For my Family, Friends and Community.
For the Earth Warriors, Water Protectors, Visionaries, Dreamers, Manifesters, and Everyone Fighting for a Better World.
For Planet Earth and All its Inhabitants.
For The Fungi.
# Table of Contents:

**Forward** .............................................................................................................................. Page 7  
**Introduction: The Role of Fungi in Our World** ............................................................... Page 8  
**Gratitude** .......................................................................................................................... Page 10  

## PART 1: Basic overview  
What is Mycoremediation, Why Does it Matter? ......................................................... Page 11  
History of Mycoremediation .............................................................................................. Page 14  
Examples of Successful Mycoremediation ....................................................................... Page 15  
The Potential of Mycoremediation ................................................................................... Page 17  

## PART 2: Considerations  
Intersectionality .................................................................................................................. Page 18  
Why/When Mycoremediation Can be Harmful ................................................................. Page 27  
How to Protect Yourself ..................................................................................................... Page 28  
How to Make a Tincture ....................................................................................................... Page 30  
Medicinal Mushroom List .................................................................................................... Page 32  
List of Herbs, Plants, Foods, Vitamins, Nutrients to Contradict Toxins ....................... Page 46  

## PART 3: How to Apply Mycoremediation  
Questions to Consider .......................................................................................................... Page 54  
Factors That Affect Mycoremediation ............................................................................... Page 55  
Testing ..................................................................................................................................... Page 59  
Heavy Metals ....................................................................................................................... Page 64  
Chemicals ............................................................................................................................... Page 70  
Microbes ................................................................................................................................. Page 78  
Fungi Species Selection ....................................................................................................... Page 81  
Bench Scale Tests .................................................................................................................. Page 107  
Pilot Tests ............................................................................................................................... Page 112  
Remediating on Land ........................................................................................................... Page 112
Enzymes.......................................................................................................................... Page 114
Enzyme List......................................................................................................................... Page 118
Compost Tea....................................................................................................................... Page 123
Phytoremediation.............................................................................................................. Page 125
Mycorrhizal ....................................................................................................................... Page 130
Water Remediation........................................................................................................... Page 132
Runoff From Parking Lots/Construction Sites................................................................. Page 135
Creeks/Streams.................................................................................................................. Page 136
Rivers.................................................................................................................................. Page 138
Cascales Project.................................................................................................................. Page 140
Ponds.................................................................................................................................. Page 143
Lakes.................................................................................................................................. Page 146
Oceans................................................................................................................................. Page 147
Oil Spills in Water............................................................................................................. Page 149
Industrial Remediation Techniques for Oil Spills in Water............................................ Page 150
Bioremediation Techniques for Cleaning Up an Oil Spill in or Near the Ocean.. Page 153

PART 4: Cultivating Fungi
Steps of Cultivation ........................................................................................................... Page 155
What Fungi Need.............................................................................................................. Page 155
Cardboard burritos ........................................................................................................ Page 157
Glovebox............................................................................................................................ Page 159
Laminar Flow Hood.......................................................................................................... Page 161
Vectors of Contamination............................................................................................... Page 165
Lab Techniques................................................................................................................ Page 167
Spore Prints....................................................................................................................... Page 168
Preparing Agar................................................................................................................. Page 169
Spore Print to Agar.......................................................................................................... Page 173
Cloning Mushrooms to Agar........................................................................................ Page 173
Petri to Petri....................................................................................................................... Page 175
Petri to Grain..................................................................................................................... Page 175
Forward

This is a humble beginning. I am not an expert, and still learning everyday. This is meant to be an introduction that is far from being finished and will constantly evolve over time. This is meant to be a spark, a hope to inspire. I hope to create a space for us to look at our waste in our world. I hope to create a space for us to look at our role in contributing to that waste, and to learn how we can use natural organisms and methods to remediate that waste. I hope to create an invitation to ally with fungi. I hope to create awareness on a paradigm shift we must fully participate in to create a livable future for seven plus generations ahead. This piece is also meant to open awareness around death and decay. The death and decay happening to biodiversity of life, clean water, soil, air, natural resources, culture, human beings, etc., and the death and decay of organic matter by decomposers, which make it possible for life to flourish. And lastly the same death and decay of the pollutants (in our bodies and in our environment) that wreak havoc on the flourishing of life. This book serves as a humble guide for those who would like to apply mycoremediation but do not have a detailed understanding of how to use fungi to address pollution. If you come across words you don’t know please address the glossary in the back. The purpose of this book is to start to rally the troops and create a “mycollective” of “myco-literate” humans ready to use fungi and other organisms as tools to heal our environment in a sustainable way. This piece was written to bring awareness to the elephant in the room, -- our over accumulation of toxic waste --, and to explore the understudied, under examined method of cleaning up that waste with fungi: mycoremediation.
Introduction

The Role of Fungi in our World

This world is inhabited by organisms that have had the benefit of 3.77-4.28 billion years of evolution. (1) Fungi are one of the earliest organisms to evolve on land, beginning over 1430 million years ago. Over time, fungi have created intricate relationships with plants and bacteria to break down organic material and build a symbiotic web. There is a theory that they evolved with blue green algae to form the trees we see today (2). Humans have only been around for the last 200,000 years and in the industrial age for just 200 years. Compared to fungi we are practically brand new to the world. However, in our short time we have reached a critical point in the amount of toxic waste and corresponding threat of human extinction we have created. We can look to the success of fungi to remediate the harm we have done.

In order to understand how to leverage the wisdom of fungi, we must understand the vital role they play in our ecosystem. “Fungi serve many purposes, from breaking down plant lignin cellulose and hemicellulose in nature, to creating nutrients for plants, to serving as food and medicine for animals and people, to acting as bioremediators to filter and break down toxic land like oil spills and agricultural run off and more.” (Ja Schindler)

Luckily for us, one role that fungi play a primary role in is the breaking down of “waste”. Each network of mycelia is like a forest where an individual tree is known as a hypha. These mighty forests hide underground, beneath the forests of trees we know and see, and they can stretch for hundreds of hectares over a forest floor (one example is an Armillaria bulbosa specimen that occupies some 2,384 acres (965 hectares) of soil in Oregon's Blue Mountains (4). They regulate the flow of nutrients and energy through their filamentous mycelial network, sweating out powerful enzymes able to dissemble cellulose, lignin and hemicellulose to provide the vital building blocks of plant life within the universal, communal eco-exchange of the forest. When a tree falls in the forest, mushrooms pop up excreting powerful enzymes to help clean up the forest floor, metabolize this pile of cellulose and lignin, and transport these nutrients and
water through its mycelial subway system in order to trade some with plants in return for some carbohydrates.

This close relationship with fungi exists outside of the forest as well. Humans use fungi to create kombucha, penicillin, beer, bread, cheese, wine, cider, gourmet mushrooms, medicinal mushrooms, and more. Basically anything fermented that we like. Every person in this world interacts intimately with fungi everyday and we must use their ubiquity and well-honed abilities to address the pollution we have created. We as humans have been honoring fungi as sacred teachers of our lives for over 7,000 years. With beautiful cave paintings, sculptures, statues, stories, burials, all over the world. Even the case of the oldest human ever was found in the Swiss Alps with two different types of mushrooms strapped onto his body (5).

To prevent our own end, we must learn from these old, wise organisms. Fungi provide vital ecosystem roles and we would have an impossible time without them. No longer can we think of ourselves as separate from "the environment". Our actions severely affect the underlying systems of the planet. If we are not conscious of these effects, they will come rippling back. As humans and stewards of this earth, we need to think of the future generations and how our actions will facilitate the survival or extinction of future life. Considering their age and evolutionary success, we can see fungi have developed the incredible ability to break down organic material. It’s crucial for our survival and our problems with waste accumulation to create an alliance with one of the humblest intelligent elders and stewards on this planet: fungi.
A Huge Thank You!

Shout out to Ja Schindler from Fungi for the People for the huge inspiration and for offering the 5 day mycoremediation workshop, Tradd Cotter for writing the revolutionary book Organic Mushroom Farming and Mycoremediation, teaching workshops on mycoremediation, and for keeping us on point with the top of the line myco-research, shout out to Peter Mccoy for writing two super influential zines, the radical mycology book with an incredible chapter on mycoremediation, for continuing the work on mycoremediation, teaching all around the country and hosting the radical mycology convergence, the Corenewal team with Mia Malts, Maya Elson, Lexie Gropper, and more who dedicate their lives to cleaning up toxic oil pits, waste water in the sucumbios region of Ecuador and to educating people in the area, shout out to Leila Darwish, Author of Earth Repair for inspiring many on the accessible forms of bioremediation, shout out to William Padilla Brown for keeping it real and always inspiring us all, shout out to Daniel Reyes for dedicating his life to this field of mycoremediation and for being the go to man, Shout out to Willie Crosby for being my first mycology teacher and a great mentor, shout out to Harbhajan Singh for writing the heady book Mycoremediation, and all the humans who contributed to writing the Fungi in Bioremediation book, For Scott Kellogg and Stacy Pettigrew for writing Toolbox for Sustainable City Living, Paul Stamets for his incredible contributions in the field of mycology especially his newest book Mycelium Running, for Savannah Carlin for helping me organize and edit this, my advisor Charles Ross for keeping me on track, shout out to Hampshire College for letting me study this amazing line of work, a huge shout out to my family for continually supporting me physically, mentally, spiritually, emotionally, and financially throughout all ups and downs. Shout outs to everyone else who I didn’t mention who worked to shape my life, if we have ever interacted in this life, you know who you are, thank you. Deep gratitude for ayahuasca for showing me this vision. And infinite gratitude for the fungi who continually break down barriers, connect the Real, reveal the Truth, and always bring us back HOME.

MUSH LOVE!
May The Spores Be With You!
Part I: Basic Overview

What is Mycoremediation? Why Does it Matter?

