Microbial ecology of the vadose zone in the vicinity of residual crude-oil contamination

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We characterized the microbial population in an 8-meter-thick, hydrocarbon-contaminated vadose zone using Most Probable Number (MPN) estimates for four physiologic types: aerobes, heterotrophic fermenters, iron-reducers and methanogens. The site is a surficial sand and gravel aquifer near Bemidji, MN, that was contaminated in 1979 when crude oil infiltrated the subsurface from a broken pipeline. Substantial liquid and vapor-phase petroleum hydrocarbons remain in the vadose zone. We examined three vadose-zone profiles located in: 1) the residual oil, 2) a vapor-contaminated area, and 3) the capillary fringe above the contaminated aquifer.

In the residual oil ~100 methanogens per gram dry weight of sediment (g^{-1}) are present throughout the profile, and fermenter numbers g^{-1} are 10,000 times those of iron-reducers, suggesting that methanogenesis is now the dominant degradation process. Analyses of extracted oil from these sediments show that substantial degradation of C_{15}-C_{35} *n*-alkanes has occurred since 1983. Moreover, gas concentration measurements indicate that methane production in this location has been active since at least 1986, raising the possibility that significant degradation of C_{15} and higher *n*-alkanes has occurred under methanogenic conditions.

In the vapor-contaminated profile, aerobe numbers g^{-1} are 10,000 times higher than uncontaminated background values. Methanotrophic activity also was detected in laboratory incubations of these sediments. Apparently, a substantial microbial population has developed that is supported by the hydrocarbon vapors and methane. Downgradient from the oil, where groundwater is contaminated but no hydrocarbon vapors are detected, fermenter and aerobe numbers g^{-1} above the capillary fringe match those of uncontaminated sediments (100-1,000 g^{-1}). Within the capillary fringe, numbers increase rapidly with depth to values typically found in the contaminated saturated zone.

In the vadose zone profiles with significant hydrocarbon sources from residual oil and vapors, microbial populations are typically 10-100 times higher than in the underlying contaminated saturated zone. Moreover, in areas with residual oil, numbers g^{-1} increase significantly upward toward the land surface. This pattern suggests that supply of an unknown, essential nutrient from the land surface may be facilitating growth in the hydrocarbon-contaminated vadose zone. In contrast, at the location with no significant vadose zone hydrocarbons, numbers g^{-1} in the capillary fringe are less than or equal to those in the contaminated saturated zone below.