

Modified Biopolymers as an Alternative to Petroleum-based Polymers for Soil Modification.

Chris Griggs

ERDC-Environmental Laboratory

Environment, Energy Security,
and Sustainability Symposium
and Exhibition

E²S² 2010



US Army Corps of Engineers
BUILDING STRONG®



Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JUN 2010		2. REPORT TYPE		3. DATES COVERED 00-00-2010 to 00-00-2010	
4. TITLE AND SUBTITLE Modified Biopolymers as an Alternative to Petroleum-based Polymers for Soil Modification.				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Army Engineer Research and Development Center,Environmental Laboratory,Waterways Experiment Station, 3909 Halls Ferry Road,Vicksburg,MS,39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 14-17 June 2010 in Denver, CO.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 26	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



This project is funded by the Environmental Security Technology Certification Program (ESTCP ER-0920).

Collaborators: Steve Larson- ERDC-EL
 Kent Newman – ERDC-GSL
 Jeff Talley– SMU
 Greg O'Connor – ARDEC



BUILDING STRONG®

Introduction

Rhizobium tropici is a catalogued symbiotic nodulator of leguminous plants. It produces a gel-like, extracellular polymeric substance (EPS).



The natural functions of the EPS include surface adhesion, self-adhesion of cells into biofilms, formation of protective barriers, water retention and nutrient accumulation around roots. These properties can be exploited for many varied military and civilian uses.



SAFR Range Sustainability

- Environmental
- Operations and Maintenance



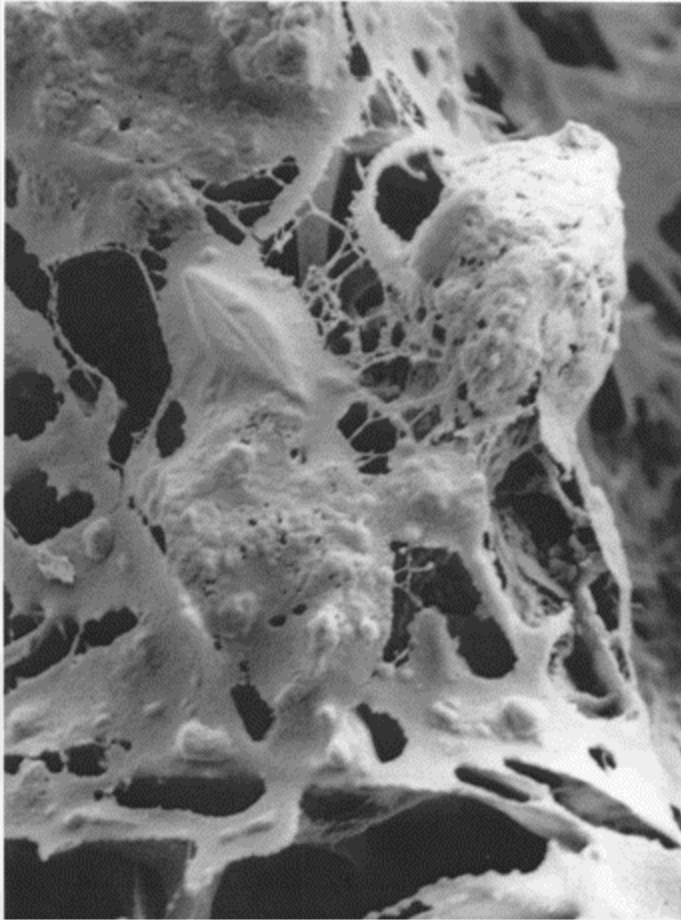
BUILDING STRONG®

Soil Modification through Biopolymer Amendment

Individual soil particles are linked together within the biopolymer matrix. This reduces their mobility which results in :

- Erosion Control
- Reduction of Suspended Solids
- Reduction in Heavy Metal Transport
- Increase in Strength of the Soil Surface Layer





Scanning electron micrograph of sediment surface coated with EPS. (Black et al. 2002)

- Cross-linkages offered by embedded EPS encourage soil particle aggregation and contribute to erosion control and soil stability
- Biomimetic technology using EPS of terrestrial bacterial origin, takes advantage of natural functions of soil adhesion, water retention, biofilm strength, and persistence in the soil.



Advantages of the biopolymer over petroleum-based polymers (COTS)

■ Fewer Logistical Concerns

- Less material, less mixing
- Eliminate the generation and transport of hazardous products and by-products

■ Smaller Footprint

- Not petroleum-based
- Renewable
- Natural component of most soils they are considered environmentally benign