One of our biggest problems right now is a huge accumulation of waste:

On the world counts website there are many statistic clocks that keep track of details like how much waste humans are dumping globally every year. "If Earth’s history is compared to a calendar year, modern human life has existed for 23 minutes and we have used one third of Earth’s natural resources in the last 0.2 seconds.” The process of extracting those natural resources, the industries they support, and the products that they become all produce hazardous waste. “Hazardous wastes are wastes that can cause substantial threats to our health and the environment. And we produce a lot of it - more than 400 million tons each year; that’s 13 tons every second. This is almost 60 kg for every single person in the world - and the amount is increasing. In just one generation the production of manmade chemicals has increased by 40,000% from 1 million to 400 million tons. This stunning amount of waste is partly because 99 percent of the stuff we buy is trashed within 6 months. Hazardous waste also comes from products that we use every day, for example, batteries, cosmetics, cleaning products, paints, pharmaceuticals, electronics…” (1)

Most humans, especially the ones responsible for producing most of them, do not consider hazardous waste and environmental damage pressing problems. There seems to be a lot of scientific evidence and clear cases of the devastating side effects of extractivism and industrialism. The lack of priority the US government places on environmental damage is apparent by the lack of funding allocated to the most polluted parts of the country. The US has 200,000 “superfund sites” or areas that have especially high amounts of hazardous waste. Their clean-up requires $1.7 trillion over the next 30 years, but “[the annual] U.S. military budget is $773.5 billion” (3). If the US redirected its military spending, money aimed at death and destruction, to superfund site clean up aimed at health and restoration for just over two years, all of the sites in the US could be funded to be restored and would save thousands of lives and cases of sickness.
The scale of environmental damage means that finding sustainable methods of disposing of hazardous waste is critical to future environmental health. However, traditional methods of hazardous waste disposal have not always been sustainable or efficacious. One promising technique is bioremediation—the use of biological processes to fully remediate pollution with the goal of full mineralization (to turn into CO2, H2O and nutrients). Up to now, using bacteria and plants to clean up toxic waste has been the focus of bioremediation research, leaving fungi lagging behind. However, recently, there has been a revival in interest in mycoremediation by people who have read Paul Stamets book *Mycelium Running* where he points out successfully using spent oyster mushroom mycelium to remediate heavily toxic oil contaminated piles.

Fungi are the unappreciated stewards, janitors, providers, healers and protectors of this planet. They play a vital role in our environment: they decompose material no other organisms can decompose, they connect to the roots of plants increasing water and nutrient uptake, they provide a network for plants to trade nutrients and communicate, they protect plants from diseases, they provide food and medicine for animals, and they do much more. Interestingly, fungi are more similar to humans than plants in the way they consume food. Rather than making it through photosynthesis, they are considered heterotrophs, consuming their food from their surrounding environment. However, unlike humans, they externally excrete enzymes to digest their food instead of internally, and then absorb it through their cell walls. The enzymes that are secreted by fungi are used to break down complex hydrocarbons, which are similar to compounds that make up common anthropogenic (human made) pollutants. The decomposition of these anthropogenic pollutants with the aid of fungi is called mycoremediation. The range of organic molecules degraded by fungi includes recalcitrant plant biomolecules, polycyclic aromatic hydrocarbons, nitroaromatics, chlorinated aromatics, BTEX compounds, as well as various dyes, pesticides, effluent compounds and even cyanide.

There are three main types of physical pollutants that fungi can help clean from our Earth: microbes, metals, and chemicals. Mycelia/mycelium (the “roots” of fungi) have antimicrobial properties that can be easily employed in water systems (generally ones where fecal matter washes into the waterways) to trap, neutralize, and/or kill any pathogenic microbes that may be present in the water. Heavy metals cannot be broken down, but they can be sequestered into or around the fungi in order to render them immobile and prevent further spreading. Fungi possess very powerful extracellular lignolytic oxidative enzymes, which are
able to break down very complex anthropogenic toxic chemicals completely into simple hydrogen, carbon and oxygen molecules, or cleave the complex molecules into smaller ones where other microbes can come in and further break them down. The way fungi break down complex chemicals can be seen on the forest floor. By looking at the different states of decay, the ways different fungi excrete various enzymes to break down specific parts of molecules is clear.

Mycoremediation is a powerful opportunity for us to heal the earth from the pollution we have inflicted on it. Fungi have been proven successful in remediating damage from bacteria, heavy metals, and chemical pollutants. Mycoremediation can be used and learned by anyone and successfully applied by anyone in their own backyard.

Its accessibility, lack of cost, and scalability mean it is one of the most promising tools we have to fight pollution.

The following chart is a brief introduction of a few key events that shaped the mycoremediation field. It shows how young this field is and how much we still need to learn and develop.
A BRIEF HISTORY OF MYCOREMEDIATION

EARLY 20TH CENTURY
Mycoremmediation is however a younger branch of the science of bioremediation and has only been practiced since the beginning of the 20th century.

1983
Interest in mycremediation increased dramatically with the discovery of the enzyme "lignin peroxidase" from the fungi P. chrysosporium (Glenn and others 1983; Tien and Kirk 1983).

1993
The stropharia mushroom mycelium tropharia rugoso-annulata is used to reduce bacteria from upland pasture runoff (Stamets 2005) Lots of other studies on mycremediation took place in the 90's.

2001
Fungi in Bioremediation was published (edited by G.M. Gadd)

2005
Mycelium Running is published by Paul Stamets

2006
Mycoremediation: Fungal Bioremediation was published (Harbhajan Singh) Pleurotus ostreatus, Irpex lacteus, Stropharia rugosoannulata, and Trametes versicolor are thoroughly reported and reviewed (Singh 2006).

2013
Earth Repair: a Grassroots guide to healing toxic and damaged landscapes published (Leila Darwish)

2017
Radical Mycology: A treatise on Seeing and Working with Fungi Published - (Peter McCoy)

600BC
Bioremediation has been common practice for a very long time, and can be traced back as far as 600BC when the Romans used bacteria to treat their wastewater (Singh, 2006).

1991
Several species of wood-degrading fungi could be grown using killed bacteria as the sole nutrient source (Femor and Wood 1981)

1990
lignin peroxidase and other fungal enzymes could efficiently co-degrade persistent chemical toxins (Aust 1990; Bumpus and others 1985)
Examples of Successful Mycoremediation

Hopefully it’s clear by now that we have a big problem to address: our over accumulation of hazardous waste. One solution presented in this piece is that fungi with perhaps the aid of other natural organisms like bacteria and plants can help remediate those toxic wastes. One question a lot of people have when they are introduced to this idea is: has it ever been done? Bioremediation (using bacteria to remediate toxic waste) has successfully cleaned up many polluted sites and has been selected or is being used at over 100 Superfund sites across the country. (4)

Here are a few examples of successful mycoremediation, some of which are outlined in more detail under species of fungi with the contaminants they address.

One of the most famous cases came from Paul Stamets which he outlines in his book Mycelium Running (5):

Paul Stamets collaborated with the Washington Department of Transportation on a site that had been used for diesel truck maintenance for over 30 years. The level of diesel and oil contamination at the site, 20,000 parts per million, was about the same concentration detected on beached after the Exxon Valdez spilled 11 million gallons (41.6 million liters) of crude oil into the Prince William Sound in 1989. Paul Stamets notes that four weeks after adding *Pleurotus ostreatus* mushroom spawn on the pile of contaminated soil the color changed from a dark black to a light brown and was covered in mushrooms. Over time, plants started to grow on the pile and insects started to inhabit it too. After eight weeks the contamination had gone from 20,000 parts per million to a shocking 200 parts per million! (5)

I conducted my own research on the degradation of polycyclic aromatic hydrocarbons (PAHs) from dirty cigarette filters. I found that crude enzyme extracts of *Pleurotus ostreatus* mycelium, just mycelium and mycelium with compost tea remediated almost 100% of PAHs in less than two weeks.

- Field et al. 1996 demonstrated *Bjerkendera* spp. degrading anthracene by 99.2% in only twenty-eight days. (7)
• *Pleurotus ostreatus* and *Bjerkendera adusta* has been shown to almost completely degrade styrene in just 48 hours with the addition of lignocellulosic materials (Braun-Lullemann et al. 1997) (7)

• Research by Lovy et al (1999) found that strains of *Zhu ling were* 100 percent effective against *Plasmodium falciparum*, the parasite that causes malaria. (5)

• Duran et al (1994) demonstrated shiitake (*Lentinula edodes*) removing 73 percent of color of effluent in five days without an additional carbon source. When Duran et al. pre-irradiated the mycelium for ten minutes in the presence of photocatalyst, ZnO the decolorization was noted in forty-eight hours. (7)

• *Phanerochaete* spp. has been shown to decolorize azo dyes up to 100 percent and breaking them down to nitrogen and a phenol compound. Other studies show that PCP, in a mixture of creosote, can be degraded by 80% in six weeks. (7)

These are just a handful of studies out there with more coming out everyday!

There is significant evidence as demonstrated by these examples for the viability of fungi to degrade a wide plethora of anthropogenic toxins in our environment. It’s time we buckle down, do more research, develop better protocols on how to implement mycoremediation in our world.
Mycoremediation is a brilliant alternative to traditional remediation techniques. It uses natural organisms that are present to our ecosystems that we interact with every day instead of harsh chemicals that sometimes make matters worse. It is also a lot cheaper and most of the time can be done on site not requiring the soil to be extracted. The only thing is that these technologies are not studied as well as they should be and with increased research and technological advancement this will be hands down no questions asked the only way to remediate toxic waste. There is a stigma that harsh chemicals work better than natural methods that nature provides us with. The use of harsh chemicals to fix the spill of harsh chemicals to get back to natural symbiosis seems illogical. Since all industries want to save money and make the most profits, this graph should speak wonders.
Part II: Considerations for Mycoremediation

- Intersectionality of Mycoremediation

In any study of environmental damage, it’s important to understand the social and political forces behind it. Any individual who wants to remediate the damage of this phenomenon must be aware of the interconnected nature of the oppression that is often present in areas of environmental damage. Intersectionality is one way to evaluate the myriad of aspects that affect those living in polluted communities. Intersectionality was first touched upon by Kimberlé Crenshaw in her 1989 essay, “Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics.” She stated that intersectionality was "the relationships among multiple dimensions and modalities of social relationships and subject formations" (1) These relationships include topics of gender, race, social class, ethnicity, nationality, sexual orientation, religion, age, mental disability, physical disability, mental illness, and physical illness as well as other forms of identity. This combines with the interactions of multiple multidimensional and interacting systems of oppression or discrimination that feed racism, sexism, classism, ableism, homophobia, transphobia, xenophobia and belief-based bigotry. Intersectionality looks at the multidimensional, intersecting, interconnected web of identity and how that relates to multiple interacting systems of oppression and/or discrimination. Understanding these concepts will be crucial to developing empathy and understanding of for example why land inhabited by indigenous people or people of color are targets for toxic waste dumps and how to bring this understanding of oppressive systems to not only remediate the land but do it with the awareness of how the human aspect weaves in.

