Cornell Waste Management Institute

Characterizing and Determining Beneficial Use of Paper Production Residuals that Otherwise Become Waste

at

Finch Paper, LLC

Glens Falls, NY

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Prepared for:

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Executive Summary

Background: Paper mill residuals differ depending on the process and associated chemicals needed to create the paper for the intended use. Finch Paper, LLC operates a paper mill in Glens Falls, New York. Finch starts with logs and produces high quality printing paper. They use the ammonium bisulfite pulping process to produce pulp from wood chips. The wastewater treatment system treats about 16 to 20 million gallons of wastewater a day. This process generates around 190 cubic yards of Waste Water Treatment Residual (WWTR) per day. Most chemical pulp mills in the United States use the Kraft process to make pulp. That process uses sodium hydroxide and sodium sulfide to make pulp from chips. As a result, Kraft WWTR contains a fair amount of sodium and sulfur. Finch's process gives off a fair amount of nitrogen and sulfur. This indicates that the WWTR could have value as a fertilizer or as a valuable ingredient in compost.

In an effort to recycle more organic materials, Finch Paper, LLC funded a two-year research project cooperatively with Cornell Waste Management Institute (CWMI), Cornell Department of Crop and Soil Sciences (CSS) with guidance from the New York State Department of Environmental Conservation (NYSDEC) and New York State Department of Agriculture and Markets (NYSDAM). The purpose of this research was to find potential beneficial uses for their WWTR. Three of the four potential beneficial uses investigated have been implemented.

Use of Finch WWTR as a component in animal bedding: Syracuse Fiber Recycling, LLC holds a permit from NYS Department of Environmental Conservation (DEC ID 7-3115-00043) as a solid waste management facility, that allows them to receive, store, manufacture, and ship animal bedding materials generated from beneficial reuses of paper mill sludge, wood chips and cement kiln dust. The bedding components have DEC Beneficial Use Determination (BUD No. 319-7-34), which allows use of the material as animal bedding.

This solid waste management permit describes what materials they may accept, as well as how much animal bedding they may manufacture using those ingredients and describes minimum and maximum mixing ratios. They DO NOT make animal bedding from the paper residuals alone. The facility can manufacture (by mixing) 3000 tons/week of animal bedding. Finch WWTR exceeds the quality to be accepted for use in accordance with the conditions of BUD No. 319-7-34 issued to Syracuse Fiber Recycling, LLC.

Leachate trial: Leaching tests are often used to evaluate the potential of a material to release contaminants to the environment. Leachate from paper mill residuals (PR) used as a compost feedstock, or directly as a soil conditioner may contain toxic metals that can contaminate groundwater. Therefore column leaching tests were conducted on agricultural soil amended with Finch PR to evaluate the impact on groundwater when using these residuals for agricultural uses. The objective of this trial was to evaluate the effects of PR additions (with and without added lime) to soil on nutrient leaching at increasing application rates equivalent to 0, 2, 5, 10 and 20 tons/acre. The United States Environmental Protection Agency's (USEPA) maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for drinking water were used as guidelines for assessing what level of each metal would be considered a risk on groundwater quality.

Nineteen metals were analyzed in the leachate from columns in this laboratory trial. There was no difference between the amount of sodium (Na), potassium (K), boron (B), aluminum (Al), manganese (Mn), nickel (Ni), zinc (Zn), arsenic (As) and lead (Pb) that would normally leach from un-amended soil (rate = 0) than leached from soil mixed with PR even up to a rate of 20 tons/acre. Therefore, the addition of PR (with or without lime) would not significantly affect groundwater concentrations of these elements. In addition, other than manganese for PR with no added lime applied at the rates of 5 and 10 tons/acre, none of the quantities of metals leached met or exceeded the standards for drinking water described.

Concentration of calcium (Ca), cobalt (Co), copper (Cu) and magnesium (Mg) were affected by rate of application. For Ca, Co and Cu, a higher application rate resulted in higher concentration in leachate. For Mg, higher application rate resulted in lower concentration in leachate. Although affected by the addition of PR, the highest concentration reached for each of these metals would have no effect on the quality of groundwater into which it could leach. For the last 5 of the 19 elements analyzed (phosphorus, chromium, iron, molybdenum and sulfur) increasing rate of application was positively correlated with concentration in the leachate, but did not meet or exceed drinking water standards. Therefore addition of PR does not appear to contribute to groundwater pollution through leaching.

Use of Finch WWTR as a compost feedstock: WWTR was delivered to a commercial compost facility that uses a turned windrow system. The paper residual was used as a compost feedstock by itself and in various combinations with other feedstocks. Compost quality is measured by several parameters, including moisture, pH, soluble salts, bulk density, organic matter (OM) content, concentration of nitrogen, phosphorus and potassium (N-P-K), carbon to nitrogen (C:N) ratio and concentration of metals. Testing of the finished compost from these trials indicated that compost made using WWTR tested well for moisture, soluble salts, OM, N-P-K, C:N ratio and metals. The pH and bulk density were slightly higher than desired indicating that these composts should be used for soil mixes or incorporation into the soil.

Use of Finch WWTR on soil growing field corn: A 1990 field study using high organic matter/low nitrogen PR showed that nitrogen deficiency was a limiting factor in plots with PR. Finch PR is relatively high in nitrogen. The important question to answer is whether or not the level of nitrogen in Finch PR is sufficiently high, and its decomposition rapid enough, to prevent a nitrogen deficiency in a growing corn crop. The PR used from Finch was not treated with lime, so that biological decomposition would not be inhibited.

In year 1, plots were planted to field corn with either 0 or 30 tons PR/acre incorporated. The addition of un-limed PR to plots prior to planting corn had no effect on yield or harvest dry matter. Although stalk nitrate concentration did not differ between treatments, the results indicated that plants took up excess nitrates, and especially so in plots treated with PR. This was confirmed by the fact that soil nitrate levels were significantly higher in the PR treated plots than the controls 45 and 129 days after incorporation. The PR was not tying up nitrogen, but releasing it. Although not significant, soil OM was consistently higher in the PR treated plots than in the control plots suggesting continuous addition of PR could possibly increase OM as well as other soil health properties that were not analyzed.

Based on these results, two separate trials were conducted in year 2. The first was a residual study to determine if PR applied in 2012 would continue to supply nitrogen to a corn crop in the 2^{nd} year without additional fertilization and the second was a rate study on new plots to determine how much nitrogen is being released and how much nitrogen fertilizer can be reduced. This could determine how much should be applied for best use.

In the residual study, there were no clear trends to indicate that incorporated PR from year 1 affected yield, corn maturity or stalk nitrate on plots planted to field corn. However, OM in the second year was significantly higher in plots that had received 30 tons PR/acre the first year than all other plots in either year. Addition of PR may have increased soil OM the following year.

In the rate trial, 4 rates of PR application (0, 15, 30 and 45 tons PR/acre) were incorporated on 16 plots with 4 plots per treatment. The addition of un-limed PR to plots prior to planting corn in a low-lying, sandy loam, high organic matter field in a flood plain showed a clear trend in silage yield as the application rate of paper fiber increased from 0 to 30 tons/acre. There was no difference in yield between 30 and 45 tons/acre. There was no significant difference in harvest dry matter or stalk nitrate between the control plots and those treated with paper residuals.

Soil nitrate, pH and OM did not show any correlation to paper fiber rates. This was probably due to the erratic weather through the growing season and the associated dynamics of organic matter decomposition. Although replication was reduced from excess rain, a clear trend in silage yield was seen as the application rate of paper fiber increased from 0 tons/acre to 30 tons/acre. Due to erratic weather through the growing season, other conclusions could not be made. Continued addition of PR to field corn may be of benefit for yield.

Recommendations: Finch should continue to work with compost producers, Syracuse Fiber and farmers interested in using their PR as a compost feedstock, component of animal bedding and soil conditioner in an effort to divert all PR. Other beneficial uses may be explored including use as a seed carrier, in erosion control, or as an animal bedding without additional components. In addition, Finch Paper, LLC produces other residuals that we were not commissioned to test that likely have beneficial use potential.

A. Project Description

Paper mill residuals differ depending on the process and associated chemicals needed to create the paper for the intended use. Finch Paper, LLC operates a paper mill in Glens Falls, New York. Finch starts with logs and produces high quality printing paper. They use the ammonium bisulfite pulping process to produce pulp from wood chips. The wastewater treatment system treats about 16 to 20 million gallons of wastewater a day. This process generates around 190 cubic yards of Waste Water Treatment Residual (WWTR) per day. Most chemical pulp mills in the United States use the Kraft process to make pulp. That process uses sodium hydroxide and sodium sulfide to make pulp from chips. As a result, Kraft WWTR contains a fair amount of sodium and sulfur. Finch's process gives off a fair amount of nitrogen and sulfur. This indicates that the WWTR could have value as a fertilizer or as a valuable ingredient in compost.

In an effort to recycle more organic materials, Finch Paper, LLC has funded a two-year research project cooperatively with Cornell Waste Management Institute (CWMI), Cornell Department of Crop and Soil Sciences (CSS) with guidance from the New York State Department of Environmental Conservation (NYSDEC) and New York State Department of Agriculture and Markets (NYSDAM). The purpose of this research is to find potential beneficial uses for their residuals.

B. Project Objectives and Scope

The objective of this project is to determine multiple beneficial uses of paper mill residuals (PR). It will be done in two parts:

- Analytical testing to fully characterize the residuals
- Determination of beneficial uses will be assessed either as fiber is produced, or through manipulation.

Task 1: Literature Review—**Completed**
A literature search of beneficial use for paper mill residuals has been completed. The report is entitled "Beneficial Use of Paper Mill Residuals: A Literature Review" (Appendix A).

Task 2: Identify Potential Beneficial Uses for Residuals - **Completed**
Potential beneficial uses of paper mill residuals within CWMI's capability to test include:

A. Determination of its value as a compost feedstock
B. Uses as a soil amendment/conditioner "as is", composted, or charred
C. As a carrier for seeding and erosion control
D. As a component in animal bedding

Task 3: Test Residual - **Completed**

A. Determination of paper residuals value as a compost feedstock: Finch paper residuals with lime were delivered to Ken Van Alstine's compost facility in Fort Hunter, NY on June 1, 2011 where several different piles were built composed of the paper residuals and other compost feedstocks Ken secured including manure, silage and food scrap. Composting of paper mill residuals on its own (with no other feedstock) may be an option but addition of spent silage, cow or horse manure, food processing residuals or spent produce, in any or all combinations appears to work well.

The compost piles started on June 1 were deemed finished by Ken on August 1 (day 61) based on temperature. There was also a small pile of paper fiber that was left alone, no other feedstock was added and it ended up producing a pretty fine product. There is potential for limed solids to compost on their own but they would have to be managed for odor in mass quantities. Unfortunately most of the research piles were washed away during Hurricane Irene flooding on August 28, 2011. A small amount of each was left from which samples were taken. Flooding appeared to add salts, increase density and decrease nutrient value, but otherwise analysis was similar to pre-flood (results can be found in **Appendix C**).

On November 15, 2011, new piles were built at Van Alstine's using papermill residuals with no addition of lime (PRNL). The fiber material not treated with lime was easy to work with and reached temperatures more quickly. There were no odor issues as the material was managed. There is an un-limed composted pile on site currently that looks promising. Sampling occurred on day 1 and then again on day 69, which was considered finished. Using the same guidelines as in Appendix C, it appears that un-limed fiber works as well as paper residuals with lime added.

Parameter	PRNL alone		Pile 1		Pile 2	
Day	1	69	1	69	1	69
Moisture (%)	68	67	65	46	72	53
pH	7.9	7.6	8.0	8.3	7.8	7.9
Soluble Salts	0.6	0.3	3.8	0.4	0.2	0.2
Bulk Density	0.5		0.7		0.6	
Organic Matter (%)	41.7	40.1	40.1	17.4	43.8	17.3
Nitrogen (%)	0.5	0.9	1.6	1.1	2.0	1.1
Phosphorus (%)	0.2	0.2	0.8	0.1	0.6	0.3
Potassium (%)	1.0	0.1	1.8	0.1	0.7	0.2
C:N ratio	66	43	17	12	17	11

B. Use as a soil amendment/conditioner:

A bench scale leaching trial has been completed. See task 5A.
A two-year field trial in Washington County has been completed. See task 5B.

C. **Use as a carrier for seeding and erosion control:** A protocol was designed for using paper mill residuals as a seed carrier (Appendix D). A small-scale trial has been completed. See task 5C.
D. **Biochar potential:** Samples of both paper residuals with and without lime were charred. See task 5D. No additional trials were undertaken using the charred residual.

Task 4: Develop physical and chemical understanding of how residuals generate strong odors.

Not done

Task 5: Perform greenhouse, field or bench-scale research to demonstrate beneficial uses - **Completed**

A. The bench-scale research project is completed. Leaching column apparatuses consisted of plexiglass-lined intact soil cores with glass wool placed underneath and water applied from above. Five paper residual application rates (0, 2, 5, 10 and 20 tons/acre) using both limed and non-limed PR in a randomized complete block design were tested with four replicates per treatment. Leaching was induced once per week for 8 weeks. Leachate was analyzed for plant-available nutrients. Column experiments started in January 2012 and ran through April 2012. **Results can be found in Appendix E**.
B. Working with Washington County Cooperative Extension, PR was used in a field corn trial beginning May 2012. Concerns about nitrogen sequestration with a high carbon product have been stated, but the higher nitrogen in Finch's PR is expected to offset this. The first year of the trial was done for this reason. A second year of the trial was started in May 2013 to test for residual effects of incorporating paper and to determine the best rate to use. **Results can be found in Appendix G**.
C. On April 15, 2012 six 3' x 3' plots were seeded at 2 locations as per protocol described in Appendix D. Soil samples were taken of each plot prior to seeding. Ten days later, most likely due to inclement weather and hard frosts, as well as the light seeding rate recommended by the seed company, none of the plots at 1 location (Richford) had any growth. Therefore, these plots were reseeded according to the amended protocol in **Appendix D** on May 6th, 2012 which also contains pictures and soil analysis. Results on site 2 (Lacona, NY) were light but there was growth.
D. Biochar was made from paper residuals with and without lime as follows:
    1. Raw paper residuals were dried at 60^{o}C for 2 days to a constant weight.
    2. The dry residuals were then pyrolyzed in the "Cornell Furnace Retrofit Batch Reactor" (see Appendix H). Furnace temperature was increased from ambient to 500^{o}C at 2.5^{o}C/minute. The highest heating temperature (HHT) was maintained for 30 minutes as verified by exhaust gas temperature. The paper residuals were continuously agitated during pyrolysis with a paddle rotating at 1 rpm. Additionally, the pyrolysis chamber was swept with 1L/minute of preheated argon until the sample was removed. Following the 30 minute soak at HHT, the

reactor was rapidly cooled via heat exchanger, external to the pyrolysis chamber.

3. The sample was removed once the reactor had cooled to ambient.
4. There was a 61% yield for paper residuals without lime and 66% yield for paper residuals with lime on a dry weight basis.
5. Subsamples of the charred material were sent to CNAL for analysis. Results are shown below. No conclusions have been drawn.

Comparison of CNAL analysis for charred paper residuals with (PR Char) and without (PRNL Char) lime to paper residuals with (PR) and without (PRNL) lime as produced.

