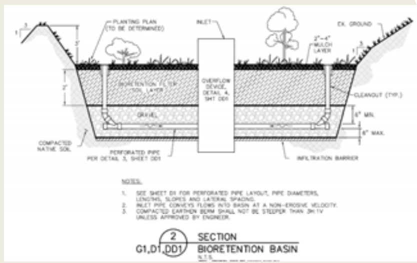
BMP ACHIEVABILITY vs. WQS:

Are there non-compliance risks for NPDES permittees AFTER BMP implementation?

1



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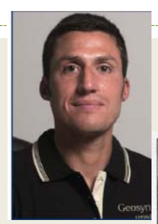
CASQA '09
NOV. 4, 2009
SAN DIEGO, CA

Geosyntec consultants

Presenters

2

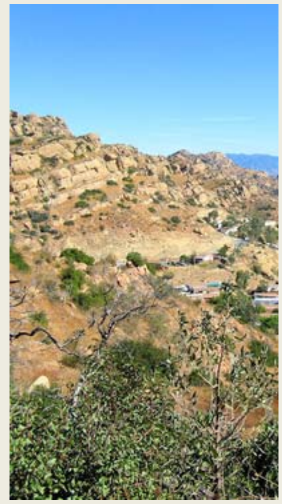
- Brandon Steets, Geosyntec
- Dr. Michael Stenstrom, UCLA
- Dr. Robert Pitt, Univ. Alabama



Presentation Agenda

3

- BMP "Achievability"
  - ASCE/EPA International BMP Database
- Impacts of "Background"
  - Metals & dioxin as examples
- "Design storm" selection
- Conclusions
- Results of media testing study



Terminology

4

- **"Achievability"** – the lower range of treated constituent concentrations that can be consistently met in BMP effluent
- **"Background"** – pollutant concentrations found in natural, undisturbed reference watersheds
- "**Design storm"** – 24-hr storm event used for BMP sizing and, if permitted, NPDES compliance determination

Site Description

5

- Large RCRA site historically operated as a field laboratory testing facility in California
- Land uses include admin buildings, roads, testing facilities, RCRA feasibility investigation areas, and significant open space

Much of the site looks like this

Regulatory Setting & Stormwater Controls

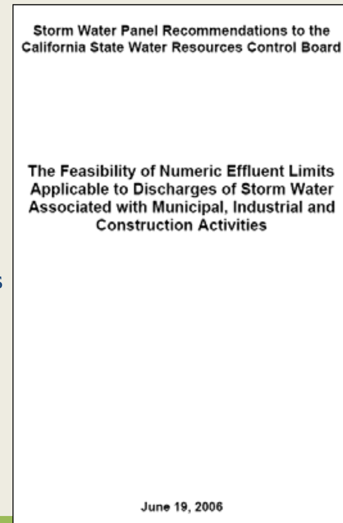
6

- Facility is permitted by RWQCB through an individual industrial NPDES permit for stormwater discharges
  - Enforceable WQS-based numeric effluent limits (NELs)
  - No design storm allowance (in terms of NEL-enforcement)
- History of stormwater quality exceedances of NELs at many of the outfalls
  - Metals & dioxins are key COCs
- Contaminated soil areas have erosion controls in place for temporary stabilization while RCRA investigations proceed
- Most NPDES monitoring “outfalls” (natural drainages) have multimedia filtration BMPs in place
  - Filter BMPs implemented where design flows are feasible to treat
  - BMPs have reduced NEL exceedances at those outfalls
- Site receives significant public attention and regulatory scrutiny

Use of NELs in NPDES Stormwater Permits

7

- SWRCB Blue Ribbon Panel report assessed feasibility of NELs for stormwater discharge permits
- Use of NELs is growing in California: e.g.,
  - recent Ph 1 MS4 permits
  - new construction general permit
  - current/draft industrial general permits
  - permits that incorporate WLAs from TMDLs (e.g., bacteria allowable exceedance days)
- Permits with **CTR-based** NELs are rarer and usually result from TMDLs, however we have such a case study site for an individual industrial NPDES permit for stormwater discharges


Storm Water Panel Recommendations to the California State Water Resources Control Board

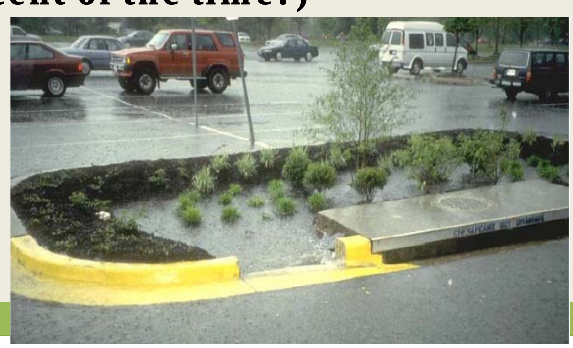
The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial and Construction Activities

June 19, 2006

Achieving NELs in Stormwater

8

Question – if WQS-based NELs are the future of stormwater discharge permitting, and treatment BMPs are the means of achieving permit limits, can we expect compliance? (and what percent of the time?)



Assessing Potential for Achieving Permit Limits

9

- We focus our discussion on 3 particularly difficult-to-comply-with CTR-based permit limit examples
  - 14 ug/L **copper**, 5.2 ug/L **lead**, 2.8x10-8 ug/L **TCDD TEQ (dioxin)**
- We evaluated "achievability" of conventional natural stormwater treatment BMPs relative to permit limits for metals using monitoring data from:
  - ASCE/EPA International BMP Database (www.bmpdatabase.org)
  - Other BMP performance studies
  - Site-specific stormwater monitoring data
- In the case of dioxin, we used TSS as a surrogate given lack of BMP performance data

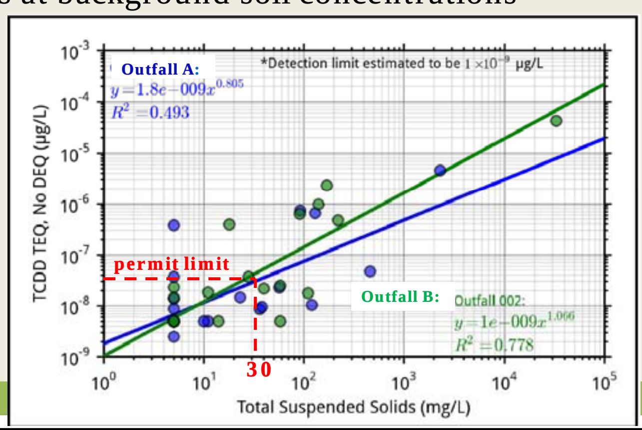
Achieving Permit Limits – Dioxin

10

Dioxin vs TSS – Findings

1. Stormwater dioxin concentrations correlate with TSS
2. Avg dioxin Particulate Strength (mg dioxin/mg susp. sediment) is at background soil concentrations