Capitalism is closely tied to many systems of oppression that affect the intersectionality of different marginalized groups. The capitalist-fueled industrial age that a lot of humans are in
has created an unsustainable, unbalanced, and hierarchical system of power focused on extractivism, oppression, individualism, and greed. A disconnection from nature compounds the negative effects of capitalism. This disconnect leads human beings to see themselves as outsiders to the intricate web of organisms that supports life on earth. The interconnectedness of oppression coupled with the capitalist disconnect from nature is especially apparent in environmental damage. Poor communities of traditionally marginalized groups are often the first to suffer damage from the capitalist urge to profit from natural resources. A great example of this would be Flint Michigan, which has a high black population of over 57%. The water there was hundreds of times more toxic than was allowed by EPA’s guidelines and the water that these people were drinking and bathing in could be classified as toxic waste. This wasn’t the first time that Flint Michigan was used as a dumping ground. Ever since 1904, industries like Buick City for General Motors has been polluting the city with no regard to the impacts of the residents who live there.

One incredibly important factor to keep in mind while evaluating mycoremediation is the factor of environmental racism. Environmental racism originated in colonial systems that were established to profit from the natural resources of poorer, non-Western countries. But this can be seen in our own cities like in Flint.

One of the ways the colonialism seeps into the everyday work of earth repair is through the dark legacy and enduring tradition of environmental racism. Indigenous communities, people of color and low-income neighborhoods are all too often sites targeted for heavy industry, military bases, waste dumps and higher levels of pollution. People in these communities suffer more health and environmental impacts than their affluent, predominantly white neighbors. Whatever laws, agreements and regulations may be present to challenge such injustices are often ignored and violated by corporations and governments. When it comes to recovering from environmental disasters and industrial accident, these communities often receive little notification, support or effective cleanup, if any all. This reality also applies to poorer countries, which have been traditionally used as dumping grounds, and whose rich environments have been exploited and destroyed by wealthier countries and their corporations.
This system starts at the level of extractivism. Though colonial systems are less obvious today as overt slavery and genocide is masked with the war on drugs, the school to prison pipeline, police brutality, the industrial prison complex, and environmental racism, wealthier countries still profit from the natural resources of poorer countries and do not address the pollution and other forms of harm their industries leave behind. Many times, this extraction is done on indigenous land without the consent of the indigenous people’s, leaving them relocated to worse areas or left in their homes and surrounded by pollution. An example of this happening is with Standing Rock where there is a pipe bound to burst and pollute their drinking water and sacred sites.

While I was in Ecuador in the fall of 2015, I saw this phenomenon first-hand with the Waorani people in Yasuni National Park. A foreign oil company started drilling oil there and stripped away the Waorani people’s way of life. They offered the Waorani people concrete houses, even though they were a nomadic tribe. They offered to build them schools instead of supporting the elders of the tribe who could have taught them important skills and information for their traditional lifestyle. With new roads they had access to markets where they could sell meat from animals in the surrounding jungle. With access to the “outside world,” capitalism was brought to them as the only way to live. After a short while, barely any animals were left in the area.

The younger generation all had smartphones and flocked to a research center to use one of the only wifi routers for hundreds of square miles. Most of the younger generation wanted to move to the city to find jobs. A lot of the younger people wanted nothing to do with their heritage and culture because they were being brainwashed that they were somehow inferior to the more “civilized” outside world. The oil company offered them jobs at the oil drilling stations and refineries, having them do hard and dangerous work, exposing them to a cocktail of toxins for minimal pay and ingraining in them that this was a better way to live.
When I visited the area in the end of 2015, almost all the oil had been drilled and the oil company was getting ready to pack up and leave. This would leave the land, water, and air polluted and toxic, and the indigenous people there, stripped of their old ways of living, without any animals to hunt for food, with concrete houses that they were not accustomed to living in, with roads but no cars/trucks, and also with roads that open up the possibility of future colonization from foreigners who will further destroy the amazon rainforest and all its inhabitants.

Extractivism leaves communities in shambles, forcing them to work in factories and be exposed to toxins. More often than not, these communities are indigenous people, people of color and other marginalized groups. Many factory workers are women of reproductive age who are dealing with carcinogens, mutagens & reproductive toxins including teratogens. When someone buys a radio for $4.99, the price doesn’t take into account the metal mined in South Africa, the petroleum from Iraq, the plastic from China, and the assembly by a 16-year-old factory worker in Mexico. The marginalized people pay for it while the most privileged people reap the benefit. Although a person buying the radio or the oil didn’t cause all these travesties, it’s privileged people's duty to help counteract the heavy cost of extractivism and consumerism and be mindful of our actions and choices and how that affects the greater interconnected web of life.

In a wider perspective, humans will quickly run out of resources and even the humans on top will run out of food to eat, fresh air to breathe, clean water to drink. We are like a frog in a pot of water slowly being heated to a boil. We are slowly getting accustomed to each plateau, and do not realize that each “degree of hotness” (toxins in our environment, climate change, cancer rates, etc) is leading us closer to our death and many more around us. We are now constantly surrounded by so many more chemicals products, pesticides, and electromagnetic pollution, compared to just 20 years ago. We must wake up and realize the effects of our actions and the repercussions it has. One way we can look at this is through what we consume.

The following graphics show an overview on our industrial system of industrialism, extractivism and consumerism that causes this pollution on our earth and in our bodies. We must go to the root of where this pollution is coming from and why it’s being made in the first place.
EVL CYCLE OF CONSUMERISM

WE WATCH ADVERTISEMENTS TO CONVINCE US THAT WHAT WE HAVE IS NOT ENOUGH AND WE NEED MORE.

WE QUICKLY THROW AWAY ALL THAT WE JUST BOUGHT.

WE BUY THE THINGS WE SEE ON THE ADVERTISEMENTS TO GIVE US A LIMITED SENSE OF SATISFACTION.

WE WORK JOBS WE HATE TO BUY THINGS WE DON'T NEED TO IMPRESS PEOPLE WE DON'T LIKE.

GET MONEY ONLY TO SPEND IT SOON.

ALL OF THIS IS HAPPENING WHILE A SELECT FEW ARE BENEFITING.
Unsustainable Linear System at PLAY

**Production**
Using those natural resources and sometimes combining them with chemicals to produce products.

**Extraction**
Plundering natural resources from our environment.

**Distribution**
Distributing those products to stores to sell.

**Consumption**
Advertising convinces people to buy buy buy, consume consume consume.

**Disposal**
99 percent of the stuff we buy is trashed within 6 months.

*Missing link*
**Decomposition**
Fungi can degrade almost anything. We need to ally with fungi in order to make this unsustainable linear system into a sustainable circular one for the benefit of all organisms.
The missing link in our unsustainable system is fungi, microorganisms and the greater lessons of death, decay and the circle of life. We must implement fungi in a paradigm shift as a society and as a species. We must work with the tools that the planet provides. Fungi are one tool. Their main role in ecosystems is to decompose, connect, and heal. This can be looked at in every aspect of the systems we are working in, whether it is an individual organism or that organism’s environment. We must learn the skills of the organisms survived and thrived the longest, which includes Achaea, bacteria and fungi. No longer can we be afraid of these organisms. No longer can we think of ourselves as separate from "the environment". Our actions severely affect the underlying systems of the planet. If we are not conscious of these effects, they will come rippling back to harm us. As humans and stewards of this earth, we need to think of the future generations and how our actions will facilitate the flourishing or extinction of future life. Looking at the data from this trial and error program of the evolution of life, we can see fungi have developed the incredible ability to break down organic and inorganic material. It’s crucial for our survival and our problems with waste accumulation to create an alliance with one of the humblest intelligent elders and stewards on this planet - fungi.

It is known that fungi can degrade a whole array of anthropogenic toxins that are polluting our earth as a byproduct of these unsustainable industries. It is time for us as a species to stop this horrible cycle that is oppressing and killing our people, polluting our waterways, destroying the most biodiverse places in the world, destroying culture, polluting our land, our air and above all the future of life on planet earth.
To counteract colonialism and extractivism with mycoremediation, be aware of the following questions:

- Whose land are you on? If it’s not your land/community, what does the community/land want?
- What is the history of the land?
- Who has been affected?
- Who/what is going to be affected by your actions?
- Who is/was profiting off this pollution?
- Are you going to be liable/sued/arrested/hurt/killed/exiled for anything that happens?
- Why are you cleaning up this pollution? (To boost ego points or because a community wants your help cleaning it up? Or other reasons)

Ways you can consider and incorporate intersectionality to maximize the benefit of your mycoremediation project:

- Ask what these people need first and be an ally with them in their fight instead of going in trying to “save the day” and doing what you think the community would want/need rather than asking them what they really need.
- Talk to politicians and lawmakers to create laws to protect against environmental pollution, and support you in your clean up initiatives.
- RemEDIATE land/water that affects predominantly people of color and indigenous people.
- Strive for free healthcare to provide people who have gotten sick from these environmental pollutants access to free resources to become better again.
- Free education in low income neighborhoods that provides tools and empowerment for remediation of land/water, food/medicine growing, wild foraging for food/medicine, building structures, medicine making, bodywork, somatics, etc. This includes teaching free/sliding scale courses/classes/workshops.
Why Mycoremediation Can be Harmful: (Pollutant Exposure)

Of course since these toxins are harmful the process of cleaning them up will open you up to a greater risk of being exposed to these toxics and reaping harmful health effects from them. Although I want to empower people with this piece to address toxic waste in our world, there is also a level of safe hesitancy one must have to protect themselves from these seriously harmful toxins. This shouldn’t be and isn’t a glorified job. Safety and awareness come first.