	Dry Matter Basis									
Sample ID	pH	Salts	OM (%)	Total N (%)	NH_4-N (mg/kg)	NO_3-N (mg/kg)	P_2O_5 (%)	K_2O (%)	Total C (%)	C:N Ratio
PR Char	10.1	0.9	18.16	0.49	1.33	1.80	0.56	0.5	29.37	59.6
PRNL Char	9.9	0.6	25.71	0.63	1.17	1.06	0.51	0.6	59.22	93.7
PR	12.2	0.2	93.49	2.59	87.86	5.61	0.46	0.4	80.67	31.2
PRNL	7.9	0.6	128.9	1.7	99.35	93.25	0.67	3.0	112.4	66.1

	Dry Matter Basis					
Sample ID	Na (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Al (mg/kg)	Mn (mg/kg)
PR Char	853	6063	41	123	6377	245
PRNL Char	1110	8566	82	131	9560	456
PR	948	3924	112	101	3459	253
PRNL	387	2294	103	45	2586	377

No further studies were conducted with this material

<u>Task 6</u>: Summarize contact, interactions with, and thoughts from:

A. New York State Department of Environmental Conservation: A draft beneficial use determination (BUD) has been started (Appendix I) which has been completed and submitted by Finch Paper, LLC to NYSDEC. In order to conduct the field trials in Washington County, NYSDEC requested a BUD be filed to test paper residual as a soil conditioner. This was renewed for the 2nd year of the field trial. The BUD petition can be found in Appendix F along with the letter of approval from NYSDEC. Use of Finch PR in the manufacture of animal bedding through Syracuse Fiber was approved under Syracuse Fiber's current BUD.

B. Private waste management companies: Van Alstine's has worked with 180 yards of fiber in different recipes. A research and development petition has been submitted to NYSDEC by Homestead Organics (Ken Van Alstine's compost facility) to be able to accept PR on a regular basis. Agricycle, a compost facility in MA is working with the material. Syracuse Fiber is receiving Finch's PR for use in the manufacture of animal bedding.

Task 7: Recommendations to Finch Paper, LLC

A. Apply for the BUD for use as a composting feedstock - **done**
B. Contract with Syracuse Fiber to take the residual for their product - **done**
C. Contact farms that may be interested in using PR as a soil conditioner for fields that do not receive manure regularly. **Farmer Organic residual meeting planned for March 2014**

C. Technical Contacts

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Appendix A: Literature Review

Beneficial Use of Paper Mill Residuals: A Literature Review

The process of papermaking starts with pulping, which takes the cellulose out of wood. Pulping is done either mechanically, which produces short, stiff fibers that still contain most of the wood's lignin, or chemically, which uses chemicals, heat and pressure to dissolve the lignin in the wood, freeing the cellulose fibers. The pulp is then either used "as is" to manufacture products such as newsprint, boxes and packaging, or is bleached to produce white paper products. Large amounts of water are added to the pulp and the resulting pulp slush is pumped onto a screen. As it travels down the screen, water is removed by gravity, resulting in a crude paper sheet on the screen. Additional water may be squeezed, pressed or vacuumed out to create a sheet of uniform thickness. This semi-dry web is then heat dried and pressed to remove the remaining water.

The characteristics of the wastewater generated from the papermaking process will depend on the type of process, the type of wood and the amount of water used, but in general it contains fiber, ammonia compounds and other chemicals. This wastewater is generally cleaned in a 2-step process which produces primary and secondary paper mill residuals (PMR). Primary residuals are the initial settling out of solids in the wastewater and consist of wood fibers, papermaking fillers and other solids that can be reused in the papermaking process. The rest of the wastewater, with the primary residuals removed, then goes through a biological treatment where through the activity of microorganisms, organic pollutants and biological oxygen demand (BOD) of the material are reduced. These secondary residuals have a larger ratio of nutrients, especially nitrogen and phosphorus, to carbon than do primary residuals which precludes their use back in the papermaking process.

Millions of tons of both primary and secondary PMR are annually discarded in the U.S. Many of these are disposed of in landfills or incinerated at substantial cost to our industries and the public. Beneficial reuse/recycling of these residuals can substitute agricultural, environmental and household uses for disposal costs and reduce the potential negative effects on the environment resulting from the release of methane gas into the atmosphere. Recycling of PMR requires practical scientific knowledge to determine if and how they can be beneficially reused safely and economically. This paper reviews the scientific literature on the use of PMR

- As a soil amendment/conditioner, "as is", composted, or charred,
- In crop production, "as is", composted, or charred,
- For disease suppression in vegetable production, "as is" or composted,
- As a manufactured topsoil
- As a mulch for turfgrass establishment,
- As a forest application,
- As an agricultural carrier or in seeding and erosion control, and

- For other uses such as building materials, fuel, kitty litter and animal feed.

The primary value of PMR to soils is the organic matter (OM). Organic matter improves soil structure, soil biology and moisture retention and helps to prevent nutrients from leaching. High OM content and low trace metal and organic pollutants in PMR suggest that these residuals may provide a valuable resource for soil amendments. Beneficial use through land application is based on their ability to favorably alter soil properties such as plant nutrient availability, soil reaction, or properties related to enhanced soil organic matter status such as cation exchange capacity, water holding capacity (WHC), tilth (physical condition of soil related to tillage, seedbed, and rooting media), and soil strength (Camberto et al., 1997). Several researchers have studied the effect of PMR application/incorporation to soils. Soil organic carbon (C) content was increased, which in turn, improved bulk density (decreased from an average of 1.21 for the control to 1.12 and 1.01 Mg/m when 45 Mg/ha and 90 Mg/ha PMR, respectively were applied) and WHC (Fahmy et al., 2008) as well as aggregate stability (Chantigny et al., 1999), which in turn increased the proportion of macropores in the soil (Chow et al., 2003). The improved aggregate stability effect reported by Chantigny et al., 1999 was still significant three years after application and was obtained because the dried paper acted as a central core with the soil coating around it. Soils under intensive potato production are often low in organic matter content and microbial activity. PMR, both raw and composted, applied at rates of 45 and 90 Mg/ha dry weight greatly increased soil OM, C:N ratio, macroaggregation, C mineralization, microbial biomass and enzyme activities. The beneficial effects on soil physical and biochemical properties were still present after 3 years of continuous cropping (Gagnon et al., 2001). In contrast to the prolonged effects reported by Chantigny and Gagnon, Curnoe, et al., 2006 found that soil OM content increased each year during application of PMR used as a soil conditioner however little evidence for long-term accumulation of OM was noted. Foley and Cooperband, 2002 also reported improved soil organic C, bulk density, macroaggregates, structural stability, saturated hydraulic conductivity, and plant-available water when residues from the pulp and paper industries were used as soil amendments.

Application rates of primary, secondary or combined residuals must be based on the physical and chemical composition of the residuals, as well as on soil type and crop needs. Primary PMR is limited in use for land application because of its high carbon to nitrogen (C:N) ratio because soil microorganisms will induce a temporary immobilization of mineral nitrogen (N). This problem can be negated by (1) adding N fertilizer, (2) adding an additional OM source high in N, such as poultry manure, (3) incorporation of it into the soil prior to planting – probably several months, (4) Apply to soil surface and allow to degrade some before incorporation – this also acts as a mulch (Cabral et al., 1998). Another way to decrease the C:N ratio is to compost it prior to use. Composted PMR amendment application successfully enhanced soil fertility, and nutrient accumulation in coarse-textured soils without any adverse effect (Fahmy et al., 2010) and PMR compost plus additional N fertilizer applied in the spring prior to planting decreased soil bulk density and increased total porosity as compared to mineral NPK alone (Sippola et al., 2003). Foley and Cooperband, 2002 reported improved soil physical properties and microbial growth and activity in a loamy sand amended with composted PMR residuals and indicated that composted paper residuals may be more efficient for restoring soil fertility than non-composted raw materials due to their relatively more stable C content. In addition, raw and composted PMR application in this same trial reduced the amount of irrigation water required for potato production by 4–30% and irrigation events by 10–90%. Charring may also produce the same effect as composting. Biochar, from slow pyrolysis of PMR, applied at 10 t/ha in a ferrosol, significantly increased pH, cation exchange capacity, exchangeable calcium and total C. In a calcarosol, application increased total C (Van Zwieten et al., 2010). This study also showed that earthworms showed preference for PMR biochar-amended ferrosol over control soils, but there was no significant difference recorded for the calcarosol.

Another benefit to the application of PMR and composted PMR is the ability to decrease nitrate leaching. The use of autumn/winter applied PMR reduced nitrate leaching over the winter period in one field and over winter and the following summer at another field. Incorporation of 40 t dry matter (DM) PMR/ha in fields previously cropped to iceberg lettuce and Italian broccoli resulted in a decrease in nitrate leaching from 177 kg N/ha in the control plots to 94 kg N/ha (Vinten et al., 1998). Curnoe et al., 2006 found that leaf total N measurements in corn plants indicated that more N was available for uptake during the growing season where PMR soil conditioner or fertilizer was added compared with the control. Low nitrate-N (NO_3-N) concentrations in the deeper soil layers posed no risk to water resources and no PMR-related changes were noted in the concentrations of P, K, Mg, or soil pH. However, Gagnon et al., 2003 reported that with application of 34 Mg PMR/ha on native lowbush blueberry, soil acidification occurred, with accumulation of P and Mn in the surface layer and increased potential risk of NO_3-N leaching to groundwater. Cabral et al., 1998, also indicates that groundwater contamination by soil nitrate leaching is a potential problem of land application of PMR. In addition, soil contamination could occur due to the existence of heavy metals and organochlorine compounds. Other researchers also indicate that high levels of aluminum (Camberto et al., 1997, O'Brien, 2001), iron and magnesium could be of concern in field application depending on what will be done with the land as these elements could be soluble in the soil and may become toxic to certain plants (Chow et al., 2003). Charring may be a solution in acidic soils where aluminum toxicity limits plant growth since a major benefit of PMR biochar comes from its liming value (VanZwieten et al., 2010).

Crop yield has increased with land application of low C:N ratio PMR and decreased with application of high C:N ratio PMR. Plant N deficiencies in high C:N ratio PMR result from N immobilization, which occurs when the N concentration of the PMR is insufficient to meet the demands of the soil microbial community. Nitrogen from the PMR and soil is then immobilized into microbial tissues, rendering it unavailable for plant uptake. Using a low C:N ratio residual, applying high C:N ratio residual well in advance of crop planting, adding additional N to satisfy microbial demand, planting legumes so that soil N is not required or composting can overcome this limitation (Camberto et al., 1997). Simard, 2001 reported an increase in cabbage and corn marketable yields and N uptake when PMR was applied to Bedford silty clay prior to planting and a residual effect on corn yield in the third year in a 3 year rotation. Greater tuber yield in a 3-year rain-fed continuous potato culture was reported by Fahmy et al., 2000 using composted and raw PMR, and Simard et al., 2000 reported the best marketable potato tuber yields were produced when compost made from PMR, liquid pig manure and solid beef manure were incorporated at 40 Mg/ha, independently of fertilizer supplement, but 120 Mg/ha was excessive and did not produce greater yields. Corn yields increased by 98 and 172% with the application of 15 and 25 Mg/ha DM of a PMR with a C:N ratio of 21, respectively (Curnoe et al., 2006). Red clover and barley biomass production were significantly increased by PMR application (Fahmy et al., 2008) and cereal crop yields were 1.6 and 3 times higher using composted PMR and mineral fertilizer, respectively as compared to unfertilized treatment over 3 years, but there was no difference between the yields obtained with composted PMR and mineral fertilizer amendments (Sippola et al., 2003). However, fresh berry yield was decreased when PMR was applied at 34 Mg/ha on native lowbush blueberry stands, while 8.5 – 17 Mg/ha improved yield (Gagnon et al., 2003).

In a study conducted by Van Zwieten, et al., 2010, when wheat was grown in biochar amended ferrosol with fertilizer, N uptake increased and biomass production was 250 times that of the control indicating improved fertilizer efficiency. In addition, biomass of radish and soybean was increased in the same soil. However, in the calcarosol, although soybean mass increased, both wheat and radish biomass was reduced. Also, in the absence of fertilizer, there was no effect of biochar on wheat and soybean, but radish biomass increased significantly. The authors say that the results of this work demonstrate that the agronomic benefits of papermill biochars have to be verified for different soil types and crops. Some negative impacts were observed in the calcarosol, especially in the presence of fertilizer, suggesting careful evaluation of biochar type and soil properties before field scale biochar application.

In addition to enhanced soil fertility and greater yields, Vallad et al., 2000 showed that the use of raw and/or composted PMR was responsible for disease suppression in a three year sandy soil vegetable rotation. *Pythium* leak incidence in stored potato tubers grown in first-year amended soils was reduced in the low rate of PMR composted with bark, the high rate of PMR composted alone and the high rate of raw PMR. All second year treatments reduced cucumber damping-off and aerial *Pythium* of snap bean. In In disease assays, using soils collected in 1999, both *Arabidopsis* and tomato plants exhibited reduced disease symptoms caused by *Pst* when grown in soils amended with composted forms of PMR compared with results in non-amended soils (control) or soil amended with a raw PMR. The authors hypothesize that this induced systemic resistance is the result of biological degradation of polycyclic aromatic hydrocarbons (PAHs) or other complex molecules by microorganisms in the soil that produce chemical intermediates, such as salicylic acid, capable of eliciting an induced resistance response in plants. It is further hypothesized by the authors that composting of the PMR is necessary for the induced disease suppression as composting will protect the PAHs from volatilization or rapid biodegradation by the soil microorganisms (Vallad et al., 2003). Unfortunately, no other research was found on disease suppression using paper mill residuals.

Paper mill residuals were used to manufacture topsoil for use in a disturbed land reclamation project. A blend of short paper fiber, biosolids and sand was applied at an 8" depth to 5 acres of farm fields that had been stripped of topsoil due to flooding in NH. It was fertilized and seeded and resulted in high yields of hay (Connelly and Carpenter, 2011). In addition, the physical properties of the wood fiber, along with the high OM content and WHC of the manufactured soil yielded exception erosion resistance on slopes as steep as 2:1. O'Brien, 2001 investigated PMR as a topsoil component for the production of wildflower sods on plastic. PMR was mixed with sand, cranberry presscake, rockdust or compost. Establishment and growth of wildflowers were suppressed in mixtures of PMR and sand. The best sods with respect to stand establishment and biomass production were with mixtures of PMR, sand, and compost or with the mixture of PMR, sand, compost, and cranberry presscake. Additions of compost generally improved the capacity of media to support sod production. As PMR may have a wide C:N ratio, N may be immobilized making it unavailable for plant growth. Rather than using a chemical fertilizer, mixing PMR with other by-products high in available N could be used to ameliorate N immobilization.