~30 mg/L TSS needed to achieve dioxin permit limit



Achieving Permit Limits – Dioxin

11

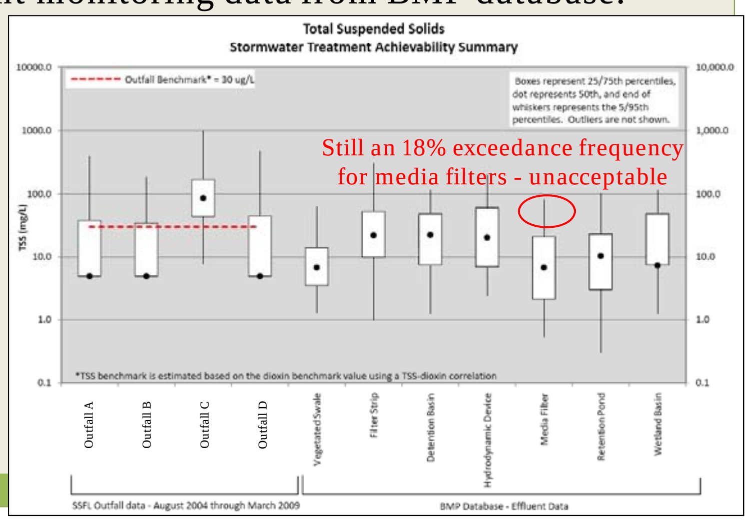
- Therefore, an acceptable compliance solution must:
  (a) consistently achieve this TSS level, and
  (b) require control of "background" soils! (more on this issue later)

Achieving Permit Limits – Dioxin/TSS

12

TSS effluent monitoring data from BMP database:

Results show difficulty for standard BMPs to consistently achieve limits

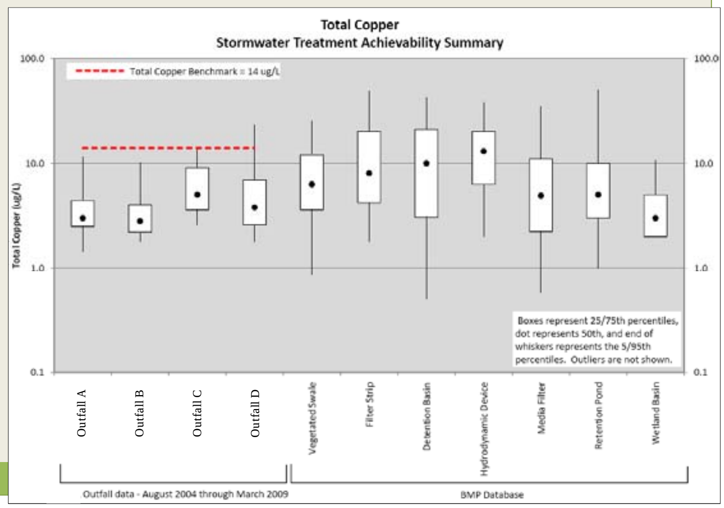


Achieving Permit Limits – Copper

13

Copper effluent monitoring data from BMP database:

Observations:
1. Best BMPs comparable to site discharges
2. Only wetlands consistently achieve limit
3. Demonstrates need for BMP trains, advanced designs, & specially-selected filter media

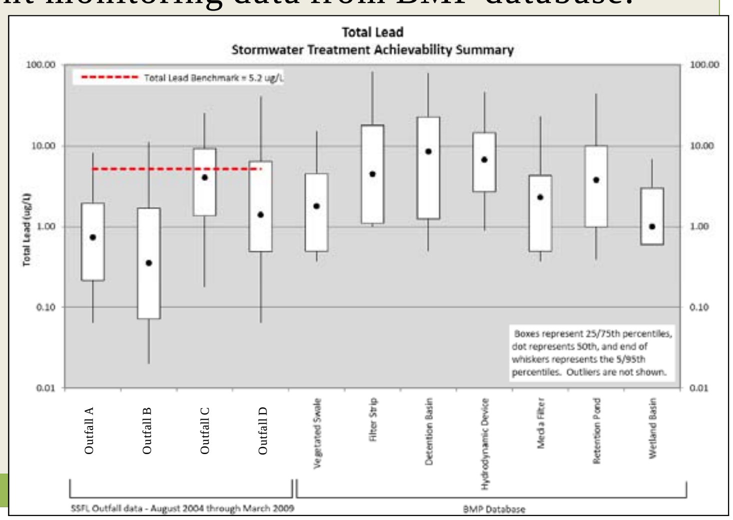


Achieving Permit Limits – Lead

14

Lead effluent monitoring data from BMP database:

Similar observations



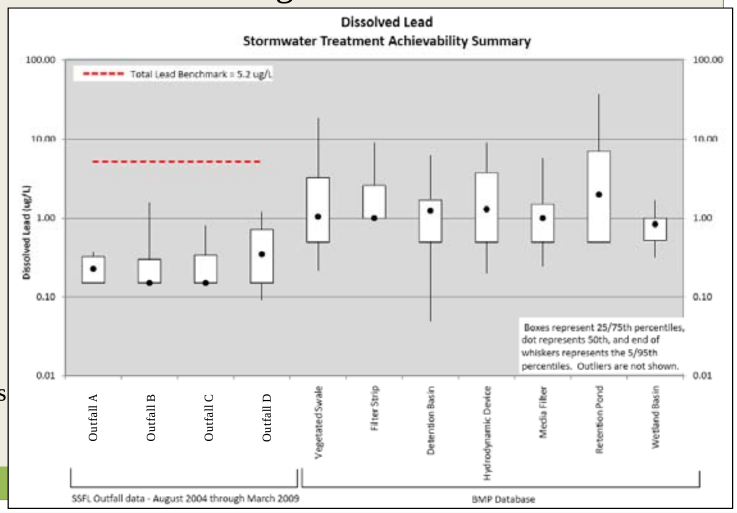
Achieving Permit Limits – Lead

15

Diss. lead effluent monitoring data from database:

Concentrations drop significantly for diss. metals…

Indicates ben. use impacts from site discharges are non-existant and standard BMPs can't be expected to reduce already low concentrations significantly



