Remedial Amendments with Integrated Control of Methane Production

J. Mueller, G. Booth (Provectus), W. Meese (IET), J. Haselow (RedoxTech) and J. Hull (AquaBlok)

INTRODUCTION

Methanogens/Archaea are often the dominant microbes in reduced environments. Methanogenesis is a practical component of anaerobic bioremediation. Given that methanogens can replicate in 1 to 2 hours (whereas *Dehalococcoides* spp. double in 24 to 48 hours) they often bloom and dominate following the addition of conventional organic hydrogen donors such as (emulsified) oils/lecithin, sugars and conventional ISCR reagents thereby liberating large amounts of methane gas (values exceeding 800 mg/L in water and >300,000 ppmv in soil gas have been reported). There are at least three important consequences of this response:

- **Cost - by utilizing hydrogen, the methanogens compete with dechlorinating microbes thus making inefficient use of the amendment (some calculations indicated >90% waste via methane production);**
- **Safety - elevated methane concentrations can exceed current and pending regulations of < 1 to <28 ppm in groundwater, and/or <0.5% v/v methane in soil gas (*e.g.*, <10% of the LEL); methane gas will induce vapor migration potentially causing indoor air issues of VOCs; and**
- **Performance – Archaea are inefficient dechlorinators and yield dead-end catabolites; rapid growth of methanogens consumes alkalinity while generating acids = aquifer acidification; biomethylation can mobilize heavy metals such as arsenic causing secondary contaminant issues.**

Application	Conventional Amendments	Technologies with AMR
Groundwater / Soil	ERD carbon sources (sugars, molasses, hydrogen release substrates e.g., EHC-L®, Newman Zone® and all other EVOs)	ERD-CH4® ERD-CH4 Ole Ego™
	ISCR amendments (EHC®, ABC+®, Ferox® and any other carbon + ZVI amendments)	Provect-IR® Provect-IRM®
Sediments	Sand caps, Sequestration / Bio	AquaGate®-CH4
DNAPL	EZVI	EZVI-CH4™

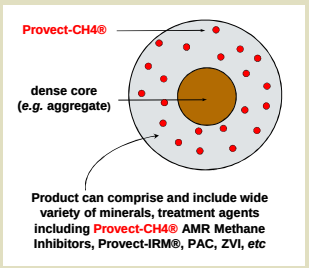
A thorough analysis of conventional (*i.e.*, no active control of Archaea) remedial amendments with those that control excessive methanogenesis should consider:

CH4 bubbles from a sealed well >12 months Post EVO (Newman Zone®) Application (source US DOD 2017)

- **Unit price (and cost to implement)**
- **Inherent safety**
- **Potential for VI and related issues**
- **Potential for COI mobilization**
- **Potential for heavy metal methylation**
- **Ease of Use**
- **Predicted performance**

In addition to multiple technical advantages, amendments that contain Antimethanogenic Reagents (AMRs) have an ability to actively control methane production and are commonly identified as the best alternatives for a given site.

AQUAGATE®-CH4™ SEDIMENT TREATMENT

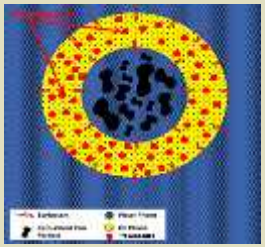


AquaGate®-CH4™ integrates methane inhibitors with AquaBlok® sediment capping and *in situ* treatment technology platform to yield a more effective remedial strategy that can help minimize problems associated with all *in situ* sediment caps. Namely, by controlling methanogen activity - at least short term - these integrated technologies can offer near-immediate conformance with eco-risk goals in a safer manner through reduced ebullition and reduced generation of methylmetal(loids) such as methylmercury and methlyarsenic.

- **Any conventional sediment cap will induce CH4 production**
- **AMRs can help minimize this response**
- **The core AquaGate particles can be supplemented with other materials**
- **Multiple Patents**

EZVI®-CH4™ DNAPL TREATMENT

- **Formulated for a given site**
- **10% to 20% (wgt basis) ZVI content (1 to 3 micron)**
- **Typical AMR at 5% of Fermentable C**
- **Up to 3 types of AMRs have been used**
- **Micelle diameters range from ca. 5 to 20 micron (shear dependent)**
- **Ships in 55 USG drums or 330 USG totes**
- **Made in USA in collaboration with NASA**



PROVECT-IR® ISCR AMENDMENT

- **Formulated for a given site**
- **Typical AMR at 5% FC**
- **Up to 3 types of AMR used**
- **Thousands of tonnes used globally**
- **Safely and effectively applied to all lithologies with proper tooling and equipment**
- **Made in USA, Italy, Taiwan**
- **Multiple Patents**

ERD-CH4® OLE Ego™ LIQUID ERD AMENDMENT

- **Formulated for a given site**
- **55% to 85% (wgt basis) fermentable carbon (FC)**
- **Typical AMR at 5% of FC**
- **3 types of AMRs have been integrated into one material**
- **Ships in 55 USG drums or 330 USG totes**
- **Density 7.9 to 8.5 lbs/USG**
- **Viscosity range 10 to 50 cP**
- **Multiple Patents**
- **Made in USA**

The addition of micro ZVI yields the only liquid ISCR reagent with active control of Archaea

Provectus Environmental Products, Inc. ô 2871 West Forest Road, Suite 2 ô Freeport, IL 61032 ô Phone (815) 650-2230
Innovative Environmental Technologies, Inc. ô 6071 Easton Road ô Pipersville, PA 18947 ô Phone (215) 766-1603
Redox Tech, LLC ô 200 Quade Drive ô Cary, NC 27513 ô Phone (919) 678-0140
AquaBlok, LTD ô 175 Woodland Avenue ô Swanton, OH 43558 ô Phone (419) 825-1325