Biodegradation of De-Icing Compounds in Columns Simulating Natural Conditions

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De-Icers

- 88% glycol, 2.5% surfactants & corrosion inhibitors, water
- glycol readily degradable under a variety of electron acceptor conditions, other additives may be toxic
- fate of the compounds in near-runway environment of interest

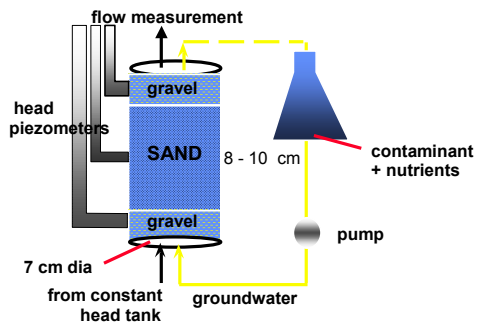
Effects of Biofilm Growth in Soil

- Biomass plugs the pore spaces, changing the hydraulic characteristics
- Plugging may in turn limit availability of electron acceptors and nutrients to the bacteria
- With de-icers, effects of intermittent exposure to the chemicals is of interest

Experiments

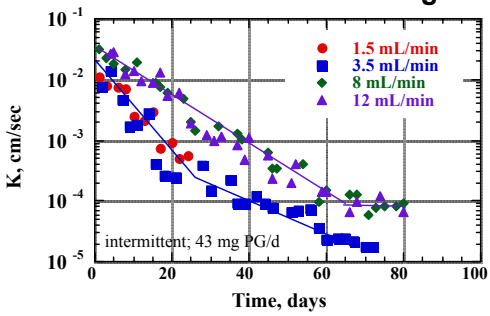
- Column tests
  - effect of groundwater flowrate
  - effect of chemical concentration
  - intermittent versus continuous loading
- 2-dimensional tank experiments
  - effect of biomass growth on tracer flow

1-D COLUMNS

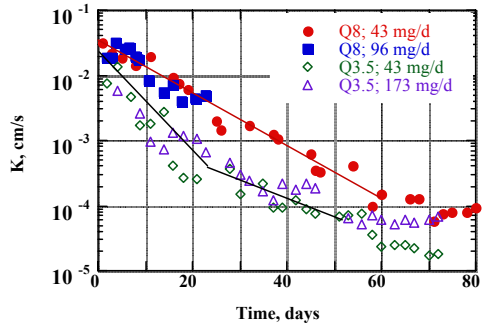


- Columns seeded with bacteria enriched from soil from Denver International Airport
- Bacteria grown long-term on PG under aerated conditions, mixed with sand prior to packing the columns
- Initially 0.13 to 0.2 mg VS/g sand

effect of flowrate on conductivity with intermittent PG loading



No significant effect of PG loading evident



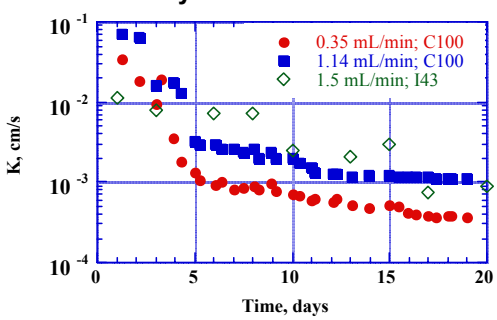
Effluent PG

Flow rate mL/min	Max Inlet PG, mg/L	Avg Daily Load, mg/d	Effluent PG, mg/L
0.35	160	80	0 - 4.4
1.1	100	110	0 - 12.4
1.5	400	43	0.50 ± 0.27
3.5	400	43	1.3 ± 0.9
3.5	1600	172	1.7 ± 0.8
8	400	43	0.44 ± 0.37
12	400	43	5.44 → 0.04

