

Utilizing Phytotechnologies: Redesigning Abandoned Gas Stations

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Introduction

Hazardous pollutants that exist in contaminated soils represent a threat to human, animal, and environmental health if left unmanaged. Phytoremediation in the U.S. was generally named and formally established in the 1980s and applied as an alternative method using plants to cleanse contaminated soils on site in a more economically and environmentally friendly way than removing contaminated soils off site. High expectations and mixed performances with failures outnumbering successes led to a crash of phytoremediation with a decline in environmental research funding by the early 2000s. “Phyto”, a book by landscape architects Kennen and Kirkwood (2015) recently reintroduces the subject with a more approachable set of planning, engineering and design tools. One commonly occurring site with a history of perpetuating contaminated land is the abandoned gas station. Abandoned gas stations are highly visible in the landscape and if soils are contaminated then remediation costs can hinder redevelopment. The focus of this paper is the redesign of abandoned gas stations through phytotechnologies by applying and expanding Kennen and Kirkwood’s (2015) framework.

Background/Literature Review

We will provide background information about the larger topic of conventional remediation and the opportunities of phytotechnologies as an effort to revitalize brownfields, introduce the specific while largely applicable phenomenon of abandoned gas stations, and provide a brief overview about current research on spatial concepts of phytotechnologies in landscape architecture. Finally we will explain major mechanisms of phytotechnologies and possible planting typologies.

Conventional Remediation and the Opportunities of Phytotechnologies: Typically, the remediation process of contaminated sites consists of a number of methods to fulfill the goal of cleansing the land of harmful pollutants. Conventional methods include the removal of soil to be dumped in a landfill or incasing the polluted soils within a membrane to prevent any leakages (Hollander et al. 2010). These methods, while effective at some levels, are expensive processes that merely dismiss environmental concerns by displacing the burden or hiding it for a later discovery.

Abandoned Gas Stations: Abandoned gas stations are establishments that proliferated throughout the United States in the 20th century as major oil companies overbuilt their chains attempting to succeed in the battle for territorial gain. This competition created an overt presence in the American landscape and in recent decades the abandoned gas station has become just as significant a symbol in our culture as they have brought a certain dereliction to almost every American neighborhood (Jakle and Skulle 1994). This has created a growing need for innovative, sustainable, low-cost methods to address the contamination issues prevalent in soils and groundwater (Kennen and Kirkwood 2015).

Spatial Concepts of Phytotechnology: Research-by-design work that incorporates multiscale, spatial frameworks into the more science-oriented theory of phytotechnologies is rare. This research provides possible links between science, practice, cultural and aesthetic values. Wilschut et al (2013) used a landscape design approach that considered scientific knowledge on phytoremediation and formed it into a spatial composition for brownfields of the port of Rotterdam (NL). Understanding a site's potential and the predicted time period for the remediation process allowed for a systematic and transitional framework with opportunities for combining community oriented programmatic elements that interacted and evolved along with the site (Wilschut et al 2013). This idea of transformative remediation as a systematic design tool provides conceptual bridges between aesthetics and ecological design that can follow principles of green infrastructure and aesthetic experience as a design and planning concept (Slegers 2014). Conceptually, green infrastructure would allow for a flexible use of remediated landscapes as ancillary components of larger green infrastructure entities that support a framework for environmental, social and economic health as well (Benedict et al 2006). The ability to integrate a remediated landscape into a more broadly defined role is one of the intriguing parts of brownfield reuse.

Phytotechnology: “Phytotechnology is about using specifically selected plants, installation techniques, and creative design approaches to rethink the landscapes of the post-industrial age” (Rock, 2015). This broader definition for phytoremediation targets the discipline of landscape architecture as it includes natural systems, considers multiple scales between site and region, emphasizes prophylactic approaches, includes green infrastructure and addresses the need to incorporate cultural values (Kennen and Kirkwood 2015). It utilizes vegetation to remediate, contain or prevent contaminants in soils, sediments and groundwater, and/or add nutrients, porosity and organic matter. This approach can be beneficial because it offers an in situ opportunity that reduces the amount of contaminated wastes that need to be disposed while

also providing a more economical option when compared to traditional remediation techniques (McCutcheon 2003).

