Filtration for Metals Removal from Stormwater Runoff

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Main Project Goals

• Contribute to the science of metals’ capture from urban runoff by filter media and grass swales.
• Provide guidelines to enhance the design of filters and swales for metals capture from urban runoff.

FOR FILTRATION MEDIA, THE GOALS WERE:
• Characterize physical properties
• Assess & quantify ability of media to capture metals
• Rank media & select media for in-depth study
• Evaluate effect of varying conditions on rate and extent of capture
• Laboratory- and pilot-scale studies of pollutant removal
• Disposal issues of used media (using TCLP)

Stormwater Media in Current Study

• Traditional Media
  – Ion Exchange Resin
  – GAC
  – Sand

• Low Cost ‘once through’ media
  – Compost
  – 2 Zeolites
  – Iron Oxide Coated Sand
  – Agrofiber
  – Cotton Mill Waste
  – Peat-Sand Mix
  – Kudzu
  – Peanut Hull Pellets

Media Capacities for Copper

Laboratory Media Studies

• Rate and Extent of Metals Capture
  – Capacity (partitioning)
  – Kinetic (rate of uptake)

• Effect of pH & pH changes due to media, particle size, interfering ions etc

• Packed bed filter studies

• Physical properties and surface area determinations
Capacity of Media for Zn

Capacity Data for Spiked Stormwater onto Media

Kinetic Studies

Rate of Uptake, Time to equilibrium, Effect of varying parameters on Mass Transfer

Order of Preference for Metal Sorption

- Peat-Sand: Cd, Pb > Zn, Cu > Cr > Fe
- Compost: Cd > Zn > Pb > Cu > Cr > Fe
- St. Cloud zeolite: Zn, Cd > Pb > Cu > Cr > Fe

Interactions of Major Ions

- Peat-Sand:
  - Ca appeared to participate in ion-exchange.
  - Quantities of Mg, K, & Na desorbed were very small and correlation with metals uptake uncertain.
- Compost:
  - Ca & Mg participated in ion-exchange.
  - Na and K were desorbed but did not appear to correlate with metal sorption.
- St. Cloud Zeolite:
  - Ca, Mg, & K appear to participate in ion-exchange.
  - Uncertain about Na.
Now The Pollutants Are “Trapped.” Would They Stay There?

Media:
• Activated Carbon
• Sand
• Municipal Leaf Compost
• Peat Moss

Analytes for Anaerobic Studies
• Dissolved Oxygen and Oxidation-Reduction Potential
• Chemical Oxygen Demand
• pH
• Conductivity
• Nutrients (Nitrate, Ammonia, Phosphate, Total Nitrogen, Total Phosphorus)
• Metals and Major Ions (Ca, Mg, Cu, Cd, Cr, Fe, Pb, Zn)

Pilot-Scale Evaluation of Downflow Filtration: Media Investigated
• Activated Carbon
• Zeolite
• Sand
• Lightweight Sand
• Loamy Soil
• Municipal Leaf Compost
• Peat Moss
• Kenaf Fiber
• Cotton Textile Waste
Sample Collection Location
Grab Samples Collected Hourly For Composting

What about Upflow Filtration to Address the Clogging Problem?
Downflow Filters
Visible Clogging Depth, Surface/Near Surface Straining

Filtration Media Under Investigation

- Play Sand
- Fine (Sandblast) Grade Sand
- Compost-Sand (50/50 v/v) Mixed Media
- Peat Moss-Sand (50/50 v/v) Mixed Media
Upflow Filter Design

Assembly: A sump is provided to collect suspended solids below the filter assembly.

Expected Advantages:
- Reduced Clogging: Sump will collect significant fraction of suspended solids loading.
- Prolonged Life: Particles trapped on the surface of the media will fall into the sump during quiescent times.
- High Flow Rates: Since large and heavy solids will be removed by way of settling in the sump prior to encountering the filter, they can be operated at higher flow rates.

Upflow Filters for Metals Removal

- Four columns: Peat-sand mix, St. Cloud zeolite, Compost, and Control.
- Monitored: Dissolved metals, particulate bound metals, total suspended solids, total dissolved solids, pH, color, and headloss.
- Variable detention time (hydraulic loading)

Column Studies TSS, TDS, and Particulate Bound Metals:
- TSS: Good removal (~90%) for all media for all runs.
- TDS: Peat-sand provided some removal, zeolite had no impact, and compost caused an increase in TDS concentrations.
- Particulate Metals: Generally 80–100% removal for Pb, Zn, Cd, and Fe and 60–95% removal for Cu and Cr.
- Residence Time: No observable impact on TSS and particulate metal removal by peat-sand and zeolite. Slight impact on compost.
- Peat had the best removal efficiencies for particulate bound metals. Removal efficiencies of compost and zeolite were approximately the same.

Pilot-Scale Testing: Turbidity

Upflow Filter Summary

- Optimal loading rates determined for each media to keep effluent turbidity between 5 and 20 NTU until breakthrough began:
  - Pool Sand : 253 m/day (4.5 gpm/ft²)
  - Fine Sand : 190 m/day (3.4 gpm/ft²)
  - Peat Sand : 278 m/day (4.9 gpm/ft²)
  - Compost Sand : 235 m/day (4.2 gpm/ft²)
- Head loss was noticeable as suspended solids loading increased. Flow rates through all the filter media were not significantly reduced unless there was clay buildup leading to media separation and turbulence in the column.
Conclusions of Filter Studies

• Ranking Media for Metals Removal Ability:
  1. Peat-Sand. However detrimental impact on pH, the greatest headloss, and showed the most potential for clogging.
  2. Compost. Also added color to the effluent.
  3. Zeolite lowest capacity of the three.

• Nitrate and metals (except for iron) retained on media even under anaerobic conditions.

• Filters DO NOT dry out between events. Release of previously-captured pollutants during future events may occur if the filters go anaerobic.

• Treatment of low-concentration metals may not be practical using filtration. Practical effluent quality was 10 – 15 µg/L for most metals.

Conclusions of Filter Studies

• Setting the initial flow rate using the hydraulic residence time (HRT) predicted from batch studies (minimum optimum contact time between media and runoff) is not accurate for long in field applications. Suspended solids loading may quickly control hydraulic residence time.

• Batch study predictions of rate constants and capacities unlikely to be valid in field. Laboratory-scale breakthrough curve studies provide better predictions of kinetics and capacity.

• Given large clogging potential, media with smaller pollutant removal capacities become more economically feasible than expensive media with large pollutant removal capacities.

• The upflow column design functioned well in laboratory tests. Work is ongoing using larger columns in laboratory and field installations.

Solid or Hazardous Waste?
Disposal options for the media.

TCLP Cadmium on Media

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<th>Peat-Sand</th>
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