Achieving Permit Limits – Other Tools

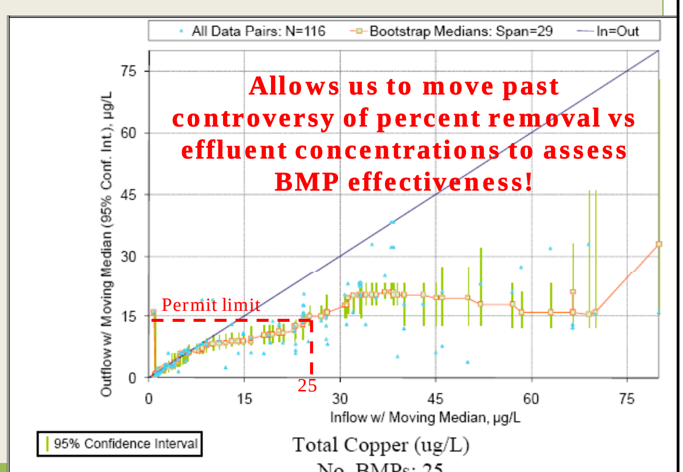
16

Using moving median influent-effluent pairs to assess performance

Ex) Vegetated swales chart for total copper:

Allows us to take raw sw concentrations and predict effluent concentrations

Also allows deeper look into BMP database to investigate:
•Irreducable effluent concentrations
•Influent concentration range which does not affect effluent



BMP Performance Optimization

17

- With such limits, site requires designs refined to a much higher degree than in typical practice
- Need to consider optimizing BMP performance through various design factors:
  - Treatment trains
  - BMP sizing
  - Basin drain time
  - Media contact time (outlet-controlled systems)
  - Specially-selected filtration media
- Bench-scale laboratory media testing!
  - Bob Pitt to present his findings at the end

Media Testing

18

- Goals:
  - To provide information for design (e.g., optimal media components, depths, & contact times)
  - To maximize the likelihood that filtration-based treatment BMPs will achieve performance objectives in the most cost effective manner
- Bench-scale lab experiments performed by university researchers (Bob to present results at the end)

Media (from left to right): GAC, Rhyolite Sand, Site Zeolite, Surface Modified Zeolite, Sphagnum Peat Moss

Effects of Background

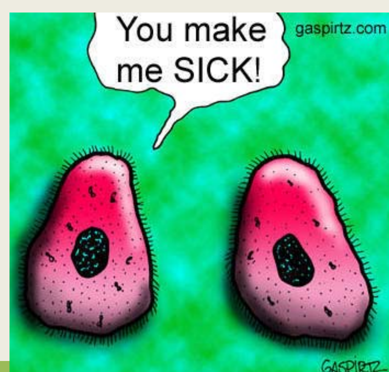
19

- Achieving NELs in some cases may mean treating background contributions
- Background trace metal and dioxin sources are well-studied and include:
  - Naturally-occurring levels in soils
  - Atmospheric deposition
  - Wildfires (especially dioxins in ash)
- However questions remain over:
  1. Defining "background" concentrations in stormwater
  2. How to account for this in permits
- We'll focus on just Q#1

Effects of Background (cont'd)

20

- As Regional Boards did with bacteria, creative TMDL WLA and permit limit solutions may be needed to account for natural sources (e.g., reference watershed concept)



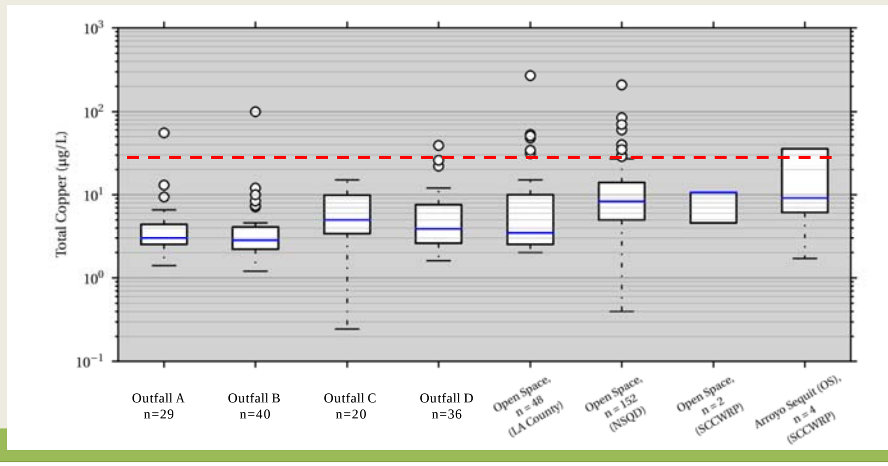
When germ relationships go bad

It's not just me!

Defining Background in Stormwater - Copper

21

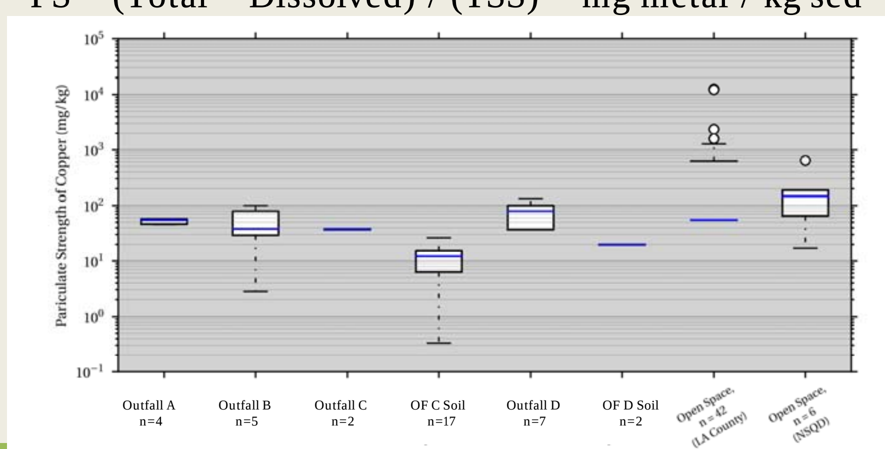
Stormwater discharge monitoring data for copper



Defining Background in Stormwater - Copper

22

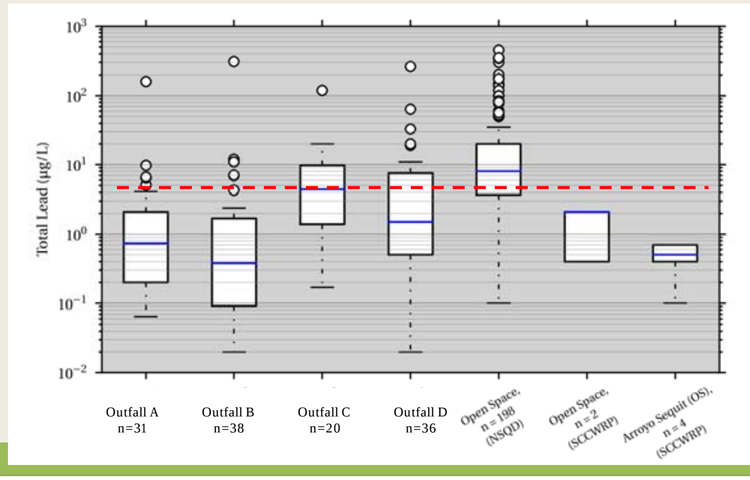
Particulate Strength (PS) data for copper, where
PS = (Total – Dissolved) / (TSS) = mg metal / kg sed