Typical Contaminants and Contaminant Subjects: The majority of pollutants seen at typical gas stations are organic chemicals that can be removed from the soil and groundwater using plant life. These are mainly petroleum hydrocarbons in lighter and heavier fractions, chlorinated solvents, and to some extent nutrients. Metals may also play a role for abandoned gas stations especially ones that have been in operation before the mid 1970's.

Phytotechnologies or Mechanism: While we shortly explain the different mechanism that evolve the modification of contaminants by plants, it is important to acknowledge that processes may happen simultaneously through plant and supporting microbial activity. Only organic substances can be transformed through phytotechnologies – mainly *phytodegradation* and *rhizodegradation*; in theory inorganic contaminants such as metals can either extracted into the plant or stabilized. Dickinson et al. (2009) state that phytotechnologies are currently – with some exceptions- not practical for field applications in treating inorganics. *Phytodegradation* describes a process that breaks down contaminants in the plant roots, stems and leaves; *rhizodegradation* defines processes when root exudates from the plant break down contaminants. *Phytovolatilization* releases a contaminant or a broken down product into the atmosphere; *phytometabolism* describes processes when contaminants, for example nutrients are stored in the plant's biomass; *phytoextraction* extracts contaminants from soils and water and moves it into plants; *phytohydraulics* occurs when plants change the hydrological flow of the groundwater to take up contaminants; *phytostabilization* holds contaminants in place and prevents mobilization and migrating. Lastly, *rhizofiltration* filters pollutants from the water and adds oxygen and organic matter to the soil. Rhizofiltration is applicable to constructed wetlands and stormwater filters and has become common practice in water and sewage management.

Phytotypologies and Plant Selection: Eleven out of eighteen phytotypologies described by Kennen and Kirkwood (2015) were selected for redesigning gas stations through phytotechnologies. Table 1 lists phytotypologies and relevant phytotechnologies, contaminant targeted and contaminant subject, and suitable plants. Table 2 briefly describes phytotypologies. Plants must be selected based on specific site conditions, including soils, groundwater, microclimate and contaminants being addressed.

Table 1. Overview Phytotypologies and Phytotechnologies

Phytotypology	Phytotechnology	Contaminant Targeted (1,2,3,4)	Contaminant Subject	Plants Suitable
Phytoirrigation (pp 207)	Phytodegradation Rhizodegradation Phytovolatilization	Petroleum Chlorinated Solvents Nutrients	Wastewater or Groundwater	Petroleum tolerant/ Chlorinated Solvent tolerant. Plants grow fast with high evapotranspiration.
Green Roof (pp 210)	Phytohydraulics		Stormwater	Green Roof Species
Groundwater Migration Tree Stand (pp 213)	Phytohydraulics	Petroleum Chlorinated Solvents Nutrients	Groundwater	Trees with deep tap roots and high evapotranspiration rates.
Interception Hedgerow (pp 216)	Phytodegradation Rhizodegradation Phytovolatilization Phytohydraulics Phytomctabolism	Petroleum Chlorinated Solvents	Groundwater	Phreatophyte Species. High evapotranspiration rates and petroleum degrading.
Degradation Bosque (pp 218)	Phytodegradation Rhizodegradation Phytovolatilization Phytomctabolism	Petroleum Chlorinated Solvents Nutrients	Soils (0-10 feet)	Petroleum Tolerant/Chlorinated Solvent Tolerant. Plants grow fast with high evapotranspiration.
Degradation Hedge/Living Fence (pp 220)	Phytodegradation Rhizodegradation Phytovolatilization Phytomctabolism	Petroleum Chlorinated Solvents Nutrients	Surface Soils (0-4 feet)	Petroleum Tolerant/Chlorinated Solvent Tolerant. Plants grow fast with high evapotranspiration.
Degradation Cover (pp 222)	Phytodegradation Rhizodegradation Phytovolatilization Phytomctabolism	Petroleum Nutrients	Soil (0-5 feet)	Deep rooted drought tolerant prairie grass species are often utilized. Mixed species.
Stormwater Filter (pp 235)	Rhizofiltration	Petroleum Chlorinated Solvents Nutrients	Stormwater	Plants that thrive with substantial water and withstand periods of drought.
Surface Flow Constructed Wetland (pp 238)	Rhizofiltration	Petroleum Chlorinated Solvents Nutrients	Stormwater Groundwater	Plants suitable for constructed wetlands.
Subsurface Gravel Wetland (pp 241)	Rhizofiltration Phytostabilization	Petroleum Chlorinated Solvents Nutrients	Stormwater Groundwater	Plants suitable for constructed wetlands/ deeper rooting depth.
Stabilization Mat (pp 202)	Rhizofiltration Phytostabilization	Metals*	Soil	Metal Excluders