Another possible use for PMR is as a mulch during turfgrass establishment. According to Karcher and Baser, 2001, mulches are used during establishment to reduce evaporative water loss from the soil, buffer temperatures near the seedbed, and prevent the washing of seeds during precipitation and irrigation. PMR have similar physical properties to other commercially available turfgrass mulches, but since they are composed partly of clay, there could be a negative impact on water infiltration into the underlying soil. This study was conducted in a greenhouse in plastic tubs using a sandy loam soil and Tall Fescue. Immediately following seeding, tubs were mulched with either PMR, straw, hydromulch (a commercial turfgrass mulch) or nothing. The results showed that all mulches were equally effective with regard to initial germination date, but the straw mulch had quicker establishment in terms of seedling height. By 12 days after seeding, all mulch treatments had significantly greater height than the control. Straw mulch initially had significantly greater turf cover than the other treatments, but by 37 days, the paper sludge and hydromulch treatments were not different from the straw. The control had significantly lower cover than all mulch after 23 days. All three mulch treatments were effective in preventing the erosion of seed. There was no difference in infiltration rates between any of the treatments. This experiment showed that PMR performed equally to the commercial turfgrass mulch treatment and can be used effectively during turfgrass establishment.

Forest application is another use since recycling of residual organic matter and nutrients back to the forest are important in intensively managed plantations where relatively large amounts of woody biomass are removed over increasingly short rotation intervals. However, this use of PMR has had mixed results. Feldkirchner et al., 2003 report no beneficial effects on forest growth when PMR used at a 2:1 ratio of primary to secondary residuals produced from a hardwood kraft process was applied to hardwood forests. Growth responses of cottonwood, Douglas fir, Noble fir and white pine seedlings grown in nursery beds were positive with residual C:N ratios up to 20:1, fair with C:N ratios between 30:1 and 40:1, and small or negative with C:N ratios greater than 100 (Vance, 2000). The positive effects of surface-applied residuals were attributed to moisture retention. However, when applied at establishment there is the problem of an increase in herbaceous or woody competition, which can increase mortality and reduce growth of tree seedling.

Granulated, PMR may be used as dust-free agricultural and home and garden pesticide carrier or when dry, it may be used as a seed carrier because with lack of water seeds remain in a dormant state. When wetted, its hydrophilic capacity makes the seed germinate and its presence may be useful in soil as an amendment (Wiegand and Unwin, 1994). A greenhouse study to determine how PMR compost compared to a commercial potting medium to support plant growth was conducted by Evanylo et al., unknow date). They measured plant seed germination and growth response to various combinations of PMR compost and Promix (potting medium) to assess the quality of the compost using 4 plant species (radish, snapbean, marigold, and hot green pepper). Pepper was the only one that had higher fruit yields in the compost mix than in the commercial potting mix. The compost mixes did not hold water as efficiently as the commercial mix and pepper may be able to use water more efficiently. In addition, the compost mixes had higher N than the commercial mix, and it was hypothesized that the compost mixes provided the additional nutrients required by pepper's longer duration of growth. In erosion control experiments PMR with 40% organic carbon incorporated at rates of 0.5, 1, 2 and 4% OM in the plow layer of a gravelly loam improved time of runoff initiation, rates of runoff and soil loss. The beneficial effects of the 4% OM treatment include 2.1 times delay in runoff initiation, and 23 and 71% reduction in runoff and soil loss, respectively (Chow et al., 2003).

Finally, other uses of PMR include building materials, fuel, kitty litter and animal bedding and as animal feed. Mixed with Portland cement, PMR fibers can add durability and the product can be used for blocks, wallboards, panels, shingles, fire retardants and filler materials for fireproof doors (Naik et al., 2004, Thomas et al., 1987, Wiegand and Unwin, 1994). Girones et al., 2010 ran experiments that showed that substitution of traditional mineral fillers by PMR in plastic processing is a feasible alternative for composites used in low mechanical demand applications such as decking or fencing. Some paper mills have dried and pelletized their PMR for fuel (Hill, et al., 2002, Wiegand and Unwin, 1994), while another has created a proprietary process that sanitizes and deodorizes prior to pelletization to be used as kitty litter or animal bedding (Wiegand and Unwin, 1994). Lastly, because cell protein is present in secondary residuals derived from fermentation, it is possible to dry these proteins and incorporate them into feed mixtures for animals (Wiegand and Unwin, 1994). Using lignin degrading enzymes for delignification is considered to have potential application in the conversion of PMR into food, animal feed and fiber products (Kannan et al., 1990). Evans, 1983 created a proprietary process that creates a product that is 83% DM, 1% moisture and 16% oil that is shredded into a powder and sold as a protein supplement for animal feed. When used in a total mixed ration at rates of 3and 7% DM, it is an acceptable substitute for conventional protein supplements (Claypool et al., 1984).

As this review has shown, there are many beneficial uses for PMR that are more environmentally sound than landfill disposal. However, which one is used will depend on the PMR produced by each paper mill and scientifically based trials should be conducted to help understand which one is best suited to the characteristics of the individual residuals. Then economic analysis needs to be conducted to see if the chosen use is not only safe to humans, animals and the environment, but will also make sense financially.

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Appendix B: Suitability of paper residuals as an animal bedding material in relation to NYSDEC's BUD for Syracuse Fiber Recycling, LLC, Syracuse, NY.

Background:
Syracuse Fiber Recycling, LLC holds a permit from NYS Department of Environmental Conservation (DEC ID 7-3115-00043) as a solid waste management facility, that allows them to receive, store, manufacture, and ship animal bedding materials generated from beneficial reuses of paper mill sludge, wood chips and cement kiln dust. The bedding components have DEC Beneficial Use Determination (BUD No. 319-7-34), which allows use of the material as animal bedding.

The solid waste management permit describes what materials they may accept, as well as how much animal bedding they may manufacture using those ingredients and describes minimum and maximum mixing ratios. They DO NOT make animal bedding from the paper residuals alone. The facility can manufacture (by mixing) 3000 tons/week of animal bedding. The material mixtures are as follows:

Maximum and Minimum Mixing Ratios

Material	Maximum	Minimum
Paper Sludge (their word, not mine)	9 by volume	7.5 by volume
Wood	4 by volume	4 by volume
Cement Kiln Dust	2 by volume	1 by volume
Medium Density Fiberboard	10% of finished product by weight	

They are currently allowed to accept paper mill sludge from Solvay Paperboard facility in Solvay, NY, the Marcal Paper Mills, Inc., facility, the Pratt Industries facility in Staten Island, NY, and the Rand-Whitney Containerboard facility in Montville, CT that meet the requirements described in the BUD for contaminants (table below).

Metals in the sludge, cement kiln dust, and animal bedding (mixture) shall not exceed the following levels and shall be expressed in parts per million on a dry weight basis.

Parameter	As	Ba	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
Limit	41	1000	10	100	1500	250	10	54	200	28	2500

The facility is allowed to store up to a total of 4000 tons of each material and animal bedding at any time, inside or in an enclosed container and control for leachate and dust. All incoming material and manufactured animal bedding must be analyzed by a NYS Department of Health

ELAP certified laboratory in accordance with the above limits. End uses of the bedding shall be in accordance with the conditions of BUD No. 319-7-34 issued to Syracuse Fiber Recycling, LLC. Other requirements (beside the contaminant levels above) of the BUD are listed below:

a) Medium density fiberboard: maximum formaldehyde concentration of 10,000 ppm in maximum amount of medium density fiberboard in bedding product is 10%
b) Final Product: Dioxins and Furans – per Memorandum of Understanding (MOU) between Mill and the USEAP regarding the Land Application of Pulp and paper mill materials dated 3/14/94: < 10 ppt TEQ (toxic equivalent quantity)
c) Final product: Moisture content – 30% average (+/- 3%)
d) Special testing – may be required if the material possesses pollutants other than those found in #1, 2 & 3 above.
e) The final bedding material cannot contain any free liquid or produce dust of offensive odors.
f) All analyses must be performed by a NYS DOH ELAP-certified laboratory.

Recommendations:
Contact Syracuse Fiber to see if they would be interested in adding Finch Paper, LLC as one of the sources of its paper mill residuals. Based on analysis by Cornell Nutrient Analysis Laboratory (CNAL) and Agricultural Analytical Services at Penn State (ALS), as well as analysis sent to us by Finch, the contaminant levels in the paper residuals are well below the limits set above.

Metal levels

Parameter		As	Ba	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
Limit		41	1000	10	100	1500	250	10	54	200	28	2500
CNAL	2/16/11 w/lime	3	158	1	19	32	14		2	7		106
	6/1/11 w/lime					112						101
	11/15/11 no lime					103						45
ALS	6/1/11 w/lime	15		2		78	43	.02	2	7	<2	102
	11/15/11 no lime	4		1		40	19	.02	3	6	<2	86
Finch	8 samples 2002 - 2010	2		1	8	31	13		2	7	1	77

In order to use the paper residuals "as is" for an animal bedding product under this BUD, the residuals would have to be dried considerably, as they are currently ranging between 60 and 70% moisture. This BUD is requiring a moisture content of 30% in the final product. Since the product doesn't meet that requirement, it may be possible to get a "Trial BUD" based on the comparisons below of other bedding materials used.
In our experience, moisture levels of up to 75% can be used successfully as animal bedding. Below is a table giving average moisture levels of dried manure solids or DMS (prepared different ways), sand and sawdust used as animal bedding. These come from research CWMI did on manure solids as bedding. Manure solids are produced by separating the liquid from the solid portion of the manure. They produce a light fluffy, absorbent bedding material that

provides a dry, comfortable surface for dairy cows.

Moisture content of dairy cattle bedding

Type	Composted DMS	Green DMS	Windrow DMS	Digested DMS	Sand	Sawdust
Number of Farms	3	3	1	1	1	1
Number of samples	85	105	22	19	33	24
Moisture Range	58-75%	51-78%	64-78%	63-76%	7-18%	14-30%
Average Moisture	66%	70%	73%	69%	12%	21%

Triplicate samples of paper residuals from Finch Paper, LLC with and without lime were sent to Quality Milk Promotion Services at Cornell University to test for mastitis pathogens (the test generally done to see if a bedding is suitable in terms of pathogen load). The residuals with lime cultured only environmental streps and gram-positive bacillus, while residuals without added lime cultured the same, plus corynebacterium species. There were NO total coliforms, *E. coli* or Klebsiella species, which are the most important mastitis pathogens. A comparison of commonly used bedding materials (including DMS) is shown below.

Bacterial analysis of dairy cattle bedding and Finch paper residuals (log_{10} colony forming units/gram wet basis)

Type	Composted DMS	Green DMS	Digested DMS	Sand	Sawdust	Paper w/lime	Paper no lime
Number of Farms	4	3	1	1	1		
Number of samples	247	240	60	81	48	3	3
Environmental Strep	7.9	7.6	7.7	7.5	8.1	4.4	7.6
Gram positive bacillus	8.1	7.6	7.4	7.4	7.8	4.0	7.0
Corynebacterium species	7.5	7.3	7.1	7.2	6.8	0	7.3
Total coliforms	6.5	6.2	5.8	5.6	6.6	0	0
E. coli	6.1	5.8	5.5	5.5	6.6	0	0
Klebsiella species	6.2	6.0	5.3	4.9	3.6	0	0

Samples of the Syracuse Fiber bedding were taken at the Cornell University Teaching and Research Center where they are using it to bed dairy heifers. Two samples were tested for dry matter internally in the drying ovens at the Teaching and Research Center using standard procedures:

The basic principle is moisture is evaporated from the sample by oven drying. Total dry matter is determined gravimetrically as residue remaining after drying.

1. Tray weights were taken on a scale with precision to 0.1 g.
2. Wet bedding was placed in the pans and weighed.
3. Pans were placed in a 105^{o}C drying oven for 48 hours
4. After 48 hours, pans were weighed and dry matter was determined using the following equation: [dry weight/wet weight] x 100. Moisture is determined by subtracting the dry matter from 100.

Sample	Wet Weight	Dry Weight	Dry Matter	Moisture
Tray 1	411.1	251.8	61.3%	38.7%
Tray 2	314.3	191.7	61.0%	39.0%

Appendix C: Results of Compost Parameter Testing of Paper Mill Residuals at Homestead Organics

Parameters of Interest:

- **Moisture Content** – The starting moisture content of a mixture should be in the range of 40 – 65%, while finished compost should be between 40 and 50%. The moisture content of compost affects its bulk density, and therefore, may affect transportation. Moisture content is also relevant because it affects product handling. Compost which is dry can be dusty, while compost which is wet can be heavy and clumpy, making it difficult to apply as well as more expensive to transport.
- **pH** – Most finished composts have a pH between 6 and 8. The ideal pH of a compost depends on the crop being grown. During the compost process, however, compost microorganisms operate best under neutral to acidic conditions, with pH's in the range of 5.5 to 8, so monitoring of pH can give one information on how the process is proceeding.
- **Soluble salts** – Finished compost should be in the range of 1 – 4 mmhos/cm. Soluble salts include all soluble ions including available nutrients (beneficial to plants) and sodium and chloride (harmful to plants in excess). Excess salts (> 4) can be toxic to plants, while low salts (< 1) indicate low nutrient status.
- **Bulk Density** – The starting bulk density of a compost mixture should be around 900-1000 lbs/yd^3 (0.53 – 0.59 kg/l) to provide enough air space to keep the pile aerobic. Finished compost should have a bulk density of around 800 lbs/yd^3 (0.47 kg/l).
- **Organic Matter** – Most growers use compost to increase the organic matter in their soil. Composts average between 30 and 70% organic matter. Organic matters > 50% indicate an immature compost, while OM < 35% indicates that the compost is old.
- **N – P – K –** Nitrogen, phosphorus and potassium are the major nutrients of interest since those are the ones that are supplied by inorganic fertilizers. A normal range for these nutrients in finished compost would be between 1 and 3.4%. Total nitrogen includes both organic and inorganic forms; in mature composts, most nitrogen should be organic. Excess phosphorus can be an environmental contaminant.
- **C:N ratio** – The starting C:N ratio of a compost mixture should be between 20:1 and 40:1 while finished compost should have a C:N ratio of around 15:1.
- **Metals** – EPA Part 503 Ceiling Concentration limits are the same as Maximum Concentration below.

DEC Part 360-5.10: Table 7 Pollutant Limits – Products:
http://www.dec.ny.gov/regs/4411.html#14688

Parameter	Monthly Average Concentration (mg/kg, dry weight)	Maximum Concentration (mg/kg, dry weight)
Arsenic (As)	41	75
Cadmium (Cd)*	10	85
Chromium (Cr—total)	1000	1000
Copper (Cu)	1500	4300
Lead (Pb)	300	840
Mercury (Hg)	10	57
Molybdenum (Mo)	40	75
Nickel (Ni)	200	420
Selenium (Se)	100	100
Zinc (Zn)	2500	7500

* If the monthly average cadmium concentration exceeds 5 ppm, dry weight basis, the cadmium/zinc ratio must not exceed 0.015.

The following show results of testing for each of the mixtures made with PR on a dry weight basis:

Pile 1: Paper residuals (PR) plus spent silage: Composition—equal parts limed PR and silage. The recipe was approximately 15 yd^3 of each. Pile build June 1. Ken deemed the compost finished based on temperature on August 1 (day 61).

