote Locations

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INTRODUCTION

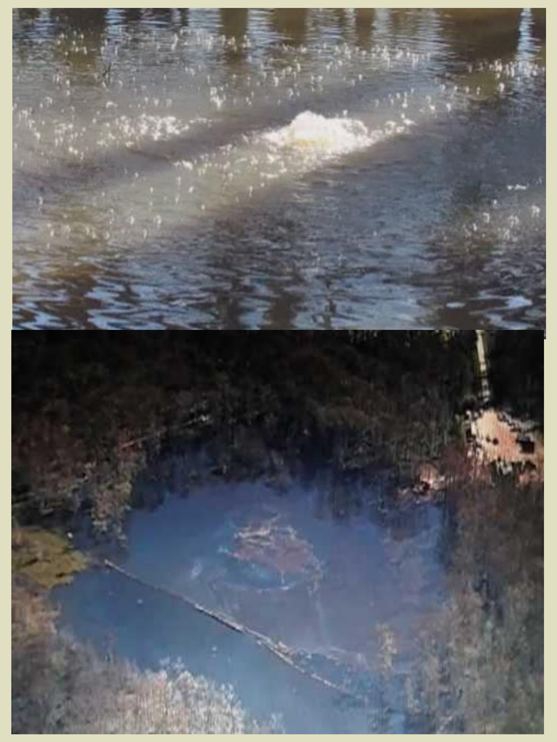
In situ sediment capping remediation systems mitigate the migration of contaminants through sediments. Two generalized approaches are common: (1) passive capping, which is the deployment of a barrier material to either diffuse pore water to acceptable levels or to sequester the contaminants by blocking pore water movement; and (2) active/reactive capping, which employs one or more additives or amendments to a relatively permeable layer in an effort to bind up and/or destroy the contaminants as they migrate through the treatment area. *In situ* sediment caps can reduces "risk of remedy" in sediment removal and *ex situ* treatment, and they avoid unsustainable practice of moving problem from sediment to landfill. The choice of approach depends on a wide variety of site-specific issues, demands and conditions.

It has been widely accepted that sulfate-reducing bacteria (SRB) as well as iron-reducing bacteria (IRB) were primarily responsible for methylation of mercury in anoxic environments, including sediments (*e.g.* Compeau and Bartha, 1985; Fimmen *et al*., 2009; Yu *et al.*, 2013). However, more recent work indicates other types of anaerobic bacteria – including methanogens – can also methylate mercury (*e.g.* Gilmour *et al*., 2013; Yu *et al*., 2013; Cossa *et al.*, 2014). No single mercury methylator seems to dominate in all anoxic environments. Rather, the prevailing mercury-methylating bacteria in any given anoxic environment, including sediment, appears to depend on a host of site-specific environmental and other factors. Thus, *in situ* sediment treatment systems that can address methylation in general can be important to remedial approaches.

PROBLEM STATEMENT

Advances in the delivery and placement technologies such as the AquaBlok® technology have greatly expanded the range of active cap designs for *in situ* treatment and receptor protection. One resulting complication of any sediment capping or the addition of reactive agents is that the implementation/construction processes themselves can create an initial spike of methanogenic activity because the sediment becomes disturbed and available carbon sources are more rapidly consumed. A second methane spike can occur later as oxygen is depleted from the remediated site, thus shifting the balance between aerobic biodegradation and anaerobic biodegradation in favor of the methanogenic anaerobes. The production of methane is problematic from several perspectives, including:

- The production of methane can create gas bubbles (ebullition) which can transport contaminants via surface tension phenomena through localized cap failures due to gas buildup (Figure 1a);
- Methane gas ebullition causes cap breaching and induced migration = sheen (Figure 1b); and
- Methanogens can generate methylmetal(loids) such as methylmercury and methlyarsenic, with many negative consequences.



Figures 1 A/B. Examples of excessive methanogenesis (top panel – A) and associated ebullition/induced migration of contaminants yielding a sheen (bottom panel - B)

REMOTE LOCATION CHALLENGES

Figures 2. Examples of mercury impacted surface soils and sediments as a result of illegal gold mining activity, very remote Jungle Region, Colombia.

Triage Approach: The scope and magnitude of Hg impacts (Figures 2) as a result of illegal gold mining activities require a focused, emergency-type response action.

Design challenges include:

- How to identify impacted areas (drone surveillance)
- Limited sampling and delineation
- Prioritization of remedial actions
- Presumptive Remedy Approach
- Uniform application of low doses of high value materials
- Rapid restoration of habitat

Implementation challenges include:

- Absence of infrastructure and basic logistics support
- Lack of implementation experience
- Limited availability of specialized equipment
- Uncommon safety issues
- General absence of clear guidelines governing performance monitoring and remedial action objectives.

ONE PARTIAL SOLUTION

AquaGate+CH4™ integrates methane inhibitors with AquaBlok®, an established sediment capping and *in situ* treatment technology platform, to yield a more effective remedial strategy that can help minimize problems associated with all *in situ* sediment caps.

By controlling methanogen activity at least short term, the integrated technologies presented can offer near-immediate conformance with eco-risk goals in a safer manner through reduced ebullition and generation of methylmetal(loids) such as methylmercury and methlyarsenic.