1: petroleum hydrocarbons pp 65-94; 2: chlorinated solvents pp 94-103; 3: nutrients pp 125-136; 4: metals: pp 136-179 (Kemen & Kirkwood 2015)

*Contaminated sites should be screened for Heavy Metals that may still occur on gas stations. Specific remediation techniques may apply including conventional remediation.

**LUST: Leaky underground storage tanks

Table 2. Description of Phytotypologies

Phytotypology	Description
Phytoirrigation	Polluted water is irrigated on plantings.
Green Roof	Stormwater is prevented from entering on contaminated areas. Contaminant mobilization is prevented.
Groundwater Migration Tree Stand	Roots tap into groundwater and keep contaminants from migrating. Trees are deeply planted in bore holes.
Interception Hedgerow	Roots tap into groundwater and keep fractions of contaminants from migrating. For smaller amount of space than full tree stands.
Degradation Bosque	Deep rooted trees and shrubs degrade contamination within the soil profile.
Degradation Hedge/Living Fence	Shrub species degrade target contaminants /Woven willows create fence. Roots target contaminants.
Degradation Cover	Herbaceous species degrade contaminants.
Stormwater Filter	Plantings and soil remove and trap contaminants from stormwater.
Surface Flow Constructed Wetland	Water is directed through a series of planted marshes and engineered soil media to remove contaminants.
Subsurface Gravel Wetland	Contaminated water is treated by pumping the water slowly through subsurface gravel beds. Filtering through plant roots and soil media.
Planted Stabilization Mats	Introduced plants hold contaminants on the site to prevent them from migrating.

Selected eleven phytotechnology planting types after Kemen & Kirkwood 2015, pp 201-244.

Goals and Objectives

To continue the current dialogue on the potential for phytotechnology as a meaningful opportunity for brownfield remediation this project's goal is to demonstrate how phytotechnologies can be applied to a gas station along the Route 9 corridor between Amherst and Northampton, Massachusetts.

Methods

This project uses a research by design method exploring phytotechnology to redesign an abandoned gas station in Western Massachusetts. The project utilizes phytotologies that are described in the book "Phyto" by Kennen and Kirkwood (2015). Their implementation is intended to remediate organic substances or prevent contaminant migration. This project combines these typologies as spatial modules in a creative and aesthetically pleasing experience on a real site as a design study in landscape architecture. Encouraging public awareness is part of the appeal to this project, so this was considered during the design process through implementing programmatic elements within the sites to encourage interaction and experience. The design process includes application of relevant literature and site analysis including GIS and other data layers and a map synthesizing opportunities and constraints.

Results

Our analysis shows that our site is adjacent to a wetland that is part of the Connecticut River watershed (Figure 1). Migrating pollutants from the abandoned gas station create a potential hazard to this environment. The site is close to the Norwottuck Rail Trail, an 11 mile path linking Northampton, Hadley, and Amherst along the former Boston & Maine Railroad right-of-way. Fostering connections from and to the site to the trail would improve the local and regional open space network. The conceptual design explorations (Figure 2) demonstrate that the theoretical design typologies could be combined comprehensively on the site in a way that accomplishes the necessary density for remediation while also creating aesthetically pleasing spaces for users. By enabling a connection to the Norwottuck Trail through the space there is opportunity for engagement in the process taking place which adds a cultural and educational component.