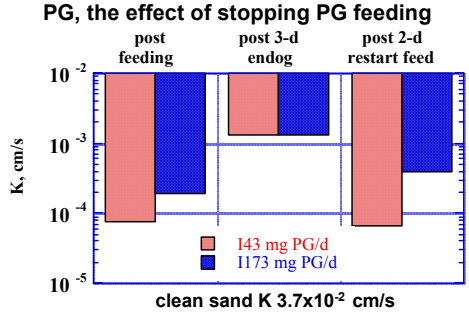
Effect of Endogenous Time

- columns spiked with PG every 2-3 days had measurable PG (0.04 to 2 mg/L) prior to respike; not endogenous
- no significant immediate increase in hydraulic conductivity when biomass without PG
- after 3 to 5 days endogenous without PG, significant increase in hydraulic conductivity
- reapplication of PG causes fast recovery of biogrowth, evident by fast decrease in hydraulic conductivity to previous levels

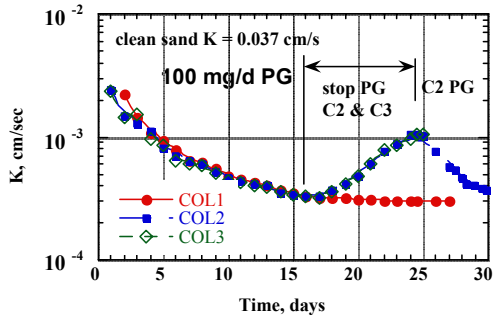
more stability with continuous PG feed



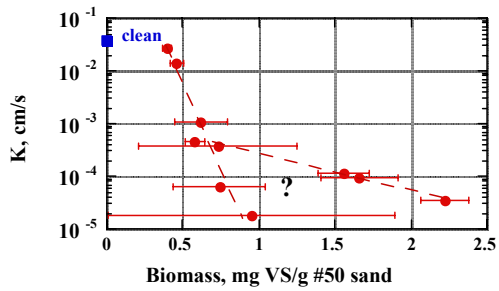
After significant hydraulic conductivity decrease in #50 sand due to biogrowth on PG, the effect of stopping PG feeding



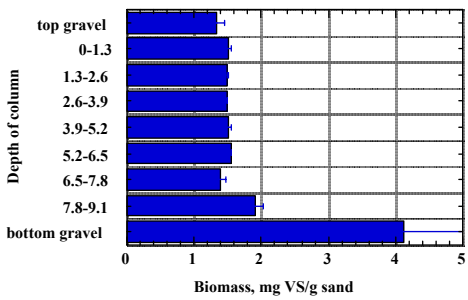
PG removed from water of continuously fed columns



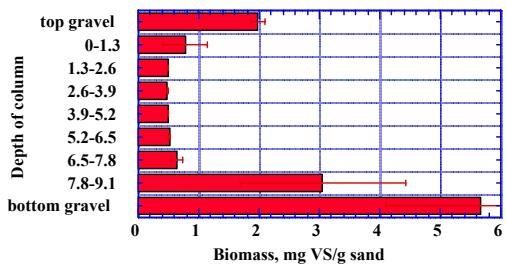
Relationship between hydraulic conductivity and biomass ?



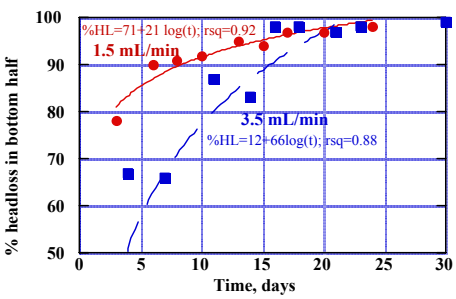
In some columns, the biomass was evenly distributed throughout the sand depth



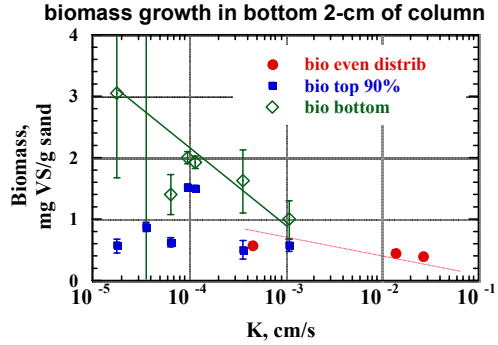
In other columns, significantly higher biomass was present at the bottom of the sand (due to the PG fed into the bottom)