“The average life expectancy of an Exxon Valdez oil spill worker is 51 years of age” – Anita M. Burke (2)

On April 20, 2010, an explosion on the Deep water Horizon oilrig killed 11 people. An estimated 4.1 million barrels of oil were released in the Gulf of Mexico waters. To clean up this spill, they skimmed the oil from the surface, burned some and also dumped 2 million gallons of a dispersant called Corexit. They used two types of the dispersant called Corexit 9500A and Corexit 9527A. (4)

Corexit combined with crude oil, and salt water create a whole new compound that off-gases butyl ethers. This combination becomes 51 times more toxic than the crude oil itself. (5)

Chemicals like toluene, benzene, xylene have been found in the blood of BP Gulf Horizon spill cleanup workers, volunteers and community members.

Other things like solvents, detergents, fertilizers are known to cause headaches, nausea, vomiting, kidney damage, altered renal function, irritation of the digestive tract, lung damage, burning pain in the nose and throat, coughing, pulmonary edema, cancer, lack of muscle coordination, dizziness, confusion, irritation of the skin, eyes, nose and throat, difficulty breathing, chemical oversensitivity, delayed reaction time, memory difficulties, stomach discomfort, liver damage, unconsciousness, tiredness/lethargy, irritation of the upper respiratory tract, hematological disorders and death. – (2) More negative side effects in the Chemicals, Heavy metals and Microbes sections.
How to Care for Yourself:

Humans are polluting the world including ourselves because of emotional/spiritual traumas unresolved in our past and a general disconnect from our selves and nature. Mycoremediation is not just about remediating the soil/water, it’s also about remediating our mental, spiritual, emotional, physical bodies as well. All of these systems work together. Fungi help remediating toxins inside and out. “By analogy, just as young mushrooms feed on decomposing forest debris, so it seems that in the human body they assist in the neutralization of psychic waste and recycle such negativity into mental clarity and optimism”- (6)

I struggled with depression and anxiety for many years as a teen. The ways this manifested for me was turning to self-harm. Whether it be cutting, using drugs, or even just overuse of screens to distract myself and not take care of myself. Through my healing journey I realized that I wasn’t alone, and that a lot of people do this, in fact most if not all of us self harm whether we realize it or not. From eating junk food, distracting and disconnecting ourselves with screens, to thinking thoughts in our mind that are harmfully directed at ourselves “I’m not good enough” “I don’t look pretty today” “I did a really shitty job”. It wasn’t until I got Lyme disease where I started learning from first hand experience about parasites. Don Miguel Ruiz does a brilliant job of explaining it in his book “The Four Agreements”. Most of us have parasitic thought patterns that have come from many different places, our parents, our teachers, the media, our friends, etc. The biggest parasite that I can think of is the thought that we are separate from everything else. This separatism is the root of racism, bullying, torture, war, depression, murder, pollution, etc. This parasitic thought leads to humans polluting the environment and our own selves’ thinking that is doesn’t affect them. This disconnect needs to be reconnected. The best way that I’ve found on my healing path to remediate this root cause parasite is through the use of fungi.

Psilocybin

Just like mycorrhizal fungi help to open up roots to increase flow of water and nutrient and help protect against outside viruses, bacteria, and diseases. Mushrooms contain a substance called germanium. Germanium is a nutrient that helps boost the oxygen efficiency within the body. Germanium also helps counteract the body's exposure to environmental toxins and helps to
increase the body's ability to fight disease. Medicinal mushrooms also contain beta-glucans, which are polysaccharides. Polysaccharides are long sugar chains with oxygen-bearing molecules. While digesting these polysaccharides, oxygen is released and made available at the cellular level. Beta-glucans attach themselves to the receptor sites on immune cells and activate them, allowing them to recognize cancer cells as foreign and create a higher level of response. Medicinal mushrooms also are packed with triterpenes, phenols, sterols, statins, indole compounds, and enzymes. Mushrooms are also high in amino acids, nicotinic acid, riboflavin, vitamins B, C, and K, and pantothenic acid. Medicinal mushrooms also contain other compounds that further enhance tumor-fighting capabilities. They also have antibacterial and antiviral properties that assist the body in fending off diseases such as Smallpox, Polio, Hepatitis-B, HIV, Influenza, HSV-1, and HSV-2. They are immunological, anti-cancer, antioxidants, antihypertensive, cholesterol-lowering, liver protective, anti-inflammatory, anti-diabetic, antiviral, anti-microbial, psychotropic, antimalarial, antiprotozoal and much more! (6, 10, 11)

There is also the world of fermented foods, which are coming into full swing recently with the studies of how important gut health is. It is shown that over 95% of your serotonin is located in your gut. (7) When the gut is healthy it has the potential to regulate mood, appetite, sleep, relaxation and promote positive feelings, Fermented foods improve digestion and absorption of your food and are claimed to increase longevity. Fermenting foods increase the vitamin content in the foods including folic acid, pyridoxine, B vitamins, riboflavin, biotin, and others.

So whether these fungi are degrading organic matter and toxic waste and turning it into life, protecting organisms from outside invaders, providing the means to allow more nutrients to be absorbed by the organism, or producing mushroom fruit bodies to be eaten by animals for food, energy, medicine and nutrition these power allies are an integral part of the ecosystem. In all the ways fungi help to serve the outside ecosystem are the same way they can serve our human bodies internally as medicine. From breaking down and cleaning out toxins, protecting us against sickness, disease, bacteria, viruses, tuning up our bodies in order to allow vital nutrients to flow through us, and providing nutrition and energy, connecting neural pathways in our brains, breaking down emotional, mental, and spiritual blockages, and connecting us to the greater whole.
There are many ways to receive the medicine from these fungi. From tinctures, teas, capsules, double extractions, triple extractions, powders from mycelium, powders from fruit bodies, infusions, eating the fruit bodies, eating the mycelium, fermentation, cooking, brewing, soups, etc. This next section will provide a list of medicinal mushroom to work with and also some ways to work with them.

**How to Make Double Extracted Mushroom Tinctures:**

- To make tincture one should fill up a mason jar half way full with your broken up dry mushroom fruit bodies
- Fill up the rest with 190 proof ever-clear alcohol. This jar should be closed and labeled, kept in a cool dry dark place like a cabinet or a drawer and shaken once a day for at least a month.
- After the allotted time, one can strain this alcohol through cheesecloth into another mason jar or into tincture bottles.

In mushrooms there are alcohol soluble compounds and water-soluble compounds so a lot of mushroom medicine makers use a double extraction method. This method calls for the combination of tea (water) and tincture (alcohol) to get a full spectrum of water and alcohol soluble compounds. One can also do a 1:5 tincture, which requires us to weigh out the dried mushrooms. An example would be 300 grams of mushrooms to 1500ml of liquid.

**To Make Tea:**

- Strain the alcohol into another container so you are left with the mushrooms. Using cheesecloth to do this is great because you can squeeze out the alcohol soaked mushrooms. If you have a tincture press this is even better.
- Put them in a pot with 10 times more parts of water. Bring to boil and reduce to a simmer for at least an hour. You want to wait until the water level is reduced by half.
- This tea can then be added to the alcohol at about a 50/50 ratio to make a double extracted full spectrum medicinal liquid blend.
• The most typical dose that I use is 1-2 droppers’ full 2-3x a day. But this all depends on what mushroom you are using and what the person needs.

One can also make powders of the fruit bodies (mushrooms) or the mycelium. The mycelium method requires one to freeze-dry it, which isn’t accessible to the average person so it’s a lot easier to take the fruit body and grind it up until it’s a fine powder. One can chop/hammer it down into small pieces or if one has a very powerful blender that works the best. This powder can then be steeped into a tea, made into a tincture, used as breading for food, be put into capsules using a little capsule machine and empty capsules, put into honey, put into soups, into flour and used with cooking, sprinkled onto food, put into smoothies or whatever your imagination can think of. This is a general illustration of what’s possible. Different species will give different results. These preparations, the information in this section is not a replacement for any medication anyone is already on. This information should not be taken as medical advice or instruction. I am not a doctor, and I am not suggesting that any of these mushrooms will cure any disease.
Here is a short basic list of a few medicinal mushrooms and a list of medicinal qualities they have:

| **Auricularia auricular** (wood ear, tree ear) | ● Anti-inflammatory  
● Antioxidant  
● Anti-thrombotic  
● Anti-cholesterol  
● Cardio protective  
(6, 9, 10, 11) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Auricularia auricular" /></td>
<td></td>
</tr>
</tbody>
</table>

| **Fomitopsis officinalis** (Agarikon mushroom) | ● Spider and scorpion bites  
● Protects against noxious drugs after vomiting  
● Strengthens the stomach  
● Eases breathing difficulties  
● Benefits the kidney  
● Relieves sciatica and pains in the spine  
● Acts as an aperient (mild laxative  
● Good for disorders of the |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2.png" alt="Fomitopsis officinalis" /></td>
<td></td>
</tr>
</tbody>
</table>

---
<table>
<thead>
<tr>
<th>Conditions</th>
<th><strong>Ganoderma lucidum</strong> - (Ling zhi, reishi, “10,000 year mushrooms” “mushrooms of immortality” “spirit mushroom” “mushroom of spiritual potency”)</th>
<th>Liver diseases such as hepatitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>For troubles of the hypochondria and groin</td>
<td></td>
<td>Kidney inflammation</td>
</tr>
<tr>
<td>Diseases of the bladder and to eliminate stones</td>
<td></td>
<td>High blood pressure</td>
</tr>
<tr>
<td>Strenguary</td>
<td></td>
<td>Arthritis</td>
</tr>
<tr>
<td>Injuries of the Achilles tendon and shoulder pain</td>
<td></td>
<td>Neurasthenia</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helps indigestion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>epilepsy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relieves the chills of fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dropsy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaundice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helps heal bruises and bad effect of falls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney diseases with difficulty in passing urine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Menstrual insufficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hysteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dysentery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilepsy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood or heart deficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal weakness of the organs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phthisis (wasting diseases with night sweats (tuberculosis))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain in the hips, loins, joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6, 9, 10, 11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Insomnia/anxiety
- Bronchitis
- Asthma
- Supports the cardiovascular system
- Gastric ulcers
- Inhibits histamine release
- Hepatoprotective
- Anti-inflammatory
- Induces apoptosis
- Inhibits cholesterol synthesis
- Anti-viral
- Antioxidant
- Anti-tumor
- CNS sedation
- Anti-microbial
- Immune modulation
- Treats cancer and is created with spontaneous remission
- Suppresses allergies
- Hypertension
- Anti-aging
- Rheumatoid arthritis
- In a number of ancient Taoist works, they mention “chi” as a plant of many colors that bring happiness and immortality. In many texts, including Pen king and the Pie lu, the words chi and mushrooms are interchangeable. It is thought that in many texts are
<table>
<thead>
<tr>
<th>Talking about Ganoderma Lucidum</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Taste: sweet and slightly bitter</td>
</tr>
<tr>
<td>Energy: neutral, slightly warm</td>
</tr>
<tr>
<td>Channels entered - heart, liver, lung</td>
</tr>
<tr>
<td>● Actions - tonifies Qi and nourishes blood. Calms the shen, transforms phlegm and stops cough</td>
</tr>
</tbody>
</table>

