

## USE OF DEEP-ROW BIOSOLID APPLICATIONS TO GROW FOREST TREES

Formerly known as “sludge,” biosolids refer to the soil-like residue of materials removed from sewage during the wastewater treatment process. They usually contain from 1-4% nitrogen and are a valuable source of fertilizer for agriculture and forest crops. The utilization of biosolids using forestry plantations of hybrid poplar trees solves many of the problems of traditional application methods and holds great promise for our region. This series of fact sheets will educate the reader about the practical application of research on this topic. More information can be found in the other *Biosolids* fact sheets of this series and at [www.naturalresources.umd.edu](http://www.naturalresources.umd.edu).

### **BIOSOLIDS & FORESTS** Research & Extension Team

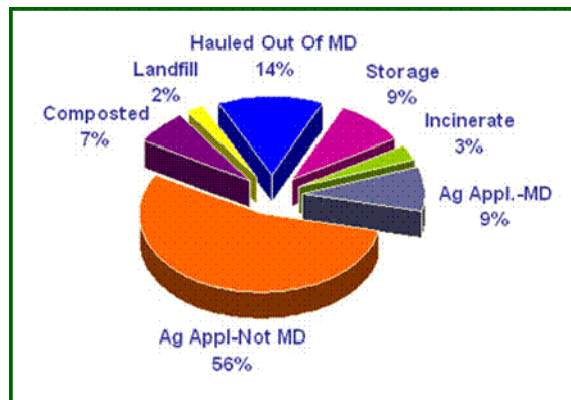


### BIOSOLIDS – RESOURCE OR DISPOSAL PROBLEMS?

Biosolids are a combination of primary (solid material produced during several stages at municipal wastewater treatment facilities), secondary (microorganisms that are responsible for converting wastewater pollutants into harmless compounds) and tertiary (sludge that has a reduced concentration of nutrients) sewage sludges. Biosolids do not contain the coarse grit and screenings removed from raw wastewater during preliminary treatments steps or ash generated from incineration of sewage sludge. In the past two decades, biosolids have become more benign, due mostly to the EPA source reduction effort.

In the Washington, D.C./Baltimore metro area, the process of using biosolids in an environmentally-sound, cost-efficient method has become increasingly complicated by new and existing state and federal regulations, county ordinance, development pressure and human conflicts. The passage of the Water Quality Improvement Act of 1998 by the Maryland General Assembly has been described as the most comprehensive farm nutrient control legislation in the country. It is likely that this legislation will reduce the amount of manure and biosolids used on farmland in Maryland. There is an increasing need for new utilization tech-

nologies that can provide beneficial use of biosolids in a cost-effective and environmentally sound way. The annual production of biosolids in Maryland is approximately 1.2 million wet tons per year and this certainly can be viewed as a disposal problem (see figure 1). However, the nitrogen available in the biosolids also has a value of approximately \$2.1 million, at \$0.25/lb N, which is clearly a resource. We simply have to develop environmentally and economically sound methods to utilize it.



Total biosolid production from Washington D.C. / Baltimore Metro area is 1.2 million wet tons (2002).

### ERCO Develops a New Technique

In response to the need for utilizing large volumes of biosolids from the Washington, D.C. area and in an effort to help reclaim biologically-sterile sand and gravel mine spoils, ERCO, Inc. developed the deep-row biosolid technique in the early 1980's using hybrid poplar

trees planted on treated land. ERCO, Inc. is a private firm involved in the beneficial reuse of biosolids on marginal and disturbed sand and gravel surface mines to produce tree crops on its property. There is the potential to apply this deep-row biosolid technique to sand and gravel spoils with similar geology in the Baltimore-Washington D.C. metropolitan areas. In fact, according to the 1998 Maryland DNR Water Management Administration, there are 12,788

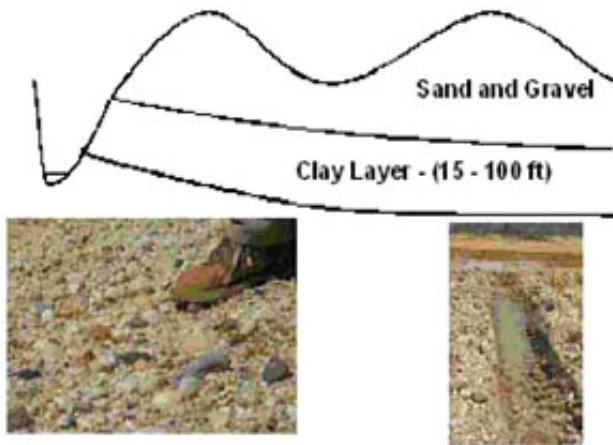


Figure 2. Pre-mining profile shows deep clay layer covered by sand and gravel, which is removed in the mining operation. A layer of sand and gravel overburden is left

acres of sand and gravel mines available in the Maryland metro area. They are broken down by the following counties: Prince Georges County, 5,887 acres; Charles County, 3,132 acres; Anne Arundel County, 2,693 acres; and Baltimore County, 1076 acres.

