Bio-Sorption Activated Media (BAM)

Marty Wanielista, Carl Spirio and Katey Earp
Outline and Purpose:

• Working with Regulatory Agencies
• History of Research
• FDOT CONNECTION WITH BAM THROUGH RESEARCH
  • Baffle Boxes
  • Nutrient Removal Up-Flow Filtration Systems
  • Retention Basins
  • Vegetated Filter Strips
  • Linear Ditch
  • Rain Gardens (a.k.a. depression storage areas)
• Benefits and Implementation
• Future Research and Applications
• Discussion and Comments.
What is Biosorption Activated Media (BAM)?

- Sorption is a physiochemical process that occurs with solid media to build-up or concentrate pollutant(s) onto the media. (Other Chemical removals also).
- Activation occurs when the media and the working environment are altered to improve removal, sometimes by physical measures or biological means. (example would be an low DO condition)
- Thus BAM is a media for pollutant removal that has sorption properties in a specific environment.
WHAT IS BOLD & GOLD (B&G)? A BAM product which is mineral and thus has minimum degradation in an expected life of at least 50 years. It is typically composed of a combination of the following materials: recycled tire, sand, clay and expanded clay. For many years, recycle tire has been used in septic tank drain fields. Clay provides surface area for organisms to live and work. Sand and expanded clay provide filtration rates and residence times. There are commonly used six mixes, all patented by the SUS.
Bio-Sorption Activated Media (BAM)

Conditions required for denitrification are:

- Nitrates present (electron acceptor)
- Oxygen very low or absent (*ongoing research*)
- Electron donor present (typically an organic carbon compound); and
- Sufficient Moisture present for Denitrifying bacteria

Removal Efficiencies:
typically 75% Nitrogen; 95% Phosphorus; 95% TSS
Some Measures of a Useful BAM for Nutrient Management

• Sorption (Adsorption/Absorption) Properties.
• Life Expectancy (for removal is for a long time).
• High surface area.
• Effluent has no biological toxic effects.
• Ease of filtration.
• Maintenance is low. Reasonably non-degradable or can be rejuvenated.
Up-Flow BAM Filters

Used to
1. Improve Performance of Wet Detention Ponds
2. To remove gross solids and nutrients directly from highway runoff.
On-Line Nutrient Separating Baffle Box with SkimBoss Filtration System in an Ultra Urban Area

Retro-fit to an existing 42” RCP
Sampling Results (estimated 70% of flow through filter)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total Nitrogen</th>
<th>Total Phosphorus</th>
<th>Total Suspended Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Influent Concentration (mg/L)</td>
<td>1.87</td>
<td>0.281</td>
<td>105</td>
</tr>
<tr>
<td>Average Filter Removal (%)</td>
<td>45</td>
<td>58</td>
<td>40</td>
</tr>
<tr>
<td>Average System Removal (%) no by-pass of the up-flow filter</td>
<td>67</td>
<td>79</td>
<td>81</td>
</tr>
<tr>
<td>Average Annual Removal (%)</td>
<td>54</td>
<td>67</td>
<td>70</td>
</tr>
</tbody>
</table>

Water Quality Lab data by ERD, Orlando Florida

There was ~30% overflow (by-pass) of the up-flow filter during high flow per year.
Dunnellon, FL
Design by FDOT Deland and CH2M Hill

DIVERSION BOX (SMART)

OFFLINE FILTER

FIBERGLASS REINFORCED PLASTIC SEE SHEET 5 FOR DETAILS (FOR MATERIAL SPECIFICATIONS SEE TECHNICAL PROVISIONS)

EXISTING 36 INCH CMP

INTEGRAL 6" REINFORCED CONCRETE WEIR
60 KSI STEEL - AREA 0.50 sq ft

12"

24 INCH RCP

OFF-LINE FILTER

24 inch RCP

SECTION

Bold & Gold

Treatment System
### Sampling Results and Installation Photos

70% of flow through filter (photo credit: FDOT Ocala)

![Inlet and Outlet Diagram with Temporary Covers]

<table>
<thead>
<tr>
<th>Average Concentration and % Removal</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>TSS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration from the Street</td>
<td>2.10</td>
<td>0.360</td>
<td>100</td>
</tr>
<tr>
<td>Concentration to the Filter</td>
<td>1.27</td>
<td>0.180</td>
<td>35</td>
</tr>
<tr>
<td>Concentration from the Filter</td>
<td>0.502</td>
<td>0.098</td>
<td>17</td>
</tr>
<tr>
<td>Average Filter Removal (%)</td>
<td>60</td>
<td>46</td>
<td>51</td>
</tr>
<tr>
<td>Overall Average Removal (%)</td>
<td>76</td>
<td>73</td>
<td>83</td>
</tr>
<tr>
<td>Annual Average Removal (%)</td>
<td>59</td>
<td>63</td>
<td>73</td>
</tr>
</tbody>
</table>
Retrofit for a Typical Failure Problem Associated with Side Bank Filters