AQUAGATE® TECHNOLOGIES

As shown in Figure 3, the resulting AquaGate+CH4™ pre-capping layer will simultaneously treat contaminants while controlling methane production which manages several problems common to *in situ* sediment capping systems, including: i) reduced ebullition of gases that may breach the barrier cap; and ii) reduced methylation of heavy metals.

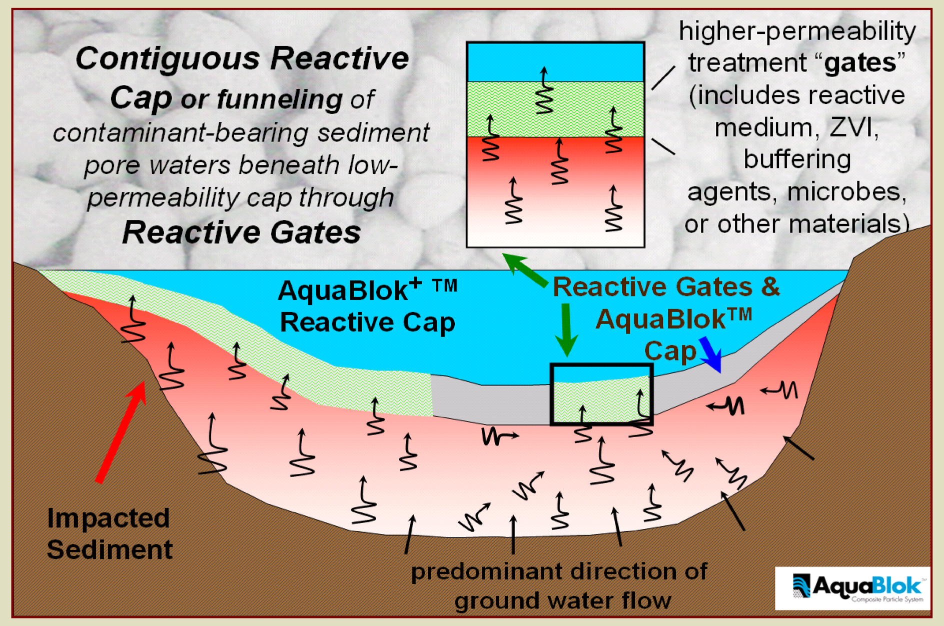


Figure 3. Model composition of antimethanogenic, (reactive) AquaGate+CH4™

Figure 4. Example Applications →

COMBINED TECHNOLOGIES

Provect-CH4® methanogen inhibitors have been combined with AquaBlok® or AquaGate™ or Blended Barrier™ to yield a composite particle (Figures 5 and 6) containing an aggregate core that is layered with the reactive amendment materials and deployed through a water column over a contaminated site.

In the AquaGate® approach, Provect-CH4® is introduced in an initial application before placing the AquaBlok® sequestration cap to inhibit methylation after cap placement.

Applications:	AquaBlok®	AquaGate+™
MGP Sites (Coal Tar)	⊙	⊙
Refinery Site (PAH, Diesel)	⊙	⊙
Pond (Metals, Mercury)	⊙	⊙
Upland Seep Zone (Arsenic)	⊙	⊙
Installation Configurations:		
Low Permeability Cap	⊙	–
Cut-off Wall	⊙	–
Upland PRB	–	⊙
Landfill Cap Repair	⊙	–
Funnel & Gate	⊙	⊙
Post-dredge Backfill	⊙	⊙
In situ Treatment	–	⊙
Reactive Capping	–	⊙
Bank Stabilization, Residual Sequestration	⊙	–
Habitat Restoration	SubmerSeed®	

AquaGate+™ (amendments)	
Organoclay	Provect-IR®
Powder Activated Carbon (PAC)	Sulfur Compounds
Zero Valent Iron (ZVI)	Aluminum Sulfate
Clinoptilolite	Microbes
Organic Carbon	Provect-CH4®
Provect-IRM®	Seeds

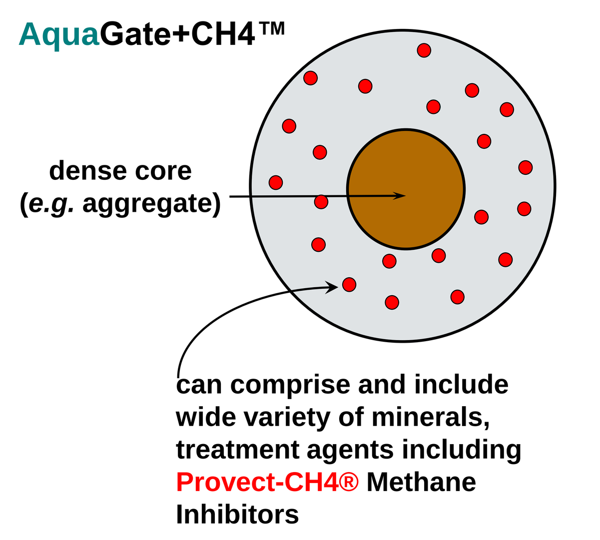


Figure 5. Model composition of antimethanogenic, (reactive) AquaGate™

Aggregate Powder AquaBlok®/AquaGate™

Figure 6. AquaBlok® Technology Platform allows Reagent Delivery through a Water Column

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