Parameter	Day 1	Day 26	Day 44	Day 61	Day 91
Moisture (%)	61.1	49.8	43.8	43.8	43.8
pH	12.2	8.6	8.6	8.3	8.7
Soluble salts (mmhos/cm)	0.25	0.04	0.03	0.05	0.07
Density (kg/l)	0.70	0.96	0.72	0.88	1.03
OM (%)	101.5	46.8	44.3	42.3	20.1
Total N (%)	2.01	3.32	2.71	2.65	1.5
Organic N (%)	1.99	2.11	2.64	2.57	0.84
P_2O_5 (%)	0.53	0.74	0.82	0.67	0.39
K_2O (%)	0.74	1.03	1.07	0.85	0.31
C:N Ratio	28.8	16.4	15.8	16.0	16.0
Cu (mg/kg)	39	70	100	69	27
Zn (mg/kg)	56	104	133	97	88

Pile 2: PR plus cow manure and horse manure: Composition—1 part horse manure to 2 parts cow manure to 2.5 parts PR. The recipe was approximately 10 yd3 horse manure, 20 yd3 cow manure and 25 yd3 PR. Pile built June 1. Ken deemed the compost finished based on temperature on Aug 1 (day 61).

Parameter	Day 1	Day 26	Day 44	Day 61	Day 91
Moisture (%)	60.6	54.1	43.3	43.3	43.3
pH	11.8	8.6	8.9	8.4	8.8
Soluble salts (mmhos/cm)	0.14	0.07	0.03	0.05	0.1
Density (kg/l)	0.78	1.23	0.93	0.98	1.0
OM (%)	76.9	59.7	34.4	35.8	22.7
Total N (%)	2.31	2.75	2.03	1.83	1.04
Organic N (%)	2.27	0.51	2.01	1.78	1.43
P_2O_5 (%)	0.46	0.64	0.76	0.63	0.37
K_2O (%)	0.85	1.05	1.03	0.85	0.34
C:N Ratio	24.2	16.5	17.8	17.7	17.7
Cu (mg/kg)	32	54	74	46	36
Zn (mg/kg)	77	94	132	99	84

Pile 5: PR plus cow manure, horse manure, silage and produce/food processing waste: Composition: 1 part of each. The recipe was approximately 10 yd3 of each. Pile built June 13. On June 27, approximately 87 gallons of H2H was incorporated into approximately 20' of the 5' wide x 4' high windrow. Ken deemed the compost finished based on temperature on Aug 1 (day 49).

Parameter	Day 1	Day 14	Day 32	Day 49	Day 65
Moisture (%)	No sample	51.8	46.4	45.5	45.5
pH		7.5	9.0	8.4	8.5
Soluble salts (mmhos/cm)		0.08	0.03	0.06	0.12
Density (kg/l)		0.59	0.89	0.82	0.82
OM (%)		50.7	41.3	34.0	19.3
Total N (%)		1.91	2.09	1.74	0.95
Organic N (%)		-0.07	2.04	1.67	0.86
P_2O_5 (%)		0.51	0.82	0.68	0.29
K_2O (%)		0.38	1.07	0.86	0.2
C:N Ratio		23.0	14.2	16.4	16.4
Cu (mg/kg)		66	73	52	37
Zn (mg/kg)		82	127	111	77

Analysis of paper mill residual composts based on ranges for finished composts listed above:

1. Moisture: All three fall into the 40-50% range.
2. pH: All three are a little bit higher than the 6-8 range.
3. Soluble salts: All three are low salt content.
4. Bulk Density: All three have a little bit higher bulk density than desired, so should be for soil mixes or incorporation.
5. Organic matter falls into the 30-50% range for all three indicating good organic matter
6. N-P-K falls into the 1 – 3.4% range for all three.
7. C:N ratio is around 16:1 for all three which is good.
8. There are no problems with metals.

Note: Day 91 for Piles 1 and 2 and Day 65 for Pile 5 were taken after the flooding on August 28 at Ken's facility with what was left of the piles. Flooding appeared to add salts, increase density and decrease nutrient value, but otherwise it was the same.

Appendix D: Grass Seeding with Paper Mill Residuals

Grass Seeding with Paper Mill Residuals

3 lb. bag Pennington Seed, Professional Contractor Penkoted grass seed mixture containing:

44% Justice tall fescue with an 85% germination rate
33% Gulf annual ryegrass with an 85% germination rate
19% Artic Green perennial ryegrass with an 85% germination rate
2.5% Inert matter
1.4% Other crop seed
0.1% weed seed

Planting rate:

- New Lawns: 10 lbs./1,000 sq. ft.
- Overseeding 5 lbs./1,000 sq. ft.

Increase planting rate to 30 lbs./1,000 sq. ft.

Planting Instructions:

- Remove all debris from planting area.
- Till or rake to loosen to 2" to 3" of soil.
- Rake smooth to create a flat, level planting area.
- Using a drop-type, rotary or hand held spreader, apply the seed evenly to avoid skips, overlapping and streaking.
- Gently rake, working seed into soil about ¼"
- Water seed area daily to keep soil moist.
- Do not allow the top ½" of the soil to become dry until seedlings have completely emerged.
- Once grass becomes established, reduce watering to ½" twice a week.

Paper residuals have a dry matter content of 39% at delivery, after 25 days they were at 41% dm.

We will want to seed three 3' x 3' plots for comparison:

- Plot 1: grass seed only. 10 lbs./1,000 sq. ft. = 0.01 lbs./sq. ft. Therefore, for 9 sq. ft., we will need 9 * 0.01 = 0.09 lbs. grass seed. Apply 0.1 lbs. grass seed to prepared 3' x 3' plot
- Plot 2: 25% grass seed and 75% paper residuals on a dry weight basis. If we are using 0.1 lbs. grass seed, then we will need (0.1 * 75)/25 = 0.3 lbs. paper residuals dry weight. At a dry matter content of 39%, 0.3 lbs. dry weight would be 0.8 lbs. wet weight (0.3/.39). Mix 0.1 lbs. grass seed thoroughly with 0.8 lbs. paper residuals and apply to prepared 3' x 3' plot
- Plot 3: 33% grass seed and 67% paper residuals on a dry weight basis. If we are using 0.1 lbs. grass seed, then we will need (0.1 * 67)/33 = 0.2 lbs. paper residuals dry weight. At a dry matter content of 39%, 0.2 lbs. dry weight would be 0.5 lbs. wet weight (0.2/.39). Mix 0.1 lbs. grass seed thoroughly with 0.5 lbs. paper residuals and apply to prepared 3'

x 3' plot.

Amended plot procedure

We will want to seed three 3' x 3' plots for comparison:

Plot 1: grass seed only. 30 lbs./1,000 sq. ft. = 0.03 lbs./sq. ft. Therefore, for 9 sq. ft., we will

- need 9 * 0.03 = 0.27 lbs. grass seed. Apply 0.3 lbs. (4.8 oz.) grass seed to prepared 3' x 3' plot
- Plot 2: 1 part grass seed to 3 parts paper residuals on a dry weight basis. If we are using 0.3 lbs. grass seed, then we will need (0.3 * 3) = 0.9 lbs. paper residuals dry weight. At a dry matter content of 39%, 0.9 lbs. dry weight would be 2.3 lbs. wet weight (0.9/0.39). Mix 0.3 lbs. grass seed thoroughly with 2.3 lbs. paper residuals and apply to prepared 3' x 3' plot
- Plot 3: 1 part grass seed to 2 part paper residuals on a dry weight basis. If we are using 0.3 lbs. grass seed, then we will need (0.3 * 2) = 0.6 lbs. paper residuals dry weight. At a dry matter content of 39%, 0.6 lbs. dry weight would be 1.5 lbs. wet weight (0.6/0.39). Mix 0.3 lbs. grass seed thoroughly with 1.5 lbs. paper residuals and apply to prepared 3' x 3' plot.

We will do all three plots, twice at two locations: Richford, NY (1 set of plots on slope, 1 set of plotson flat), Lacona, NY (2 sets of plots- one slope, 1 flat).

May 6: Flat plots 1 (left), 2 (middle) and 3 (right) in Richford at seeding.

May 28: Flat plots 1 (left), 2 (middle) and 3 (right) in Richford 22 days later

June 14: Flat plots 1 (left), 2 (middle) and 3 (right) in Richford on day 39

The plots on the slope are growing about the same and growth does not appear to be much different between the plots.

Appendix E: Leachate Trial

Introduction

Leaching tests are often used to evaluate the potential of a material to release contaminants to the environment. Leachate from paper mill residuals used as a compost feedstock, or directly as a soil conditioner may contain toxic metals that can contaminate groundwater. Therefore column leaching tests were conducted on agricultural soil amended with Finch paper mill residuals (PMR) to evaluate the impact on groundwater when using these residuals for agricultural uses. The objective of this trial was to evaluate the effects of PMR additions (with and without added lime) to soil on nutrient leaching at increasing application rates. As a guideline for assessing what level of each metal would be considered a risk on groundwater quality, US EPA's maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for drinking water are used (EPA 2011). MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. MCLs are the highest level of a contaminant that is allowed in drinking water and are enforceable standards. In instances where there is no MCLG or MCL other standards are listed. Table 1 below shows these values for the regulated metals analyzed in this project. There were no regulations found for calcium (Ca), cobalt (Co), magnesium (Mg), phosphorus (P), potassium (K) or sulfur (S).

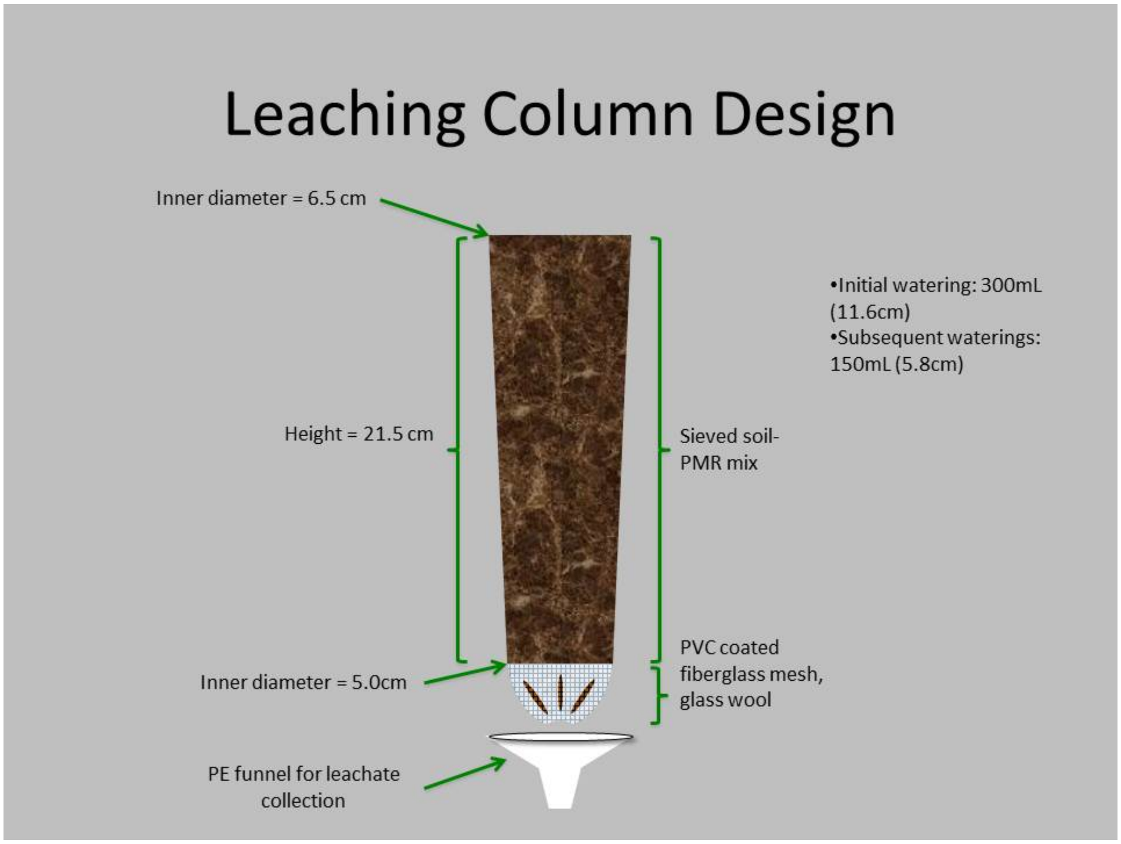
Table 1: United States Environmental Protection Agency Drinking Water Standards selected chemicals and metals (adapted from EPA 2011)

Chemical/Metal	MCLG (mg/l)[1]	MCL (mg/l)	LHA[2] (mg/l)	DWATT[3] (mg/l)	SDWR[4] (mg/l)
Aluminum (Al)					0.05 – 0.2
Arsenic (As)	0	0.01			
Boron (B)			6		
Cadmium (Cd)	0.005	0.005			
Chromium (Cr)	0.1	0.1			
Copper (Cu)	1.3	1.3			
Iron (Fe)					0.3
Lead (Pb)	0	0.015			
Manganese (Mn)			0.3		
Molybdenum (Mo)	0.002	0.002			
Nickel (Ni)			0.1		
Sodium (Na)				30 - 60	
Zinc			2		

[1] mg/l = milligrams per liter = parts per million
[2] Lifetime Health Advisory (LHA) is an estimate of the concentration of a chemical in drinking water that is not expected to cause any adverse non-carcinogenic effects for a lifetime of exposure
[3] Drinking Water Advisory Taste Threshold (DWATT) gives a concentration at which the majority of consumers do not notice an adverse taste in drinking water. For Na, levels of 20 mg/l can be a health threat for individuals on a 500 mg/day restricted sodium diet.
[4] Secondary Drinking Water Regulations (SDWR) are non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

Materials and Methods

Soil (pH =5.02, organic matter = 3.6%) was sampled from agricultural fields at the Cornell University Teaching and Research Center in Dryden, NY. Sixty-eight leaching columns (21.5-cm long, 5.0 – 6.5-cm inner diameter, bottom to top, respectively) were set up by placing sterilized glass wool at the bottom of each column. Sterilized sand was poured into the bottom and pressed with a plunger. Columns were shaken gently to ensure uniform packing. The soil was air-dried, ground to pass a 2-mm sieve, and poured into columns in 5 cm increments pressing gently with the plunger and gently shaking the column to ensure uniform packing to a height of 21.5 cm. Soil in the columns was pre-wet by slowly lowering each column into a large graduated cylinder nearly filled with 0.01 M $CaCl_2$. Paper mill residual, with and without added lime, from Finch Paper Company, LLC, Glens Falls, NY was mixed uniformly within the top 5 cm of soil in the column at application rates of 0, 2, 5, 10 and 20 tons PMR per acre equivalent in a randomized complete block design with 4 replicates. The columns were covered with glass beads to evenly distribute leaching fluid when induced. Leaching was induced the first time by slowly adding 300 ml of an artificial acid rain. Leachate was collected after 24 hours and frozen. This same procedure was repeated once a week for 7 more weeks but with 150 ml of the acid rain formula, rather than 300. Leachates were analyzed by Cornell Nutrient Analysis Laboratory, Ithaca, NY for P, Na, Mg, Al, K, Ca, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Cd, Pb, S and B using inductively coupled plasma spectroscopy (ICP).



Results and Discussion:

The total amounts of Na, K, B, Al, Mn, Ni, Zn, As and Pb that leached in a total of eight pore volumes (150 ml each) of leachate are shown in Table 2 below. Linear regression of the amount of each element leached by the rate of application was not significant for any of the elements listed in Table 1, regardless of whether or not lime had or had not been added to the paper mill residual. As there is no difference between the amount of each of these elements that would normally leach from un-amended soil (rate = 0) than leached from soil mixed with PMR even up to a rate of 20 tons/acre, the addition of PMR (with or without lime) would not significantly affect groundwater concentrations of these elements. In addition, other than manganese for PMR with no added lime applied at the rates of 5 and 10 tons/acre, none of the quantities of metals leached meets or exceeds the standards for drinking water described in table 1 above.

