Using Green Roofs to Minimize Roof Runoff Pollution

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Green Roofs: The New BMP (at least in the US)
- Green roofs = vegetated roof covers
  - Plants
  - Growth media
  - Drainage layers
  - Waterproof membranes
- Green roof medium (Extensive green roof)
  - Depth: 2.5 to 6 inches
  - Low organic content
  - Plant selections: typically alpine-type (most are drought-, wind-, frost-, and heat-tolerant)

Green Roof Benefits
- Provide green space in ultra urban areas
- Increased roof life → Decreased roofing costs
- Reduction of urban heat island effect
- U.S. Green Building Council: The Leadership in Energy and Environmental Design (LEED) program
- Increased insulation and energy efficiency

Montgomery Park
Baltimore, MD.
Wildlife Habitat

Green Roof Design Considerations

- Cost comparison for new construction:
  - Green roof - $10-$30 per square foot
  - Traditional roof - $5-$15 per square foot
- Roof load evaluation required for retrofits
- Roof slope considerations
- Tested membranes highly recommended
  - Plastic root barrier above membrane?
  - Flood testing and leak detection units
  - Membrane testing underway at Penn State Univ. (UP campus)

Green Roof Benefits for Stormwater Management

- Water retention and detention properties
  - Monitoring by Penn State Center for Green Roof Research:
    - 55% of annual average rainfall in Pennsylvania remained on a green roof (DeNardo, 2003).
- In areas with SSO/CSO, lighten load on the sewer system?
- Relating to traditional stormwater design methods:
  - Rational coefficients of green roofs:
    - Green roofs have a rational coefficient of about 0.5
    - Equivalent to a “grass lawn”
    - NOTE: Variable with time of year and rainfall intervals

Research: Green vs. Non-Green Roof

Looked at both stormwater runoff volume and flow rates

Retention Volume

\[
\text{Retention Volume} = 6.18 \text{ in}
\]

Peak Intensity Reduction

\[
\text{Peak Intensity Reduction} = 0.15 \text{ in/hr}
\]

Data collected on 10/25/2002

Jarrell et al.
Quality Issues Due to Wet Deposition – Can Green Roofs Help?

Objectives of This Project

1. To develop an effective medium for green roofing that will improve roof runoff quality while maintaining the known stormwater retention benefits of green roofs.
2. To demonstrate that green roofing can reduce the pollutant loadings from roof runoff compared to traditional roof materials since traditional materials were shown to be a source of pollutants in a Penn State Harrisburg study.

METHODOLOGY: Phase I

- **Goal.** Determine most effective medium for filtering atmospheric pollutants while not leaching additional pollutants into its runoff.
- **Task 1.** Evaluate the mineral component. Media used: two gradations of expanded shale, two expanded clays (with and without nutrient additives), and an expanded slate.
- **Focus:** Isolate contribution of mineral-only layer.

Laboratory Test Setup
Testing Methodology

- Replicates for all media columns
- Control columns
- Simulated rainwater at a pH of 4.5 and spiked with common stormwater pollutants poured through the columns using a spreading device
- Additional Data Collected: Weight of Media and Volume of “Rain” Recovered

Methodology – Additive Evaluation

- **Task 2.** Evaluate several filter sorbents, cation exchange materials, and anion exchange materials
- These materials were added to the mineral medium (selected in Task 1) using recommended dosages.
- Hypothesis: The addition of these materials will increase the ability of green roof media to capture pollutants
- Loads evaluated in similar manner to that of the original mineral evaluation