**Lentinula edodes** - (shiitake)

- Anti viral
- Cancer protective
- High levels of B vitamins and provitamin D2
- Gastric cancer
- Increased survival, reduced side effects from chemotherapy and improved quality of life of life in patients with colorectal, hepatocellular breast cancer and metastatic prostate cancer
- Controls cholesterol
- Improves liver function
- Protects from hepatitis B
- Increases the T-cell count in HIV patients with AIDS symptom
- Anti microbial
- Anti candidal
| Taste: sweet  
| Energy: neutral  
| Channels entered: stomach, spleen, lungs  
| Actions: tonifies Qi and blood  
| (6, 9, 10, 11) |

**Trametes versicolor** - (turkey tail)

- Lowers cholesterol
- Immune enhancing
- A meliorate chemotherapy and radiotherapy side effects
  - Stomach cancer, colorectal, lung cancer, esophageal, nasopharyngeal, breast cancer, and cervical/uterine cancer
- Anti-HIV
- Reduces the frequencies of herpes
- chronic fatigue syndrome
- Hepatoprotective

Taste: sweet and slightly bitter
Energy: slightly warm
Channels entered: lung, liver, spleen
Actions: dispels damp, reduces phlegm, nourishes the mind
(6, 9, 10, 11)
Psilocybe spp. - (magic mushrooms)  

Contain psilocybin, psilocin, baeocystin, norbaeocystin

• Helps terminally ill go through their dying process
• Helps people open up and discuss problems with a therapist
• Depression
• Helps break addictions
• Catalyst in learning how to eat more healthfully
• Developing a sensitivity to the cycles of nature and how we can be in harmony with its processes
• Can help to guide a receptive person through the often-held attachment of inhabitants of industrial societies to controlling nature, rather than enjoying the stay on mother earth as a caretaker and cohabitant with all the other animals, plants, and living beings.
• Catalyst in learning how to heal specific ailments
• Heightened sensitivity to the beauty and mystery of nature
• Increased reverence for life
• Pain
• OCD
• Anxiety
- Increase sense of well-being and life satisfaction
- Cluster migraines
- Schizophrenia

There is even a theory by Terence Mckenna, made famous by his book *Food of the Gods* that describes the theory of Humans evolving so quickly and developing the tool of verbal communication because through wild harvesting humans found psilocybin-containing mushrooms and ate them having mystical experiences of the Divine, opening their minds and consciousness’s and the only way to communicate these experiences was through developing verbal language

(6, 9, 10, 11, 12)

<table>
<thead>
<tr>
<th>Cordyceps Spp.</th>
<th>Anti-aging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improves brain function</td>
</tr>
<tr>
<td></td>
<td>Improves antioxidative enzyme activity</td>
</tr>
<tr>
<td></td>
<td>Improves cardiovascular function</td>
</tr>
<tr>
<td></td>
<td>Improves athletic performance (1990's record breaking Chinese athletes for example]</td>
</tr>
<tr>
<td></td>
<td>Improves energy output and oxygen capacity</td>
</tr>
<tr>
<td></td>
<td>Improves sexual function and has possible benefits for female libido. Increases levels of male sex hormones, improves testes</td>
</tr>
</tbody>
</table>
| **Cordyceps militaris** | morphology, sperm quantity, and quality Increases female fertility
| | Triggers release of insulin Increase hepatic glucokinase Increase sensitivity of cells to insulin
| | • Hepatoprotective, inhibits hepatic fibrosis and helps restore liver function
| | • Kidney protective
| | • Treats respiratory ailments, including asthma
| | • Antiviral, used in the treatment of viral infections including HIV and hepatitis
| | Anti-cancer
| | Stimulates endocrine
| | Builds bone marrow
| | • Taste: sweet
| | • Energy: slightly warm
| | • Channels entered: lung and kidney
| | • Actions: tonifies kidney - yang and lung - 3nn. Augments the essence. Transforms phlegm and stops cough
| (6, 9, 10, 11) |

**Flammulina velutipes** – (Enokitake)

| Anti-cancer
| Anti-viral
| Food allergies
| (6, 9, 10, 11)
**Grifola frondosa** - (Maitake, Hen of the woods)

- Cancer, increases benefit of chemotherapy, and alleviates side effect of chemotherapy (loss of appetite, vomiting, nausea, hair loss, leukopenia,) synergy between D-fraction and vitamin C
- Helps improve diabetes and blood pressure/blood sugar level
- Reduces cholesterol
- Reduces hypertension
- Antipyretic
- Anti-gonorrheal
- Diuretic
- Improves stomach and spleen conditions and hemorrhoids
- Calms the mind and nervous system
- Neuralgia
- Palsy
- Various forms of arthritis
- Anti-cancer effect in lung, stomach, breast, liver, colorectal, prostate, bladder and liver. As well as leukemia
- Anti-tumor

(image credit -20)
*Hericium erinaceus* - (lion's mane)

- Effects of dementia
- Improves functional capacity (understanding, communication, memory, etc.) and functional independence (eating, dressing, walking, etc.)
- Improves MS
- Improves neuropathy
- Recover from nerve damage
- Anti-MRSA activity
- Anti-bacterial
- Anti-gastritis
- Improves digestion
- Gastric ulcers
- Neurasthenia
- Boosts immune system
- Extends the life of cancer patients
- Anti-fungal
- Anti-tumor
- Useful for bronchitis
- Nerve tonic

Taste: Sweet

Channels entered: spleen, stomach, heart
Actions: strengthens the stomach and regulates Qi, tonifies the spleen and promotes digestion, calms the shen and...
Inonotus obliquus - (chaga)

- Cancer: inoperable breast cancer, hip, gastric, parotid, pulmonary, stomach, skin, rectal and Hodgkin's disease, malignant brain tumors, ovarian cancer, leukemia, malignant head and neck squamous cell cancers
- Anti-viral
- Tuberculosis
- Stomach ache
- Heart, liver or stomach disease
- Worms
- Internal cleansing agent
- Prevents intoxication and regurgitation
- Improves appetite
- Reduces pain
- Inhibits oxidative stress
- Anti-tumor
- Improves immune system
- Psoriasis
- Antioxidant

Fomes fomentarius - (tinder polypore, tinder conk)

- Reduces stasis of digestive vitality
- Rheumatism
- Arthritis
- Esophageal cancer

strengthens the brain.
(6, 9, 10, 11)
• Gastric future carcinomas

(6, 9, 10, 11)

**Pleurotus ostreatus** - (Oyster mushroom)

• Joint and muscle relaxation
  • lumbago, numbed limbs, and tendon and blood vessel discomfort
• High cholesterol
• Antioxidant
• HIV
• Antitumor

(6, 9, 10, 11)
We must treat our bodies as potential toxic sites contaminated by pollutants from industry. Mushrooms are another solution for remediating these toxins. If we are working on remediating a toxic site we must nourish our bodies and take care of ourselves and the people around us with the same manner as we heal the earth. Our bodies work on a principle called selective uptake, meaning that the body will select whatever minerals are available no matter the quality or if it’s contaminated. If we are lacking calcium and strontium-90 is available (radioactive), our bodies will uptake strontium-90 since it is similar to calcium. This is something to keep in mind when remediating a site or encountering people who have been exposed. If we do not take care of our bodies and provide the proper amount of nourishment we could replace vital minerals with harmful chemicals and radiation wreaking havoc on our health.

Below is a list of herbs, plants and foods that can be put in the remediators tool belt. This information should not be taken as medical advice or instruction. I am not a certified doctor. If a toxic substance affects you or anyone you know, please seek help from a health care professional. Some of the different plants interact poorly with prescription medication. Please consult your doctor before making any changes to your diet or medication.

