Arkansas Native Plants for Phytoremediation

Part I: Using Native Plants to Improve Stormwater Quality in Urban and Suburban Landscapes, *By Eric Fuselier*

Native plants have been getting a lot of well-deserved attention in recent years. As the public has become increasingly aware of troubling population declines in pollinator and wildlife species, due in part to habitat loss, we are starting to see native plants used more and more in gardening and landscaping practices.

This is, of course, great news and encouraging to see. But for all the buzz around native plants, there is another benefit many of these species can provide that I believe has been thus far mostly overlooked.

Phytotechnology and Phytoremediation

Phytotechnology is an emerging field that makes use of the naturally existing properties of plants in order to accomplish defined outcomes in a designed environment. One such application of phytotechnology is contaminant removal, otherwise known as phytoremediation. The benefits of using this approach include providing habitat for wildlife while being more sustainable, costing less, and providing better aesthetics than traditional methods of environmental remediation.

Phytoremediation makes use of the natural ability of certain plant species to accumulate, sequester, or breakdown contaminants found in the environment. Much research has been devoted to testing the suitability of certain plant species for remediating specific contaminants, with many of the species looked at in these studies being native to one region or another. This approach to environmental remediation is more often applied on large scales (for instance, for the remediation of contaminated soil at brownfield sites). However, the concepts and body of knowledge regarding phytoremediation using native species also can be applied, on much smaller scales, to the mutual benefit of both the ecosystem and society.

In this article, we will focus on the use of phytotechnology to address a serious problem that most cities, municipalities, and land managers face: polluted stormwater. Because impervious surfaces such as roads, parking lots, and buildings occupy a significant portion of the urban and suburban landscape, they prevent the soil from absorbing stormwater. Instead, most of this stormwater flows laterally across these surfaces, transporting any contaminants it picks up along the way into the nearest storm drain. From there the contaminated water flows directly into a local stream or water body. Any contaminants that do not make it into the body of water typically are absorbed by soil near the contaminant's source.

Let's consider how we can implement phytotechnology using native plant species to improve stormwater runoff before it enters these habitats, as well as some of the common contaminants which may affect the health of soil and aquatic habitats.

How it Works

There are five main phytotechnological mechanisms that we can make use of when trying to improve stormwater quality:

Phytodegradation makes use of the ability of certain plant species to take up the contaminants through their roots and break them down internally through the plants' metabolic processes. Through phytodegradation, contaminants are degraded, incorporated into the plant tissues, and used by the plants as nutrients. Fast-growing species may take up and store contaminants faster and in larger amounts than species with more average growth rates. Nitrogen-fixing pioneer species are also currently being studied due to their fast growth rate, high biomass, and hardiness.

Phytostimulation is the process by which contaminants are broken down in the soil by microbial activity that is enhanced by the compounds exuded from the roots of a plant. Many of the microorganisms in soil, such as yeast, fungi, and bacteria, can utilize harmful organic substances as their nutrient sources, and in the process degrade them into harmless substances. Natural exudates from plant roots, such as sugars, alcohols, and carbon-containing acids, provide food for these soil microorganisms and enhance their metabolic activity. In addition, the loosening of soil by plant roots and water availability in the root zone also aids the phytostimulation process. While it is a slower process than phytodegradation, phytostimulation is very effective.

Phytoextraction refers to the absorption and uptake by plants of large amounts of inorganic contaminants such as heavy metals and mineral nutrients from the environment, and to the translocation of these contaminants into the aboveground parts of these plants. With this technique, consider using woody species that produce high biomass and are classified as hyper-accumulators of these contaminants. If hyper-accumulator species are not available or not ideal to use at a site, then species known to accumulate a targeted contaminant in lesser quantities, but that still produce high biomass, can also be effective for phytoextraction.