### Sand and Gravel Spoils

Prior to development of the tree farm, the site consisted of heavily gullied clay subsoil with occasional remnants of sand and gravel; the legacy of sand and gravel surface mining. The mining operation removed the sand and gravel at the surface (approximately 20' to 30' thick) and left the heavier deposits exposed to weathering (figure 2). The underlying clay-layer is a deep restricting clay layer that minimizes vertical leaching while tree roots colonize the site and utilize the nutrients. The average thickness of clay layers in Southern Maryland is 40 feet. The layers consist of clay, sandy clays and silty clays.

### Deep-row Biosolid Technique with Hybrid Poplar Trees – A Beneficial Reuse Technique

Deep-row technique refers to the application of biosolids in a series of thirty-inch-deep trenches that are promptly covered with overburden (figure 3), which eliminates odor problems and maintains the biosolids in a fairly stable anaerobic environment. After the site is graded, it is planted with nitrogen-demanding hybrid poplar trees that grow rapidly for approximately 6 - 8 years, consuming the nutrients buried in the trenches.

ERCO has been commercially using the deep-row biosolid technique since 1983. Stringent regulatory monitoring of

wells, trenches, and vegetation has shown no adverse water quality effects after over 19 years. The site is located in Prince George's County and within 25 miles of most large municipal wastewater treatment plants. The spoil has a clay layer of 15 feet or more. Approximately 10 acres were treated each year starting in 1984. After six or more years, each of the 10-acre sections were harvested and subsequently cross-trenched for another biosolid application.

State regulations required intense monitoring to detect leaching of metals, nitrogen or other nutrients into the water table. Seven monitoring wells ranging from 20 to 100 feet deep have been installed since 1983 and checked biannually for nutrients, pH, metals and coliform. No elevated level of any parameter was detected. On-site measurements and observations, as well as the work of the other researchers, suggest that the lack of oxygen in the buried biosolids resulted in anaerobic conditions, whereby nitrogen is held in organic forms that are not easily leached.

The ERCO sand and gravel spoil, previously incapable of supporting any significant vegetation and subject to massive erosion, was reclaimed and transformed into a stable



Figure 3. These pictures show the process of digging a trench, filling it with biosolids, and covering the trench with

forested habitat with abundant wildlife using deep-row bio-solid application and forestry (figure 4).

The deep clay layer underlying more than 10,000 acres of sand and gravel spoils in southern Maryland has this same potential. The clay layers in St. Mary's County ranges from 12 to 40 feet thick and are located from 3 to 62 feet from the surface. Sand and clay layers are interbedded in the upper portion of the Potomac Group in Prince Georges County. Along the Western Shore, clay ranges from a few feet to 100 feet thick with exposed layers going from older to younger – north to south. When all this clay is combined with the growth of nitrogen demanding hybrid poplar trees, a natural recycling system will occur that will utilize nutri-



Figure 4. Hybrid poplar trees after six year's growth.

ents on-site, produce forest products, generate wildlife habitat and reduce erosion while reclaiming abandoned, biologically dead soils created by sand and gravel surface mining operations. After a six-to-eight-year rotation utilizes most of the available nutrients, trees will be harvested and biosolids will be re-applied in deep rows perpendicular to the original trenches.

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## HYBRID POPLAR TREES

Poplar is the general term for trees in the genus *Populus*. Thus, poplars include cottonwoods (poplars) and aspens. Hybrids are produced when plants of different varieties and sometimes species are cross-bred. Hybrid poplars are fast-growing trees and can be harvested in a much shorter time than other species. They also thrive in heavier textured soils such as clay. Finally, hybrid poplars have a high nitrogen demand. They are capable of utilizing at least 200-360 lbs. N per year, similar to corn crops. The deep roots of the trees provide a source of oxygen for mineralization of the biosolids and then capture the nitrogen provided by the biosolids. It's a win-win situation. The hybrid poplars absorb the nitrogen and in return grow substantially into a small ecosystem.

## RESULTS OF A RECENT TRIAL TO DETERMINE THE STRONGEST HYBRID POPLAR CLONES

Recently, a two-year study was completed on the ERCO Tree Farm to test a variety of hybrid poplar clones to see which performs best in the deep row application. The clone used in the plantings until 2000, was HP308, but problems with cottonwood beetle, slow growth and the changing makeup of biosolids required experimentation with new clones.