Defining Background in Stormwater - Lead

23

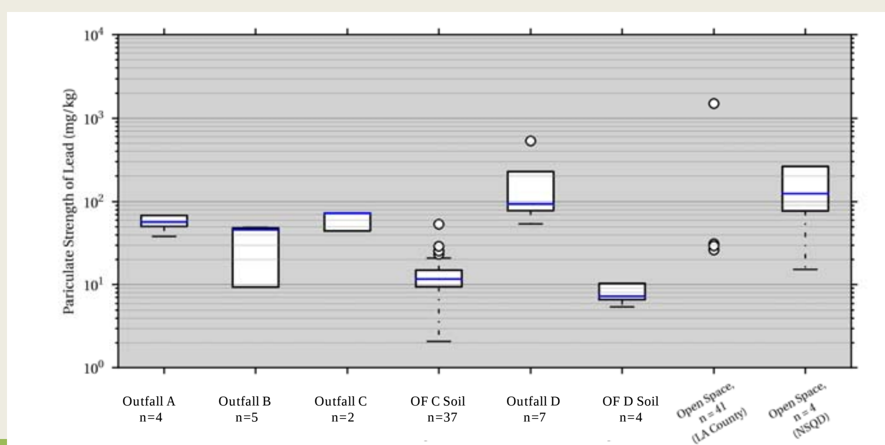
Stormwater discharge monitoring data for lead



Defining Background in Stormwater - Lead

24

Particulate strength data for lead



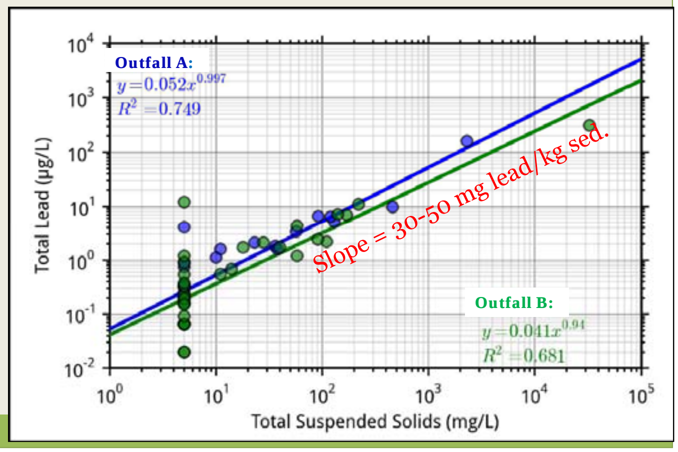
Defining Background in Stormwater - Metals

25

And like with dioxin, lead management comes down to erosion and sediment control

Dioxin well-correlated with TSS based on site discharge monitoring data

Slope comparable to site-specific soil background concentration for lead (34 mg/kg) indicating NEL exceedances triggered by soil background levels

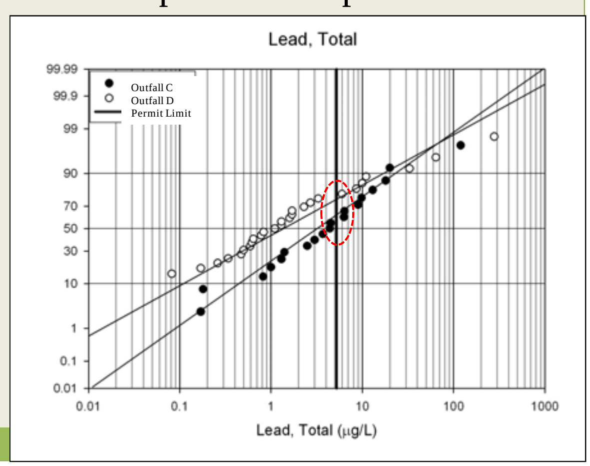


Defining Background in Stormwater - Metals

26

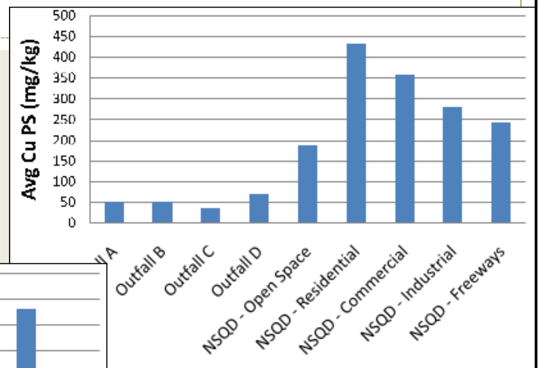
These exceedance frequencies can be significant when you're talking about NPDES permit compliance!

Based on samples collected at these two outfalls:
~28-40% exceed for lead,
~5-8% exceed for copper,
lower for other metals

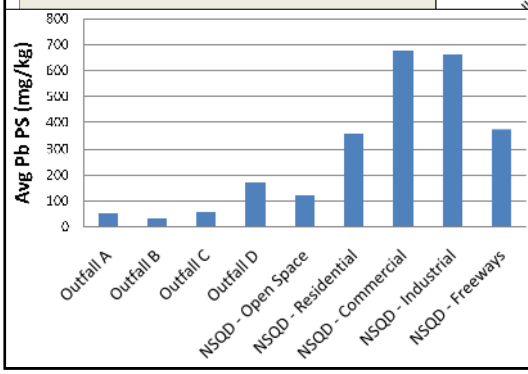


Defining Background in Stormwater - Metals

Site discharges look even better when compared with urban land use monitoring sites



Copper



Lead

Table 24. Los Angeles River Watershed Loads and Deposition Flux

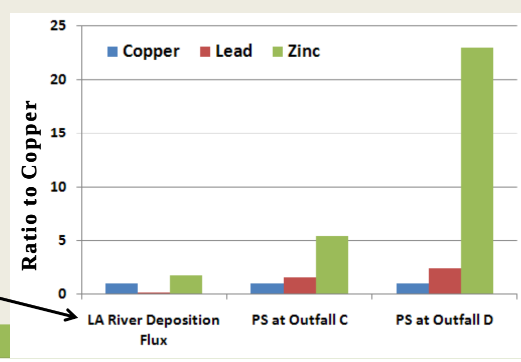
Defining Background in Stormwater - Metals

28

Q: So is the source most likely atm deposition or is it erosion of natural soils?
A: Metal concentrations not likely explained by atm deposition given metal ratios found in stormwater discharges at the site

It's the soils!

