



Pulp Mill By-products as Soil Amendments: Suitability Studies

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Sustainable Soils Forum
Raleigh, NC
September 18, 2014



Virginia Tech CSES Industrial By-product Testing Program & Cooperating State Agencies

- Virginia Department of Agriculture & Consumer Services (VDACS) – Labels and regulates fertilizers, liming products, soil amendments, potting soils, etc.
- Virginia Department of Environmental Quality (DEQ) – Their waste definition allows for industrial by-products that are beneficially recycled to be excluded from “waste” designation and be considered as a VDACS-registered soil amendment.

Assumptions for Screening By-products for Beneficial Use

- Use as a soil amendment or in blended products must be **beneficial** use, not low cost disposal.
- Industry or mine must provide data, e.g. elemental analyses & TCLP, demonstrating that the residual is not hazardous per VA DEQ and US EPA criteria.
- VDACS is the final arbiter of quality and labeling for such residuals despite our testing and recommendations.
- Part or all of a prescribed three-step screening procedure must be followed and reported to VDACS.

VT/VDACS Waste Screening Protocols – Step 1.

- Comprehensive analysis of basic physical and chemical properties of residuals proposed for beneficial use must be performed, including pH, soluble salts, organic matter, total and extractable elements (nutrients, trace inorganics), particle size/texture, etc.
- If the proposed residual is well-understood, such as wood ash or gypsum, this level of analysis is usually sufficient for label development.

Wood (100%) Ash Analysis

Parameter	Value	Parameter	Value
1:1 pH (ash:water)	12.5	As (mg/kg)	8.2
Saturated Paste EC (dS/m)	28	B (mg/kg)	115
Calcium carbonate equivalence, CCE (%)	37	Cd (mg/kg)	1.2
Total C (%)	1.5	Cr (mg/kg)	20
Total N (%)	0.02	Cu (mg/kg)	16
P (%)	0.13	Mo (mg/kg)	0.31
K (%)	2.3	Ni (mg/kg)	7.6
S (%)	0.35	Pb (mg/kg)	26
Ca (%)	5.9	Se (mg/kg)	0.80
Mg (%)	0.65	Zn (mg/kg)	44

Label Recommendation Memo to VDACS



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MEMORANDUM FOR THE RECORD
 TO: Dr. Greg Evanylo, Pulp Mill Research Coordinator
 FROM: Dr. Greg Evanylo, Pulp Mill Research Coordinator
 SUBJECT: Label Recommendation for Wood (100%) Ash

As described in our report, wood ash contains a wide range of nutrients and micronutrients. The ash is a natural by-product of the wood pulping process and is not a synthetic fertilizer. The ash is a natural by-product of the wood pulping process and is not a synthetic fertilizer. The ash is a natural by-product of the wood pulping process and is not a synthetic fertilizer.

- This by-product should be applied as a liming source according to soil testing lab recommendations.
- Over-application can lead to excessive soil pH and potential salt toxicity.
- Higher application rates may be useful for acid mined land reclamation.



Fly Ash Analysis




Parameter	Value	Parameter	Value
Solids (%)	59	As (mg/kg)	56
Volatile solids (%)	15	Cd (mg/kg)	1.3
Saturated Paste (SP) pH	8.28	Cu (mg/kg)	57
SP EC (dS/m)	1.17	Pb (mg/kg)	30
CCE (%)	6	Hg (mg/kg)	0.5
Total P (%)	0.10	Mo (mg/kg)	4.1
K (%)	0.32	Ni (mg/kg)	36
Ca (%)	1.24	Se (mg/kg)	13
Mg (%)	0.17	Zn (mg/kg)	64
Fe (%)	1.97	Mn (mg/kg)	514




Lime Mud Analysis



Parameter	Value	Parameter	Value
Solids (%)	77	As (mg/kg)	<5
Volatile solids (%)	2.3	Cd (mg/kg)	<5
Sat Paste pH	12.9	Cu (mg/kg)	<10
EC (dS/m)	11.9	Pb (mg/kg)	<5
CCE (%)	93	Hg (mg/kg)	<0.05
Total P (%)	0.14	Mo (mg/kg)	<10
K (%)	0.05	Ni (mg/kg)	<20
Ca (%)	36	Se (mg/kg)	<5
Mg (%)	0.96	Zn (mg/kg)	<20
Fe (%)	0.39	Mn (mg/kg)	260



WWTP Sludge Analysis



Parameter	Value	Parameter	Value
TKN (%)	1.34	Ca (%)	11.8
NH ₄ -N (%)	0.09	Mg (%)	0.28
Organic N (%)	1.25	Fe (%)	0.16
(NO ₃ + NO ₂)-N (%)	<0.01	Trace element concentrations 1-2 orders of magnitude < USEPA 503 Rule standards.	
Volatile solids (%)	45.7		
C:N	19.8		
P (%)	1.34	Cu (mg/kg)	13
K (%)	0.04	Zn (mg/kg)	54
S (%)	0.61		

VT/VDACS Waste Screening Protocols – Step 2.


