MYCOREMEDIATION:

FUNGI BREAK IT DOWN

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THE RUNDOWN: KEY FACTS

- The diversity of fungi gives us the potential to use fungi to decompose chemicals of different classes, including hydrocarbons.
- Oyster mushrooms exhibit exceptional hydrocarbon-degrading capability.
- Some fungi can act as an accumulator of metallic compounds.
- Paul Stamets is a figurehead and leading researcher in using fungi for bioremediation.
- Non-profit organizations like Living Mandela and OceanBlueProject are using mycoremediation as an environmental solution.

THE RIGHT FUNGI FOR THE JOB

There is great diversity in the Kingdom of Fungi. Fungi differ in their sexual cycles, preferred habitat, and what they consume. We can use different fungi to our advantage based on what they derive energy from, especially in the remediation of polluted soil and water.

Certain species have an affinity in remediating particular contaminants whether by biologically breaking them down or accumulating them and essentially removing them from the environment. While King Stropharia is effective in removing *E. coli*, Shaggy Mane is more effective in removing arsenic, and King Oyster in removing Agent Orange. The key is to determine the right fungal species to target the chemical of concern.

MYCOREMEDIATION OF FUELS

Fossil fuels contain a class of compounds known as polycyclic aromatic hydrocarbons **(**PAHs**)**. The accumulation of PAHs in animals and their potential to disrupt ecosystems are a cause for concern. PAHs can bind to fatty tissue, and about 44% of the PAHs are listed as harmful and cancer-causing. We increase the abundance of PAHs in the environment through incomplete combustion (e.g. car exhaust), manufacturing products like coal tar, and oil spills. The Deepwater Horizon Oil Spill caused surrounding water to have 40 times the abundance of PAHs than recorded previously. A related problem arises when altered hydrocarbon polymers are made into plastics, which make up 11% of landfills that can resist degradation virtually forever.

Fungi have the ability to break down these compounds for the carbon resources and can deal with environmental stress that comes from the buildup of PAHs, such as lack of oxygen or water. Fungi can break down wastes that are higher in molecular weight, compared to bacterial decomposers, which is important because the heavier isotopes of PAHs can range anywhere from harmless to extremely toxic. There is a positive outlook on the idea of fungi and bacteria working together to break down PAHs-- with fungi breaking down the hydrocarbons, bacteria can do the remaining work in remediating polluted and contaminated areas.

One particular PAH-degrading fungus is the Oyster mushroom, which has been shown to break down 80-95% of PAHs within 80 days. Paul Stamets' company, Fungi Perfecti, has been working with Battelle Marine Sciences Laboratory in Washington to investigate fungi capable of remediating sediments that are contaminated by oil and petroleum products.

Oyster mushrooms -- *Pleurotus ostreatus* -- are the species of fungi Stamets and Battelle decided to use for their pilot study. They looked into the efficacy of oyster mushroom mycelia at breaking down hydrocarbons. Three piles of contaminated soil were compared: one from a 30-year-old vehicle maintenance building, one soaked with diesel, and the last containing gasoline. After four months, the smell of oil had completely disappeared from all of the piles. Over 97% of the hydrocarbons had been removed from the piles. The piles were also fruiting mushrooms at this point, which were tested and found to contain no petroleum. Additionally, native plants began growing in the mycoremediated piles a few weeks after the study ended. The control piles resulted in no change of hydrocarbon concentrations after the four month period (Klotter, 2002).

In a separate study conducted in 2012, oil-contaminated soil from a former screw manufacturing plant was used. This study used different remediation techniques: addition of inorganic nutrients, addition of hydrocarbon-degrading microbial consortium and inoculation of the white-rot fungus, *Trametes versicolor*. The study confirms that *T. versicolor* is "an effective remediation and detoxifying strategy" (Llado et. al, 2012).

MYCOFILTRATION OF METALS

Fungi have also been explored for water treatment. The EPA has released details investigating the feasibility of mycofiltration on surface waters. Paul Stamets and Fungi Perfecti were the main investigating bodies of these assessments.

Various fungi mycelia were tested for their ability to remove *E. coli* from flowing water in a laboratory setting. Evidently, several species showed a capacity as an antibacterial mechanism in the removal of both sediment-bound bacteria as well as dissolved bacteria. This has implications for future water treatment in industry and agriculture, and urban environments.

In municipal wastewater treatment, biosolids are of significant concern due to the high-energy-cost methods being implemented. Mycofiltration of wastewater sludge is a comparably low-cost option. It effectively breaks down and removes pathogens and chemicals rather than just physically separating them. However, the potential for hyperaccumulation of toxic metals in the fruiting bodies could cause other problems.

Paul Stamens suggests in his book, *Mycelium Running: How Mushrooms Can Help Save the World*, that the harvested toxic mushrooms could be taken to a toxic waste site and either be buried, stored, or incinerated. Residual metals could then be sold to the metal recycling industry. In effect, mushrooms could be the medium of recycling heavy metals! This has implications in remediating sites near nuclear energy and weapons industry, whose by-products include cadmium, mercury, lead, copper, and arsenic. Fungi can also take in and concentrate cesium-134 and cesium-137. Evidence of this came after Chernobyl, when lichens in even Sweden served as sponges and absorbed cesium-137, which bioaccumulated in reindeer that consumed the lichens.

Paul Stamets giving a TED lecture on mycoremediation

NONPROFITS AND MYCOREMEDIATION

Two examples of non-profit groups that are exploring mycoremediation to solve current pollution problems are Living Mandala and OceanBlueProject. The fact that nonprofit organizations are using mycology to solve societal and environmental problems attests to the potential in mycoremediation.

Living Mandala is a "DBA" company that focuses on educational and consultation of socially and ecologically responsible practices. In 2010, they supported two programs, "Oil to Soil: Bioremediation Technologies for Oil Spill Clean Up" and "Ecuadorian Political Ecology, Oil Pollution, and Mycoremediation." Both were courses that use Ecuador as a case study. According to the company, a huge land-based oil spill in the diverse and unique Sucumbios province of the Ecuadorian Amazon region has persisted since the 1960s, thanks to oil companies intentionally dumping petroleum waste, failing to follow safety regulations, and ignoring corroded pipelines. The "mycorenewal" project investigates the feasibility of using fungi to sequester and metabolize petroleum. Living Mandala also collaborates with other organization that use various bioremediation techniques. The organization also offers other related courses and activities each year for those interested.

OceanBlueProject is based in Oregon and focuses on conservation education and service. Part of their Urban Restoration Proposal involves mycofiltration to remove pathogens from storm water. Streams and rivers are the main targets of their approach, but they cite mycofiltration as a solution to water pollution that makes business sense and environmental sense alike.