Table 2: Total quantities of elements leached in a total of eight pore volumes of leachate from PMR mixed with soil at different application rates.

			Rate of PMR addition (Tons/acre equivalent)				
Element	Standard	Lime	0	2	5	10	20
Na (mg)	30-60 mg	No	8.9	9.8	9.2	8.9	8.7
		Yes	8.9	10.5	10.2	9.7	9.5
K (mg)	N/A	No	10.3	24.9	6.6	6.1	17.5
		Yes	10.3	5.3	4.7	14.4	5.4
B (mg)	6 mg	No	1.3	1.4	1.5	1.5	1.2
		Yes	1.3	1.7	1.6	1.5	1.3
Al (µg)	50-200 µg	No	15.6	33.8	44.6	47.4	17.6
		Yes	15.6	16.7	17.0	14.2	22.1
Mn (µg)	300 µg	No	68.1	181.3	300.8	428.7	134.0
		Yes	68.1	31.1	85.0	67.5	27.4
Ni (µg)	100 µg	No	0.3	1.3	0.4	1.0	2.4
		Yes	0.3	0.0	0.8	3.0	2.7
Zn (µg)	2000 µg	No	4.4	12.3	17.6	14.1	3.9
		Yes	4.4	2.6	2.8	4.3	5.4
As (µg)	10 µg	No	4.4	2.5	3.5	3.4	3.8
		Yes	4.4	5.8	5.1	4.5	2.4
Cd (µg)	5 µg	No	0.1	0.0	0.0	0.0	0.0
		Yes	0.1	0.0	0.0	0.0	0.0
Pb (µg)	15 µg	No	0.5	0.3	0.0	0.0	0.0
		Yes	0.5	0.0	0.8	0.4	0.5

Total quantities of Mn (µg) leached by date for PMR/soil mixtures without (WOL) and with (WL) added lime at each rate are shown in table 2. The bulk of manganese, regardless of rate of application or presence of lime, was leached during the first watering.

Table 3: Total quantities of Mn leached from PMR/soil mixtures by date

Rate	**0**		**2**		**5**		**10**		**20**	
Date	WOL	WL	WOL	WL	WOL	WL	WOL	WL	WOL	WL
2/14/12	63.3	63.3	180.1	31.1	296.8	85.0	420.8	67.2	128.9	26.4
2/21/12	2.0	2.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
2/28/12	0.2	0.2	0.0	0.0	2.5	0.0	7.6	0.1	3.8	0.4
3/7/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.5
3/14/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
3/15/12	0.0	0.0	0.8	0.0	1.5	0.0	0.0	0.0	0.0	0.0
3/28/12	2.2	2.2	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0
4/4/12	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0

Table 4 shows the total amounts of Ca, Mg, Co and Cu that leached in a total of eight pore volumes of leachate. For all four of these elements the total amount leached was significantly affected by the rate of PMR application, but only for PMR with lime added for Ca, Co and Cu and only for PRM with no added lime for Mg. There are no published drinking water standards for Ca, Mg and Co, but both Ca and Mg are common mineral substances in groundwater. Water that contains a lot of Ca and Mg is considered to be hard. The United State Geological Service (USGS 2012) reports that water is considered soft if it contains 0 to 60 mg/l, moderately hard from 61 to 120 mg/l, hard between 121 and 180 mg/l and very hard if more than 180 mg/l. In this case, the amount leached increased 1.5 mg for each ton/acre PMR added to the soil. However, the highest value of 40.5 mg Ca would still be considered soft water and would have no effect on the quality of the groundwater into which it leached. In addition, the amount of Mg leaching with increasing additions of PMR to the soil decreased at a rate of 0.06 mg/ton per acre equivalent PMR added. According to the British Columbia Ministry of Water, Land and Air Protection (2004), the mean ambient cobalt concentration in groundwater in British Columbia is 21.1 µg/l. The highest amount leached from the PMR/soil mixtures was 2.4 µg. The MCL for Cu, from table 1 above is 1.3 mg/l, while the highest amount leached from the PMR/soil mixtures was 0.0355 mg.

Table 4: Total quantities of elements leached in a total of eight pore volumes of leachate from PMR mixed with soil at different application rates and regression analysis of application rate.

Element	Ca (mg)		Mg (mg)		Co (µg)		Cu (µg)	
Standard	N/A		N/A		N/A		1300 µg	
Rate	WOL	WL	WOL	WL	WOL	WL	WOL	WL
0	33.2	33.2	7.1	7.1	0.3	0.3	12.1	12.1
2	34.6	37.1	7.4	6.5	0.5	0.2	15.2	15.4
5	35.5	39.8	7.0	5.9	0.9	0.7	18.5	19.2
10	33.6	40.5	6.4	5.4	1.1	1.2	17.2	31.1
20	36.2	35.0	6.3	6.5	0.8	2.4	21.0	35.5
Regression Analysis								
Intercept	33.9	32.0	7.2	6.4	57.6	0.15	14.1	13.7
Slope	0.1	1.5	-0.06	-0.02	0.0	0.1	0.4	1.2
r^2	0.40	0.91	0.80	0.09	0.33	0.98	0.74	0.91
p-value	0.25	0.01*	0.04*	0.62	0.31	0.002*	0.06	0.01*

* p-values < 0.05 are significant

The total quantity of elements leached in a total of eight pore volumes of leachate from PMR mixed with soil at different application rates for the rest of the elements analyzed (P, Cr, Fe, Mo and S) were significantly affected by rate of application, but not by addition of lime. For those that have drinking water standards (Cr, Fe and Mo), even at the highest level of elements leached, none of them meet or exceed that level.

Table 5: Total quantities of elements leached in a total of eight pore volumes of leachate from PMR mixed with soil at different application rates and regression analysis of application rate.

Element	P (µg)		Cr (µg)		Fe (µg)		Mo (µg)		S (mg)	
Standard	N/A		100 µg		300 µg		2 µg		N/A	
Rate	WOL	WL	WOL	WL	WOL	WL	WOL	WL	WOL	WL
0	47.9	47.9	0.0	0.0	4.7	4.7	0.0	0.0	2.1	2.1
2	64.6	34.1	0.0	0.0	6.4	4.2	0.0	0.1	3.3	5.3
5	101.5	70.1	0.1	0.1	11.3	13.2	0.0	0.2	6.0	11.4
10	144.0	108.0	0.0	0.3	27.5	27.3	0.1	0.9	9.8	18.3
20	176.3	157.7	0.1	0.3	36.0	46.8	0.8	2.1	24.2	30.5
Regression Analysis										
Intercept	59.0	38.3	0.0	0.0	4.8	2.7	-0.1	-0.2	0.9	3.1
Slope	6.5	6.1	0.01	0.02	1.7	2.2	0.04	0.11	1.1	1.4
r^2	0.93	0.95	0.88	0.84	0.94	0.99	0.86	0.98	0.98	0.99
p-value	0.01*	0.00*	0.02*	0.03*	0.01*	0.00*	0.02*	0.00*	0.00*	0.00*

* p-values < 0.05 are significant

Conclusion

Addition of PMR with added lime as a soil conditioner does not appear to contribute to groundwater pollution through leaching. The same is true for PMR without added lime in all cases except when applied at the rate of 5 and 10 tons/acre where excess manganese could be leached into groundwater.

References Cited

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United States Geological Survey (USGS), 1999. Quality of Ground Water, In: Ground Water, U.S. Geological Survey General Interest Publication. Available on the USGS website: http://pubs.usgs.gov/gip/gw/index.html, accessed 7/18/12.

Appendix F: Petition to DEC for Field Trial as Soil Amendment

To: New York State Department of Environmental Conservation Solid Waste Division
Re: Petition for Beneficial Used Determination (BUD) for Finch paper-manufacturing secondary residuals to be used as a soil amendment
From: Finch Paper, LLC

1. In accordance with Subdivision 360-1.15(d), Finch Paper, LLC is petitioning for a beneficial use determination for their secondary paper mill residuals as a soil conditioner for soil growing field corn:
   - **(i) Description of Finch paper mill residuals and proposed use:** Finch Paper, LLC uses an ammonium bisulfite pulping process to produce pulp from wood chips. The resulting paper residuals are treated with lime to stabilize them. Previous work with paper mill residuals has shown them to be valuable as a soil amendment due to the high organic matter content. Organic matter improves soil structure, soil biology and moisture retention and helps to prevent nutrients from leaching. High OM content and low trace metal and organic pollutants in PMR suggest that these residuals may provide a valuable resource for soil amendments. Specifically, Curnoe et al., 2006 found that leaf total N measurements in corn plants indicated that more N was available for uptake during the growing season where paper mill residual soil conditioner or fertilizer was added compared with the control. Low nitrate-N (NO_3-N) concentrations in the deeper soil layers posed no risk to water resources and no PMR-related changes were noted in the concentrations of P, K, Mg, or soil pH. In a different study, corn yields increased by 98 and 172% with the application of 15 and 25 Mg/ha DM of a paper mill residual with a C:N ratio of 21, respectively (Curnoe et al., 2006).
   - **(ii) Chemical and physical characteristics of Finch paper mill residuals with and without additions of lime:** Analysis of the paper residuals conducted by Cornell Nutrient Analysis Laboratory in Ithaca, NY for compost parameters and at Agricultural Analytical Services Laboratory, Pennsylvania State University, State College, PA indicate that its properties (Table 1) are similar to those used in the above referenced study. In addition, early data on leachate from laboratory columns of Finch paper residuals over soil indicate that there are no potential pollutant issues when applied at between 5 and 20 tons/acre.
   - **(iii) Demonstration that there is a known or reasonably probable market of Finch paper residuals:** At this point, we do not know if there is a market for this or not, but if it can replace chemical fertilizer without adversely effecting corn yields (or especially if it increases them), then it would be a welcome addition for any farmer in NY.
   - **(iv) Demonstration that the management of Finch paper mill residuals will not adversely affect human health and safety, the environment, and natural resources:** At this point, we request to be able to test the effectiveness of these paper mill residuals as a soil conditioner on fields in Washington County that are not currently receiving any manure. The objective will be to determine if paper mill waste when spread during the spring of

corn planting will supply nitrogen or compete for it with the field corn. The basic protocol will be as follows:

A. Establish two treatments in field-length strip trials, four replicates, one treatment with the recommended amount of fertilizer and a second treatment with the recommended amount of fertilizer plus 30 tons/acre of sludge, as-is-moisture (~70%).
B. Soil sample before planting and fertilizer/amendment applications; soil sample in mid-July; soil sample after harvest. Run a standard nutrient analysis, Illinois soil nitrogen test (ISNT) (pre-plant and post-harvest), and nitrates. This will establish the amount and form of nitrogen in the soil.
C. Analyze stalk samples just before harvest for nitrates, corn stalk nitrate test (CSNT). This test determines if the corn crop had inadequate, adequate, or excess nitrogen.
D. Weigh yields from each plot and sample forage to determine dry matter content.
E. Monitor and photograph plants every two weeks through the season to note any nutrient deficiencies and general growth and conditions (including weed pressure).

Table 1: Characteristics of Finch paper mill residuals (PR) in comparison to other paper residuals successfully used on fields to grow corn.

Chemical Properties	Paper residuals used on corn[1]	Paper residuals used on corn[2]	PR with lime	PR no lime (PRNL)
Soldis (%)	28 - 32		39.5	330
pH	7.9 – 8	7.3 -7.8	12.2	7.6
Organic Matter (g/kg DM)		735 – 854	935	1214
C (g/kg DM)	347 - 496	381 – 462	807	1163
C:N ratio	28 - 42	16.1 – 26.7	31	43
Total N (g/kg DM)	11.8 – 12.4	17.3 – 33.6	25.9	27
Total P (g/kg DM)	2.2 – 2.4		4.6	4.6
Potassium (g/kg DM)	1.8 – 4.6	0.8 – 1.4	4.0	3.6
Calcium (g/kg DM)	2.1 – 2.6	13.6 – 34.7	70	6.3
Magnesium (g/kg DM)	0.6 – 2.2	0.5 – 1.9	3.3	4.4
Sodium (g/kg DM)		0.9 – 1.2	0.6	0.1
EPA 503 Pollutants	Standards (ppm dry wt. basis)			
Arsenic	41 -75		14.8	4.3
Cadmium	39 -85		1.8	1.3
Copper	1500 -4300		77.6	40.1
Lead	300 - 840		42.5	18.7
Mercury	17 - 57		0.02	0.02
Molybdenum	75		2.4	2.9
Nickel	420		7.1	6.0
Selenium	100		<1.8	<1.6
Zinc	2800 - 7500		102.0	85.9
PCBs	1 – 10[3]		<0.04	<0.08

[1]Simard, 2001, [2]Curnoe et al., 2006, [3]PCB standard is from NYS Part 360: 1 for Class 1 and 10 for Class 2

References:

Curnoe, W.E., Irving, D.C., Dow, C.B., Velema, G., and Unc, A., 2006. Effect of spring application of a paper mill soil conditioner on corn yield. Agronomy Journal 98(3):423-429.

Simard, R.R., 2001. Combined primary/secondary papermill sludge as a nitrogen source in a cabbage-sweet corn cropping sequence. Canadian Journal of Soil Science 81:1-10.

Approval Letter for Soil Amendment Trial

New York State Department of Environmental Conservation
Division of Materials Management
Bureau of Waste Reduction & Recycling, 9th Floor
625 Broadway, Albany, New York 12233-7253
Phone: (518) 402-8706 • Fax: (518) 402-9024
Website: www.dec.ny.gov

Joe Martens
Commissioner

May 18, 2012

Jean Bonhontal
Cornell Waste Management Institute
Cornell University
111 Rice Hall
Ithaca, New York 14853

Dear Ms. Bonhotal:

Re: BUD No. 1033-5-58
Field Trail – Use of Finch Paper Residuals fro Growing Corn

The New York State Department of Environmental Conservation (Department) has reviewed your May 1, 2012 petition for a beneficial use determination (BUD) for an agricultural filed trial on a farm in Washington County involving the use of Finch Paper residuals for the growth of field corn. The Department has determined that the use of this material as described in your petition is a beneficial use pursuant to 6 NYCRR 360-1.15(d). The BUD is subject to the following conditions:

1. All activities must conducted under guidance from staff of the Cornell Waste Management Institute and in accordance with the protocol outlined in the May 1, 2012 petition.

2. A summary report must be provided to the Department within 6 months of completion of the field trial. The report must include a summary of the information outlined in the petition and an evaluation and assessment of results. This report, and any other correspondence related to this BUD must be sent to:

   Sally Rowland, PhD, PE
   Bureau of Waste Reduction & Recycling
   Division of Materials Management
   NYSDEC
   625 Broadway, 9th Floor
   Albany, NY 12233-7253

   Kevin Wood, PE
   NYSDEC Region 5
   232 Golf Course Road
   Warrensburg, NY 12885

3. This BUD will expire one year from the date of this letter. A renewal may be granted upon written request and justification.