- If the basic analytical data is not clear cut “clean” and/or the material does not have a well-documented history of land application, then a greenhouse screening bioassay is required.
- The bioassay is performed with tall fescue (tolerant) and soybean (sensitive) using standard Virginia topsoil(s) at either the proposed material loading rates or at a range of rates.

Soybean Phytotoxicity Bioassay


Treatments:

- Control: K only
- Control: NPK
- Control: Lime + K
- Lime Mud 1x CCE + NPK
- Fly Ash: 1x CCE + NPK
- Sludge: 1x PAN + K

Soybean management:
 Seeded: 8-19
 Harvested: 10-12



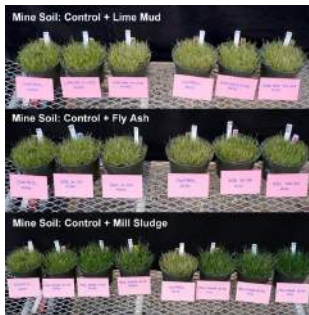
Comparison of lime mud, sludge & fly ash on fescue growth in Piedmont soil



- Biomass & N uptake:
 - Sludge > fly ash = lime mud = control
- Soil pH:
 - Sludge (5.4, 6.4)
 - Fly ash (5.3, 5.6)
 - Lime mud (6.1, 6.7)
 - Control (4.9, 4.8)

Treatments:
 Controls: NPK and K only
 Lime mud: 1x & 2x CCE + NPK
 Ash: 1x & 2x CCE + NPK
 Sludge 1x & 2x PAN + K

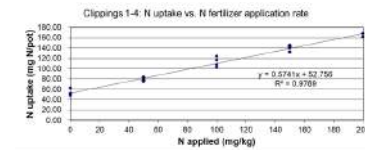
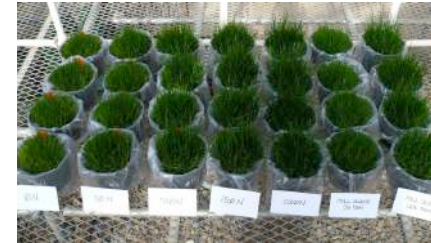
Comparison of lime mud, fly ash & sludge on fescue growth in mixed & acid mine spoil.



- Biomass
 - Acid (pH = 3.3) spoil: Sludge > lime mud = control > fly ash
 - Mixed (pH = 5.4) spoil: Sludge > fly ash = lime mud = control
- Limitations
 - Sludge → excessive soil P
 - Fly ash → water soluble Se↑

WWTP Sludge PAN Calculation Study

(Seeded: 3/15/2012; Final harvest: 5/15/2012)



WWTP Sludge PAN Estimation

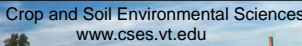
- Organic N mineralization rate = 12.6%
- PAN fertilizer equivalent = 18.4%
- Recommended rates:
 - Agriculture – based on agronomic N rate using 18% availability factor
 - Mined land reclamation – 60-75 dt/acre

VT/VDACS Waste Screening Protocols – Step 2.

- If the bioassay results are conclusive and (a) no toxicity is observed and (b) some beneficial plant growth or soil quality response is noted, a positive recommendation is provided to VDACS.
- That recommendation includes label guidance, loading rate max, and other application restrictions.

VT/VDACS Waste Screening Protocols – Step 3.


- If the bioassay results are not conclusive, a full replicated field trial is necessary to confirm field response in the “real world.”
- We have tested residuals that did not perform well in the greenhouse, but did well in the field.



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Conclusions

- All residuals were suitable for land application, providing varying benefits
 - WWTP sludge – N, P, S, Ca & organic matter source
 - Fly Ash – K, Ca, & Mg source
 - Lime Mud – liming agent
 - Wood ash – liming agent, Ca & K supply (no bioassay)
- Advantages of labeling
 - Required for regulatory exemption
 - Marketing – demonstrated benefits & positive recycling image



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