**Methane Production During Anaerobic Bioremediation**

Dissolved methane in groundwater and elevated methane concentrations in the vadose zone are often observed when electron donors are injected for anaerobic bioremediation. Methane in air is potentially explosive at concentrations ranging from 5% to 15% by volume. For that reason, we are taught in safety training classes that any indoor air concentration of 10% LEL (0.5% in air) should be treated as a serious safety hazard.

When oxygen is absent and electron donor concentrations are high, biogas in the form of methane and carbon dioxide is produced and methane can accumulate. It is not uncommon for methane concentrations in the vadose zone to be as high as 40% (800% of the LEL) just from the decaying of natural organic matter. After being taught that 10% LEL is dangerous it is not surprising that field technicians can be alarmed when they see these high concentrations in monitoring wells or soil gas samples.

***Will methane produced from electron donor injections become a safety hazard?***

Methane is only present in the subsurface when oxygen is absent, and when methane is transported into the vadose zone with oxygen present it will biodegrade to carbon dioxide very rapidly. Even when biogenic methane is present in shallow soil gas at high concentrations it is very unlikely to become an explosive hazard in a building. Most buildings exchange a full volume of air with the atmosphere more than 10X per day (EPA 2010). For that reason, it is nearly impossible to create a 5% methane concentration in a building by diffusion – you need pressure and advective flow to move huge quantities of methane quickly enough to maintain a 5% LEL concentration.

The slow biogenic production of methane and diffusion cannot produce enough of a methane flux from sub-slab soil gas in a building to create an explosive atmosphere. Biogenic methane can only become a significant hazard when there are high methane concentrations are combined with elevated soil gas pressures that allow for advective gas flow. A good example of this is hazard would be biogas in landfills that unless properly vented may be trapped by a landfill liner and cap until elevated pressures are produced.

For clients that have concerns about assessing the risk of biogenic methane we strongly recommend that they follow the recommendations of ASTM E2993-16. When high methane concentrations are detected near buildings in the vadose zone collecting samples of indoor air almost always results in methane concentrations that are not significantly above atmospheric background concentrations. A quick summary of ASTM E2993-16 suggests the following biogenic methane hazard assessment process:

* If you have less than 5% methane in the vadose zone (less than 100% LEL) no further action.
* If you detect 5% to 30% methane in shallow soil gas (100% to 600% LEL) test for a pressure differential between sub-slab soil gas and the indoor air – if less than two inches water gauge there is no further action.
* If more than two inches water gauge pressure is detected between sub-slab soil gas and the building and shallow soil gas concentrations greater than 30% (600% LEL) collect indoor air samples.

***Should we inject methane inhibitors to reduce biogenic methane production?***

A great deal of research has been conducted on methane inhibitors to reduce methane production by livestock. In most cases the effect of the methane inhibitors only lasts a few weeks and methane production in ruminants returns to background levels. The same is likely to occur at bioremediation sites and the methane inhibitors are unlikely to persist and would require frequent reapplications.

***Does methane production “waste” a significant amount of injected electron donors?***

Our emulsified vegetable oil (EVO) products produce far less methane than fast release electron donors. Slow release electron donors like Newman Zone 55 produce a slow and steady supply of molecular hydrogen at relatively low concentrations often <10 nanomolar. Dechlorinating microbes like Dehalococcoides mccartyi (Dhc) can grow on molecular hydrogen concentrations of < 1.0 nanomole, while methanogens need much higher concentrations to support their growth (Loffeler, Tiedge 1999). McCarty suggests that keeping molecular hydrogen concentrations between 2-11 nanomolar optimizes dechlorination while minimizing methane production (Yang, McCarty 1998). In fact, our vegetable oil-based products contain triglycerides whose long chain fatty acids inhibit methanogenesis (Lalman 2000, Lalman 2001).

***Microcosm***

RNAS Remediation Products has compared our EVO products to industry standard fast release electron donors. As suspected, we found that our EVO produces less methane. When spiked with 10 mg/L of PCE, a Dhc based bioaugmentation culture, and equal concentrations of electron donors, the following results were produced.

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| **MICROCOSM STUDY: 10 mg/L PCE; KB-1 Culture Inoculum** |  |  |
| **Methane Production After 180 Days Incubation** |  |  |  |
| **Electron Donor** | **Methane Mass** | **Dry Weight** | **Methane**  | **Dry Mass Donor** | **Methane Mass** |
|  | **Per Mass Donor** | **mg/Liter** | **mg/Liter** | **milligrams** | **milligrams** |
| **Sodium Lactate** | 0.0176 | 500 | 8.8 | 125 | 2.200 |
| **Sweet Whey** | 0.0168 | 500 | 8.4 | 125 | 2.100 |
| **Glycerol** | 0.0082 | 500 | 4.1 | 125 | 1.025 |
| **Newman Zone EVO** | 0.0022 | 500 | 1.1 | 125 | 0.275 |
| **Newman Zone HRO** | 0.0017 | 500 | 0.85 | 125 | 0.213 |

***Results***

Over a period of six months PCE was converted to ethene in all treatments (fast release donors and our EVO). Methane production in the EVO based microcosms was an order of magnitude lower than that of fast release electron donors like sodium lactate. “Wasted” electron donor was <2% even in the fast release microcosms, so methane production seems to consume very little donor across all treatments.