Analytes and “Rain” Concentration

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Average “Rain” Concentration</th>
<th>Analytical Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.72</td>
<td>S.M. 4500-H-B</td>
</tr>
<tr>
<td>Conductance</td>
<td>0.27 mS/cm</td>
<td>S.M. 4500-H-B</td>
</tr>
<tr>
<td>Ammonia</td>
<td>11.1 mg/L NH₃ as N</td>
<td>HACH Water Handbook…3rd ed. Method 10031</td>
</tr>
<tr>
<td>Nitrate</td>
<td>13.6 mg/L NO₃ as N</td>
<td>S.M. 4500-NO₃-D</td>
</tr>
<tr>
<td>Total Phosphate</td>
<td>14.8 mg/L</td>
<td>S.M. 4500-F-3.5</td>
</tr>
<tr>
<td>Diss. Cadmium</td>
<td>21.8 µg/L</td>
<td>S.M. 3113 B</td>
</tr>
<tr>
<td>Diss. Copper</td>
<td>82.3 µg/L</td>
<td>S.M. 3113B</td>
</tr>
<tr>
<td>Diss. Lead</td>
<td>16.8 µg/L</td>
<td>S.M. 3113B</td>
</tr>
<tr>
<td>Diss. Arsenic</td>
<td>*Samples not yet analyzed</td>
<td>S.M. 3113B</td>
</tr>
<tr>
<td>Diss. Mercury</td>
<td>*Samples not yet analyzed</td>
<td>EPA – NERL Method 245.1</td>
</tr>
<tr>
<td>Diss. Zinc</td>
<td>*Samples not yet analyzed</td>
<td>S.M. 3111B</td>
</tr>
</tbody>
</table>

Mineral Testing Phase (from Upper Left to Lower Right): Empty Filter Column, Drainage Material (Control), Filter Fabric (Control), Expanded Clay, Expanded Slate, Medium Grade Expanded Shale, Fine Grade Expanded Shale, and Expanded Clay with Other Additives).
Methodology - Organics

- **Task 3.** Evaluate several organic matter sources (in low volumes (1-2%)) to the mineral and additive combination selected in Task 2 using same testing methods of previous two phases.
  - Leaf litter compost
  - Peat

**NOTE:** This phase will begin ~ Nov. 1, 2006.

RESULTS AND DISCUSSION – Mineral Media Only

- Runoff pH is elevated compared to the acid rain, indicating neutralization/buffering of the acid rain.

### Total Phosphorus

- Retention occurs in fine grade expanded shale, and to a lesser extent, in other media types.
- Expanded clay with additives increases nutrient concentration in the runoff, likely due to added fertilizers.

### Dissolved Copper

- Similar results seen for dissolved lead and cadmium.

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**Phosphorus Values for Green Roof Media Leachate After Four Simulated Acid Rain Storms**

**Copper Values for Green Roof Media Leachate After Four Simulated Acid Rain Storms**
RESULTS AND DISCUSSION – Mineral Media

- Mineral media have little effect on nitrate levels, while ammonia levels are only slightly lowered, especially by the fine graded expanded shale media.

- Metal loads (Cu, Pb, Cd) are substantially lowered in all of the media. They are the least in the fine graded expanded shale.

- Fine-graded expanded shale selected for Task 2.

RESULTS AND DISCUSSION – Column Tests Filter Additives

- Nutrient reductions based on effluent concentration:
  - GAC and Zeolite #2 provided slightly better reduction than other media
  - For mass-loading-on-media, GAC “best”

- Additives had little effect on metals removal
  - At low concentrations seen in “rain”, Expanded Shale effective alone

**Total Phosphate**

GAC provided “best” removal on a per-weight basis.
Also true for nitrate.

**Dissolved Copper**

Similar results seen for dissolved lead and cadmium.
Future Research: Field Testing

- Phase II. Following these tests, pilot scale roofs will be built outside on the Penn State Harrisburg campus – Late Fall 2006
- Compare: control roofs (Plexiglass), traditional roofs and green roofs side-by-side
- All setups will have a drain at the bottom to capture all the runoff. Setup includes:
  - Weather station
  - Flow measurement (rate)
  - Collecting cistern
- The quality of the runoff will be tested at PSH for at least two storms per month.

Conclusions to Date

- Based on these results, the expanded shale should be used in the engineered mix of green roof media, but needs to be mixed with coarser-grade medium to improve hydraulic properties.
- Of the additives, GAC provided benefits. Its addition needs to be re-evaluated after testing of organic media. GAC may not provide additional benefits compared to adding only peat or compost.

Conclusions to Date

- Engineering a green roof media for water quality improvement is possible.
- Evaluation methodology should consider mineral portion first since it makes up the majority of volume and mass.
- Green roof media can buffer acid rain pH.
  - Fine-grade expanded shale had the highest buffering capacity

Questions?