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Evaluation of Factors Affecting the Initiation of Methanogenesis in Solid Waste

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Decomposition of organic matter in various anaerobic ecosystems (e.g. landfills, soil, sediments, peat, rumen, termite gut, etc) progresses through distinct phases, occurring both temporally and spatially. In refuse, these phases have been defined as aerobic, acid, accelerated methane and well-decomposed or decelerating methane. Of these, the acid phase is brought about by rapid fermentation and hydrolysis reactions that typically cause an accumulation of carboxylic acids, thereby driving down ecosystem pH. Typically, refuse pH minima in the acid phase range between 5.5 and 6. Over time, accumulated acids are consumed and pH increases to neutral. It is widely accepted that under these conditions methanogenic *Archaea* (methanogens) are the primary microorganisms that consume carboxylic acids or their metabolites, but the mechanisms by which this occurs are poorly characterized. One difficulty is that most methanogens isolated in pure culture have an optimal pH range between 6.5 and 7.8 and optimal pH for methane production in refuse has been reported as 6.8 to 7.2. If true for all methanogens, one would expect methane formation (methanogenesis) to be absent or at least severely inhibited when pH is sub-optimal. However, previous research in refuse, peat and anaerobic bioreactors has shown methanogenesis initiation can occur when bulk pH of the ecosystem is around 5.75, 4 and 6, respectively.

There are currently two hypotheses on how methanogenesis is initiated in landfills. The first is that acid-tolerant methanogens consume acids until the bulk pH is amenable for the establishment of pH-neutral methanogens. Thus far, acid-tolerant methanogens have been definitively identified in peat bogs, suggesting that the potential exists for acid-tolerant methanogens in refuse. The second hypothesis is that localized areas of neutral pH exist while bulk pH is acidic. It is presumed that these zones act as methanogenesis initiation centers and expand as acids are consumed; however, the presence, size and abundance of any pH-neutral zones have not been evaluated. The objectives of this research are to: 1) determine the role acid-tolerant methanogens may have in facilitating the transition from the acid phase to the accelerated CH_4 phase during refuse decomposition, and 2) evaluate the importance of localized pH-neutral areas.

An enrichment study was performed to detect the presence of acid-tolerant methanogens using refuse in the acid and well-decomposed phases of decomposition. Peat from a bog containing known acid-tolerant methanogens was used as an external reference. Both decomposed refuse and peat were blended and squeezed through a mesh material to create liquid inocula and volatile fatty acids were added and maintained at high levels (8,150 mg/L acetic, 812 mg/L propionic, and 6,580 mg/L butyric) commensurate with those seen in decomposing refuse during the acid phase. Liquid inocula were constantly mixed to eliminate the spatial effects (e.g. diffusion gradients). Sub-samples from each treatment were maintained at four different pHs: 5, 5.75, 6.25 and 7 (4, 5, 6 and 7 for peat) throughout the enrichment period (~165 days).

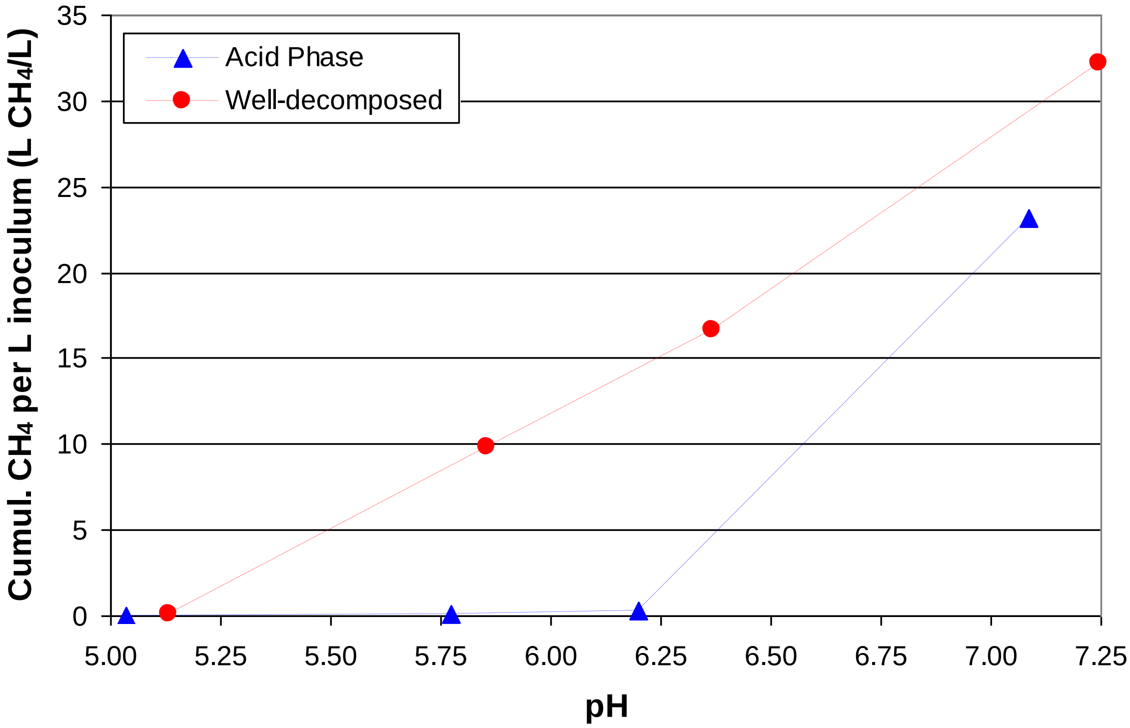

Figure 1: Effect of pH on cumulative CH_4 production in inocula derived from acid and well-decomposed refuse at ~165 days of operation.

Generally, acetic acid and butyric acid were consumed at different rates and propionic acid was not measurably degraded (data not shown). Cumulative CH_4 production for both types of refuse is shown in Figure 1. The well-decomposed inoculum showed measurable methane (CH_4) production at a pH ~5.75. For all inocula, the lag time until CH_4 production was observed successively increased with lower pHs. Methane production in the acid phase inoculum started roughly 30 days after reactor initiation and occurred primarily under neutral pH conditions. However, some CH_4 production at pH 6.25 was observed only after a long lag time (~160 days). Significant CH_4 production occurred in the peat inoculum at pH 6 and higher. In contrast to acid phase refuse, the pH 6 peat inoculum had a lag time of only 100 days before substantial CH_4 production was observed (data not shown). The well-decomposed inoculum produced CH_4 over a broader pH range (5.75 and higher) compared to the acid phase inoculum (neutral pH). These data show starting microbial community structure affects resiliency at lower pH. Data also show that methanogens may be more tolerant under high volatile fatty acid/low pH conditions than originally thought. Microbial community structure from extracted DNA and RNA is currently being assessed via cloning libraries to determine which methanogens are active at low pH and to ascertain the importance of symbiotic relationships between key species within the community.

To assess the importance of spatial differences, reactors are being operated until % CH_4 and pH exhibit an increase, indicating methanogenesis initiation. Reactors will be destructively sampled by cutting the reactor into 20 mm slabs. For each slab, pH will be measured at ~10 locations and areas exhibiting pH differences will be analyzed for microbial community structure. Collectively, both studies will elucidate more clearly the mechanisms that contribute to methane formation in landfills.