This chart and the one after have been adapted from Leila Darwish’s book *Earth Repair*. If this information intrigues you and you want to learn more, I highly recommend buying her book! The following pages come from one source, which is an incredible resource for anyone interested in this topic.
<table>
<thead>
<tr>
<th>Group</th>
<th>Function</th>
<th>Common Examples</th>
</tr>
</thead>
</table>
| Minerals, Vitamins, and nutrients | When our bodies have all the nutrients, vitamins and minerals we need we are less likely to uptake toxins to replace them. (2) | ● Sea Vegetables (Minerals including iodine and alginate)  
● Dandelion (vitamins and minerals)  
● Hawthorn berries (bioflavonoids)  
● Lemon balm (minerals)  
● Milky oat tops (minerals)  
● Miso and other fermented foods (minerals and protein)  
● Bee pollen (vitamins and protein)  
● Whole grains (bioflavonoids, fiber, minerals, protein)  
● Dark-colored fruits and vegetables (bioflavonoids, fiber, minerals, protein)  
● Nutritional yeast (protein, vitamins and minerals)  
● Garlic and white oak bark (minerals) (2) |
| Astringents                    | Tighten tissues and causes pores to close. This is a barrier against chemicals and radiation. (2) | ● Yarrow + eleuthero - (Protect the body from radiation and electromagnetic waves.)  
● Wild cherry bark + Kudzu - (helps mitigate symptoms from crude oil exposure.)  
● White oak bark, Wild Cherry Bark, |
<table>
<thead>
<tr>
<th>Category</th>
<th>Functions</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resins, Gums and Demulcents</td>
<td>Helps maintain the integrity of the body’s tissues and fluids. Resins and gums tend to draw out and trap unwanted debris so they can be removed from the body. Demulcents are slimy and lubricate the tissues.</td>
<td>Resinous plants - chaparral, tree resins, grindelia, lomatium, and balsamroot. Demulcent plants - mullein, marshmallow, and slippery elm.</td>
</tr>
<tr>
<td>Diaphoretics</td>
<td>Plants that promote sweating to release heat and toxins from the body. Best if they are taken with hot tea, or combined in a hot bath with Epsom or sea salt.</td>
<td>Yarrow, red clover, elder flowers or berries, boneset, mugwort, calendula, chamomile, garlic, horseradish, rosemary, oregano, peppermint, lemon balm, lavender cilantro and hyssop.</td>
</tr>
<tr>
<td>Diuretics</td>
<td>Promotes detoxification by flushing/protecting</td>
<td>Dandelion, nettles, cleavers, golden rod, uva ursi, chamomile, agrimony, chicory, cornsilk,</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Examples</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Expectorants</td>
<td>Help remove toxins from the lungs. Best when combined with astringents and demulcients (2)</td>
<td>Wild cherry bark, elecampane, grindelia, mullein, angelica, basil, celandine, coltsfoot, garlic, hyssop, red clover, thyme and yarrow. (2)</td>
</tr>
<tr>
<td>Emetics</td>
<td>If a chemical is swallowed, high amounts of emetics will induce vomiting (2)</td>
<td>Boneset, chaparral, lobelia, and vervain (2)</td>
</tr>
<tr>
<td>Laxatives</td>
<td>Commonly high in fiber and increase the flow of water to the colon, promoting the excretion of solid wastes. (2)</td>
<td>High fiber plants: Flax, psyllium, whole grains, vegetables, legumes, beans and fruits, yellow dock, cascara sagrada, senna, chicory, fennel, Oregon grape root and plantain. Also coffee, tobacco (highly toxic and addictive), fermented foods, and probiotics like kimchi, sauerkraut, pickles, kombucha, and probiotic capsules can work as laxatives as well. (2)</td>
</tr>
<tr>
<td>Bitters</td>
<td>Stimulation of the digestive systems. Also help the body remove toxins by causing the gallbladder to increase</td>
<td>Mugwort, wormwood, goldenseal, yarrow, boneset, gentian and hops. (2)</td>
</tr>
<tr>
<td>Category</td>
<td>Function</td>
<td>Herbs and Ingredients</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Alteratives</strong></td>
<td>Bile production, which breaks down fats and helps the body remove waste and toxins.</td>
<td>Dandelion, yellow dock, burdock, sassafras, spikenard, echinacea, turmeric, chickweed, cleavers, gotu kola, holy basil, prickly ash, celery root and seed, spilanthes, and red clover. (2)</td>
</tr>
<tr>
<td><strong>Other detoxifiers</strong></td>
<td>Cleanses and purifies the blood, the lymphatic system and the mucous membranes. Also help the body's action of flushing out toxins and metabolic wastes</td>
<td>Lemon, sumac bark, japanese knotweed, and fermented foods. A combination of chlorella, cilantro and sometimes alpha-lipoic acid is a good combination to detox heavy metals. The chlorella binds to the heavy metals and the cilantro (2)</td>
</tr>
<tr>
<td><strong>Rest and Relaxation</strong></td>
<td>Soothe and rebuild the nervous system</td>
<td>St. John’s wort, yarrow, chamomile, hyssop, lavender, calendula, agrimony, and catnip. Plantes the encourage sleep: valerian, california poppy, wild lettuce, passionflower, and hops. (2)</td>
</tr>
<tr>
<td><strong>Revitalization and resilience</strong></td>
<td>Improving body’s integrity, fights against stress and fatigue, protective layer, helps</td>
<td>Eleuthero, devil’s club, American ginseng, astragalus, ashwaganda, licorice root, Cordyceps mushroom, holy basil, hyssop, milky oat tops, lemon, maca, schizandra</td>
</tr>
<tr>
<td></td>
<td>maintain balance in the ebbs and flows of whatever is thrown at you. (2)</td>
<td>peppermint, and rhodiola (2)</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>phytoestrogens</td>
<td>Less likely to uptake the toxic endocrine-disrupting substances in the environment like PCB, DDT and dioxin (2)</td>
<td>Red Clover, Legumes (chickpeas, soybeans), licorice, flax seeds, blueberries, hawthorn (2)</td>
</tr>
</tbody>
</table>
| Liver Support      | Helps filter toxins                                                      | Milk thistle seed - (grind the seed, take two to three tablespoons every three to four hours for a week or so, then follow with two tablespoons a day for up to six months)  
  *Bupleurum falcatum* (Chinese thoroughwax) - works harder than milk thistle, only recommended for 2-3 weeks. Recommended dose is $\frac{1}{2}$ teaspoon of tincture two-three times a day  
  Bitter plants - Dandelion root, artichoke leaf, bitter greens (e.g. radicchio, arugula, dandelion leaves) have bioflavonoids that are great at increasing the liver function and decreasing inflammation.  
  These three combined with ginger (anti-inflammatory) and fennel, to help with nausea and appetite loss that might accompany acute poisoning. You also don’t want the toxins which you are trying to detox to absorb back |
into you so lots of fiber will help flush out the toxins via bile. The herb celandine (15-30 drops) forces bile to come out of the liver in cases of serious liver damage from chemical poisoning. Also drinking lots of water is a great way to flush out toxins from your liver. (2)

| Carcinogens/ Cancer-causing contaminants | Cancer takes a long time to develop. Fighting cancer takes a lot of long term planning and prevention/protection/healing. (2) | Medicinal mushrooms - modulate the immune system, increasing immune system vigilance to cancer cells, and help with multiple chemical sensitivity. (2) |

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Counteracting Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Calcium, fiber lecithin, magnesium, vitamin c, zinc. (2)</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cabbage family vegetables, calcium, copper, fiber, iron, manganese, pectin, selenium, vitamins c and D, zinc (2)</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Eleuthero, vitamins A, B complex and C, cysteine, bee pollen, nutritional yeast (2)</td>
</tr>
<tr>
<td>chlorine</td>
<td>Vitamins C and E (2)</td>
</tr>
<tr>
<td>copper</td>
<td>Manganese, molybdenum, vitamin C plus, bioflavonoids, zinc (2)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>fluoride</td>
<td>Calcium, magnesium, vitamins C and E (2)</td>
</tr>
<tr>
<td>Hexavalent chromium</td>
<td>Vitamin c (2)</td>
</tr>
<tr>
<td>Lead</td>
<td>Chlorophyll, cysteine, eleuthero, iron, legumes and beans, pectin, lecithin, phosphorus, cabbage family vegetables, selenium, sodium alginate, vitamin A, B1, B2, B complex, C, D, and E, Zinc. (2)</td>
</tr>
<tr>
<td>Mercury</td>
<td>Cabbage family vegetables, calcium, fiber, lecithin, pectin, selenium, sodium, alginate, vitamins A, B complex, C and E, cysteine, nutritional yeast. (2)</td>
</tr>
<tr>
<td>Nitrates and nitrites</td>
<td>Bee Pollen, Lecithin, Nutritional Yeast, Vitamins A, B complex, C and E (2)</td>
</tr>
<tr>
<td>Nitrogen dioxide and ground level ozone</td>
<td>Bee pollen, eleuthero, panax ginseng, vitamins A, PABA with B complex, C and E (2)</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>Calcium, pantothenate, cysteine, iron, selenium, vitamins A, B1, B2, B complex, C and E (2)</td>
</tr>
<tr>
<td>Endocrine disrupters (alkylphenols, DDT, PCBs, phthalates, parabens, bisphenol A, polybrominated diphenyl ethers, polychlorinated biphenyls, dioxin)</td>
<td>Bee pollen, lecithin, vitamins A, B complex and C, fermented foods, sauna therapy, juice fast and other detox methods (2)</td>
</tr>
<tr>
<td>cesium-137</td>
<td>Potassium (2)</td>
</tr>
<tr>
<td>Substance</td>
<td>Vitamin</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>cobalt-60</td>
<td>Vitamin-b12 (2)</td>
</tr>
<tr>
<td>iodine-131</td>
<td>Iodine (2)</td>
</tr>
<tr>
<td>Plutonium-238 and 239</td>
<td>Iron (2)</td>
</tr>
<tr>
<td>Strontium 90</td>
<td>Calcium (2)</td>
</tr>
<tr>
<td>Sulfur-35</td>
<td>Sulfur, chaparral (2)</td>
</tr>
<tr>
<td>zinc-65</td>
<td>Zinc (2)</td>
</tr>
</tbody>
</table>
Part III: How to Apply Mycoremediation

There are many techniques and methodologies to remediate a polluted site. Below is a chart, which describes some techniques widely used today:

Many of these techniques are very costly but are widely commercially used. Industrial remediators gravitate towards the physical and chemical methods since they more often than not take a shorter time to remediate the site, but at a cost of using harsh chemicals and making further physical modifications to the land. The alternative to these harsh practices is biological
methods. Although the focus of this book is on mycoremediation, many methods of remediation must be used including phytoremediation and bio or bacterial remediation as well. To restore nature to its natural state, we must implement natural techniques, and use all the kingdoms nature offers.

Questions to consider:

- Where contamination is (or might be) located in the site?
- What concentration of contamination(s) is/are there in/on the site?
- How old is the site?
- It is the site tied up in any lawsuits?
- Who polluted this site? Are they responsible for cleaning it up?
- How variable concentrations may be and how much spatial patterning may be present
- How are the contaminants moving through the environment?
- Is there a potential for them to disperse through the environment?
- Who might be exposed to contaminants or harmful degradation products?
- How can one help mitigate the risk of exposure from these toxins?

- Factors that Affect Mycoremediation
  - Contamination Concentration

Too high of a concentration will limit, stunt or even kill mycelial growth.
- **Site characteristics**
  This includes most everything below. Also includes the layout of the side. It is on a heavy slope, it is in a very fast moving river. Some physical factors could limit the possibility of fungi being used.