Also, prior to 2000, ERCO planted hybrid poplar cuttings at a dense spacing of 3,000-4,000 trees per acre. This created stands with small average diameters (less than 5 inches diameter at 4.5 feet from the ground) and could not be harvested economically. The trees were basically harvested, chipped wet, and HP308. Individual trees were planted on a 10 ft. by 10 ft. spacing. Each block contained 120 acres.

After two years, the OP367 clone is the superior performer of all the clones tested (figure 5). It had the highest survival at 96% and had superior height growth at 297 cm. A full report on the clonal trials can be found at the following

website: [www.naturalresources.umd.edu/Pages/Clone\\_FS/Clone\\_FS.htm](http://www.naturalresources.umd.edu/Pages/Clone_FS/Clone_FS.htm) . The clonal trials will continue and updates will be available at [www.naturalresources.umd.edu](http://www.naturalresources.umd.edu).

### WHAT'S GOING ON IN THOSE TRENCHES?



Figure 5. Height differences between clones during the first growing season. The OP367 hybrid poplar clone has proven superior to the HP308 used in initial plantings.

The basic dimensions of the trenches are 42 inches wide and 36 inches deep (figure 6). The conditions of the trenches include: they are surrounded by clay, the water content is high (80-95%), there are 6 – 12 inches of overburden above the biosolids and the soil temperature is about 54 degrees F at 30 inches. When biosolids are applied, the top of the trench becomes densely rooted and peat-like in one year. The top and middle become brown and odorless after 4 years.

When the biosolids are applied, which is a one-time application of 171 dry tons per acre, they have zero nitrates. Most of the nitrogen is bound in the organic material. As

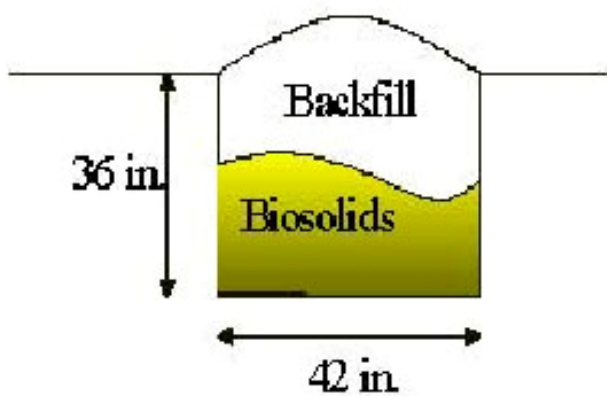


Figure 6. Basic dimensions of deep row.

the normal course of process and nitrate results. The organic material remains anaerobic until the tree roots provide a route for oxygen. The wet, anaerobic environment in the deep row suggests denitrification and it is likely a factor in the conversion of as much as 40% of the nitrogen in the biosolids to atmospheric N.

### Testing for Nitrogen Uptake

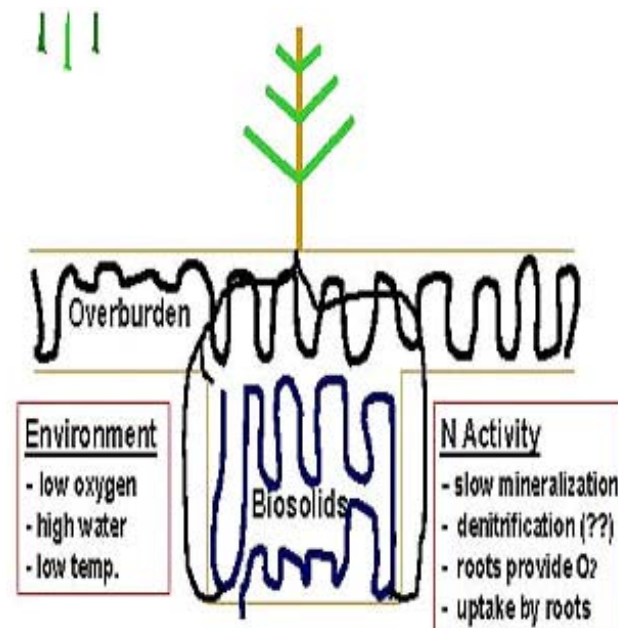


Figure 7. Nitrogen dynamics in deep row application.