Some Failure Problems

• Filters are difficult to access to properly clean
• Because of slow filtration or no filtration, exotics take over
• Often difficult or very costly to replace
Improved Treatment Using Up-flow Filters with Wet Pond

Filters installed after wet detention

- Filters can be designed to remove nitrogen without media replacement
- For phosphorus, media replacement time is specified
- Can be used in BMP & LID Treatment Train Applications with other treatment
Up-Flow Input from Wet Detention to Filter

- Performance
  - Concentration
  - Averages based on field data
  - Average yearly based on 1.0 inch design for filter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TN</th>
<th>TP</th>
<th>TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Influent Concentration (mg/L)</td>
<td>1.83</td>
<td>0.73</td>
<td>42.7</td>
</tr>
<tr>
<td>Expected Average Pond Removal (%)</td>
<td>38</td>
<td>63</td>
<td>79</td>
</tr>
<tr>
<td>Average Pond + Filter Removal (%)</td>
<td>70</td>
<td>72</td>
<td>91</td>
</tr>
<tr>
<td>Average Annual System Performance</td>
<td>67</td>
<td>70</td>
<td>89</td>
</tr>
</tbody>
</table>
Briarwood Inter-event Up-flow Filters

- Four 160 LF by 5 FT diameter parallel upflow filters
- 4 Ft Deep anaerobic zone with B&G ECT media
- Integrated wetland treatment
- Two pump stations that continuously treat 2 MGD

Overall annual performance improved by about 25% or an additional 45% removal
Wekiva Parkway Section 6

Limit of Eagle Buffer Zone

Pond RS8-E-1

2 Control Structures
Installation Drawing
with water spray nozzles for cleaning
Design Equation

Note: safety factor of 2 added to rate of treatment or filter rate obtained by lab and field test is 2 gpm/SF.

• Volume Treated = Runoff Volume at Design Storm Event
• One-half the volume treated in the first day is equal to the volume treated in the next two days
• Volume Treated = 1 GPM/SF x $\text{SF of filter}$ x .0022288 CFS/GPM x 86,400 sec/day = CF
Hydrograph (volume treated)
Example: one inch from 24 acres EIA

Volume = 87,264 CF x 12 (in/ft) / 24 acres / 43,560 (SF/acre) = 1.00 inches
# Design Chart Assistance

<table>
<thead>
<tr>
<th>Inside Dim ftxft</th>
<th>Filter Area (SF)</th>
<th>Max CFS</th>
<th>Release (CF) 1st Day*</th>
<th>Release (CF) next 2 days</th>
<th>Total volume 3 days (CF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 4</td>
<td>14</td>
<td>0.0312</td>
<td>1347</td>
<td>1347</td>
<td>2695</td>
</tr>
<tr>
<td>4 x 8</td>
<td>30</td>
<td>0.0668</td>
<td>2887</td>
<td>2887</td>
<td>5775</td>
</tr>
<tr>
<td>5 x 10.5</td>
<td>42.5</td>
<td>0.0947</td>
<td>4091</td>
<td>4091</td>
<td>8181</td>
</tr>
<tr>
<td>6 x 12</td>
<td>54</td>
<td>0.1203</td>
<td>5197</td>
<td>5197</td>
<td>10395</td>
</tr>
<tr>
<td>6 x 15</td>
<td>72</td>
<td>0.1604</td>
<td>6930</td>
<td>6930</td>
<td>13860</td>
</tr>
<tr>
<td>8 x 17</td>
<td>107.5</td>
<td>0.2395</td>
<td>10347</td>
<td>10347</td>
<td>20694</td>
</tr>
<tr>
<td>10 x 20</td>
<td>164</td>
<td>0.3654</td>
<td>15785</td>
<td>15785</td>
<td>31570</td>
</tr>
<tr>
<td>10 x 25</td>
<td>200</td>
<td>0.4456</td>
<td>19250</td>
<td>19250</td>
<td>38500</td>
</tr>
<tr>
<td>12 x 25</td>
<td>240</td>
<td>0.5347</td>
<td>23100</td>
<td>23100</td>
<td>46200</td>
</tr>
</tbody>
</table>

Note: rate of maximum filtration is 0.002228 CFS/SF

* half the maximum

Example Calculations for a 14 SF filter.