- **CEC** - Cation Exchange capacity determines the quantity of nutrients a soil can hold. PH, water concentration and microbial populations affect CEC. They directly influence heavy metals interactions, with high CEC content in soils being able to hold more heavy metals than a low CEC level soil. (1)

- **PH** - different pH’s affect not only the microbial community including mycelium but also include whether some heavy metals are soluble or not.

- **Nutrients**
  Microbes need nutrients to grow

- **Temperature**
  Too cold and very limited microbes can grow, and if they do grow they grow very slowly and digest the contaminants very slowly as well. On the flip side, too hot and it may kill off the microbes.

- **Money**
  Remediation projects require a lot of funding not only to implement the process but also to maintain it, test it, etc.

- **People/politics**
  The site could be tied up in a lawsuit, which will prevent you from doing work on the site. They company who made the pollution in the first place could not want you meddling with the site and putting publicity on the site for fear it may make them look bad. Or simply the team of bioremediators that you are working with has disagreements and splits up. No team = no remediation.
Steps

1. Do research on the site (history, ownership of site, suspected contamination, water flow, soil, impact on flora fauna and local humans, politics/legal workings, logistics, accessibility, possible funding, etc)
2. Get a team
3. Make a plan
4. Funding/community outreach
5. Testing
6. Bench scale
7. Pilot test
8. Full on remediation

Team: roles you might want to fill

- Health and safety (knowledgeable about herbs, trained in first aid, CPR and more, doctor/nurse, taken HAZWOPER training etc.)
- Fundraising (great at writing grants, and outreach to people to get $ to fund projects)
- Lab rat (great lab skills for cultivating fungi, running bench scale tests, cloning, testing, running experiments, etc.)
- Field coordinator (great people skills, organizer)
- Mushroom specialist (knows a lot about cultivation, low tek skills, etc)
- Bacteria specialist
- Plant/phytoremediation specialist
- Hydrologist (the way water affects the site and carries pollutants)
- Soil expert (this is important to know how the chemicals/pollutants and the microbes are interacting with the soil)
- Composter (always need compost/good soil for the project)
- Politics (it’s so necessary to work the game of politics when cleaning up super toxic sites that affect ecosystems, and communities, that have ties in political interests)
Communication is key. Get your group and communicate as openly and honestly and as often as possible. Go through all the details of the site and ask and answer any questions that come up. Design a plan for moving forward that works with the logistics and constraints of the site and the resources you have available.

Grant writing/crowd funding, outreach might be the next step. If you already know your site is contaminated the next step is to get money to figure out how much it is contaminated and move forward with treating the site and testing to see if what you have done was effective.

If you know anyone interested in this who is still in university, they might want to take this up as a project to get credit. There is always funding at universities that can definitely be put to great use. The mycological society of America had grants they give out that you can definitely apply to. There are sometimes grants given out by the EPA depending on how big your project is. You can find wealthy people looking to fund your project. The non-profit Corenewal offers to umbrella their non-profit status to other organizations, which makes getting grant money a lot easier and also gives incentive for rich people to donate to get a tax write off. There is also the realm of crowd funding with indiegogo, go fund me etc. Which some people have success with and some people don’t. Lastly you can get a really well paying job, buy your essentials and pay out of pocket, but it’s always better to find someone else to pay for it! Rule of thumb when asking for money: always ask for more than you need because more than likely you will not get all that you ask for.
Testing

Making friends with local scientists and labs is crucial for the testing phase. Testing for toxins adds up really quick when in a remediation project. There are various DIY ways to find the pollutant and the concentration without paying for a lab to do it for you. One problem with a lot of these sites is that there is a cocktail of pollutants that makes it very difficult to separate and analyze them individually. Thin Layer Chromatography is a method of putting compounds in a liquid solution of the bottom of a sheet of glass, plastic, or aluminum soil that has been coated with a thin layer of cellulose, silica gel, or aluminum oxide. This sheet can be placed on a shallow plate with a solvent. The solvent will combine with the drops of the solution and the compounds in the mixture will begin to separate into different layers on the plate. Once separated, one can scrap off the layers and test them individually. This testing is usually done by a spectrometer, which is generally a very expensive machine. There is a company out there called Public Lab which is an open source research group that developed a technique on their website to make and use your own spectrometer for a few bucks using a webcam, a DVD disc, and some paper! (1) This can be hooked onto your phone as well!

(Image credit: 2)
Public Labs also has a great oil testing kit in the works that works on similar principles.
There is also a book that goes with it called “DIY Oil Testing” that you can find online for $10.50.

There are other DIY ways to see the toxicity level of different toxins in/on your site. Bioassays are methods of using living organisms including fish, crustaceans, worms, and plants that are sensitive to toxins to determine the toxicity of the site. If a site was say contaminated with atrazine. A series of dilutions of pure atrazine in can be set up and beans can germinate in the dilutions. The highest concentration of atrazine will kill the beans and they will not
germinate, then gradually getting better until the lowest dilatation beans are able to still grow a healthy plant. By making this scale you can plant a bean in your contaminated site and depending on how your bean grows you can put it side by side the scale you just made and determine around where the concentration of atrazine is. This method is described in Tradd Cotter's Book Organic Mushroom Farming and Mycoremediation. One can set up 14 test tubes with a series of dilutions of the chemical, with one being the control. Each test tube will start with 9 ml of water except the control, which will have 10 ml of water. One should prepare a 1% dilution of the chemical, and add 1 ml of this dilution to the first test tube. After this test tube is shaken up, 1 ml of this test tube is pipetted up and put into the second test tube, this is shaken and 1 ml of this is put into the third test tube and so on. The first dilution that was prepared was one part per one hundred of the toxin, the first test tube is one part per one thousand the second test tube is one part per ten thousand and so on. After one soaks 5 beans per test tube for 24 hours, one can plant the beans in separate containers making sure to label them and continue to water them with the leftover water in the test tubes.
One can also test biological contaminants by using a technique called cell counting. This is a tool that tracks the growth rates of organisms such as bacteria. This is incredibly important if one is working on a mycofiltration project to figure out the efficiency of the filter. One can buy a gram stain kit, which can be purchased, online or from many science supply stores for under $30. Or the Easy Gel coliform detection kits, that don’t have to the autoclaved, can be tested anywhere and you don’t need a microscope.

One can also get field-testing kits, which are portable and small scale, which one can do on site making it convenient especially if the site is nowhere close to a lab, saving time and money. PetroFLAG is a device that measures total petroleum hydrocarbons in soils which costs around US $850.00. The Hanby Field Test Kit tests for various petroleum products and PCB’s either in soil or water, which cost around US $1295.00. Clor-N-Oil and Clor-N-Soil are kits that test for the presence of PCB’s in soil and oil but do not test for the concentration. The cost of a 10-test kit is US $10.00. DEXsil L2000DX Analyzer is a device that measures the concentration of chlorinated organics in soil, water, dielectric fluids, and surface wipes, which costs US $4,333.00. Site Lab is a company that rents equipment that tests for compounds derived from petroleum based fuels in soil, sediment, and water which range from US $500-900 a week. (1)

It is also important to test the macro and micro biota, soil pH, CEC, and nutrient and mineral content.
Heavy Metals

Out of the 118 elements on the periodic table, 53 are considered heavy metals. Getting to know these metals, where they come from and the effects they have on the body/environment are very important. Substantial metals may lead to a wedge in cell membranes restraining the capability of precious nutrients moving into and out of the cells and may similarly lead to oxygen muscle impairment in nerves causing nucleic acid transmutations and finally cancer.

Arsenic (As) – The main way arsenic gets into the environment is the process of conserving lumber and board derivatives under pressure, casting, mining of non-iron elements and also usage of insecticides, pesticides and herbicides. Arsenic can also be found in light-emitting diodes, lead acid batteries, bullets and lead shots, pyrotechnics, semiconductors, metals and soaps.

If a person is poisoned by arsenic for a long time it can lead to cancer of the prostate, liver, kidney, bladder, lungs and also the skin. Also, can cause Vitamin A deficiency, and night blindness. Adverse effects of breathing the toxic inorganic arsenic in high levels include irritation of lungs, damage to throat and eventually death as a result of breathing impairment.

Contact of minimalistic levels of the arsenic element resulting abnormal heartbeat, impairment of blood vessels, reduced production of red and white blood cells, nausea and vomiting and redness of the skin. Nevertheless the composite can be transformed to a less toxic version of arsenic, arsenate via bioremediation. (1,6)

Cadmium (Cd) - Cadmium is one of the most prevalent heavy metal poisons and the industrial growth is dumping this lingering contaminant in the setting by scorching fossil fuels, usage of phosphate fertilizers, , sweltering coal, metropolitan compacted waste and producing of steel metals and alloys, ferrous-iron, non-ferrous metals and epoxy resin. Cadmium is also a bio product of making of zinc and its alloys. Sited in pigments, batteries, plastics, paint and metal lacquers.

Breathing in lingering heights of the element Cadmium may strongly lead to injury of lungs, and struggle and pain during ingesting, can cause diarrhea, nausea and vomiting. Long-
term low-level contact to Cadmium can lead to kidney diseases and Cadmium builds up in the kidneys. It can also lead to lung impairment and brittle bones. (1,6)

**Lead (Pb)** – Lead enters the environment in various ways. From Lead mining and smelting, fusible amalgams, pewters, masses, solders, as a radioactivity shield, metal in guttering material, lead-acid batteries, cladding, flashing, bullets and shots gutters, gutter joints, roof parapets, PVC plastic, electrical cord coating, coloring agents in ceramic glazes, additives lead-based semiconductors and aeronautics petroleum in piston-driven airplanes, and for photovoltaic cells and infrared detectors, lead based paints in older houses, buildings, and toys, old leaded gasoline, and pesticides for fruit orchards before the 1950’s.