LA River Watershed Atmospheric Deposition Flux



Defining Background in Stormwater - Metals

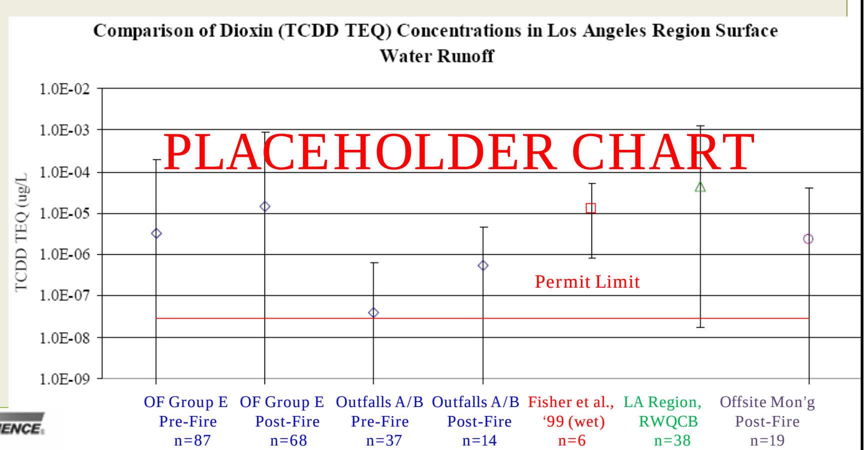
29

- Bottom line: Despite site discharges being comparable to open space land use sites and reference watersheds, and natural background soils being the likely explanation, *permit compliance issues persist at the site*

Defining Background in Stormwater - Dioxin

30

- (From Stenstrom) Dioxin TEQ chart - stormwater concentrations vs urban runoff



FLOW SCIENCE

Defining Background in Stormwater - Dioxin

31

- (From Stenstrom) Congener chart – stormwater vs contaminated soils vs background soils/wildfire runoff/ash?

Defining Background in Stormwater - Dioxin

32

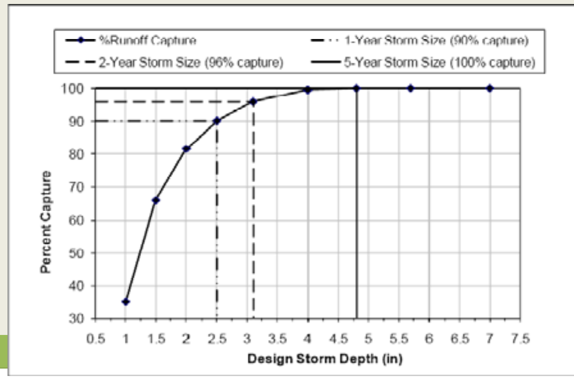
- Findings:
  - dioxin concentrations in site discharges comparable to reference site, less than urban land use sites
  - congener fingerprints indicate origins not from soil contamination but rather more closely resemble wildfire sources
  - [to come from Stenstrom]

BMP Sizing & NEL Applicability

33

Some permits currently do not allow for NEL offramps during high flow events, therefore dischargers are without guidance on how big to size treatment BMPs

- Design or "compliance" storm determinations should account for longterm runoff volume capture through use of continuous simulation models
- In this case 1, 2, & 5-yr (24-hr) site specific design storms were evaluated
- Also need to weigh environmental benefits – i.e., BMP treatment vs footprint



Conclusions

34

- 3 bottom-line take-home messages:
  1. Individual standard treatment BMPs should not be expected to meet WQS-based NELs 100% of the time
  2. Stormwater discharges from reference watersheds and open land use sites also do not meet WQS-based NELs 100% of the time
  3. NELs can't be expected to be met under all storm conditions
- Therefore, if WQS-based NELs continue to be used in NPDES permits for stormwater, these questions need to be addressed:
  1. How to account for limits of BMP achievability?
  2. How to account for background sources/concentrations?
  3. How to limit NEL applicability for large storm events where BMP sizing becomes infeasible/impractical (balancing environmental benefits)?

Conclusions

35

- Additional value of this work:
  While researching these questions, we've developed several data analysis approaches for predicting compliance that may be used by regulators and permittees alike for developing feasible stormwater discharge permits requirements, e.g.,
  - What can BMPs achieve
  - How to define background
  - How to size design storms

Additional Outstanding Questions

36

- Regulatory status of treatment BMPs:
  - If used on RCRA sites, do regulations require treatment BMPs to be re-classified or examined later on if contaminants build up to above soil screening criteria where they may be regulated by DTSC or RWQCB?
- What is the long-term status of treatment system use, maintenance, and removal if they were only temporary (~10-15 yr design lifetime) to begin with?
  - How will not only installation, but removal, be perceived by the stakeholders down the line?

Media Testing

37

- Goals (again):
  - To provide information for design (e.g., optimal media components, depths, & contact times)
  - To maximize the likelihood that filtration-based treatment BMPs will achieve performance objectives in the most cost effective manner

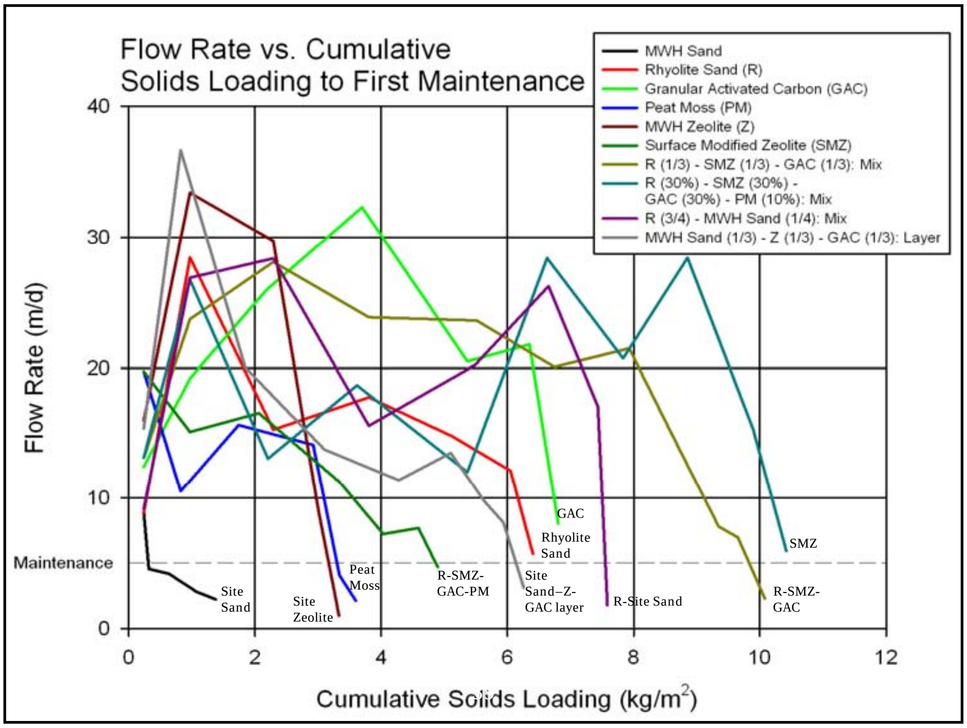
Media (from left to right): GAC, Rhyolite Sand, Site Zeolite, Surface Modified Zeolite, Sphagnum Peat Moss