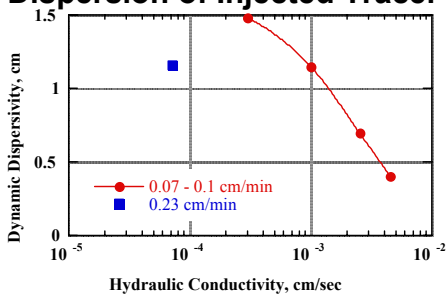
predominance of biogrowth at the bottom of the column also evident from the headloss in the bottom half of the column



average conductivity controlled by higher biomass growth in bottom 2-cm of column

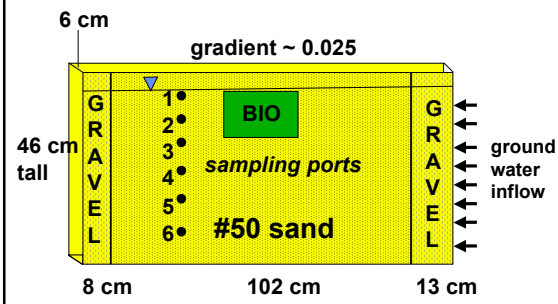


Dispersion of Injected Tracer

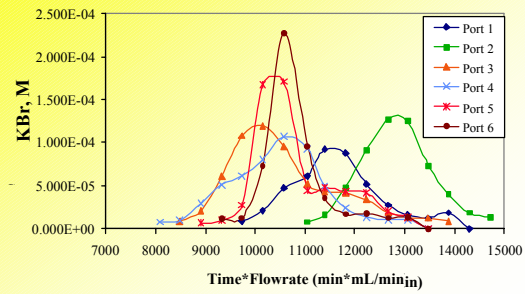


at low flow, dispersivity tends to increase as the conductivity decreases due to biomass growth

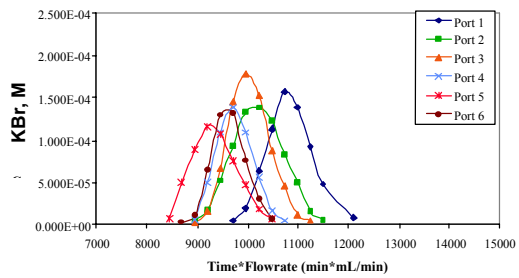
2-D TANK



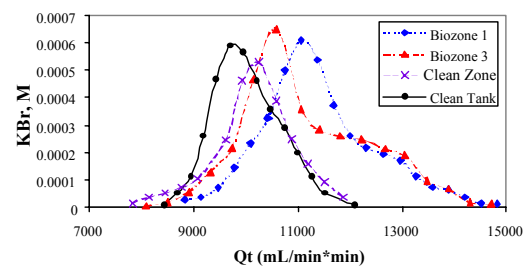
Tracer breakthru downgradient of biozone at ports along the depth of the tank



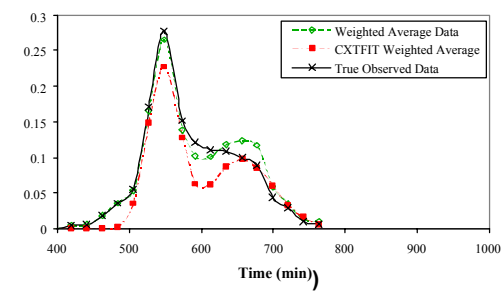
Tracer breakthru with no biomass in Biozone



Cumulative Tracer Breakthru



CXTFIT model results for cumulative tracer breakthru in 2-D tank with Biozone



CONCLUSIONS

- **Ability to naturally attenuate PG in porous media via attached biofilms**
- **Significant reduction in hydraulic conductivity occurs and changes the groundwater flow characteristics in both 1-D and 2-D systems**
- **Intermittent use of de-icers may minimize plugging effects**
- **Work on the effects of the de-icer mixture vs. PG alone, higher loading, and electron acceptor availability are underway**