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Phytostabilization is the use of certain plant species to immobilize contaminants found in soil and groundwater through various mechanisms, including absorption and accumulation of the contaminant by the roots of these plants, adsorption of the contaminant onto the surface of the plants' roots, or through the precipitation of the contaminant within the root zone of the plants. This latter mechanism makes use of certain chemicals exuded by the roots of these species which can immobilize or precipitate the targeted contaminant. Moreover, the transport proteins associated with the root zone of certain species are able to irreversibly bind and stabilize some contaminants. Alternatively, these contaminants can be taken up by the roots and thus become sequestered by the root system. It should be noted that this technique does not remove the contaminants from the site, but effectively immobilizes or stabilizes them, making them unavailable for entry into the food chain.

Phytohydraulics refers to the ability of certain plant species to capture, transport, and transpire water from the environment. With this technique, plants can be used to draw contaminated groundwater toward their roots in order to change the speed or direction of groundwater flow, or to modify groundwater levels at a site. Species with high evapotranspiration rates are best used for this purpose, however such species are often not drought tolerant, so irrigation may be needed depending on site conditions. It is important to note that this mechanism does not degrade the targeted contaminants, but can be combined with other mechanisms such as phytodegradation or phytostimulation to serve this purpose.

Phytoremediation is best suited for sites with low to moderate levels of contamination, where the level of toxicity is not high enough to inhibit plant growth. Potential applications of these phytotechnological mechanisms to improve stormwater quality include their use in rain gardens, bioswales, detention ponds, and other stormwater control structures strategically located to accept runoff from parking lots, roadways, dry cleaners, autobody shops, industrial and manufacturing sites, and other sites where contaminants commonly occur in the runoff. Specific contaminants are discussed below, along with the native plant species that can be used to remediate or control them using the phytotechnological mechanisms discussed above.

Sediment and Turbidity

Turbidity, which is the measure of the amount of suspended sediment in water, can negatively impact aquatic ecosystems by restricting the depth to which sunlight is able to reach. Without sunlight, algae in the water are unable to perform photosynthesis, a process which aquatic organisms such as fish and macroinvertebrates depend upon to provide them with the dissolved oxygen in the water which they need to breathe. High turbidity levels can also lead to soil particles becoming lodged in fish gills, which can restrict their ability to breathe and cause suffocation.

A common source of sediment causing high turbidity levels in our waterways is erosion originating from construction sites, agricultural fields, logging activities, and eroding streambanks. Phytotechnology can offer an effective way to remove this sediment from stormwater before it enters the local waterways.

To effectively contain on-site sediment, we can select fast growing species that produce dense foliage and a high quantity of biomass. The density of the foliage and high biomass helps to slow down and filter stormwater as it enters a body of water, facilitating the deposition of any sediment it may contain. Below is a list of native plant species that meet these criteria which can be combined with other Best Management Practices for erosion control to contain on-site sediment more effectively.

TABLE 1: NATIVE SPECIES FOR SEDIMENT CONTROL	
Scientific Name	**Common Name**
Andropogon gerardii	Big Bluestem
Bouteloua curtipendula	Side Oats Grama
Bouteloua gracilis	Blue Grama
Elymus canadensis	Canada Wild Rye
Panicum virgatum	Switchgrass
Schizachyrium scoparium	Little bluestem
Sorghastrum nutans	Indiangrass

Including these species within the riparian buffers along the banks of streams and rivers, along the edges of lakes and ponds, and downslope or adjacent to construction sites and logging activities are additional measures companies can take to reduce turbidity levels in local waterways, and prevent the adverse impacts that turbid stormwater runoff can have on sensitive aquatic ecosystems.

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Nutrient Pollution

While aquatic habitats require nutrients to support the organisms that live in them, excessive levels of nutrients lead to eutrophication, a process that creates harmful algal blooms that can result in fish kills and other damage to aquatic ecosystems. Common sources of excess nutrients in our local waters include fertilizers applied to lawns, fields, and agricultural lands, dead or freshly cut vegetation entering streams and water bodies, and even sediment originating from sources listed above in the previous section of this article.

