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Natural attenuation potential of the urban hyporheic zone: observations from research sites on the River Tame, Birmingham, UK

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Hyporheic zone (HZ) conditions in gaining rivers may be more conducive to contaminant natural attenuation (NA) occurrence than those widely found in the preceding aquifer pathway for discharging groundwater plumes. We overview research from several field sites developed on the River Tame headwaters in Birmingham, UK to assess the NA potential of the urban hyporheic zone. Hyporheic zone and supporting data have been obtained at the city-scale for a 7 km reach receiving baseflow from the Birmingham sandstone aquifer and several sub-reaches containing various inorganic solutes, metals and chlorinated volatile organic compound (VOC) plumes. Baseflow fluxes to the 7 km urban reach were up to 3500 t/yr (tonnes per year) for major ions, up to 50 t/yr for minor ions, and up to 500 kg/yr for toxic metals and chlorinated volatile organic compounds (VOCs). Generally, baseflow quality was not as poor as might be anticipated from the degree of urbanisation present. However, sporadic high-concentration groundwater plume baseflow discharges where found and subject to varied NA in the hyporheic zone. Local sub-reach scale spatial variability in plume discharges and NA were evident with for example contrasting chlorinated VOC plume biodegradation (dechlorination) observed within a 50 m reach. The surface-water – groundwater mixing zone was generally limited to around 0.25 m invasion depths. However, there were some evidences of deeper transient penetration into the HZ. Modelling and field observation indicated gas accumulation and storage in the HZ, possibly due to denitrification, may assist deeper invasions. Transient flow reversals caused suppression of baseflows and potentially increased NA opportunity, but only lasted a few hours around storm-event hydrograph peaks. The HZ was often weakly oxic with evidences of denitrification activity and discrete zones of iron/manganese reducing conditions. Surface water mixing in the HZ and dilution of baseflows was conveniently accessed via chloride concentrations that were elevated in the river permitting concentration trends departing from expected dilution-calculated concentrations to be assigned to NA occurrence, particularly when corroborated by supporting geochemical trends. There was some evidence of unwanted baseflow quality declines in passage through the HZ – this was perhaps due to release from historically contaminated sediments. These potentially originated from accumulation of urban riverine contaminated sediment over the past two centuries of urbanisation and, or prior influent conditions and leakage through the HZ induced by historical mining of the aquifer by industry abstractions. Overall, although the urban HZ offers NA potential, this potential is spatially and temporally variable and contaminant specific. There are also concerns that the bulk of baseflow is potentially transmitted through the higher permeability, lower NA potential zones thereby short-circuiting the better NA potential zones. The potential for NA of a plume is inevitably site specific thereby requiring site specific evaluations and a typical line-of-evidence MNA approach suitably modified for the HZ. Challenges with development and enforcement of HZ MNA protocols, however, may still cause a regulatory preferred position to perhaps be continued implementation of primary bankside monitoring well compliance points, but nevertheless recognizing the HZ may offer some additional protective benefit.