**Foliar Sampling.** The percentage of N found in leaves of a specific tree species at the end of the growing season is a good indicator of the amount of available nitrogen in the soil. Foliar leaf samples are taken once a year and are mixed into one composite sample to provide one foliar N value. Fully-illuminated mature leaves are collected in mid August from the upper third of the crown of five trees. Past research on hybrid poplar indicates that when foliar leaf samples fall below 3.5 percent nitrogen, the majority of the biosolids have been mineralized, and reapplication is possible.

**Soil Sampling.** The mineralization of the biosolids occurs as tree roots supply oxygen and organic forms of nitrogen are converted into nitrate that can be taken up by the trees. Once 70% of the biosolids are mineralized, they are fairly stable and have the appearance of peat moss. To assess the amount of mineralization, soils samples are taken. Using a backhoe, a composite sample is taken from the bottom, middle and top rows of the biosolids in the trench. Composite samples from the five locations are mixed into one sample and the N content is measured to provide one value for each 10-acre section. Using the holes dug for this

process, assessments are made from the root growth patterns and decomposition. As nitrogen is mineralized, roots tend to penetrate the trenches more completely.

In the past, when ERCO has cross-trenched for additional applications, total soil nitrogen was measured 6 inches under the trench and on both sides. The nitrogen level in the old trench was about 1.7 percent. Six inches into the soil, the nitrogen level was 0.01 percent, which is similar to the original soil content. This indicates that nitrogen is not leaving the trenches, although this is just one point in time. The use of soil measurement techniques that allow constant sampling of soil water could determine if nitrogen has moved through the profile at other points in time.

### ADDRESSING MAJOR QUESTIONS

The deep row technique holds great promise, but the data taken since 1983 has been mostly monitoring data, not rigorous research. Before the deep row technique can be implemented on other spoils, adequate research is needed. The following statements provide an overview of what is

known and the questions that need to be addressed through research.

**Land Use.** By putting six years worth of nutrients in a trench in a single operation, less is expended in spreading costs. The ability to apply biosolids during the winter also provides logistical benefits. For the same level of biosolids, it is assumed that the total cost will be less for trenching than for surface application due to its one time application.

**Application Rate.** The infertility of the spoils dictates that all nutrient needs must be met by the nutrients present in the biosolids. *Research is needed based on the units of N per area, not gross biosolids volume applied.*

**Odor.** Lime stabilized sludge is buried the same day that it arrives from the wastewater treatment plant. Hence odor is not a problem.

**Managing Tree Density for Optimal Forest Production.** The pulp market for hybrid poplar in the Mid-Atlantic area can likely provide a break-even commercial market for hybrid poplar associated with deep row application. *However, research is needed to understand the optimal plant spacing and biosolids application rate that can produce the largest possible tree in the shortest amount of time, without impacting water quality*



Figure 8. Hybrid poplar roots travel along the surface and then drop down to access nutrients in deep rows (left). The picture on the right shows an older deep row in a clay layer with overburden. Note the many tree roots protruding from around and within the deep row. The environment in the clay layer provides for mineralization and denitrification.

**Erosion and Runoff.** The forestry operation establishes a canopy and a layer of duff or litter beneath the trees. The combination of raindrop interception by the canopy and high infiltration into the duff layer effectively prevents surface runoff from occurring and, hence, reduced flood problems in the immediate vicinity. The increased infiltration may help maintain anaerobic conditions or may facilitate leaching. *This is one of the phenomena we want to understand.*

**Water Pollution.** When it arrives from the wastewater treatment plant, the sludge has no (zero) nitrate. All of the nitrogen is bound in the organic material. As the normal course of decay occurs, oxygen is utilized in the nitrification process and nitrate results. However, in the ERCO project, the solids appear to remain anaerobic until the tree roots provided a route for oxygen and, hence, little nitrate was generated until roots were in the vicinity to utilize the nutrients.

It was a self-regulating system, with no groundwater pollution after 15 years of operation. *However, research is needed to understand how the water and nutrients move in this system. And how does this change as tree roots permeate the soil profile over the six-to-eight-year rotation?*

**Wildlife Benefits.** The growth of trees on a site previously

## The Nitrogen Cycle

The Earth's atmosphere is 78 percent nitrogen gas, but most plants and animals cannot use nitrogen gas directly from the air as they do carbon dioxide and oxygen. Instead, plants — and all organisms from the grazing animals to the predators to the decomposers that ultimately secure their nourishment from the organic materials synthesized by plants — must wait for nitrogen to be “fixed,” that is, pulled from the air and bonded to hydrogen or oxygen to form inorganic compounds, mainly ammonium (NH<sub>4</sub>) and nitrate (NO<sub>3</sub>), that they can use. This is called mineralization.