Biopolymer Structure

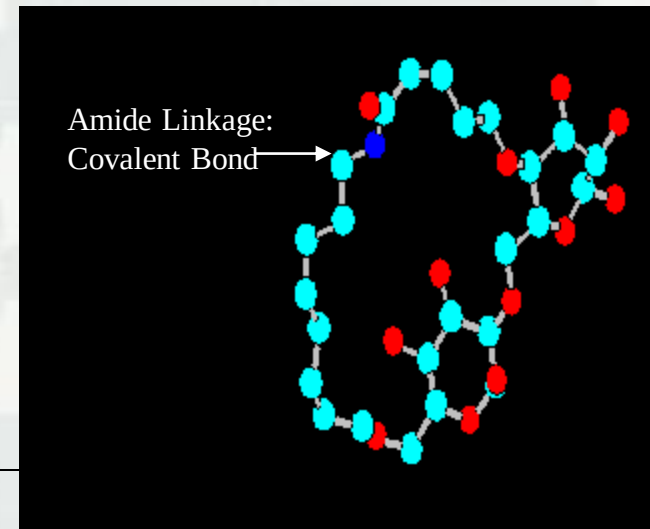
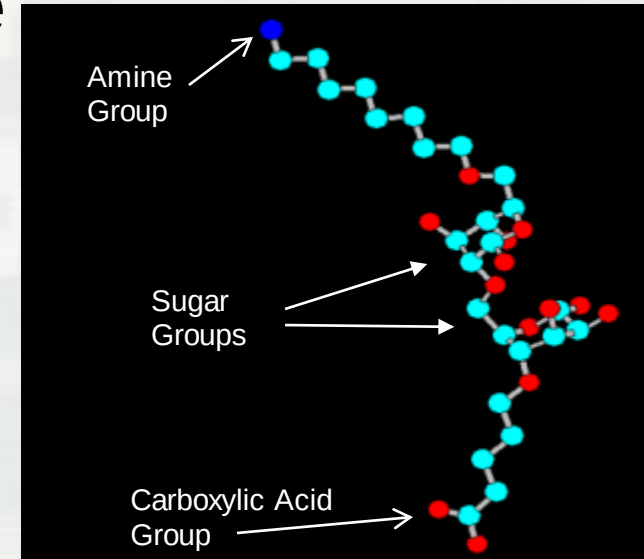
Both synthetic and biopolymers have a “primary structure” of repetitive monomeric units.

Synthetic polymers:

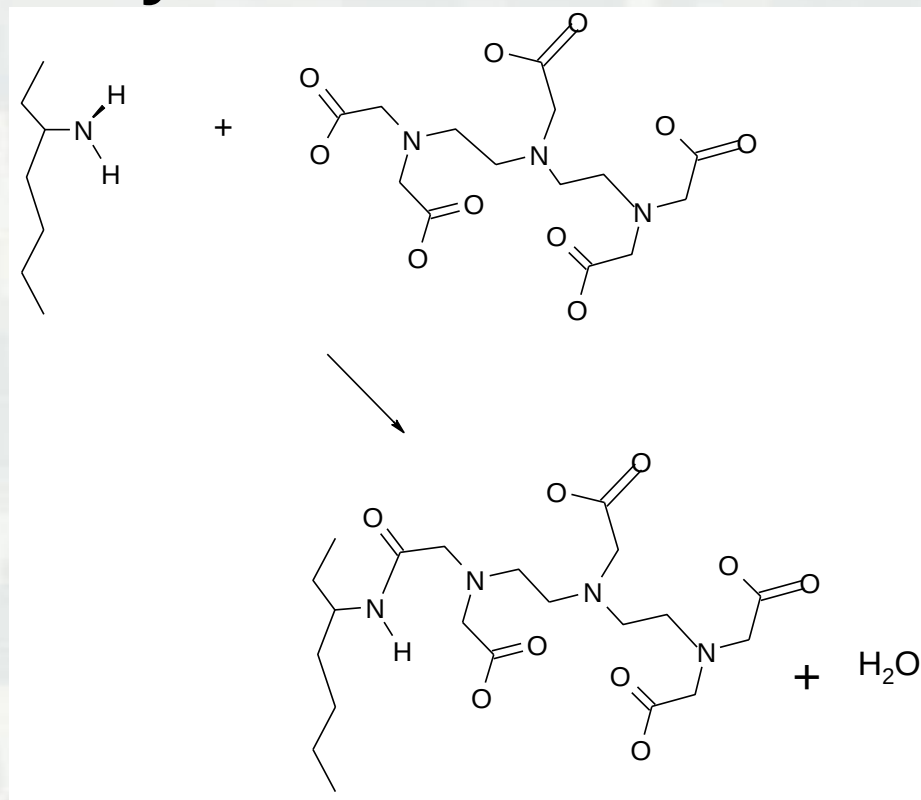
- ▶ Simpler, less varied structure

Biopolymer:

- ▶ more complex
 - Folding, crosslinkages → changes shape and chemical properties
 - Complex pendant moieties that display highly specific functionalities.



