ANOMALOUS CONDUCTIVITY IN HYDROCARBON SPILL ZONES – NEW EXTENSIONS TO THE WMU MODEL

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Two important extensions have been added to the working model which explains the anomalously high conductivities that develop at the base of the vadose zone and upper part of the unconfined aquifer areas of mature LNAPL spills. This model, developed at Western Michigan University (hereafter referred to as the WMU model), appears to hold for LNAPL spills more than a year old in temperate climates in unconsolidated soils, typical of mid-latitude glaciated regions in the northern hemisphere. It combines the dynamic effects of seasonal vertical movements of the water table elevation, with bacteriological activity that produces a variety of organic acids as well as carbonic acid, and chemical leaching reactions in response to the lowered pH. The final result of the above three processes is that a conductive inorganic leachate plume is formed in and below the zone of intense aerobic bacterial action. This water typically contains 3-5 times more dissolved solids than the unimpacted ground waters of the same area. The first extension to this model is the recent laboratory discovery that the oil-degrading bacteria also produce surfactants, as can be evidenced by the pronounced lowering of the surface tension of water sampled from the active zone. This has the important effect of allowing water to at least partially replace LNAPL as the wetting phase in the initially hydrocarbon-wetted sediments. This discovery helps greatly to explain how electrically conductive paths can develop across a zone that appears to be dominantly LNAPL-saturated. The second development is the discovery of anomalous conductivity in the vadose zone many meters above the water table at one field site. We have mapped with EM induction small, conductive perched zones, sometimes in channel-form, which retain residual LNAPL. Many of these probably represent horizontal transport paths of the LNAPL spills along permeability boundaries in otherwise sandy environments. This confirms our early speculations that anomalous conductive zones could develop anywhere that oxic conditions hold and where there is residual hydrocarbon present for the bacteria to metabolize. The significance of this conceptual model for contaminant hydrogeology is that electrical resistivity / conductivity methods can be used to map active biodegradation zones, as well as to monitor temporal changes in the biodegradation activity of these zones.