Woody species with high growth rates are excellent for reducing the amount of nutrient pollution that enters waterways. Phreatophytes, which are deep-rooted trees and shrubs that obtain a significant portion of the water they need from the water table, meet these criteria and can be very useful for this purpose. Often found growing in arid locations or in areas with standing or running water, phreatophytes typically have fast growth rates, and can thus take up a lot of nutrients in a short amount of time as they incorporate these nutrients into their biomass. Utilizing these special qualities for both phytohydraulics and phytoextraction can help remove nutrients from stormwater before they enter local waterways. See below for a list of phreatophytes native to Arkansas.

TABLE 2: NATIVE PHREATOPHYTES FOR NUTRIENT POLLUTION	
Scientific Name	**Common Name**
Acer negundo	Box Elder
Acer rubrum	Red Maple
Magnolia virginiana	Sweetbay Magnolia
Populus deltoids	Eastern Cottonwood
Quercus alba	White Oak
Salix caroliniana	Coastal Plain Willow
Salix eriocephala	Missouri Willow
Salix humilis	Prairie Willow
Salix interior	Sandbar Willow
Salix nigra	Black Willow
Sambucus nigra	Elderberry
Taxodium distichum	Bald-cypress

Additionally, herbaceous species that have both high growth rates and produce high biomass can also be effective for reducing the amount of nutrients entering our waterways. Below is a list of native herbaceous species that possess these qualities. Including these species and/or phreatophytes in stormwater detention structures, such as rain gardens, bioswales, and detention basins, will allow for additional uptake of nutrients, preventing them from entering local bodies of water.

TABLE 3: NATIVE HERBACEOUS SPECIES FOR NUTRIENT POLLUTION	
Scientific Name	**Common Name**
Andropogon gerardii	Big Bluestem
Panicum virgatum	Switchgrass
Schizachyrium scoparium	Little Bluestem
Sorghastrum nutans	Indiangrass
Spartina pectinata	Prairie Cordgrass
Vicia americana	American Vetch

The species listed in Tables 2 and 3 can also be planted in other types of sites to reduce the amount of nutrients that are entering aquatic ecosystems and to prevent eutrophication of downstream water bodies. These locations include riparian buffers along the banks of streams and rivers, the edges of lakes and ponds, and in vegetative filter strips, constructed wetlands, and other stormwater control infrastructure receiving runoff from sources containing excess nutrients.

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Petroleum

Most petroleum products have a density less than water, and thus tend to float and spread into a thin layer on the water surface (called a *sheen*). Once in the water they can be harmful to wildlife and have adverse impacts to aquatic ecosystems.

Sources of petroleum in stormwater can include fuel spills from engine maintenance and repair activities, petroleum extraction activities, and leaks from above- and underground storage tanks. Other sources are engines dripping motor oil, grease, gasoline, and diesel fuel onto the surfaces of parking lots, driveways, roadways, and railyards.

Some categories of petroleum are easy to degrade. These include gasoline and diesel fuel; methyl tert-butyl ether; benzene, toluene, ethylbenzene, and xylene; and other aliphatic hydrocarbons. Phytotechnological mechanisms useful for remediating these categories of petroleum include phytostimulation and phytodegradation.

Other categories of petroleum, such as polycyclic aromatic hydrocarbons, coal tar, crude oil, and heating oil are much more difficult to degrade. Because of this, phytostimulation is the only useful phytotechnological mechanism for remediating soil and water contaminated with these categories of petroleum.

Below is a list of species shown through research to have the ability to remediate soil contaminated with the petroleum categories listed for each one. Including