**Column 3:** Max CFS = 1 GPM/SF x 0.002228 CFS/GPM x 14 SF = 0.0312 CFS

**Column 4:** Release in 1st day = 0.0312 CFS x 86,400 sec/day / 2 = 1347 CF

**Column 5:** Remaining half is released, thus 1347, extended value is 1347.49

**Column 6:** Sum of water released in 3 days (round off values)
Down-Flow Filtration

BAM Dry Retention Basin Schematic
Low Water Table

Typically for lower volume of runoff (1e., 0.25 – 3 inches)
BAM Dry Retention Pond Forebay

Typically for higher volume of runoff (1e., 3-15 inches) or land-locked basins
BAM Dry Retention Basin Schematic
High Water Table
# Field SITE COMPARISONS

<table>
<thead>
<tr>
<th>Sandy Soil SW Basin</th>
<th>Parameter</th>
<th>BAM type Soil SW Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deeper</td>
<td>Water Table</td>
<td>Shallower</td>
</tr>
<tr>
<td>Less</td>
<td>Silty/Clayey Soils</td>
<td>More</td>
</tr>
<tr>
<td>Lower</td>
<td>Cation Exchange Capacity</td>
<td>Higher</td>
</tr>
<tr>
<td>Higher</td>
<td>Infiltration Rate</td>
<td>Lower</td>
</tr>
<tr>
<td>Higher</td>
<td>Dissolved Oxygen</td>
<td>Lower</td>
</tr>
<tr>
<td>Lower</td>
<td>Alkalinity</td>
<td>Higher</td>
</tr>
<tr>
<td>Lower</td>
<td>Organic Carbon</td>
<td>Higher</td>
</tr>
<tr>
<td>Higher (median=2.2 mg/L)</td>
<td>Groundwater Nitrate</td>
<td>Lower (median=0.03 mg/L)</td>
</tr>
<tr>
<td>No</td>
<td>Nitrate Decline with Time</td>
<td>Yes</td>
</tr>
</tbody>
</table>
SOIL CHARACTERISTICS

- Textural differences contributed to large differences in the soil moisture retention curves.

Native Sandy  Native BAM

Sample depth = 0.3 m

BAM
South Oak
K=0.34 m/d

Sandy
Hunter’s Trace
K=2.1 m/d
Infiltration treatment with BAM
Regional basins (springs and estuary protection)

A retrofit to an existing basin was completed using CTS media

1. Excavation of native soil in the bottom of a portion of the basin;

2. Emplacement of a 2 feet thick amended soil layer (“Biosorption Activated CTS Media” mix): tire crumb (to increase sorption capacity), silt+clay (to increase soil moisture and sorption capacity), and sand (to promote sufficient infiltration); and

3. Construction of a berm forming separate nutrient reduction and flood control basins.
Regional Basin using CTS media

- Reproduce soil conditions that exist at a natural BAM basin by using CTS media:
  - Increase soil moisture
  - Reduce oxygen transport
  - Increase sorption capacity
Basin with BAM – NITRATE

- 73% reduction for **two feet** deep B&G layer.

Basin with BAM – PHOSPHORUS

- > 80% reductions in total dissolved phosphorus (TDP) from pre-construction (2007–2009) to post-construction (2009–2010) median concentrations in soil water
Before and After BAM Residual Soil Moisture at a Regional Infiltration Basin

Field measurements were obtained by continuous monitoring using time domain reflectometry and tensiometers.

Laboratory derived soil moisture retention curves were measured for the main drying curve on undisturbed soil cores using the pressure cell method.

Note: 1 meter head = 9.8 kPa  
Field Capacity of soil = ~ 3.3 meters
SYSTEM DYNAMICS MODEL

- 1-D vertical, 4 layers
- Only water phase (gas and solid phases not modeled)
- Model layers approximate field conditions, e.g. BAM layer and locations of instrumentation
CONCEPTUAL MODEL

- Simulate advective inflow/outflow, fixation, ammonification, nitrification, denitrification, and plant uptake
CALIBRATION & VALIDATION

- Calibrate model for period 1–15 December 2009
- Validate model for period 2 March – 7 April 2010

Conclusion: YES, we can expect a reduction in Nitrogen
For 2 feet of BAM, 75% reduction in TN
BMPTRAiNS MODEL AND Users Manual

BMPTRAiNS: an EXCEL and Visual Basic model for sizing BMPs and estimating annual removal effectiveness.

It’s acronym is derived from the analysis of stormwater BMPs in series, but can also evaluate parallel and series treatment.