Synthesis

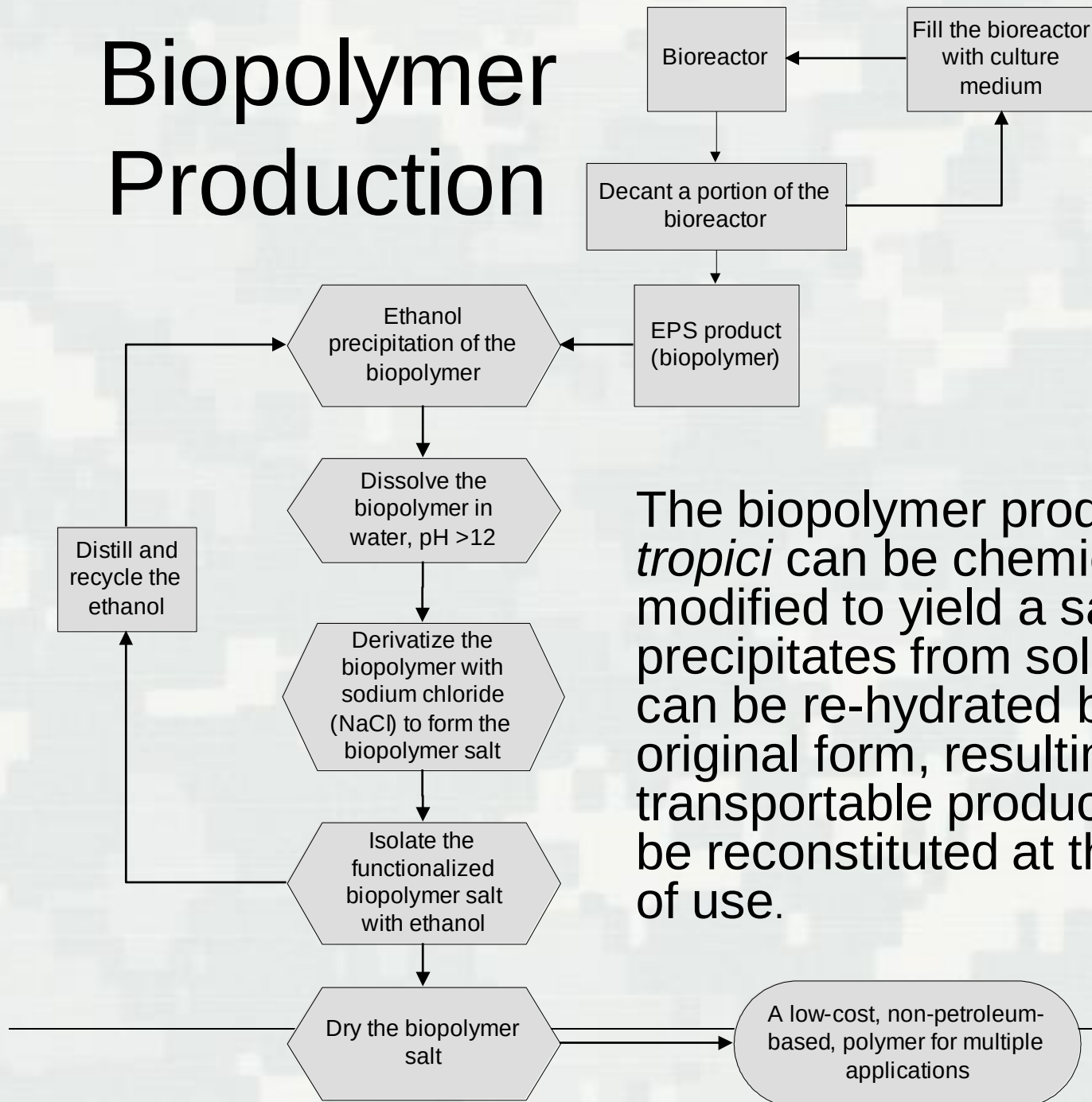


Sequestration of heavy metals through the use of biopolymers modified with chelating groups

Carboxyl group of DTPA reacts with biopolymer amino group releasing water in a dehydration (condensation) synthesis. Derivative is a polydentate ligand for metals sequestration.



Biopolymer Production



The biopolymer produced by *R. tropici* can be chemically modified to yield a salt that precipitates from solution and can be re-hydrated back to its original form, resulting in a transportable product that can be reconstituted at the location of use.



BUILDING STRONG®

Optimization through manipulation of growth medium, temperature, oxygen flow, and bioreactor pH



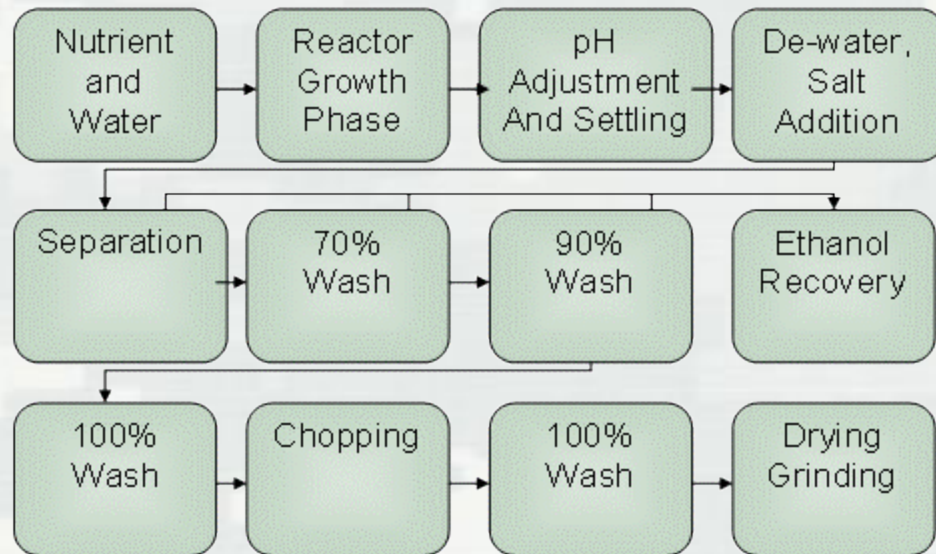
Biopolymer Production Process

Production has gone from bench-scale to pilot-scale. We can now make kg of biopolymer each week for testing of new and varied applications, both military and civilian.