TABLE 4: NATIVE SPECIES FOR PETROLEUM POLLUTION

TREES & SHRUBS

Scientific Name	Common Name	Contaminant Targeted*
Celtis occidentalis	Hackberry	BTEX, TPH, PAH
Cercis canadensis	Redbud	PAH
Fraxinus pennsylvanica	Green Ash	PAH
Gleditsia triacanthos	Honey Locust	BTEX
Juniperus virginiana	Eastern Red-cedar	BTEX
Morus rubra	Red Mulberry	PAH
Pinus echinata	Shortleaf Pine	MTBE, TBA
Populus deltoides	Eastern Cottonwood	Aniline, Phenol, m-Xylene, PAH, BTEX, MTBE, DRO, TPH
Quercus macrocarpa	Bur Oak	BTEX
Quercus phellos	Willow Oak	Dioxin
Robinia pseudoacacia	Black Locust	PAH, MOH
Salix caroliniana	Coastal Plain Willow	DRO, TPH, BTEX, PAH
Salix eriocephala	Missouri Willow	DRO, TPH, BTEX, PAH
Salix humilis	Prairie Willow	DRO, TPH, BTEX, PAH
Salix interior	Sandbar Willow	DRO, TPH, BTEX, PAH
Salix nigra	Black Willow	DRO, TPH, BTEX, PAH

GRASSES, RUSHES AND SEDGES

Scientific Name	Common Name	Contaminant Targeted*
Andropogon gerardii	Big Bluestem	PAH
Bouteloua curtipendula	Side Oats Grama	TPH, PAH
Bouteloua gracilis	Blue Grama	PAH
Carex cephalophora	Ovalhead Sedge	PAH
Carex stricta	Upright Sedge	TPH
Elymus canadensis	Canada Wild Rye	TPH, PAH
Elymus hystrix	Bottlebrush Grass	PAH
Juncus effusus	Common Rush	PAH
Panicum virgatum	Switchgrass	Anthracene, PAH (total priority), Pyrene, TPH,
Schizachyrium scoparium	Little Bluestem	PAH
Scirpus atrovirens	Green Bulrush	PAH, Phenol, BOD, COD, Oil and gasoline, TSS
Scirpus cyperinus	Woolgrass	Phenol, BOD, COD, Oil and gasoline, TSS

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Scirpus georgianus	Georgia Bulrush	Phenol, BOD, COD, Oil and gasoline, Phenol, TSS
Scirpus pendulus	Nodding Bulrush	Phenol, BOD, COD, Oil and gasoline, TSS
Sorghastrum nutans	Indiangrass	TPH, PAH
Spartina pectinata	Prairie Cordgrass	PAH
Tripsacum dactyloides	Eastern Gamagrass	TPH, PAH
Typha domingensis	Southern Cattail	DRO, Oil and gasoline, Phenol, TSS, BOD, COD
Typha latifolia	Broadleaf Cattail	DRO, Oil and gasoline, Phenol, TSS, BOD, COD

FORBS & WILDFLOWERS

Scientific Name	Common Name	Contaminant Targeted*
Helianthus annuus	Common Sunflower	PAH
Sagittaria latifolia	Arrowhead	TPH
Senna obtusifolia	Coffee Weed	PAH
Solidago altissima	Tall Goldenrod	TPH, PAH
Solidago arguta	Forest Goldenrod	TPH, PAH
Solidago caesia	Blue-stemmed Goldenrod	TPH, PAH
Solidago flexicaulis	Zigzag Goldenrod	TPH, PAH
Solidago gigantea	Giant Goldenrod	TPH, PAH
Solidago hispida	Hairy Goldenrod	TPH, PAH
Solidago missouriensis	Missouri Goldenrod	TPH, PAH
Solidago nemoralis	Gray Goldenrod	TPH, PAH
Solidago odora	Sweet Goldenrod	TPH, PAH
Solidago petiolaris	Downy Ragged Goldenrod	TPH, PAH
Solidago radula	Western Rough Goldenrod	TPH, PAH
Solidago rigida	Stiff Goldenrod	TPH, PAH
Solidago rugosa	Rough Goldenrod	TPH, PAH
Solidago speciosa	Showy Goldenrod	TPH, PAH
Solidago ulmifolia	Elm-leaved Goldenrod	TPH, PAH

these species in rain gardens, bioswales, vegetative filter strips, riparian buffers, and constructed wetlands in locations receiving stormwater that may contain petroleum could help reduce the damage to aquatic ecosystems.

