In Indiana, poplar trees are helping soils reduce nitrate levels in rivers. Red oaks are doing the same along the Mississippi River. In abandoned gas station lots in Chicago, wild flowers such as purple coneflower and yarrow are cleaning soils of hydrocarbon pollution. Research is showing that soils and valuable soil microbes can work in conjunction with plants to reduce or remove contaminants, a process known as phytoremediation.

How plants remove contaminants depends on the contaminant itself. Some plants are more tolerant than others are, and some are even “superstars.”

According to Paul Schwab, a professor at Texas A&M, poplar trees have a tremendous capacity to take up water. “A wall of nitrates could be coming toward trees [in a buffer strip], but on other side of the tree line, the nitrate levels are below drinking water levels.” Poplar trees are fast growers, with deep root systems. They process the nitrates naturally as a nutrient source and can tolerate very high levels—levels that might kill other plants.

Poplars help with hydrocarbon remediation, too. Schwab remembers that in southern Indiana, there was a bottomless silo at the top of a hill filled with residuals from coal manufacturing. “The sludge oozed out into the wetland, creating a disaster.” Soil microbes need a lot of oxygen to degrade hydrocarbons, but since the wetland soils were saturated with water, their oxygen levels were greatly reduced. Cleanup efforts were stalled, so the cleanup team used the poplars to bring the water levels down. This, in turn, allowed microbial degradation of the hydrocarbons to occur.

Schwab’s work in phytoremediation caught the eye of Frances Whitehead, a Chicago artist with a special vision. Through her “Embedded Artist” program, she wanted to rehabilitate abandoned gas stations dotting the urban Chicago landscape. “It wasn’t just about the aesthetics,” Whitehead says. “I wanted to think about the entire system. I knew about what plants and soils could do working together, and when I found Paul, I knew we could find some big-picture solutions. I wanted to recreate the soil column in the city” (see sidebar).

**Dual-Purpose Remediation**

Cristina Negri, an agronomist and environmental engineer with Argonne National Laboratory, researched a dual-purpose remediation: removing solvents from soil while establishing ground cover to control surface erosion and facilitate restoration. “You can create resilient systems that address more than one problem,” Negri says.

Agronomist Cristina Negri collects poplar samples to measure the pollutants removed from the soil. Photo by George Joch, Courtesy Argonne National Laboratory.

The problem site she was given was Area 317-319 at Argonne, a site used for a waste treatment facility in the 1960s. Back then, it was state of the art, but the end result was contaminated soils and groundwater enriched with volatile organic compounds (VOCs).

The research team planted 1,000 poplar and willow trees. They are among a group of plants called phreatophytes, which have extensive and deep root systems and are hardy against many soil contaminants and growing conditions. “Every tree was a ‘pump’ for the plume used for groundwater discharge,” Negri says. “Our models showed that areas of the plume could be dewatered after four years.”

“Phreatophyte plants are excellent tools for remediation,” Negri says. “They naturally have deep roots when water stressed. Cottonwood, willows, and poplar trees are ready to cope with drought and flooding… when stressed for drought, they push roots deeper. In 2005, there was a drought… trees were yellowing.
Soil Horizons

Frances Whitehead is an artist who is a fan of soils and the environment. Not many artists can throw out terms like “soil microbes,” “multipurpose remediation,” and “phenology” while talking to a group of renowned soil scientists, as Whitehead did at the recent “Soils in the City” conference held in Chicago.

According to Whitehead, it was a lucky day for her Embedded Artists program when she uncovered the work of Texas A&M professor Paul Schwab, who at the time was working at Purdue University.

Whitehead’s vision was to “embed artists into government agencies, giving a big-picture view to solutions.” She wanted to remediate the soil in Chicago’s abandoned parking lots while also “giving them an aesthetic quality, providing a variety of vegetation for wildlife, and providing public education—a multipurpose remediation project.” Her concept was of “slow cleanup,” working with nature to fix the soil over time.

Although there are hundreds of abandoned gas stations in Chicago, there are no pressing reasons to “fix” ones in the urban neighborhoods. The land in suburbs has a higher-value real estate and was quickly fixed for urban sprawl. “In the city, they would maybe take out [the gas station] building and leave a fence,” Whitehead says. She combed the city looking at various sites, and then her project began.