Biopolymer Production

Schematic of biopolymer production process



Older reactor (400 gal, left) and newest reactor (800 gal, right)



The cost driver of the production process was determined to be the ethanol usage and energy costs associated with re-distillations of the used ethanol. Process modifications have been introduced to reduce the ethanol usage by a factor of 20.



BUILDING STRONG®

Biopolymer Production

Soil Amendment

Final Product

A finely-ground dry biopolymer salt → ready to be added to soil.

Soil Amendment

Dry addition: Add dry biopolymer to the soil, mix well (manually), add any non-potable water and allow to dry.

Wet addition: Mix dry biopolymer with non-potable water and mix well. The solution will become thick. Apply the gel mixture to the soil using a standard sprayer. Allow the soil to dry. Repeat the process several times to get the most complete coverage.



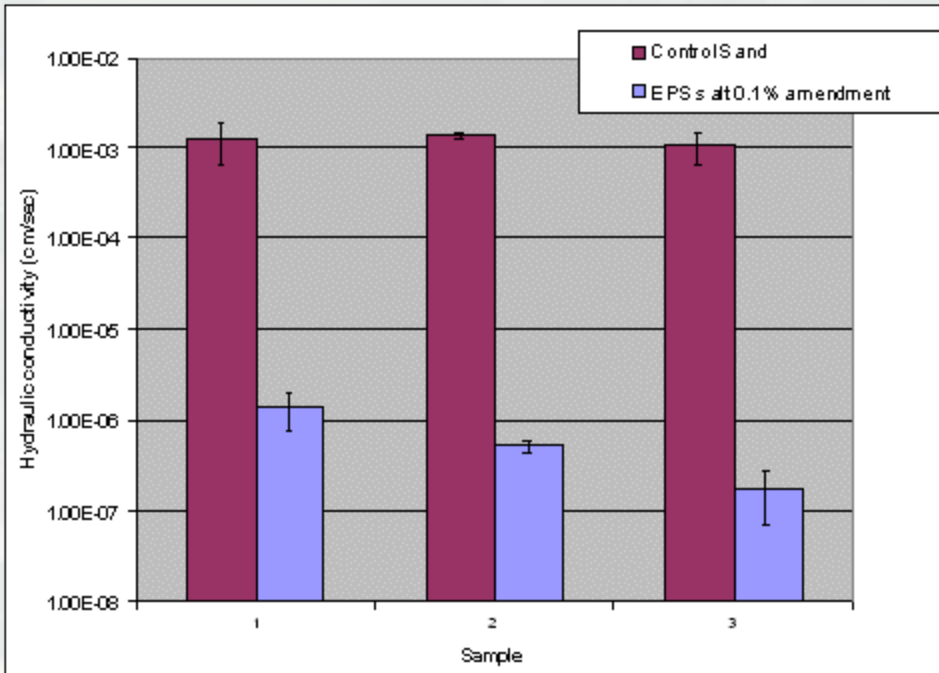
Biopolymer required for 0.2% mass loading

Treatment depth (inches)	gr BP /yd ²	Kg BP /acre	Kg BP / hectare
1	56	7	17
3	168	21	50
8	448	54	132
18	1.0 kg	120	295

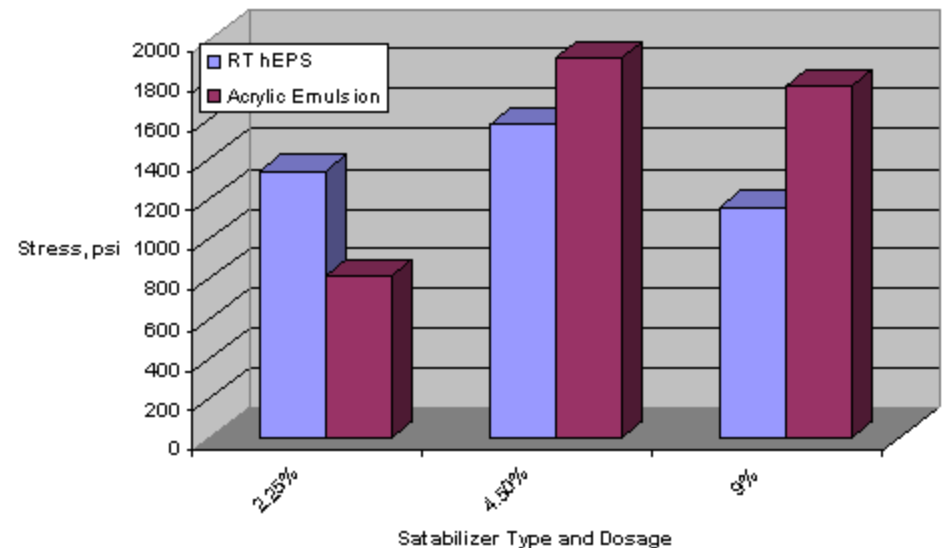


Results: Bench-scale study – Geotechnical

Comparison of **hydraulic conductivity** in a silty sand soil.



