

## New Antimethanogenic Reagents (AMRs)

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**Background/Objectives.** At many groundwater remediation sites, excessive production of methane has been observed following the addition of conventional organic hydrogen donors such as (emulsified) oils/lecithin, sugars and conventional ISCR reagents. This is because methanogens are commonly the most ubiquitous indigenous microbes in anoxic aquifer settings. This is attributed to the fact that methanogens replicate in 1 to 2 hours (whereas *Dehalococcoides* spp. for example double in 24 to 48 hours), they often bloom and dominate following the addition of organic hydrogen donors, thereby wasting a significant amount of the hydrogen donor (typically >30%) by liberating large amounts of methane gas. There are at least three potential consequences of this response: Cost - by utilizing hydrogen, the methanogens compete with dechlorinating microbes; 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) and methane gas can induce vapor migration potentially causing indoor air issues of VOCs) and exceed LEL; and Performance - rapid growth of methanogens consumes alkalinity while generating acids increasing the potential for aquifer acidification (which may liberate heavy metals such as arsenic causing secondary contaminant issues). Hence, evaluating the need to actively control excessive methanogenesis during remedial actions is now commonplace among seasoned professionals as the positive effects on remedial performance, safety, regulatory compliance and sustainability become well understood.

**Approach/Activities.** In 2014, Provect-CH4® containing specially processed red yeast rice (RYR) extract was introduced as a means to specifically and proactively control Archaea growth during ERD and ISCR remedial actions. Efforts to improve the technology have focused on expanded mode of action and extended longevity to better manage challenging sites. Toward this end, Provect-CH4 Ego™ is a mixture of Essential Garlic Oil (Ego) used in combination with RYR to more effectively control the growth and proliferation of methanogenic Archaea. Being oil-based this advanced AMR is more compatible with certain ERD/ISCR amendments, such as EVO and EZVI.

**Results/Lessons Learned.** Multiple essential oils were evaluated under laboratory conditions for their antimethanogenic potential. In various trials, garlic oil was effective at rapidly reducing ORP, stimulating reductive dechlorination reactions, maintaining pH, and reducing methane production >75% as compared to the active control. Additional data from laboratory and field studies evaluated longer reaction times and have shown efficacy up to 60 and 90 days under various aquifer and test conditions. These essential oil-based AMRs have been combined with RYR and integrated into various remedial amendments (e.g., liquid ERD, solid ISCR, EZVI, sediment capping materials) and are currently the subject of independent laboratory and field studies evaluating performance, efficacy, longevity and impacts on environmental microbiology. Information on the reagents modes of action, dosing / application requirements, and lessons learned during their field implementation will be presented along with results of field performance monitoring and application costs.