Media Tests (cont'd)

38

- Column tests:
  - Clogging, breakthrough, and removal
  - Effects of contact time and media depth on removal
- Batch tests:
  - Media uptake capacity & removal kinetics
  - Aerobic and anaerobic effects on pollutant mass removed



Statistically significant removals for the media mixes examined

(paired sign test of influent vs. effluent)

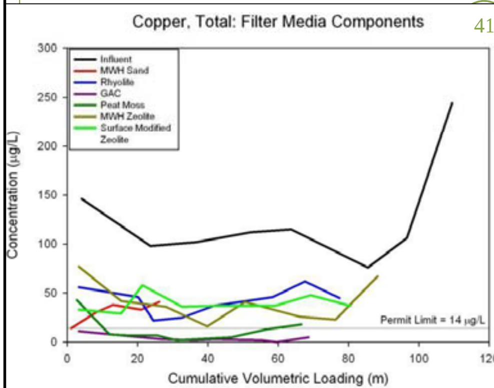
Media Type	SSC	As, B	Cr, Cu, Sb, Al	Pb, Zn	Mn	Cd, Ni, Tl, Fe	Hg	NO_3	TN	TP	TCDD
R-SMZ	Y		**T**	**T**	T	T, F	Y			Y	
R-SMZ-GAC	Y	T, F	**T, F**	**T**	T, F	T, F	Y	Y	Y		**Y**
R-SMZ-GAC-PM	Y	T, F	**T, F**	**T**	T	T, F	Y		Y		**Y**
S-Z-GAC (layered)	Y	T, F	**T, F**	**T (Zn)**	T, F	T, F	Y	Y			**Y**

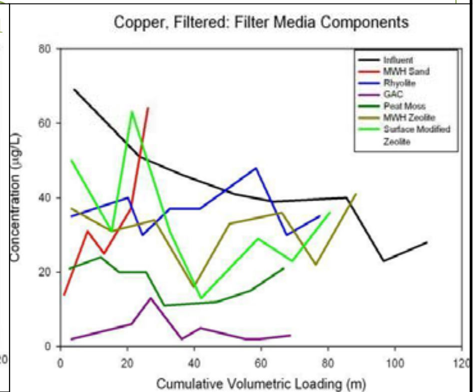
R = rhyolite; SMZ = surface modified zeolite; GAC = granular activated carbon; PM = peat moss; S = site sand; Z = site zeolite

Y = removal (only analyzed on total form); T = removal for total form (unfiltered); F = removal for filtered form (passed through 0.45-μm membrane filter)

Long-Term Column Tests: Removal as a Function of Pollutant Form

41

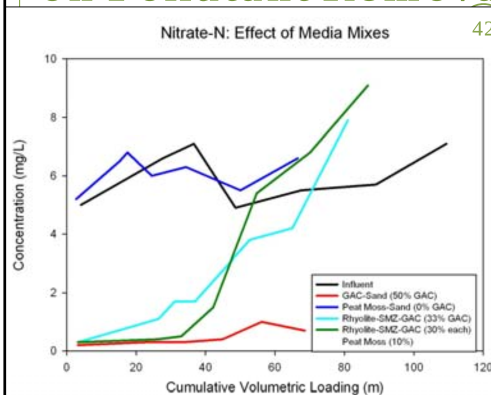


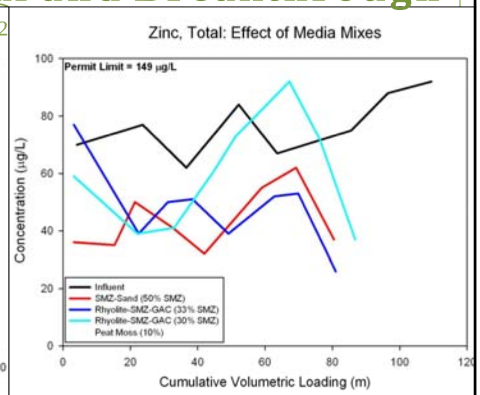


- Excellent removals of particulate-associated pollutants, but removal of dissolved/colloidal components vary greatly by media
- Primary removal mechanism is physical straining/removal of part-associated copper
- Removal by GAC and then peat may be related to organic complexation of copper in influent water or complexation with the organic content of the media
- Poorer removal by zeolites and sands (typically associated with CEC)

Long-Term Column Tests: Effect of Mixes on Pollutant Removal and Breakthrough

42

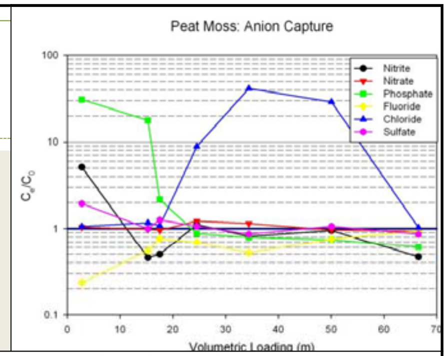


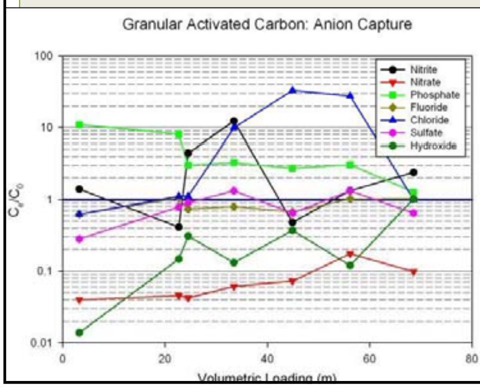


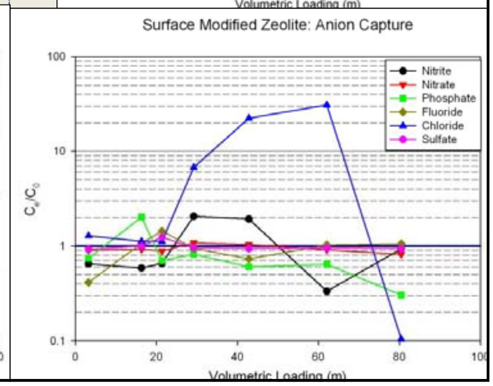
- Nitrate removal excellent in GAC. Breakthrough occurs more rapidly as the fraction of GAC in the media mix decreases
- Similar trends noted for SMZ for zinc, although not as pronounced. Effects seen later in media life, rather than during initial sample collection when washout is occurring from other components in the media mix