Comparison of **peak stress** for unconfined compressive tests in a silty sand soil.



Erosion Study – Suspended Solids and Turbidity

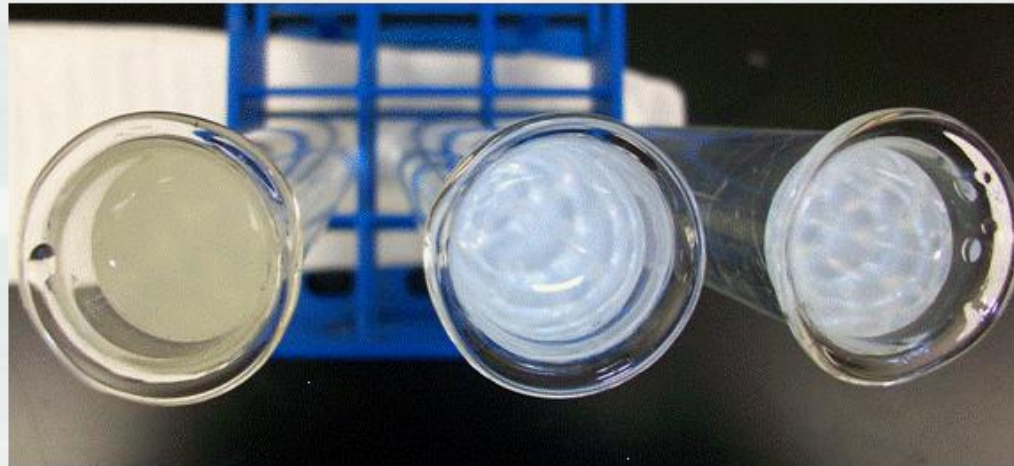
- The appearance of surface runoff water from soil treated at increasing loading rates of biopolymer.
- Higher loading rates demonstrate decreased suspended solids and turbidity.

Biopolymer % by soil weight:

0.0

0.10

0.20



Turbidity of water
Post settling:

19 NTU

6 NTU

4NTU



Static Lysimeter Cells – Erosion Control



Untreated soil. Exposed gravel due to surface water runoff after 19 rain events (>2.5 year rainfall).

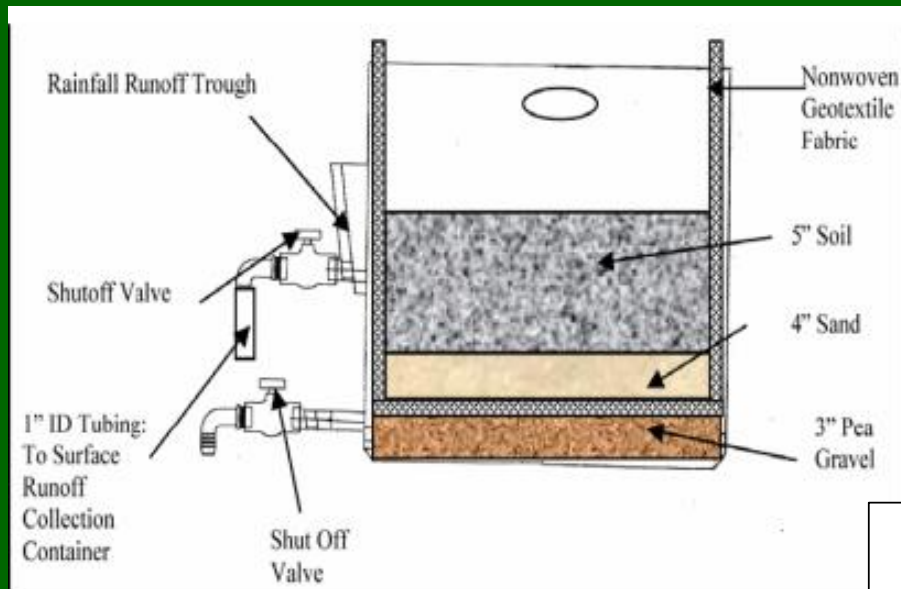


Biopolymer-treated soil demonstrating surface durability and resistance to erosion after 19 rain events (>2.5 year rainfall).