4. This BUD does not exempt you from other local, state or federal requirements applicable to your project. Furthermore, the Department, in accordance with 6 NYCRR 360-1.15(d)(4), reserves the right to rescind or modify this BUD at any time if it finds that any matter serving as the basis for this BUD is incorrect or no longer valid, or if the Department finds there has been a violation of the conditions of this BUD.

Please contact me if you have any questions in regard to this determination.

Sincerely,

Sally Rowland

Sally Rowland, Ph.D., P.E.

Appendix G: Washington County Field Trial – Paper Residual Field Trial on Soil Growing Field Corn

Aaron Gabriel, Capital Area Agriculture and Horticulture Program
Jean Bonhotal and Mary Schwarz, Cornell Waste Management Institute

Objective Year One

To determine if paper mill residual when spread during the spring of corn planting will supply nitrogen or compete for it with the field corn.

Rationale

A previous (1990) field study using high organic matter/low nitrogen paper mill residual showed that nitrogen deficiency was a limiting factor in plots with the paper mill residual. Finch paper mill residual is relatively high in nitrogen. So, the important question to answer is whether or not the level of nitrogen in Finch paper mill residual is sufficiently high, and its decomposition rapid enough to prevent a nitrogen deficiency in a growing corn crop. The paper mill residual used from Finch was not treated with lime, so that biological decomposition would not be inhibited.

Basic Protocol

1. Field Location – 43.29087 latitude: -73.552222 longitude, about 1 ¼ acre.
2. Establish two treatments in field-length strip trials, four replicates, one treatment with the recommended amount of fertilizer and a second treatment with the recommended amount of fertilizer plus 30 tons/acre of sludge, as-is-moisture (~70%).
3. Soil sample before planting and fertilizer/amendment applications; soil sample in mid-July; soil sample after harvest. Run a standard nutrient analysis, Illinois soil nitrogen test (ISNT), and nitrate analysis. This will establish the amount and form of nitrogen in the soil.
4. Analyze stalk samples just before harvest for nitrates, corn stalk nitrate test (CSNT). This test determines if the corn crop had inadequate, adequate, or excess nitrogen.
5. Measure yields from each plot on a dry matter basis, and measure harvest area.
6. Monitor and photograph plants every two weeks through the season to note any nutrient deficiencies and general growth and conditions (including weed pressure).

Procedure

1. Plots were mapped out on May 9, 2012. Eight 30' x 225' plots were flagged out (12 rows wide, center 6 rows harvested for yield measurements). Soils were sampled at two depths in each plot, 8" and 12", to provide two soil samples per plot; 15 soil cores per sample. The 8" samples were sent to the Cornell Nutrient Analysis Lab (CNAL) for a standard fertility test (package 1030) and to the Nutrient Management Spear Program lab (NMSP) for the Illinois Soil Nitrogen Test (ISNT). The 12" samples were analyzed for

ppm nitrates at CNAL.

2. On June 11, 2012, 30 yards of paper mill residual was delivered by Finch Paper, LLC. The residual was spread on the designated plots using a truck-mounted side-slinger spreader. The truck was driven over the control plots as if being spread to equalize the amount of soil compaction in all the plots. All the plots were tilled with a chisel (which incorporated the paper mill residual) and the seedbed was prepared with a roller harrow by Ideal Dairy. Weeds had grown up, so they were cut down around the flags. Even so, on the second pass with the truck spreading the residual, we did cross into an un-intended plot. Adjustments were made so that we have 4 plots with 30 tons/acre of residual as planned, two plots with 0.5 tons/acre and two plots with no paper residual as shown below.

North

Silty loam

Plot 1: 30 tons/acre paper	Plot 5: 30 tons/acre paper
Plot 2: 0.5 tons/acre paper	Plot 6: 0.5 tons/acre paper
Plot 3: 30 tons/acre paper	Plot 7: 0 tons/acre paper
Plot 4: 0 tons/acre paper	Plot 8: 30 tons/acre paper

Sandy loam

Because of rain delays, weeds grew tall before spreading the residuals. Weeds around flags were cut to expose flags.

Treated plots had 30 tons/acre of residuals applied with a truck-mounted side-slinger manure spreader. Application rate was checked by the volume going in the spreader and what was left over after each plot. Plus we set out pans to sample the amount being spread. 30 tons/acre covers the ground with ¼" to ½" of material.

Residuals were incorporated with a chisel the day they were spread. Later a roller harrow went over the field to prepare a smooth seedbed.

3. June 12, 2012 - a western bean cutworm trap was set up in the field. Weekly trap monitoring facilitated looking at the plots each week when the insect trap was checked.
4. June 24, 2012 – plots were planted with Pioneer, P9630AM1 seed. 12 rows were planted per plot at a depth of 1 ½ to 2 ½ inches. At planting, 3 gallons of pop-up fertilizer was applied on the seed and 27 lbs. of nitrogen was applied as starter fertilizer in a band 2" to the side of the seed. Previously (November 2011), 10,000 gallons of liquid manure was spread and incorporated with an Aerway tillage tool.

Plots were one planter width wide, which is 12 rows or 30 ft. Planted June 24, 2012.

5. June 28, 2012 - germination, but no emergence.
6. July 6, 2012 – corn at 2 to 3 leaf stage. Plant population counts taken. No visual differences between plots relating to plant health or size. Turkey damage around field perimeter, but not in plots.

Seedling corn on July 7, 13 days after planting.

7. July 26, 2012 – Soil sampled plots 1 through 8. Eight-inch deep and 12-inch deep samples; about 12 soil cores per plot. Soil dried, crushed and mixed the same day. Eight-inch deep samples analyzed by CNAL with their standard analysis (package 1030) and by NMSP for ISNT. The 12-inch deep samples were analyzed for nitrates by CNAL. Some large weeds not killed by tillage are sparse and found in all the plots.

Corn on July 30 when mid-season soil samples were taken. Notice that the corn across the plots is quite uniform.

8. August 20, 2012 – corn is pollinating. All the lower leaves are green on all the plants.
9. September 7, 2012 – northern corn leaf blight mostly on the upper half of plants. From 4 to 14 lesions per plant. Bird damage in one large area, 20 to 40 foot diameter. Kernels in the milk stage.
10. September 20, 2012 – northern corn leaf blight throughout the plots. 5% of foliage infected. Kernels at end of milk stage. Bird damage (kernels at tip of ears eaten) throughout the plots.
11. Sept 20, 2012 - nitrogen/drought stress observed by counting the number of leaves which are yellow or dead, starting at the base of the plant:
    a. Plot 1 (paper) – all bottom leaves are green
    b. Plot 2 (no paper) – lower leaves from 1 to 5 are yellow
    c. Plot 3 (paper) – lower leaves 1 to 2 yellow or dead
    d. Plot 4 (no paper) – east end has lower leaves 1 or 2 dead; west end leaves yellow up to #6
    e. Plot 5 (paper) – lower 1 to 2 leaves dead
    f. Plot 6 (no paper) – middle of plot only with 1 to 5 leaves yellow or dead
    g. Plot 7 (no paper) – lower 1 to 2 leaves dead
    h. Plot 8 (paper) – lower 3 to 4 leaves dead or yellow

On September 20, observations were made of the leaves below the ear, to determine if there was nitrogen deficiency or drought stress. Corn was in the milk stage. A couple areas within the field had some drought stress, and there was no noticeable nitrogen stress.

12. October 8, 2012 – stalk samples taken for the Corn Stalk Nitrate Test. Kernels denting, but milk line has not yet developed. Beginning and end of plots marked with plastic flagging.
13. October 17, 2012 – plots harvested (middle 6 rows) with a John Deere self-propelled chopper with yield and moisture monitor.

Corn before harvest. Harvest rows (6 center rows) are marked by bending over the stalk just above the ear. Yield was measured in an area 6 rows wide and about 200 feet long. It was harvested with a self-propelled chopper that had a yield monitor and moisture meter.

14. October 18, 2012 – plot length measured with a measuring wheel and post-harvest soil samples taken at eight and 12-inch depths. Soil samples analyzed as before.

Results Year One

Plant data

		July 6	Yield		Stalk Nitrate	
Plot	**Treatment**	**Plants/acre**	**Tons/Acre**	**Harvest DM**	**ppm**	**level**
1	30 t paper	26,282	25.0	41.7	11,000	Excess
2	No paper	28,678	25.3	43.0	2,789	Excess
3	30 t paper	29,694	27.9	42.1	8,830	Excess
4	No paper	28,097	24.9	44.6	938	Optimum
5	30 t paper	25,629	24.0	39.8	10,757	Excess
6	No paper	28,097	25.0	41.0	6,570	Excess
7	No paper	27,531	24.8	40.7	8,040	Excess
8	30 t paper	25,919	26.4	44.2	11,800	Excess

1. Plant population on July 6: There was no significant difference in plant population between plots with 30 tons of paper residual per acre incorporated (average 26,881 plants/acre) compared with plots that had no paper added (average 28,261 plants/acre).
2. Yield: There was no significant difference in yield between plots with 30 tons of paper residual per acre incorporated (average 25.8 tons/acre) compared with plots that had no paper added (average 25.0 tons/acre).
3. Harvest Dry Matter: There was no significant difference in harvest dry matter between plots with 30 tons of paper residual per acre incorporated (average 41.96%) compared with plots that had no paper added (average 42.30%).
4. Stalk Nitrate: Stalk nitrate levels in plots that were treated with 30 tons/acre paper residual were significantly higher (10,597 ppm; p=0.0142) than those that had no paper added (4,584 ppm). However, only one plot had an optimum level of stalk nitrate. This indicates that plots with paper had more available nitrogen for the plant. Corn will take up excess nitrogen if available.

Soil data

Plot	Treatment	Critical ISNT (ppm) 5/9/12	Critical ISNT (ppm) 7/26/12	Critical ISNT (ppm) 10/11/12
1	30 t PR	246	253	260
2	No PR	239	231	245
3	30 t PR	256	255	266
4	No PR	232	227	231
5	30 t PR	277	279	288
6	No PR	242	241	245
7	No PR	267	263	264

8	30 t PR	224	227	229

Parameter	Treatment	5/9/12	7/26/12	10/18/12
NO_3-N (mg/kg)	30 t PR	7.28	29.81	16.63
	No PR	7.16	18.14	5.61
Organic Matter (%)	30 t PR	2.29	2.49	1.79
	No PR	2.13	2.08	1.58
pH	30 t PR	6.74	6.66	6.48
	No PR	6.73	6.65	6.53

1. Critical ISNT: There was no significant difference in critical ISNT by treatment or by date. ISNT measures the amino-sugars in the soil, to indicate the amount of organic matter that might be mineralized in the short term (one to three years).
2. Nitrate: There was no significant difference in soil nitrate N on 5/9/12 prior to incorporation of paper residuals (PR). However, there was a significant difference between the amount of NO_3-N in the soil of plots that received 30 tons PR/acre versus those that received none on both July 26 ($p = 0.0390$) and on October 18 ($p = 0.0123$). This indicates that the paper was providing additional nitrates to the soil.
3. Organic Matter: There was no significant change in soil organic matter by treatment or date. Applying 30 tons/acre of paper at 33.5% organic matter, provides 20,100 lbs. of organic matter. This is equivalent to 1% organic matter in the soil. Not being able to detect this change in organic matter in the plots with PR shows how difficult it is to accurately sample for soil organic matter.
4. pH: There was no significant response for the pH of the soil by treatment or by date.

Discussion Year One

Plant Data: The addition of un-limed paper residuals to plots prior to planting corn in a sandy to silty loam soil had no effect on yield in the first year. Dry matter at harvest is an indication of corn maturity. This can be influenced by soil moisture, nitrogen and other parameters. The dryer it is the more mature it is. As there was no significant difference in maturity between the control plots and those treated with paper residuals, the paper residuals did not appear to affect corn maturity. The stalk nitrate test indicates if too little, an optimum, or an excess of nitrate was available to the corn plant during its growth. If excess nitrogen is taken up by corn, it can be measured in the lower stalk. On this field, that had received manure in the past, all plots, except one, showed excessive stalk nitrates at the end of the season. The addition of paper only added to the amount of excess nitrogen.

Soil Data: Based on the critical ISNT values, in the beginning of the season, the soil did not have enough nitrogen and additional nitrogen input was recommended. Critical ISNT did not change over time, nor was there a difference in ISNT levels between plots treated with PR and controls. However, stalk nitrate levels indicated that plants took up excess nitrates, and especially so in plots treated with paper residuals. This is also confirmed by the fact that on July 26 and on

October 18, soil nitrate levels were significantly higher in the PR treated plots than the controls allowing for greater N to be taken up by those plants. The PR is not tying up nitrogen, but releasing it. Although not significant, soil OM was consistently higher in the PR treated plots than in the control with an average of 2.2% versus 1.9%, respectively. Continuous addition of PR could possibly increase OM as well as other soil health properties that were not analyzed, such as water holding capacity, aggregate stability and cation exchange capacity. Soil pH was not affected by the addition of PR.

Conclusions Year One

Un-limed paper mill waste spread during the spring of corn planting does not compete with field corn for nitrogen, but rather releases it. Additional trials should be conducted to determine if applications of PR over a period of time can act as a source of slowly decomposing organic matter promoting aggregate stability and increasing porosity and water-holding capacity.

Next Steps

1. Now that we are confident that un-limed residuals release nitrogen, the next step is to do a rate study and determine how much nitrogen is being released and how much nitrogen fertilizer can be reduced. This will take a larger field and many more treatments and plots.
2. The field used in 2012 can be left untreated in 2013 and monitored for nitrogen mineralization in year two. The plots would be left "as is"; no manure or fertilizer should be applied. Corn should be planted in the spring and then soil and plants analyzed as in the 2012 study.
3. Soil health analysis should also be done to determine the effect of continuous application of PR on physical properties of the soil including aggregate stability, porosity and water-holding capacity. These properties can lead to better yields, as well as better production in times of drought.

Objective Year Two: Residual Effects of Paper Application in Year 1

To determine if paper residuals (PR) applied in 2012 will continue to supply nitrogen to a corn crop in the 2nd year without additional fertilization.

Rationale

Data from corn plots planted in 2012 with either zero or 30 tons/acre paper fiber residuals indicated that un-limed paper mill residuals spread during the spring of corn planting does not compete with field corn for nitrogen, but rather releases it. The 2013 trial was conducted to determine if the application of PR continues to supply nitrogen to corn.

Basic Protocol

1. Field Location – 43.29087 latitude: -73.552222 longitude, about 1 ¼ acre.
2. Monitor the **previously** established field-length strip trials, four replicates, one

treatment with the recommended amount of fertilizer and a second treatment with the recommended amount of fertilizer plus 30 tons/acre PR, as-is moisture (~70%), applied in 2012 (fertilizer only in 2013).

3. Soil sample before planting and fertilizer/amendment applications; soil sample in mid-July; soil sample after harvest. Run a standard nutrient analysis, Illinois soil nitrogen test (ISNT), and nitrate analysis. This will establish the amount and form of nitrogen in the soil.
4. Analyze stalk samples just before harvest for nitrates, corn stalk nitrate test (CSNT). This test determines if the corn crop had inadequate, adequate, or excess nitrogen.
5. Measure yields from each plot on a dry matter basis, and measure harvest area.
6. Monitor and photograph plants every two weeks through the season to note any nutrient deficiencies and general growth and conditions (including weed pressure).