Ion-Exchanging Media: Trade-Offs between Pollutant Removals and Releases

43

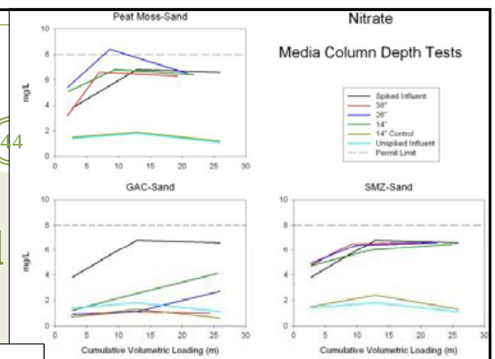


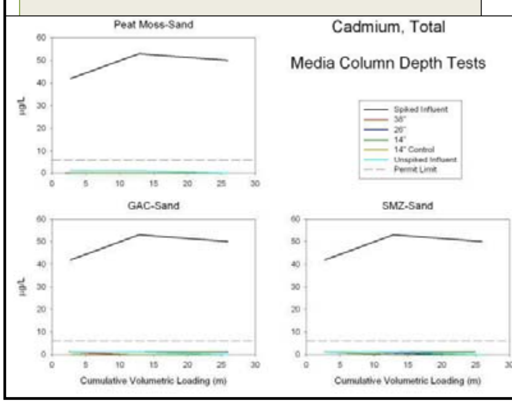




Media Depth Tests: Contact Time vs. Pollutant Removal

44





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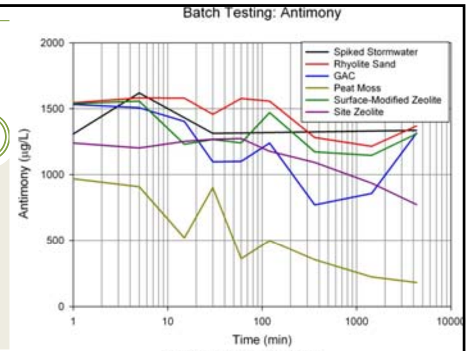
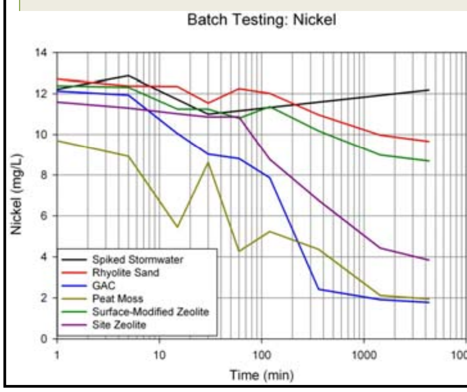
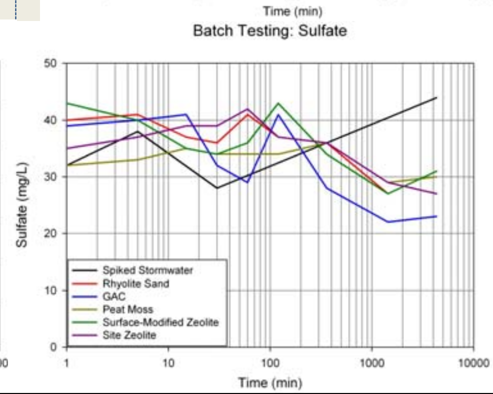
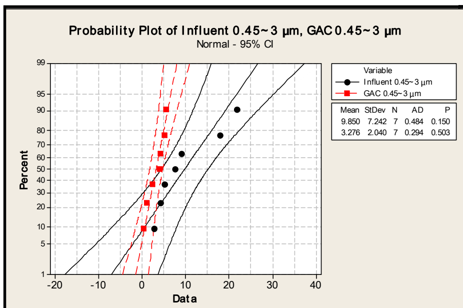
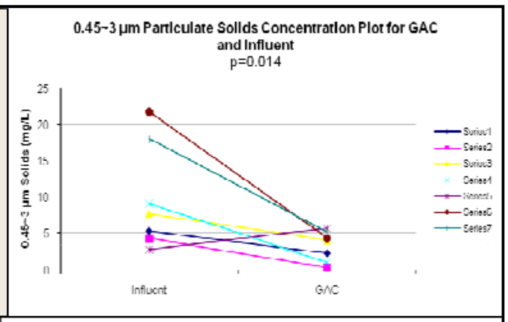
Batch Testing to Optimize Contact Time