BUILDING STRONG®

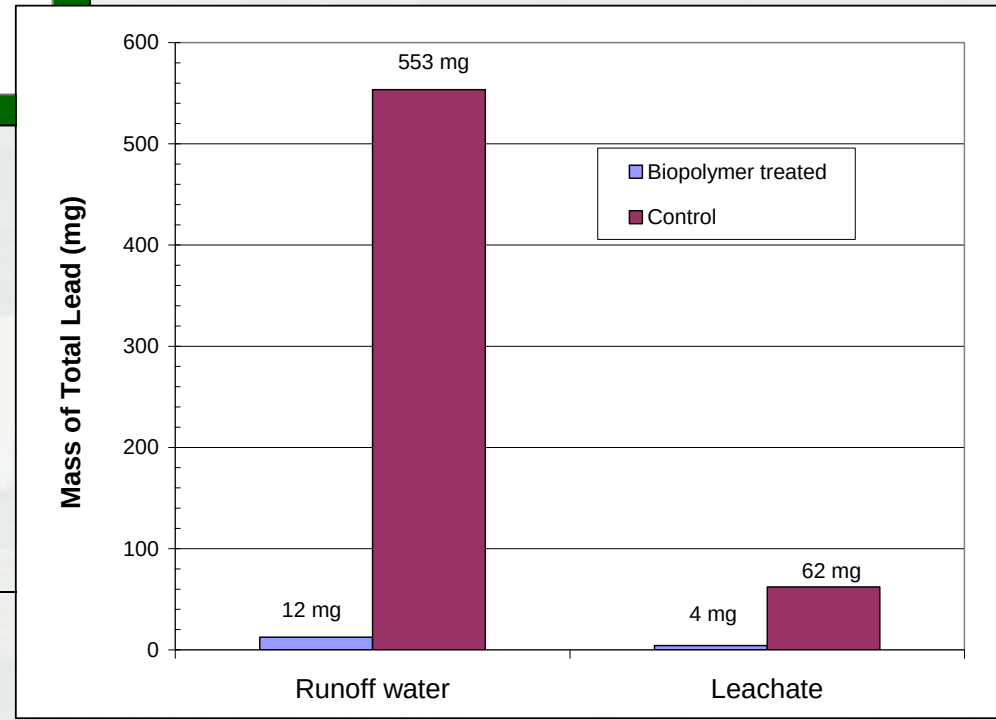
Performance Objectives – Metal Stabilization



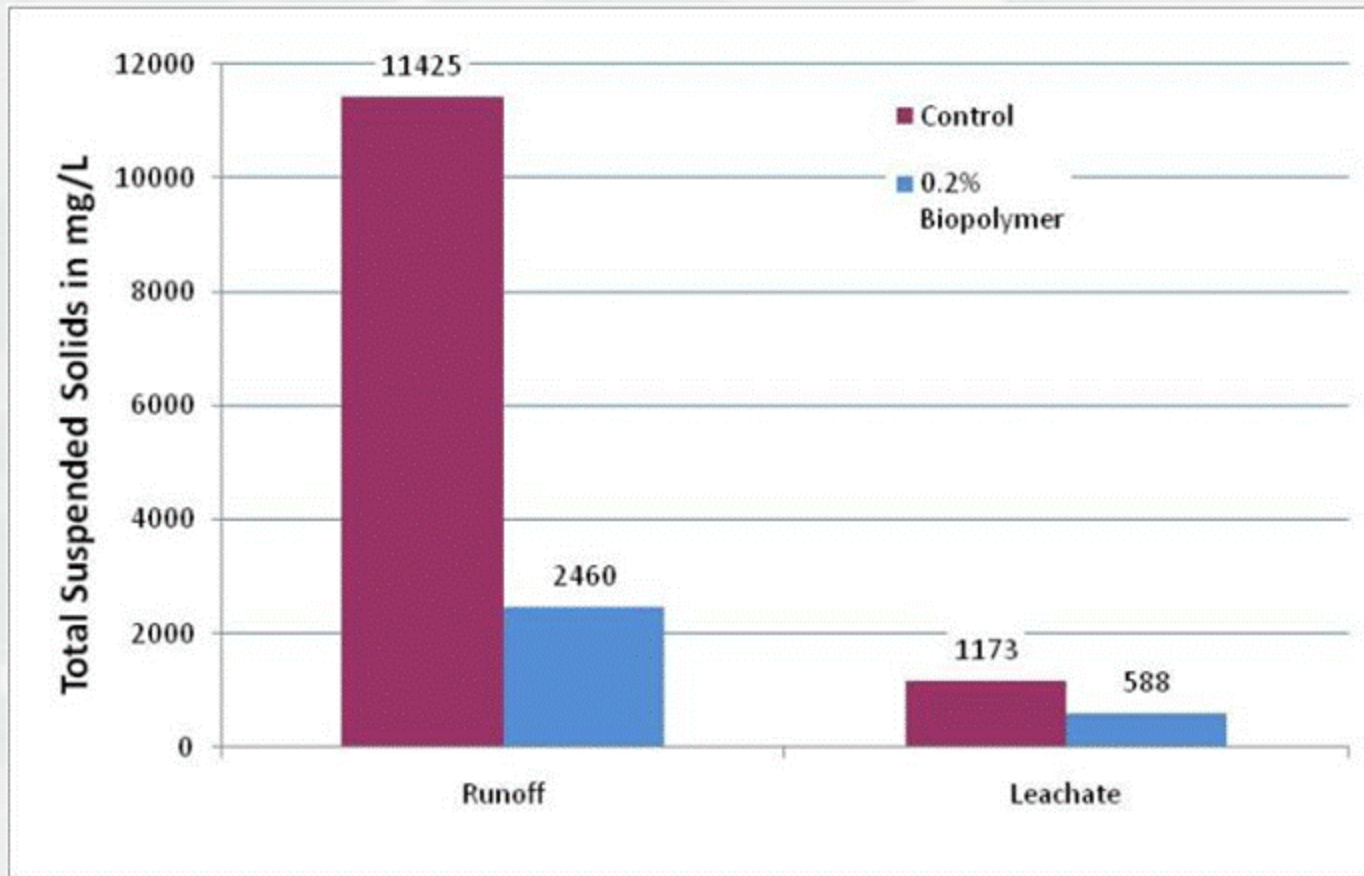
These results are from the use of the unmodified biopolymer in soil.