*****Acronyms: BOD, biological oxygen demand; BTEX, benzene, toluene, ethylbenzene and xylene; COD, chemical oxygen demand; DRO, diesel range organics; MOH, mineral oil hydrocarbons; MTBE, methyl tert-butyl ether; PAH, polycyclic aromatic hydrocarbon; TBA, tert-butyl alcohol; TPH, total petroleum hydrocarbon; TSS, total suspended solids.

Pesticides

Pesticides can enter aquatic ecosystems through stormwater runoff from lawns, fields, agricultural lands, roadsides, rail corridors, and utility corridors. Once in the aquatic environment, pesticides can cause direct harm to fish and aquatic invertebrates, as well as reduce the availability of aquatic plants and insects that serve as habitat or food for fish and other aquatic organisms.

Below is a list of species that have been shown through research to have the ability to remediate soil and water contaminated with specific pesticides, using various phytotechnological mechanisms such as phytodegradation, phytoextraction, phytostimulation, and phytostabilization.

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TABLE 5: NATIVE SPECIES FOR PESTICIDE POLLUTION			
Scientific Name	**Common Name**	**Vegetation Type**	**Pesticide Targeted**
Andropogon gerardii	Big Bluestem	Grass	Atrazine, Chlorpyrifos, Chlorothalonii, Pendimethalin, Propiconazole
Betula nigra	River Birch	Tree	Bentozon
Ceratophyllum demersum	Coontail	Aquatic	Metolachor
Elodea canadensis	Pondweed	Aquatic	Atrazine, Copper sulfate, Dimethormorph, Flazasulfron
Juncus effusus	Common Rush	Rush	Anthracene
Lemna minor	Common Duckweed	Aquatic	Demeton-8-methyl, Copper sulfate, Dimethomorph, Flazasulfron, Glyphosate, Isoproturon, Malathion, Metolachlor
Morus rubra	Red Mulberry	Tree	Anthracene
Panicum virgatum	Switchgrass	Grass	Atrazine, Pendimethalin
Populus deltoides	Eastern Cottonwood	Tree	Alachlor, Atrazine, Chlorpyrifos, Dinoseb, Dioxane, Metolachlor, Metribuzin
Salix nigra	Black Willow	Tree	Bentazone
Sorghastrum nutans	Indiangrass	Grass	Altrazine, Pendimethalin
Tripsacum dactyloides	Eastern Gamagrass	Grass	Anthracene, Chlorpyrifos, Chlorothalonil, Pendimethalin, Propiconazole
Typha domingensis	Southern Cattail	Grass	Atrazine
Typha latifolia	Broadleaf Cattail	Grass	Atrazine

Useful locations for these species include rain gardens, bioswales, vegetative filter strips, and constructed wetlands, as well as edges of streams, rivers, lakes, and other waterbodies that receive stormwater runoff from parks, orchards, fields, transportation and utility corridors, and residential areas where these pesticides are being used.

Conclusion

It is my belief that native plants are currently not being utilized to their fullest potential when selected for native gardens or landscapes. The list of species and contaminants covered in this article is by no means exhaustive. Other potential contaminants that could be targeted using phytotechnology include chlorinated solvents originating from current or historical dry-cleaning operations; air pollutants originating from roadways, interstates, and airports; and heavy metals originating from agricultural activities, industrial sites, and from mining and smelting operations. By utilizing the growing body of research available regarding the phytotechnological use of native plant species, such species can be strategically selected and placed on the landscape to either degrade or extract a variety of contaminants found in the soil, water, and air.

I believe native plants have immense potential in the field of phytotechnology. So I encourage anyone with an interest in landscaping, native plant gardening, or the health of aquatic environments to consider how surrounding land uses may be impacting the environment by contaminating stormwater. With the help of native plants, pollutants and contaminants can be removed or degraded and environmental quality improved.

In time, my hope is that native plant gardeners and landscapers, as well as professionals responsible for managing stormwater, will become just as knowledgeable about the native plant species useful for remediating specific contaminants as they are about species beneficial for particular pollinators. By applying these additional functions of native plants to the landscape in a thoughtful manner, we can work not only to improve the plight of pollinators, but to improve the environment as a whole.

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