Procedure

1. April, 2013 – Plots were previously mapped out in 2012. Eight thousand gallons of manure was mistakenly applied to plots 3, 4, 7 and 8.
2. May 6, 2013 - The same eight 30’ x 225’ plots were flagged out (12 rows wide, center 6 rows harvested for yield measurements). About 15 soil cores at 8” depth were taken per plot. Samples were sent to the Cornell Nutrient Analysis Lab (CNAL) for a standard fertility test (package 1030) and to the Nutrient Management Spear Program lab (NMSP) for the Illinois Soil Nitrogen Test (ISNT).
3. May 9, 2013 – plots were planted with Pioneer, P0216HR seed. 12 rows were planted per plot at a depth of 1 ½ to 2 ½ inches. At planting 3 gallons of pop-up fertilizer (9-18-0) was applied on the seed and 18 lbs. of nitrogen was applied as starter fertilizer in a band 2” to the side of the seed.
4. June 4, 2013 –Plant population counts taken. Plants were counted in 40 feet of row in the six center rows of each plot.
5. July 15, 2013 – Soil sampled plots 1 through 8. Ten soil cores at 8” depth were taken per plot. Soil dried, crushed and mixed the same day. Samples were sent to the Cornell Nutrient Analysis Lab (CNAL) for a standard fertility test (package 1030) and to the Nutrient Management Spear Program lab (NMSP) for the Illinois Soil Nitrogen Test (ISNT).
6. August 26, 2013 – Plant height was measured and number of yellow and green leaves below the ear was counted for a representative plant in each plot.
7. September 20, 2013 – stalk samples taken for the Corn Stalk Nitrate Test.
8. October 5, 2013 – plots harvested (middle 6 rows) with a John Deere self-propelled chopper with yield and moisture monitor.
9. October 10, 2013 – post-harvest soil samples taken at eight-inch depth. Soil samples analyzed as before.

Results Year Two: Residual Effects of Paper Application in Year 1

Plant data

	Treatment		Plants/acre		Tons/Acre		Harvest DM	
Plot	**2012**	**2013**	**7/6/12**	**6/4/13**	**2012**	**2013**	**2012**	**2013**
1	30 t PR		26,282	33,614	25.0	19.6	41.7	44.0
2	No PR		28,678	32,888	25.3	20.5	43.0	47.1
3	30 t PR	Manure	29,694	32,815	27.9	22.5	42.1	43.3
4	No PR	Manure	28,097	32,670	24.9	18.3	44.6	45.3
5	30 t PR		25,629	33,323	24.0	18.7	39.8	40.6
6	No PR		28,097	33,323	25.0	21.1	41.0	43.7
7	No PR	Manure	27,531	32,960	24.8	21.2	40.7	42.6
8	30 t PR	Manure	25,919	33,541	26.4	21.5	44.2	45.7

			Stalk Nitrate			
	Treatment		2012		2013	
Plot	**2012**	**2013**	**ppm**	**Level**	**ppm**	**Level**
1	30 t PR		11,000	Excess	307	Marginal
2	No PR		2,789	Excess	139	Low
3	30 t PR	Manure	8,830	Excess	632	Marginal
4	No PR	Manure	938	Optimum	70	Low
5	30 t PR		10,757	Excess	774	Optimum
6	No PR		6,570	Excess	338	Marginal
7	No PR	Manure	8,040	Excess	470	Marginal
8	30 t PR	manure	11,800	Excess	102	Low

1. Plant population on June 4, 2013:
   a. There was no significant difference in plant population between plots with 30 tons of paper residual per acre incorporated in 2012 (average 33,325 plants/acre) compared with plots that had no paper added at that time (average 32,962 plants/acre).
   b. There was no significant difference in plant population between plots that received manure (33,179) and those that did not (33,470).
   c. There was no significant difference between plots that had received 30 tons PR in 2012 and manure in 2013 (33,179), 30 tons PR in 2012 without manure in 2013 (32,816), no PR in 2012 and manure in 2013 (33,470) and no PR in 2012 without manure in 2013 (33,107).
2. Plant population comparison between 2012 and 2013: Comparison of the residual effect of addition of PR on plants per acre between the first and second year showed there were significantly more plants in the second year than in the first for both treatments. Because the treatments do not differ, this effect is more likely due to the growing

conditions and other environmental variables, rather than due to any possible residual effects from PR:

Year	Treatment	Average Plants/Acre
2012	No PR	28,261[a]
2012	30 t PR/acre	26,881[a]
2013	No PR 2012	32,962[b]
2013	30 t PR/acre 2012	33,325[b]

3. Yield 2013:
   a. There was no significant difference in yield between plots with 30 tons of paper residual per acre incorporated in 2012 (average 20.5 tons/acre) compared with plots that had no paper added at that time (average 20.3 tons/acre).
   b. There was no significant difference in yield between plots that received manure (22.0) and those that did not (19.2).
   c. There was no significant difference between plots that had received 30 tons PR in 2012 and manure in 2013 (22.0), 30 tons PR in 2012 without manure in 2013 (19.8), no PR in 2012 and manure in 2013 (19.2) and no PR in 2012 without manure in 2013 (20.8).
4. Yield between 2012 and 2013: Comparison of the residual effect of addition of PR on yield between the first and second year showed a significantly higher yield in year 1 as compared to year 2, but not because of treatment. Because the treatments do not differ, and because yield was higher in year 1, this effect is more likely due to the growing conditions:

Year	Treatment	Average Yield (Tons/Acre)
2012	No PR	25.0[a]
2012	30 t PR/acre	25.8[a]
2013	No PR 2012	20.6[b]
2013	30 t PR/acre 2012	20.3[b]

5. Harvest Dry Matter (DM) 2013:
   a. There was no significant difference in harvest DM between plots with 30 tons of paper residual per acre incorporated in 2012 (average 43.4%) compared with plots that had no paper added at that time (average 44.7%).
   b. There was no significant difference in harvest DM between plots that received manure (44.5) and those that did not (42.3).
   c. There was no significant difference between plots that had received 30 tons PR in 2012 and manure in 2013 (42.3), 30 tons PR in 2012 without manure in 2013 (44.0), no PR in 2012 and manure in 2013 (44.5) and no PR in 2012 without manure in 2013 (45.4).
6. Harvest DM between 2012 and 2013: Comparison of the residual effect of addition of PR on harvest DM between the first and second year, weighted by days to harvest (115 for year 1 and 149 for year 2) showed a significantly higher yield in year 1 as compared to year 2, but not because of treatment. Because the treatments do not differ, and

because yield was higher in year 1, this effect is more likely due to the growing conditions:

Year	Treatment	Average Harvest DM (%)
2012	No PR	42.3[a]
2012	30 t PR/acre	42.0[a]
2013	No PR 2012	44.7[a]
2013	30 t PR/acre 2012	43.4[a]

7. Stalk Nitrate (ppm) 2013:
    a. There was no significant difference in stalk nitrate between plots with 30 tons of paper residual per acre incorporated in 2012 (average 453.8 ppm) compared with plots that had no paper added at that time (average 254.3 ppm). Only 1 plot had optimum stalk nitrate (30 t PR/acre in 2012 and no manure in 2013), while all the rest were marginal or low.
    b. There was no significant difference in stalk nitrate between plots that received manure (389.5) and those that did not (318.5).
    c. There was no significant difference between plots that had received 30 tons PR in 2012 and manure in 2013 (367.0), 30 tons PR in 2012 without manure in 2013 (540.5), no PR in 2012 and manure in 2013 (270.0) and no PR in 2012 without manure in 2013 (238.5).
8. Stalk nitrate between 2012 and 2013: Comparison of the residual effect of addition of PR on stalk nitrate between the first and second year, showed a significant effect for treatment, year and treatment crossed with year. The biggest difference is in the year where 2012 stalk nitrate concentration averaged 10,597, while 2013 stalk nitrate concentration averaged only 454. In addition, when the year is crossed with the PR treatment, both first year stalk nitrate concentrations are significantly higher than 2nd year stalk nitrate concentrations but there does not appear to be a residual effect as 2nd year concentrations are not significantly different from each other.

Year	Treatment	Average Stalk Nitrate (ppm)
2012	No PR	4,584.3[a]
2012	30 t PR/acre	10,596.8[b]
2013	No PR 2012	254.3[c]
2013	30 t PR/acre 2012	453.8[c]

Results Year Two: Residual Effects of Paper Application in Year 1

Soil data

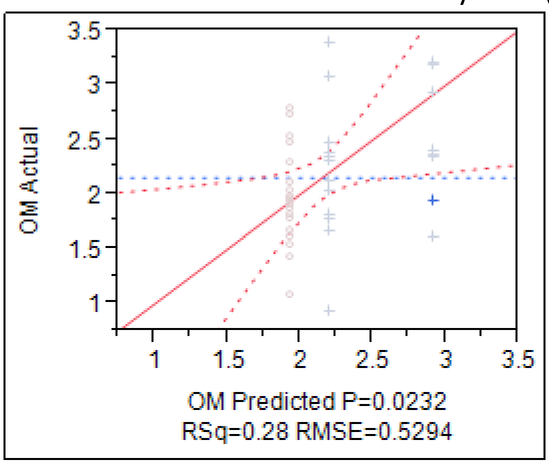
	Treatment		Critical ISNT (ppm)					
			2012			2013		
Plot	**2012**	**2013**	**5/9**	**7/26**	**10/11**	**5/15**	**7/15**	**10/10**
1	30 t PR		246	253	260	247	255	249
2	No PR		239	231	245	234	234	232
3	30 t PR	Manure	256	255	266	255	266	259
4	No PR	Manure	232	227	231	229	232	230
5	30 t PR		277	279	288	283	278	274
6	No PR		242	241	245	240	240	236
7	No PR	Manure	267	263	264	261	261	254
8	30 t PR	Manure	224	227	229	230	226	229

1. Critical ISNT: ISNT measures the amino-sugars in the soil, to indicate the amount of organic matter that might be mineralized in the short term (one to three years).
   a. Regression by treatment shows a significant difference (p=0.0421) between plots that had received 30 t PR/acre in 2012 (254.3 ppm) versus those that received none (240.2 ppm). The regression equation is: Critical ISNT = 240.2 + 0.4695 x ton PR/acre.
   b. Regression by treatment, manure and treatment crossed with manure yielded a significant difference with a p value of 0.0192 with a poor fit (r-square = 0.38). Plots that had 30 ton PR/acre in 2012 had significantly higher critical ISNT in 2013 (254.3 ppm both with and without manure) than those that did not have any paper incorporated (240.2 ppm both with and without manure), and plots that received 30 ton PR/acre in 2012 without the addition of manure in 2013 (see table below) had significantly higher critical ISNT in 2013 than all other plots. However, prior to PR application in 2012, there was already a pattern of high and low ISNT over the plots, so this difference is probably not due to PR incorporation.
   c. There was no significant difference in Critical ISNT by treatment or by date.
   d. There was no significant difference in critical ISNT between years when plots that received manure are included, but when those plots are not included, there is a significant difference (p=0.0146, r-square=0.28). In 2013, plots that received 30 t PR/acre in 2012 had significantly higher critical ISNT than those that did not receive any PR in 2012. However, as mentioned previously, this ISNT pattern existed before PR was ever applied to the plots.
2. Organic Matter: Applying 30 tons/acre of paper at 33.5% organic matter, provides 8,000 lbs of organic matter. This is equivalent to 0.4% organic matter in the soil. Detecting changes in organic matter is difficult.

Parameter	Treatment		2012			2013		
	2012	2013	5/9	7/26	10/11	5/15	7/15	10/10
Organic Matter (%)	30 t PR		2.29	2.49	1.79	2.76	3.07	--
	No PR		2.13	2.08	1.58	1.93	1.9.	--
	30 t PR	Manure				2.16	2.01	--
	No PR	Manure				2.07	2.04	--

a. There was no significant change in soil organic matter by treatment at each sampling date when plots that received manure are included. When they are not, soil OM in May was significantly higher (3.07%) for plots that had 30 t PR incorporated in 2012, versus those that did not (1.93%), p=0.0142, r-square=0.97).

b. There was no significant difference in soil OM between years when analyzed both with and without the plots that received manure in 2013. There was a significant difference though when analyzed without the plots that received manure. OM in 2013 on plots that had received PR in 2012 (2.91%) was significantly higher than all other plots (No PR in 2012 – 1.93%, 30 t PR/acre in 2012 – 2.19%, 2013 OM on No PR in 2012 – 1.93%). Higher OM in 2013 on plots that received PR may have been due to a residual effect. OM regression when plots that received manure are not included yielded the following equation: OM= 1.5+ 0.01 x treatment + 0.4 x year + (0.02 x (year-1.25) x (Treatment-15))



Treatment	Year	Average OM (%)
30 t PR/acre	2012	2.19[b]
30 t PR/acre (2012)	2013	2.91[a]
No PR/acre	2012	1.93[b]
No PR/acre (2012)	2013	1.93[b]

3. pH:

Parameter	Treatment		2012			2013		
	2012	2013	5/9	7/26	10/11	5/15	7/15	10/10
pH	30 t PR		6.74	6.66	6.48	6.54	6.57	6.30
	No PR		6.73	6.65	6.53	6.50	6.25	5.81
	30 t PR	Manure				6.48	6.47	6.57
	No PR	Manure				6.45	6.63	6.34

a. There was no significant response for the pH of the soil by treatment on any date in 2013.
b. There was no significant difference in soil pH between years when analyzed both with and without the plots that received manure in 2013.

Discussion: Year Two Residual Effects of Paper Application in Year 1

Plant Data: There were no clear trends to indicate that either paper fiber waste from 2012 or manure in spring 2013 affected yields on plots planted to field corn. Dry matter at harvest is an indication of corn maturity. This can be influenced by soil moisture, nitrogen and other parameters. The dryer it is the more mature it is. As there was no significant difference in maturity between the control plots and those treated with paper residuals, paper residuals applied the previous year did not appear to affect corn maturity. The stalk nitrate test indicates if too little, an optimum, or an excess of nitrate was available to the corn plant during its growth. If excess nitrogen is taken up by corn, it can be measured in the lower stalk. In 2013, stalk nitrate levels were significantly lower than in 2012 with only one plot in 2013 reaching optimum stalk nitrate concentration. There appeared to be no residual effect of the addition of paper residuals on any of the plant data in 2013.

Soil Data: Critical ISNT did not change over time in 2013, nor was there a difference in ISNT levels between plots treated with PR and controls in 2013. Differences in critical ISNT existed on the plots prior to application of PR in 2012 therefore any differences in 2013 cannot be attributed to PR or manure. OM in 2013 was significantly higher in plots that received 30 t PR/acre in 2012 than all other plots (either in 2012 or 2013). Addition of PR may have increased soil OM the following year. Soil pH was not affected by treatment, date, manure or year.

Conclusions: There does not appear to be a residual effect of the addition of PR in the 2nd year on yield or harvest data for field corn. ISNT and pH did not appear to be affected either. However, there does appear to be some difference in soil OM from the addition of PR the year before.

Objective Year Two: Rate Trial

To do a rate study on new plots to determine how much nitrogen is being released and how much nitrogen fertilizer can be reduced.