Simulated weathering time = 2.5 years

Rainfall based on average Southeast rainfall of 47-51 inches per year.



Performance Objectives – Soil Stabilization



Simulated weathering time = 2.5 years

Rainfall based on average Southeast rainfall of 47-51 inches per year.



BUILDING STRONG®

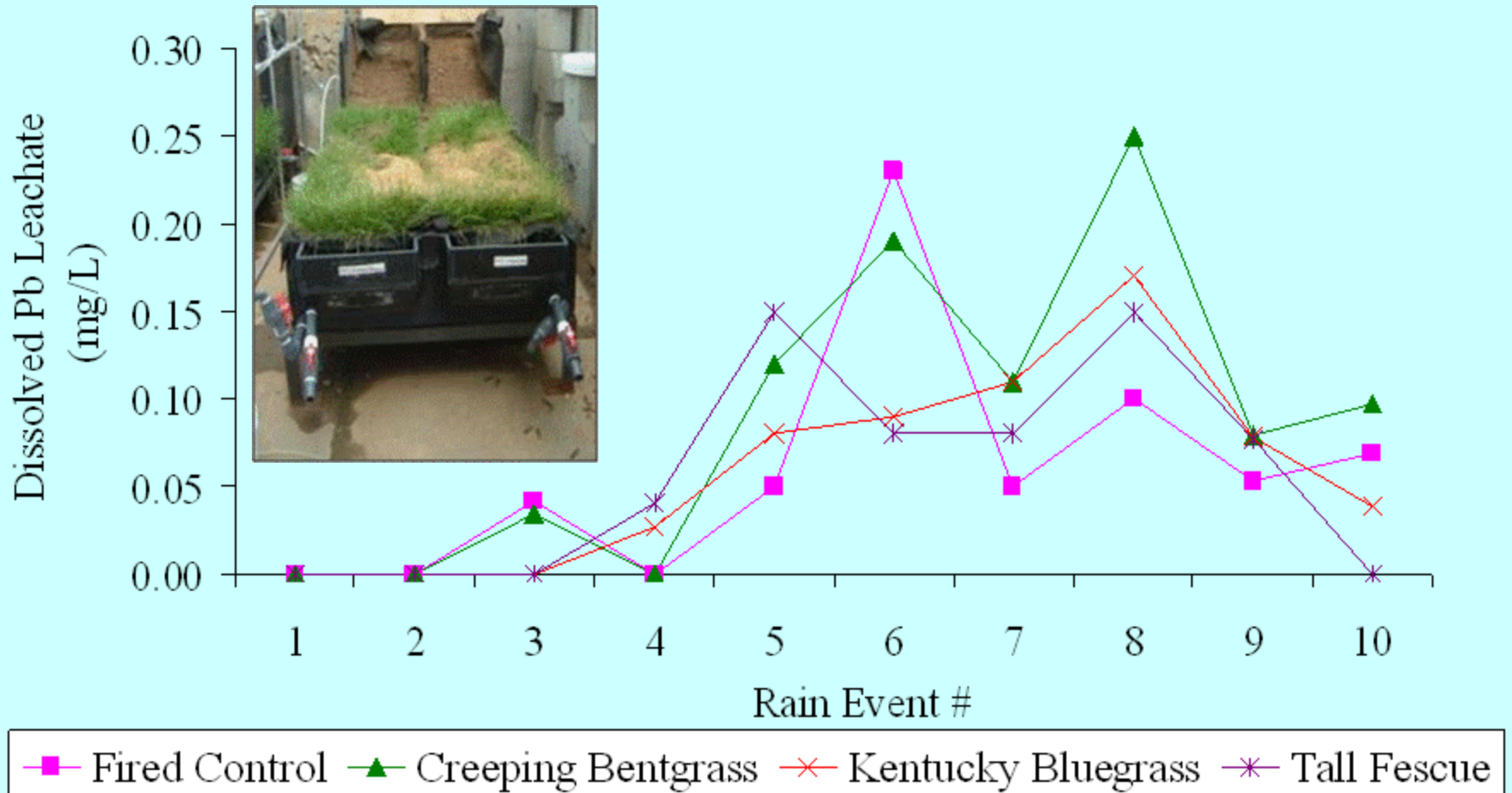
Vegetative Range Floor– TSS/ Runoff Control