Schwab’s lab tested a variety of ornamental, flowering, and fruiting plants to determine their ability to degrade hydrocarbons in soil. “Petro-contaminated soils are not toxic to the plants because the volatile parts are gone,” Schwab explains. “Some can grow through tar and diesel—they are very tolerant.” Schwab selected plants that were good remediators and tested some new ones. The research found that there are plants that accelerate remediation. For example, black cherry, dogwood, service berry, and sumac pulled out nearly 50% more petroleum hydrocarbons than nature alone, as did walnuts, wild rose, witch hazel, and elderberries.

Whitehead’s next project has her working with the Morton Arboretum on another Chicago urban soils project: three miles of reclaimed rail line property that will be “re-wilded” to withstand public use as a park and pathway.

out… but a week later, they were green because roots had grown down. There is potential for more microbial community in a root-enriched system. Naturally decaying roots are food for microorganisms. When the roots die, this creates air paths in the soil. Living willow and poplar plants also develop a way to transport air down into the roots.” She recommends using these trees to manage plumes and for urban landscapes.

Negri has also researched other common urban soil contaminations, such as lead and arsenic. “If you want to remove the inorganics, it’s difficult,” she admits. But plants will take up lead and metals if they are available in the right form.

“Most of the brownfields have been there a long time, so what is left is typically very stuck to the soil.” Using biosolids and composts can bind the mobile fractions of the heavy metals to the organic parts of these media. Binding the contaminants in this way can reduce their risk of becoming airborne or waterborne. “You can also reduce human and animal exposure to the contaminants by creat-
Jeff Hatten agrees that remediation projects could address more than one problem at a time. Hatten, professor at Oregon State University, was studying how soils affected acorn production along the Mississippi. But, he also wondered about the other roles the red oak trees may have on the soil. His research found that, in floodplains connected to rivers, red oaks were excellent at reducing the amount of nitrate that reached the river. If there was any type of barrier or break between floodplain and river—levees, dams, or other flood control—the river did not receive any benefit from the presence of red oaks.

“Connected floodplains did sequester some nitrogen,” Hatten says. Five of the six study sites were national wildlife refuges—the sixth was a national forest. “These types of areas are now being created by Conservation Reserve Programs. They are a passive way to produce a cleanup effect.”

Reconnecting Tile Flow to Riparian Buffers

In some cases, previous practices have incapacitated natural phytoremediation systems from doing their work. Dan Jaynes has been working with farmers to get more nitrates flowing through natural phytoremediation systems. Jaynes, a soil scientist with the USDA Agricultural Research Service, researched how to reconnect the flow from underground tiles, which are found below some farm fields to removes excess water from the soil subsurface, to riparian buffers, or areas of vegetation that remove sediment and nutrients in runoff. The Iowa Science Assessment estimated that water channeled through riparian buffers would have 91% of the nitrates removed. The research was published in Journal of Environmental Quality earlier this year.

“Tiles drain water above the riparian buffer,” Jaynes says. The figure below illustrates how tiles prevent water from going through the natural cleanup provided by riparian buffers. “We replumbed the buffers to redirect tile water into the shallow groundwater system of the buffers. This does not impact the farm operation at all. Our goal is not just to delay the arrival of the nitrates into the rivers, but to remove it completely through denitrification. Our research in 2011 and 2012 found we removed 110 kg of nitrate each year that otherwise would have discharged directly into the stream. In 2013, it was closer to 150 kg.”

Plants, working together with valuable soil microbes, can clean up soils. Plants remove hydrocarbons and nitrates by using them as food and nutrients; they metabolize hydrocarbons and nitrates and remove them completely from the environment. Heavy metals are a different story. Plants can pull the metals out of soils, but the metals are not metabolized, and remain in the plants. Thus, the plants need to be harvested and removed. However, plants are helpful in slowly cleaning the soil of heavy metals, while preventing erosion and providing a barrier to human and animal contamination. And, as Whitehead has proven through her art, while the plants are providing cleanup, they also provide a more beautiful environment for humans and a habitat for wildlife.