Rationale

Because it was determined from the 2012 trial that nitrogen was being released for use by the corn plants, 4 rates of PR application were studied to determine how much should be applied for best use.

Basic Protocol of Rate Trial:

1. Monitor the field-length strip trials, four replicates of four treatments: 18 lbs/acre starter N fertilizer with pop-up fertilizer on all plots, and 0, 15, 30 and 45 tons/acre of PR, as-is moisture (~70%).
2. Soil sample before planting and fertilizer/amendment applications; soil sample in mid-July; soil sample after harvest. Run a standard nutrient analysis, Illinois soil nitrogen test (ISNT), and nitrate analysis. This will establish the amount and form of nitrogen in the soil.
3. Analyze stalk samples just before harvest for nitrates, corn stalk nitrate test (CSNT). This test determines if the corn crop had inadequate, adequate, or excess nitrogen.
4. Measure yields from each plot on a dry matter basis, and measure harvest area.
5. Monitor and photograph plants every two weeks through the season to note any nutrient deficiencies and general growth and conditions (including weed pressure).

Procedure:

1. Plots were mapped out on May 5, 2013. Sixteen 30' x 70' plots were flagged out (12 rows wide, center 6 rows harvested for yield measurements).
2. May 6, 2013 - Ten soil cores at 8" depth were taken per plot. Samples were sent to the Cornell Nutrient Analysis Lab (CNAL) for a standard fertility test (package 1030) and to the Nutrient Management Spear Program lab (NMSP) for the Illinois Soil Nitrogen Test (ISNT).
3. On May 7, 2013, paper mill residual was delivered by Finch Paper, LLC. The residual was spread on the designated plots using a truck-mounted side-slinger spreader. The truck was driven over the control plots as if being spread to equalize the amount of soil compaction in all the plots. All the plots were tilled with a chisel (which incorporated the paper mill residual) and the seedbed was prepared with a roller harrow by Ideal Dairy. The rate was 0, 25, 50 and 75 cubic yards per acre, or 0, 1.2, 2.4 and 3.6 cubic yards per plot. The plot layout is shown below.

Rate ploy layout 2013, tons/acre (t/a) of paper fiber residual

Plot 4 – 15 t/a	Plot 8 – 30 t/a	Plot 12 – 15 t/a	Plot 16 – 0 t/a
Plot 3 – 30 t/a	Plot 7 – 45 t/a	Plot 11 – 30 t/a	Plot 15 – 45 t/a
Plot 2 – 0 t/a	Plot 6 – 0 t/a	Plot 10 – 0 t/a	Plot 14 – 30 t/a
Plot 1 – 45 t/a	Plot 5 – 15 t/a	Plot 9 – 45 t/a	Plot 13 – 15 t/a

4. May 9, 2013 – plots were planted with Pioneer, P0216HR seed. 12 rows were planted per plot at a depth of 1 ½ to 2 ½ inches. At planting 3 gallons of pop-up fertilizer (9-18-0) was applied on the seed and 18 lbs. of nitrogen was applied as starter fertilizer in a band 2" to the side of the seed.

5. June 4, 2013 –Plant population counts taken. Plants were counted in 40 feet of row in the 6 center rows of each plot.
6. July 15, 2013 – Soil sampled plots 1 through 16 as previously described.
7. August 26, 2013 – Plant height was measured and number of yellow and green leaves below the ear was counted for a representative plant in each plot.

Plot	Tons/acre PR	Plant Height (ft)	# Yellow Leaves	# Green Leaves
1	45	11.0	2	6
2	0	6.0	4	1
3	30	8.0	2	4
4	15	9.2	4	3
5	15	11.2	3	3
6	0	9.3	7	0
7	45	11.5	2	5
8	30	10.5	2	5
9	45	11.0	3	4
10	0	9.3	6	0
11	30	11.3	2	5
12	15	10.5	2	5
13	15	10.2	2	5
14	30	10.0	1	6
15	45	9.5	1	5
16	0	6.0	6	0

8. September 20, 2013 – stalk samples taken for the Corn Stalk Nitrate Test.
9. October 5, 2013 – plots harvested (middle 6 rows) with a John Deere self-propelled chopper with yield and moisture monitor.
10. October 10, 2013 – Soil sampled plots 1 through 14 as previously described.

Results of Rate Trial:

Plant data

Plot	Tons/Acre PR	June 4 Plants/Acre	Yield Tons/Acre	Harvest DM	Stalk Nitrate ppm	Level
1	45	30,056	23.3	44.2	74	Low
2	0	29,984	*	*	449	Marginal
3	30	17,351	*	*	201	Low
4	15	26,499	16.1	47.5	45	Low
5	15	33,541	18.4	42.7	110	Low
6	0	33,178	14.0	47.3	40	Low
7	45	31,799	24.1	42.8	597	Marginal
8	30	28,604	22.9	46.0	169	Low
9	45	33,396	25.1	44.3	47	Low
10	0	33,323	14.2	45.9	1229	Optimum
11	30	32,525	25.2	40.5	52	Low
12	15	32,597	20.2	46.5	64	Low
13	15	32,234	18.1	47.0	64	Low
14	30	32,743	19.9	45.3	229	Low
15	45	---------	*	*	432	Marginal
16	0	26,063	*	*	1042	Optimum

* Rain drowned plants in these plots so that no yield data could be taken.

1. Plant population on June 4: There was no significant difference in plant population between any of the rate plots. Average plants/acre: 0 t/a – 30,638; 15 t/a – 31,219; 30 t/a – 27,806; 45 t/a – 31,752.
2. Yield: There was a significant difference in yield between plots ($p<.0001$, r-square=0.83, Yield = 14.7 + (0.2 x Treatment).

Treatment (tons PR/acre)	Average Yield (tons/acre)
0	14.1[a]
15	18.2[a]
30	22.7[b]
45	24.2[b]

3. Harvest Dry Matter: There was no significant difference in harvest dry matter between plots with 0 t/a (average 46.6%), 15 t/a (average 46.0%), 30 t/a (average 43.9%) and 45 t/a (average 43.8%).
4. Stalk Nitrate: There was no significant difference in stalk nitrate concentration between plots with 0 t/a (average 690 ppm), 15 t/a (average 71 ppm), 30 t/a (163 ppm) and 45 t/a (288 ppm). Only two plots had optimum levels of stalk nitrate, three had marginal and the rest were low.

Soil data

	Average Critical ISNT (ppm)		
Treatment (tons PR/acre)	**5/15/13**	**7/15/13**	**10/10/13**
0	333.4	331.0	335.7
15	321.3	314.6	323.8
30	328.6	322.8	327.1
45	334.0	335.0	333.6

Parameter	Treatment (tons PR/acre)	5/15/13	7/15/13	10/10/13
NO_3-N (mg/kg)	0	0.65	6.50	13.63
	15	1.24	23.00	7.01
	30	0.00	5.71	14.37
	45	9.45	25.93	30.12
Organic Matter (%)	0	6.28	6.34	-
	15	6.95	7.25	-
	30	7.03	7.84	-
	45	6.59	7.33	-
pH	0	6.00	6.47	5.97
	15	6.02	6.44	6.44
	30	5.99	6.47	6.33
	45	5.92	6.47	6.52

1. Critical ISNT: There was no significant difference in critical ISNT by treatment or by date. ISNT measures the amino-sugars in the soil, to indicate the amount of organic matter that might be mineralized in the short term (one to three years).
2. Nitrate: There was no significant change in soil nitrate by treatment or date.
3. Organic Matter: There was no significant change in soil organic matter by treatment or date.
4. pH: There was no significant response for the pH of the soil by treatment or by date.

Discussion: Rate Trial

Plant Data: The addition of un-limed paper residuals to plots prior to planting corn in a low-lying, sandy loam, high organic matter field in a flood plain showed a clear trend in silage yield as the application rate of paper fiber increased from 0 to 30 tons/acre. There was no difference in yield between 30 and 45 tons/acre. Dry matter at harvest is an indication of corn maturity. This can be influenced by soil moisture, nitrogen and other parameters. The dryer it is the more mature it is. As there was no significant difference in maturity between the control plots and those treated with paper residuals, the paper residuals did not appear to affect corn maturity. The stalk nitrate test indicates if too little, an optimum, or an excess of nitrate was available to the corn plant during its growth. If excess nitrogen is taken up by corn, it can be measured in the lower stalk. There was no difference in stalk nitrate between any of the plots regardless of treatment.

Soil Data: The soil tests (nitrate, Illinois Soil Nitrogen Test) and the Corn Stalk Nitrate Test did not show any correlation to paper fiber rates. This is probably due to the erratic weather through the growing season and the associated dynamics of organic matter decomposition. Soil organic matter and soil pH were not affected by the addition of PR.

Conclusions of Rate Trial: Although replication was reduced from excess rain, a clear trend in silage yield is seen as the application rate of paper fiber increases from 0 tons/acre to 30 tons/acre. Due to erratic weather through the growing season, other conclusions cannot be made. Continued addition of PR to field corn may be of benefit for yield.

Appendix H: Cornell Furnace Retrofit Batch Reactor

The Lehmann lab Charcolator is now officially dubbed the "Cornell furnace retrofit batch reactor".

Please acknowledge fabrication by:
Akio Enders, technician
Lehmann Lab
Department of Crop and Soil Science
Cornell University

As of 15-Feb-2012, all internal surfaces are 304 stainless steel.

Furnace
- Fisher Scientific, Isotemp model 126 (Catalog No.: 10-650-126); Pittsburgh, PA 15275
- Power consumption: 4600 W
- Chamber volume: 1.26 ft^3 (12" wide x 13" high x 14" deep)

Pyrolysis insert
- Canister: mild steel cylinder 8-1/8" (20.638 cm) inner diameter, 1/4" (0.635 cm) wall thickness, 11-11/16" (29.686 cm) long
- End flanges: mild steel flat stock – 9-1/8" (23.178 cm) square, 3/16" (0.476 cm) thick
- End plates (doors): 304 stainless steel flat stock – 9-1/8" square, 11 ga (0.303 cm) thick
- Liner: 304 stainless steel flat sheet – 11-5/8" (29.528 cm) wide, 26" (26.040 cm) long, 28 ga (0.396 mm) thick
- Volume:

Agitation
- Paddle assembly: 304 stainless steel rectangular stock – 1 paddle, 1" (2.540 cm) wide, 11-1/2" (29.210 cm) long, 1/8" (0.318 cm) thick mounted to 304 stainless steel round tube – 3/4" outer diameter
- Dayton 1LNG2A gearmotor: 1 RPM, 100 in-lb torque

Sweep gas: 1 L/min high purity argon, preheated in 304 stainless steel tubing wrapped around pyrolysis cylinder – 1/4" (0.635 cm) outer diameter, 9.04' (2.755 m) long

Post pyrolysis cooling: via water flowing through 304 stainless steel tubing wrapped around pyrolysis cylinder – 1/4" (0.635 cm) outer diameter, 45.21' (13.780 m) long

Temperature data: type K thermocouple mounted in exhaust stream directly above pyrolysis cylinder, acquired by Omega Engineering, OM-DAQPRO 5300 datalogger; Stamford, CT 06907

Heating rate: exhaust gas maximum temperature rise to 700˚C is 2.5˚C/min

Appendix I: Beneficial Use Determination (BUD) Petition as Compost Feedstock

To: New York State Department of Environmental Conservation Solid Waste Division
Re: Petition for Beneficial Used Determination (BUD) for Finch paper-manufacturing secondary residuals to be used as a compost feedstock
From: Finch Paper, LLC

(1) In accordance with Subdivision 360-1.15(d), Finch Paper, LLC is petitioning for a beneficial use determination for their secondary paper mill residuals as a feedstock in the composting process:

- (i) Description of Finch paper mill residuals and proposed use: Finch Paper, LLC uses an ammonium bisulfite pulping process to produce pulp from wood chips. This process gives off a fair amount of nitrogen and sulfur, indicating that the residual can be used as a carbonaceous ingredient in the composting process. In addition, as the residual comes from wood (the usual bulking/carbon material for composting) its use in composting is intuitive.
- (ii) Chemical and physical characteristics of Finch paper mill residuals with and without additions of lime: Analysis of the paper residuals conducted by Cornell Nutrient Analysis Laboratory in Ithaca, NY for compost parameters and at Agricultural Analytical Services Laboratory, Pennsylvania State University, State College, PA indicated that its properties (Table 1) were in the right range to be used as a compost feedstock/bulking material in combination with other higher nitrogen feedstocks.
- (iii) Demonstration that there is a known or reasonably probable market of Finch paper residuals: testing of the paper mill residuals as a compost feedstock was done by Cornell Waste Management Institute at Ken VanAlstine's Nursery/Horticultural Services Compost Facility in Fort Hunter, NY. Results of several combinations of paper mill residuals with other feedstocks Ken uses show that a quality compost can be made in 60 days (Table 2). VanAlstine is interested in taking 100 cubic yards of the 1,000 cubic yards Finch generates weekly to produce compost. The resulting compost is similar to the compost Ken already produces for which VanAlstine has long standing markets for the compost product. There are other compost facilities in the area convenient to Finch Paper, LLC that have also expressed interest in receiving this feedstock.
- (iv) Demonstration that the management of Finch paper mill residuals will not adversely affect human health and safety, the environment, and natural resources: All paper residuals delivered to the compost facility will be incorporated into compost piles with other feedstock within 24 hours of arriving at the facility. Therefore, there will be no need for storage of the residuals at the composting facility. Complete analysis of this product was preformed on the paper fiber, limed paper fiber and various compost mixes and end-products.

Table 1: Characteristics of Finch paper mill residuals (PR) alone and mixtures with other feedstocks

Parmeter	Ideal range for composting	PR with lime	PR mixture 1	PR mixture 2	PR no lime (PRNL)	PRNL mixture 1	PRNL mixture 2
Moisture (%)	45-60	61	61	61	68	65	72
C:N ratio	25:1—35:1	31	28	24	66	17	17
Bulk density (lbs/cu yd)	1000	1530	1180	1350	843	1112	1062
EPA 503 Pollutants	Standards (ppm dry wt. basis)						
Arsenic	41-75	14.8			4.3		
Cadmium	38-85	1.8			1.3		
Copper	1500-4300	77.6			40.1		
Lead	300-840	42.5			18.7		
Mercury	17-57	0.02			0.02		
Molybdenum	75	2.4			2.9		
Nickel	420	7.1			6.0		
Selenium	100	<1.8			<1.6		
Zinc	2800-7500	102.0			85.9		
PCBs	1-10*	<0.04			<0.08		

* PCB standard is from NYS Part 360: 1 for Class 1 and 10 for Class 2

Table 2: Characteristics of finished compost from 2 mixtures of paper mill residuals

Parmeter	Ideal range for finished compost	PR mixture 1	PR mixture 2
Moisture (%)	40—50	43.8	43.3
pH	6—8	8.3	8.4
Soluble Salts (mmhos/cm)	1—4	0.05	0.05
Bulk density (lbs/cu yd)	800	1480	1650
Organic Matter	30—70	42.3	35.8
N—P—K (%)	1—3.4	2.7—0.7—-0.9	1.8—0.6—0.9
C:N ratio	15:1	16:1	17:1
Cu (mg/kg allowed by EPA)	4300	69	46
Zn (mg/kg allowed by EPA)	7500	157	99