The amount of gaseous nitrogen being fixed at any given time by natural processes represents only a small addition to the pool of previously fixed nitrogen that cycles among the living and nonliving components of the Earth's ecosystems. Most of that nitrogen, too, is unavailable, locked up in soil organic matter — partially rotted plant and animal remains — that must be decomposed by soil microbes. These microbes release, or “mineralize” nitrogen as ammonium or nitrate, allowing it to be recycled through the food web. Nitrogen being released back into the air is called denitrification.

Nitrogen-fixing organisms include a relatively small number of algae and bacteria. Many of them live free in the soil. The presence or absence of oxygen will usually determine if nitrogen is available for plant uptake. When oxygen is present in the soil, organic forms of nitrogen, such as those found in biosolids, are mineralized into nitrate and ammonium, which are taken up by plant roots. In the deep row system, tree roots likely provide the source of oxygen, which allows mineralization and nitrogen uptake. In anaerobic (no oxygen) conditions that are cold and wet, bacteria will usually convert organic forms of nitrogen into nitrogen gas that is released back into the atmosphere. Given the cold, wet, anaerobic conditions found in the deep rows, it is likely that denitrification is a major source of utilization of nitrogen in biosolids.

devoid of significant vegetation provides habitat for deer, turkey, songbirds, quail and a variety of other species that now use the site. In general, plantations provide habitat at least as favorable for native birds and mammals as agricultural croplands, but not as good as a natural forest.

**Carbon Sequestration.** The growth of wood biomass on sites incapable of supporting vegetation results in the sequestration of carbon, at least in the short term. Carbon sequestration is touted as a carbon dioxide reducing strategy.

### RESEARCH PROJECT OBJECTIVES

In January of 2002, the Washington Suburban Sanitary Commission provided \$265,000 in funding to the University of Maryland College of Agriculture and Natural Resources to implement a replicated research project at the ERCO site. Findings of this research can be found in the other information sheets of this series.

The objectives were as follows:

**Objective 1.** Determine the effect of tree density and biosolid application rate on water quality around deep rows on gravel mine spoil.

**Objective 2.** Determine the effect of tree density and biosolid application rate on the above ground growth, production and survival of hybrid poplar with deep row biosolid

applications.

**Objective 3.** Determine the economic feasibility of deep row application with forest trees at different planting densities and application rates, as well as the value of its environmental benefits. Its feasibility relative to other biosolid disposal methods (or other reclamation activities) will be assessed.

**Objective 4.** Educate state and local environmental professionals about the use of deep-row biosolid applications to develop sustainable forest crops and simultaneously rehabilitate disturbed soils.

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## References:

Felton, G. K, J. S. Kays, C. U. Buswell, & E. Flamino. (2005). *Determination of Optimal Tree Density and Biosolid Application Rate and the Effect on Water Quality and Tree Growth Using the Deep Row Biosolids Incorporation Method*. Keedysville, MD: UMCP, MCE. 127 pp.

[www.naturalresources.umd.edu/biosolids.cfm](http://www.naturalresources.umd.edu/biosolids.cfm)

*High Yield Hybrid Poplar Plantations in the Pacific Northwest*; PNW356 – A Pacific Northwest Regional Extension Bulletin.

*Use of Deep-Row Biosolid Applications to Grow Forest Trees: A Case Study*. J.S. Kays, G. Felton, E. Flamino and P.D. Flamino. Cooperative Extension Service, University of Maryland, Keedysville, MD and Cooperative Extension Service, University of Maryland, College Park. <http://www.naturalresources.umd.edu/biosolids.cfm>

*Deep-Row Application of Biosolids to Grow Forest Crops on Mine Spoils: Potential Utilization for the Baltimore, MD-Washington, D.C. Metro Area*. J.S. Kays, G. Felton, E. Flamino and P.D. Flamino. Cooperative Extension Service, University of Maryland, Keedysville, MD. <http://www.naturalresources.umd.edu/biosolids.cfm>

*Results of Hybrid Poplar Clone Trial After Two Years at the ERCO Tree Farm in Prince George's County, Maryland*. [http://www.naturalresources.umd.edu/Pages/Clone\\_FS/Clone\\_FS.htm](http://www.naturalresources.umd.edu/Pages/Clone_FS/Clone_FS.htm)

*Biological Resources Engineering Topics. Information Bulletin*. Department of Biological Resources Engineering, College Park, MD.

*Human Alteration of the Global Nitrogen Cycle: Causes and Consequences*. Peter M. Vitousek, Chair, John Aber, Robert W. Howarth, Gene E. Likens, Pamela A. Matson, David W. Schindler, William H. Schlesinger, and G. David Tilman.