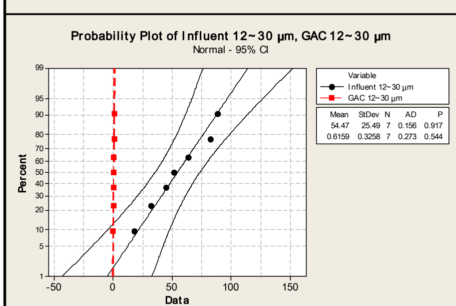


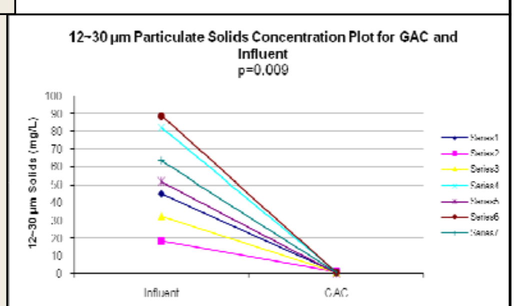








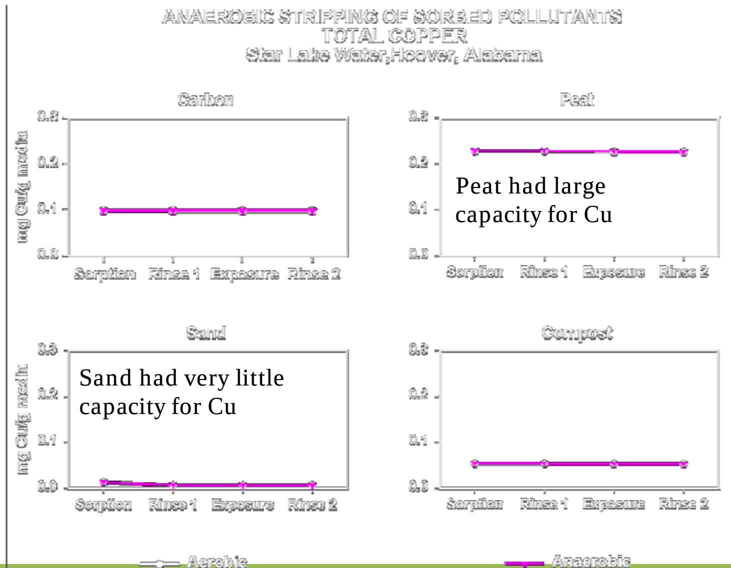




Media very effective for a wide range of particle sizes

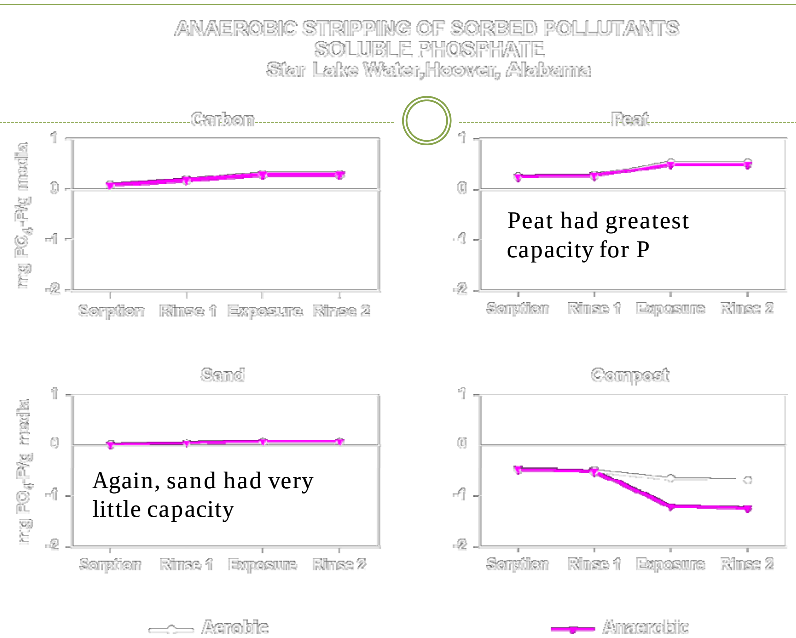
46

Contaminant Losses during Anaerobic vs. Aerobic Conditions between Events



No significant stripping of copper during aerobic and anaerobic conditions

47



Compost leached soluble P during all conditions, especially if anaerobic

48

Media Study Conclusions

49

- Media mixtures perform better than individual components separately.
- Fine grained sands clog quickly and have poor flow rates, while large-grained media flow too quickly with very short residence times, and likely poorer effluent quality.
- Some constituents break-through before others, but clogging by sediments likely occurs before chemical retention capacity is exceeded for most bioretention devices and media mixtures. Highly effective pretreatment is therefore critical to reduce the sediment load.
- Maintenance by scraping the surface layers is only partially effective and for only short durations. It is expected that plants in a biofilter, with underlying media mixtures, will provide the longest run times before clogging.

Media Study Conclusions (cont'd)

50

- Longer retention times (deeper media beds or slower flow rates and larger surface areas) improve effluent quality for some constituents, but not all. These tests all had relatively slow flow rates and long retention times (5 to20 meters/day).
- Both anion and cation exchange occurs in media filters, with different releases for different media types. Phosphorus, potassium, and sodium are commonly released constituents, along with pH shifts.
- Some constituents and some media require a certain contact time before retention, while others are more capable of pollutant retention more rapidly and at lower influent concentrations.
- Anaerobic conditions may occur in filters that do not experience much water exchange, with potential release of phosphorus.

Media Study Conclusions (cont'd)

51

- During these studies, the media and mixtures that had the longest time before clogging and the highest flow rates were:
  - Sand & zeolite currently in use at the site and GAC (layered mixture)
  - Rhyolite sand
  - Granular Activated Carbon (GAC)
  - Rhyolite sand, SMZ, and GAC mixture
  - Surface modified zeolite (SMZ)
- The Rhyolite sand, surface modified zeolite, plus granular activated carbon mixture had significant removals for all constituents measured, except for phosphorus and gross beta radioactivity. Media breakthrough would limit the duration of these removals.
- The layered sand/zeolite/GAC mixture resulted in all effluents meeting the current site permit limits, except for a slightly elevated pH, when maximum site runoff conditions were considered.

Media Study Conclusions (cont'd)

52

- Nitrate removals were excellent with the GAC. Breakthrough occurred more rapidly as the fraction of GAC in the media mixture decreased. However, significant phosphorus releases occurred with the GAC.
- Phosphorus and phosphate had significant (but relatively small) removals in the rhyolite sand, the site sand, the site zeolite and the surface modified zeolite.
- The filtered forms of cadmium, thallium, and nickel had significant removals by most media, while filtered lead and filtered zinc were poorly removed by all of the tested media and mixtures. Filtered copper removals were significant, but small.
- All of the media tests had very good removals of particulates, even down to very small particle sizes, and concurrent good removals of pollutants strongly associated with the particulates.
- Radionuclide, mercury and TCDD also had significant removals by most of the media mixtures tested.

Final Conclusions

53

- Media performance studies demonstrate significant strides in optimizing BMP design and effectiveness
  - Although in some cases such design elements (e.g., specially selected media) may only apply for somewhat costly advanced treatment systems
- Questions remain regarding how permits with WQS-based NELs will account for limits of BMP achievability, background issues, and design storm issues

Acknowledgements

54

Thanks to many, but special thanks to:
Eric Strecker, Geosyntec
Paul Hobson, Geosyntec
Other esteemed members of the Expert Panel
Shirley Clark, Univ. Penn. Harrisburg

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Additional Slides if needed

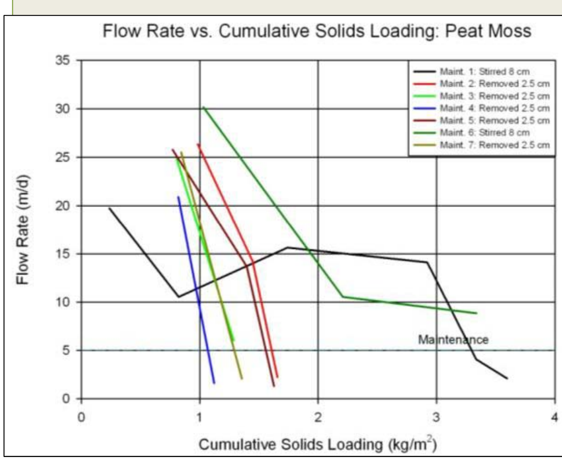
55

Unused Pitt media testing slides

Long-Term Column Tests: Maintenance

56

- Infiltration rates typically decrease over a device's life due to solids capture on the surface of and in the media



- Sample examination of potential maintenance options once flow rate < 5 m/d (effects of disturbing media vs. removing media from filter)
- Media removal generally more effective, but must remove at least 4 – 6" because clogging solids are captured deep in the media (deeper than visible solids buildup)