The model is used to evaluate Best Management Practice Treatment options for Removal on an Annual basis by those Interested in Nutrients in Stormwater.

Available from: www.stormwater.ucf.edu

What's New


Credit and thanks for the programming and technical skills of: Dr. Mike Hardin, Dr. Harvey Harper, Dr. Ikiensinma Gogo-Abite, Eric Livingston, and Chris Kuzlo
INTRODUCTION PAGE

Model requires the use of Excel 2007 or newer

1) There is a users manual to help navigate this program and it is available at www.stormwater.ucf.edu

2) This spreadsheet is best viewed at 1280 BY 1080 PIXELS screen resolution. If the maximum resolution of your computer screen is lower than 1280 BY 1080 PIXELS you can adjust the view in the Excel VIEW menu by zooming out to value smaller than 100 PERCENT.

3) This spreadsheet has incorporated ERROR MESSAGE WINDOWS. Your analysis is not valid unless ALL ERROR MESSAGE WINDOWS are clear.

4) PRINTING INSTRUCTIONS: Many options. One is to print the page to MICROSOFT OFFICE DOCUMENT IMAGE WRITER (typically the default) or ADOBE PDF, save the page as an image document, then print the document you saved.

5) Click on the button located on the top of this window titled CLICK HERE TO START to begin the analysis.

Disclaimer: These workbooks were created to assist in the analysis of Best Management Practice calculations. All users are responsible for validating the accuracy of the internal calculations. If improvements are noted within this model, please e-mail Marty Wanielista, Ph.D., P.E. at martin.wanielista@ucf.edu with specific information so that revisions can be made.
### 15 BMPS to from which to choice

Select one of the BMPS below to analyze efficiency or review the summary data.

<table>
<thead>
<tr>
<th>RETENTION BASIN</th>
<th>WET DETENTION / MAP</th>
<th>EXFILTRATION TRENCH</th>
<th>RAIN GARDEN</th>
<th>SWALE</th>
<th>USER DEFINED BMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERVIOUS PAVEMENT</td>
<td>STORMWATER HARVESTING</td>
<td>FILTRATION</td>
<td>View Media Mixes</td>
<td></td>
<td>NOTE !!!: All individual system must be sized prior to being analyzed in conjunction with other systems. Please read instructions in the CATCHMENT AND TREATMENT SUMMARY RESULTS tab for more information.</td>
</tr>
<tr>
<td>GREENROOF</td>
<td>RAINWATER HARVESTING</td>
<td>LINED REUSE POND &amp; UNDERDRAIN INPUT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VEGETATED NATURAL BUFFER</td>
<td>VEGETATED FILTER STRIP</td>
<td>TREE WELL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** All of the BMP can have BAM added.
# Removal and mixes

Note: The location of BAM (first BMP or in a series) is important

<table>
<thead>
<tr>
<th>DESCRIPTION OF MEDIA</th>
<th>MATERIAL</th>
<th>PROJECTED TREATMENT PERFORMANCE *</th>
<th>TYPICAL OPERATING LIMITING FILTRATION RATE (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media and Typical Location in BMP Treatment Train</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B&amp;G ECT (ref A) A first BMP, ex. Up-Flow Filter in Baffle box and a constructed wetland (USER DEFINED BMP)</td>
<td>Expanded Clay² Tire Chips¹</td>
<td>70% 55% 65% 96 in/hr</td>
<td></td>
</tr>
<tr>
<td>B&amp;G OTE (ref A,B) Up-flow Filter at Wet Pond or Dry Basin Outflow (FILTRATION)</td>
<td>Organics⁸ Tire Chips¹ Expanded Clay⁴</td>
<td>60% 45% 45% 96 in/hr</td>
<td></td>
</tr>
<tr>
<td>B&amp;G ECT3 (ref C) After Wet Detention using Up-flow Filter</td>
<td>Expanded Clay⁴ Tire Chip¹</td>
<td>60% 45% 45% 96 in/hr</td>
<td></td>
</tr>
<tr>
<td>SAT (ref D) A first BMP, as a Dow n-flow Filter (FILTRATION)</td>
<td>Sand³</td>
<td>85% 30% 45% 2 in/hr</td>
<td></td>
</tr>
<tr>
<td>B&amp;G CTS (ref E,F) Dow n-Flow Filters 12” depth*** at wet pond or dry basin pervious pave, tree well, rain garden, swale, and strips</td>
<td>Clay⁶ Tire Crumb⁵ Sand⁷ &amp; Topsoil⁹</td>
<td>90% 60% 90% 1.0 in/hr</td>
<td></td>
</tr>
<tr>
<td>B&amp;G CTS (ref E,F) Dow n-Flow Filters 24” depth*** at wet pond or dry basin pervious pave, tree well, rain garden, swale, and strips</td>
<td>Clay⁶ Tire Crumb⁵ Sand⁷ &amp; Topsoil⁹</td>
<td>95% 75% 95% 1.0 in/hr</td>
<td></td>
</tr>
</tbody>
</table>
Notes and References