Live-fire Lysimeters



Vegetated Range Floor Enhanced Pb Leaching



Operations and Maintenance– Erosion Control and Slope Stability

Loess (Silt) soil type



Control
0.0% biopolymer



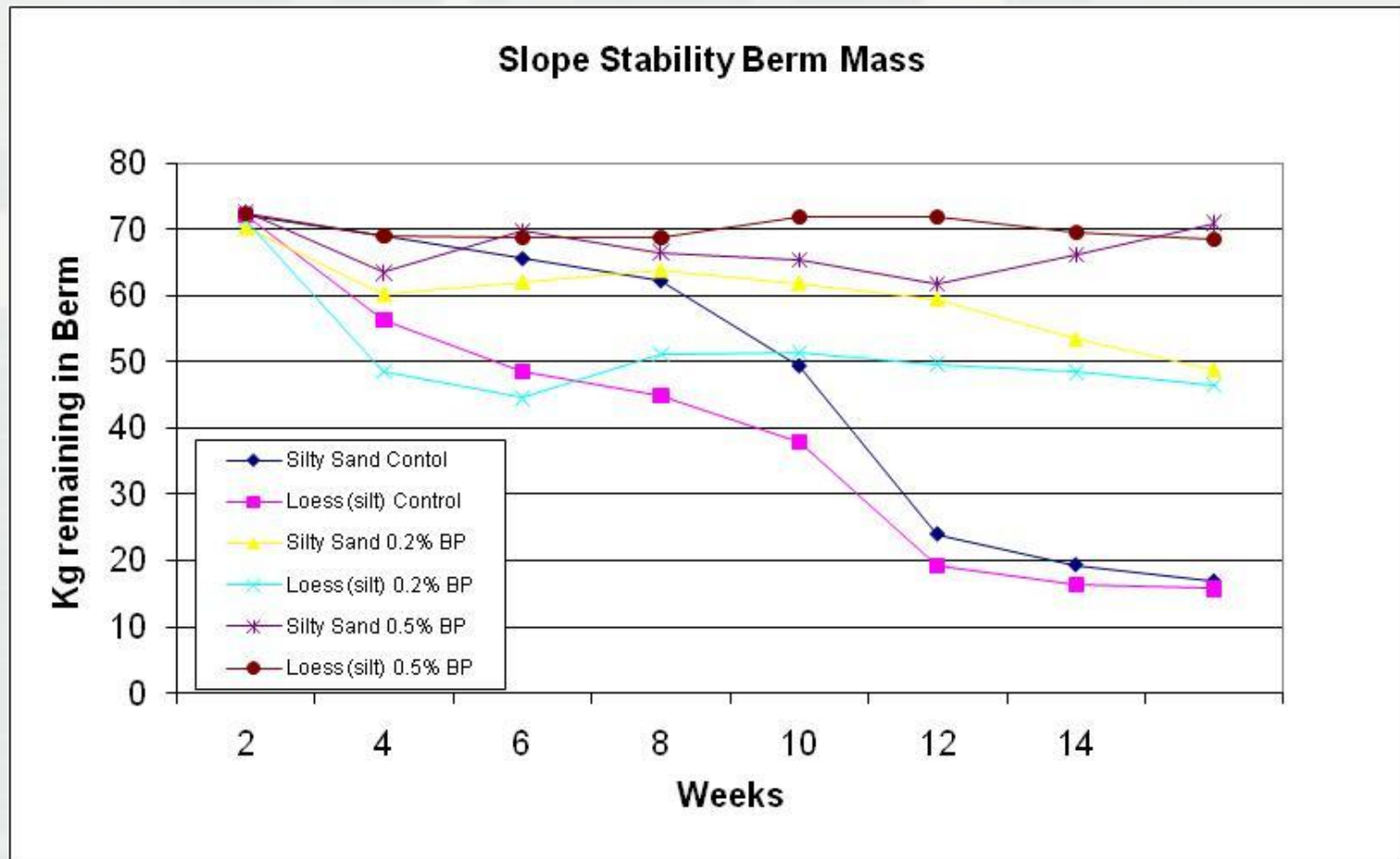
0.2% biopolymer



0.5% biopolymer



Performance Objectives – Erosion Control and Slope Stability



Summary

The potential advantages of the biopolymer over conventional petroleum-based polymers as a soil amendment are:

- ▶ decreased soil loss through reduced erosion,
- ▶ reduced berm maintenance costs,
- ▶ ease of storage and use,
- ▶ decreased potential for transport of particulates (such as heavy metals) in water (suspended solids) and in air (fugitive dust).
- ▶ decreased carbon footprint in production of the biopolymer,
- ▶ it is a “green” technology that reduces/eliminates the use of/generation of hazardous substances in its production,
- ▶ Increase in public acceptance of the soil treatment.
- ▶ Reduced use within the DoD of petroleum-based compounds



Questions ?



BUILDING STRONG®