Figure 1. Site Located between the Norwottuck Trail and Connecticut River Wetland

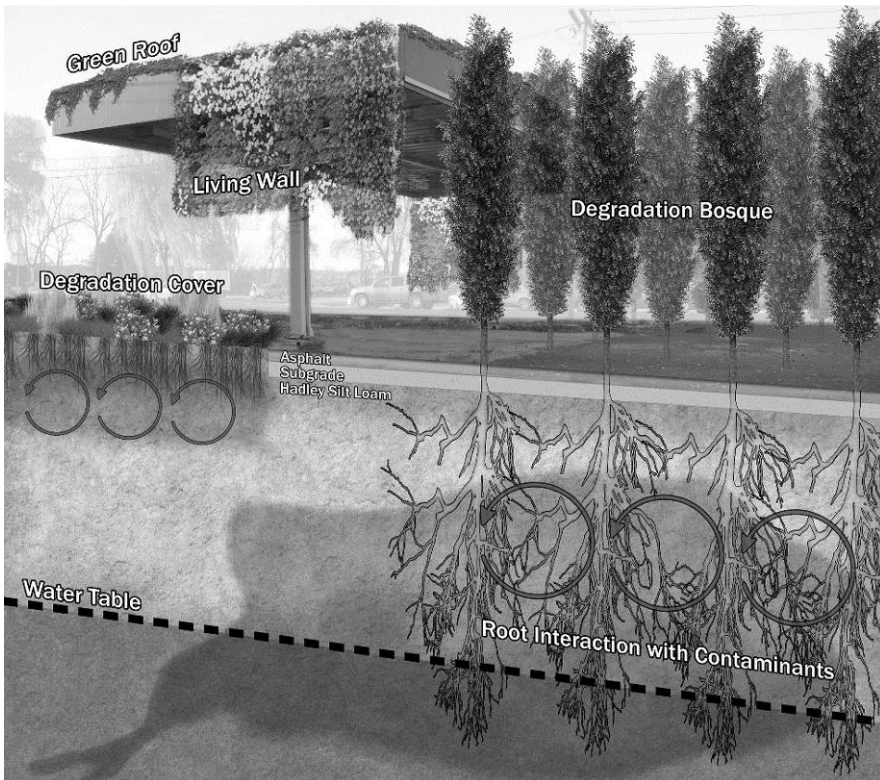


Figure 2. Conceptual Design Explorations Utilizing Several Phytotypes

Discussion

This research by design project exhibits the complexity of redesigning small brownfields such as contaminated gas stations. While the study worked with the design palette of 11 phytotypologies there are still other possibilities and combinations that were unexplored. Kennen and Kirkwood's research was very valuable to test a theoretical framework on a real site as visionary project. Our study expanded from that framework to address opportunities available for these sites to benefit the community in a way not merely relegated to its final product, but through an experiential process of education and interest. Our design visions are capable of improving aesthetics while maintaining ecologically pertinence and cultural relevance. We find that phytotechnologies are theoretically capable of being used to achieve an acceptable level of site cleanup and that this process can be done in a way that creates an aesthetic and ecologically beneficial experience.

Conclusion

Phytotechnology as a means for remediating small sites polluted with organic chemicals is a step in promoting this technology and proving its worth for other, larger and more complicated brownfield. While this study explores one possibility of redesigning an abandoned gas station on a highway corridor in Hadley, Massachusetts (USA) it is necessary to expand design possibilities on other abandoned gas stations with different contexts and conditions. The results should also be extended to gas stations in operation to apply phytotechnologies as a preventive method. This design study is relevant for the profession of landscape architecture because it merges design aesthetics with science-related technologies. There are still aspects that have been overlooked or need more exploration: process-oriented strategies especially public participation. Implementing and promoting this type of remediation will require community support and involvement, of which can be directed and associated with an experiential transformation of such abandoned and contaminated sites. These findings may be accompanied within a regional process of identifying and networking potential sites while considering them within an established city greenspace or greenway plan.

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