1. Tire Chip 3/8" and no measurable metal content (approximate dry density = 730 lbs/CY)
2. Expanded Clay 5/8 and 3/8 blend (approximate dry density = 950 lbs/CY)
3. Sand ASTM C-33 with no more than 3% passing #200 sieve (approximate dry density = 2200 lbs/CY)
4. Expanded Clay 3/8 in blend (approximate density = 950 lbs/CY)
5. Tire Crumb 1-5 mm and no measurable metal content (approximate density = 730 lbs/CY)
6. Medium Plasticity typically light colored Clay (approximate density = 2500 lbs/CY)
7. Sand with less than 5% passing #200 sieve (approximate density = 2200 lbs/CY)
8. Organic Compost (approximate density of 700 lbs/CY) Class 1A Compost or Mix of yard waste
9. Local top soil is used over CTS media in dry basins, gardens, swales and strips, is free of roots & debris but is not used in other BMPs.

D - City of Austin Environmental Criteria Manual, Section 1.6.5, Texas, 2012
F - Improving Nitrogen Efficiencies in Dry Ponds, Williams and Wanielista, Florida Stormwater Association, June 18 2015
## User Defined mixes

<table>
<thead>
<tr>
<th>MIX:</th>
<th>TN Removal %</th>
<th>TP Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>B&amp;G ECT</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>B&amp;G OTE</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>B&amp;G ECT3</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>SAT</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>B&amp;G CTS12</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>B&amp;G CTS24</td>
<td>75</td>
<td>95</td>
</tr>
<tr>
<td>UDM1*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDM2*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDM3*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDM4*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* User Defined Media Mix
FDOT Sponsored Research in the Future

PROJECT #1

BAM in Karst Environments

- Partnered with FDEP & UCF Stormwater Academy
- Two dry retention basins (horizontal, vertical applications)
- Silver Springs Springshed - State Road 35
- Site selection complete
- Construction completed in May 2017

What is going on now?
FDOT Sponsored Research

PROJECT #2

BAM in Linear Ditch

• Partnered with SRWMD & UCF Stormwater Academy
• BAM Trench (Bold & Gold / Wood Chip Blend)
• Fanning Springs Springshed - State Road 26
• Analyzing effects of groundwater, added carbon & toxic compounds
• Construction scheduled for completion summer 2017
Groundwater Well
• Treats stormwater and
• “hot” groundwater during dry periods
• Similar to the Briarwood inter-event filter
UCF Bold & Gold / SRWMD Wood Chip

Expanded clay, tire crumb & sand
FDOT Benefits: Bio Activated Sorption Media (BAM)

Another Tool in the Toolbox

- Enhanced nutrient removal in impaired springsheds
- Developed by FDOT & UCF Stormwater Academy
Above the Cody Scarp impermeable uplands are drained by a stream network.

Below the Cody Scarp the Floridan Aquifer is unconfined and rainfall moves vertically through thin soils into the limestone aquifer and surface runoff is rarer.
Springshed Sensitivity

Unconfined aquifers

• No confining layer to protect against pollutants
• “Direct Discharge” into groundwater
• Current research rebuts presumptive criteria
FDOT Future Research Possibilities

• BAM in Vegetated Natural Buffer (Roadside Shoulders)
• Chemical Activated Media (CAM) – Increased Phosphorus Removal Lifespan
• Modeling Efforts to Evaluate BAM/CAM Efficiencies on Springs
• Improving BMPTRAINS to include solutions acceptable to reviewing agencies
FDOT Implementation

• Add a Section to the **Drainage Design Guide**
  • Design Examples for Upflow Filter, Forebay Sizing & more.
• Researched Removal Efficiencies
• Preferred FDOT Media Mixes
• Material Specifications
• Upgrades to BMPTRAINS
FDOT Research: Bio-Sorption Activated Media (BAM)

Another Tool in the Toolbox

- Enhanced nutrient removal in impaired Springsheds and Estuaries
- Developed by FDOT & UCF Stormwater Academy
Bio-Sorption Activated Media (BAM)

Questions and Comments

Marty Wanielista, Carl Spirio and Katey Earp