Exposure to Lead damages the nervous system. Scientist have proven that lead enduringly diminishes the mental efficiency of kids, causing learning and behavior disorders as it accumulates in both soft tissues and bones. It also causes brain and blood syndromes and fairly is lethal to the heart, reproductive systems intestines, kidneys, and the bones. In small amounts, it causes minor upsurges in anemia symptoms and the body’s blood pressure. Chronic echelons of Lead contact causes kidney and also brain impairment, and in addition, miscarriages in pregnant women, reducing fertility in Men, and delaying puberty in girls. (1,6)

**Chromium (Cr)** – One can find Chromium in the environment from attrition of rocks that usually contain chromium and volcanic eruptions. The metal is similarly disseminated into the environment in the process of wood preservation, pigments and dyes, steel formation, brick formation, leather tanning, cement, car brake lining, catalytic converters, and primer paint.

Chromium contact usually leads to exasperation to skin and nose, itching sensation, sneezing, nosebleed, liver impairment and even cancer. (1,6)

**Mercury (Hg)** – Mercury can be found in the manufacturing of industrial chemicals, electrical and electronic appliances, dye, gold recovery, thermometers, electrical switches, float regulators, explosives, electrochemistry, tooth fillings, medical products, gold mining, batteries, coal plants, mascara, fluorescent bulbs, coolant in some nuclear reactors, barometers in some herbicides and wood preservatives pre 1995, chlorine, caustic soda, and mercury mines. When mercury gets trapped in anaerobic conditions in the environment it is converted into methyl mercury, which is a more toxic form of mercury. Minamata Bay, Japan and several other mercury poisoning incidents illustrated the tragic human consequences of methyl mercury bio magnification in aquatic ecosystems. Current scale of human poisoning in Amazon River basin is
staggering. It is also an effectual lodestone for gold. The initial California sappers regularly crinkled gutters with mercury to amalgamate the precious metal.

Exposure to mercury causes irritation of the eyes, lungs and rashes to the skin. A powerful toxin Methyl Mercury that majorly affects the nerves has the capability of impairing neurological growth of fetuses and children and may also depreciate and impair the central nervous system of grown-ups. Tapering of the pitch vision, diminished balance, speech and hearing impairment and impassiveness in feet and hands are signs of damage to the central nervous system. The neurotoxin similarly corrodes the skin, damages the mucous membrane, unintentional muscle movement and difficulty in swallowing and chewing. With very high levels of exposure, symptoms could include insanity, paralysis, coma and death. (1,6)

**Cesium (Cs)** – Cesium can form 39 different isotypes, which most of which are radioactive. The most notable is Cs-137, which was abundant in the radioactivity in the fallout area surrounding Chernobyl and in areas in Japan and North America, which were affected by the Fukushima Reactor meltdown in 2011. (1,6)

**Selenium (Se)** – Selenium exists in the soil in four states depending on the soil’s Ph, redox potential, and overall composition. The four states are: Fundamental selenate (SeO4^{2-}), selenite (SeO3^{2-}), Selenide (Se^{2-}) and Selenium (Se)(1,6)

Additional substantial metals to monitor are Cobalt (Co), Antimony (Sb), Beryllium (Be), Barium (Ba), Selenium (Se), Copper (Cu), Iron (Fe), Uranium (U), Thallium (Ti), Lithium (Li), Aluminum (Al), Zinc (Zn), Manganese (Mn), Nickel (Ni), Silver (Ag), Molybdenum (Mo), Tin (Sn) and Vanadium (V) some of these are essential at trace amounts.

Heavy metals are found naturally in rocks, soil systems and bedrock and become released into our environment through the erosion of these substances or the eruption of volcanoes. When this happens it’s generally at such a low concentration that it has little to no impact. Where heavy metals get dangerous is when they are concentrated during the processes of industrial ore extraction and processing, or waste deposition making agrochemical fertilizers, sewage sludge, pesticides, metal mining, smelting, oil and gas operations. When heavy metals enter the environment they are either bound or unbound. They can bind to clay particles, which limit their
movement, not posing a threat onto living organisms. When they do not bind to clay particles, they are free to move around the environment. As stated above heavy metals not only inhibit the cell membranes, limiting the ability of nutrients to move in and out and also cause oxidative tissue damage but actually replace essential elements in the body which leads to enzyme pathway malfunction, overall degradation, and mineral deficiency. (1)

There are four ways to remediate heavy metals with fungi:

1. Mycosorption,
2. Solubilization,
3. Translocation

**Mycosorption** is the process of using the fungal mycelium to bind up the heavy metals via an ion exchange mechanism. Mycosorption is the process of binding heavy metals to the surface of mycelium through the action of an ion exchange to later be chelated, adsorbed, crystallized, precipitated, entrapped in the polysaccharide cell wall, and then diffused through the well wall and membrane. It has been shown the dead mycelium can still sorb heavy metals on the surface of the mycelium. Many different factors affect the efficiency of this sorption: ambient pH, ionic form, concentration of the metals, the functional site on the fungal tissue, the fungal species, temperature, and the presence of other ions. The practice of mycosorption is best practiced to clean up heavy metal contaminated waterways so that the water can pass through this mycofilter while the mycelium binds up the heavy metals. This practice can also be done to capture precious metals as well. (1) "$21 billion per year in gold and silver alone goes into making electronics. In fact, the bulk of that $21 billion per year ends up in a landfill." – (7) In 2014, VTT Technical from Finland used this mycosorption process to salvage 80% of the gold produced through the processing of old cell phones and other electronics. "The first step is crushing the old phones into a fine powder. That powder is sieved and passed through the mycelium, which was chemically engineered to attract gold. The researchers say this process recovers 80 percent of the gold, compared to just 10 or 20 percent in the common but toxic chemical processes." – (8)

**Solubilization** is the use of mycelium to make metals more soluble and/or immobilize these elements by producing various metabolites that cause reduction, methylation or
dealkylation reactions. These metabolites are organic acids, siderophores, and other compounds. Organic acids are negatively charged and form complexes with positively charged metal cations. Siderophores are low-molecular-weight ligands that chelate and solubilize environmental iron (Fe (3)) for their own metabolism. Other compounds bind with metal either by releasing into the environment or staying on the surface of the mycelium. An example would be the arbuscular mycorrhizal fungi, which release go-betweens which include metallothionein, phytochelatin and glomalin, which upsurge halt of substantial metals. The process of solubilization is best practiced with using mycorrhizal fungi in combination with plants on contaminated soil sites. (1)

**Translocation and mycoaccumulation** is the action of accumulating toxins into mycelial networks. Heavy metal ions and radioactive isotopes can be channeled through the mycelial network and into fruiting bodies, which is essentially the mycelium’s way of purging them out of the soil. (1) This may lead into more problems than solutions though. If the mycelial network is pumping all these radioactive isotopes and heavy metal ions into their fruiting bodies, they are also food for animals, which can damage the environment and local life even more. Also, if nothing eats the mushrooms, they will soon decompose and enter the soil once more. A “whack-a-mole” strategy can be developed where you have people always on watch to see when these contaminated mushrooms pop up and when they do they can be picked and disposed of correctly. But then the question lies “what does one do with a contaminated mushroom?” There are various answers. One could ship the mushrooms to a landfill or other toxic waste disposal site. If those are inaccessible for you, one can make a lined pit to dump them in and plant a non-fruit bearing tree over it to hyperaccumulate the heavy metals. Worm castings can also be used to potentially bind up the cations. The last thing one could do is put them in a constructed wetland where the PH is above 5 where bacteria converts meals sulfates into sulfides where they are very stable and insoluble, allowing them to stay at the bottom of the wetland for decades. (1)

Other methods for remediating heavy metals are biostimulation, adjusting PH and chitosan. Biostimulation is the use of phosphates in compost to real metal adsorption and precipitation rates. One can poke holes in contaminated sites, and pour compost tea in the holes, increasing aeration and beneficial remediative microbes. Adjusting PH changes the mobility of many heavy metals. At a low PH, metals tend to become free ions or soluble organometallics. At a high PH the metals tend to become insoluble. This raise of PH can be administered through the
addition of lime. Chitosan is a water soluble, biodegradable commercial product made from modified shrimp shells that carries a free amine functional group that binds to heavy metal cations. (1)

One more high tech mycoremediation approach would be the use of fungal biosorption reactors for heavy metals in water. The types of reactors commonly used are: batch stirred-tank reactors, continuous-flow stirred-tank reactors (CFST), fixed packed-bed reactors, immobilized reactors, pulsating-bed reactors, fluidized-bed reactors, multiple bed-reactors, and others. Common fungi that are used in these bioreactors are Rhizopus arrhizus, R. P. sanguineus, Saccharomyces cerevisiae, Trametes versicolor, Ganoderma lucidum, Fomitopsis carnea, Schizophyllum commune, Stereum hirsutum, Aspergillus oryzae, A. niger, Pycnoporus sanguineus, etc. (11)
Chemicals

The next most common group of toxins, which is probably the most abundant, is chemicals. As talked about above is how the enzymes which fungi use to degrade wood are the same ones used to degrade chemicals. Saprophytic fungi or fungi that live off dead or decaying matter can be broken up into three sections: Brown Rot Fungi, White Rot Fungi, Soft Rot fungi. Brown Rot fungi digest the cellulose and hemicellulose leaving behind the lignin. These fungi have not been heavily researched for their mycoremediation capacities. The next group, the White Rot Fungi is the most heavily researched group of fungi, which degrade the lignin. The last group is soft rot, which has not been heavily researched but is incredibly interesting. Ascomycetes and micro fungi slowly degrade tree species that white rot and brown rot won’t touch because it is too cold, too hot, or too wet. This ability to degrade things that are too extreme for white rot and brown rot makes it seem like a great group to study for mycoremediation but has yet to be studied intensively.

White rot fungi are able to produce extra cellular oxidative ligninolytic enzymes, which are able to completely mineralize lignin and carbohydrate compounds of woods to co2 and h20. Lignin is the hardy layer attached by covalent bonds to the hemicellulose and cellulose walls of a plant, which is what gives the plants protection and rigidity. It is a three dimensional aromatic polymer said to be the most difficult biopolymers to be degraded by microbial enzymes. Fungi have the hard task of bio converting the lignocellulose waste into basic usable molecules. White-rot fungi mostly use three specific enzymes that can break down these industrial wastes: lignin peroxidase, manganese-dependent peroxidase, and laccase. Some fungi just produce one of these enzymes, some produce two, and a handful, which are most widely used for mycoremediation, are able to produce all three. Fungi also produce low-molecular-weight oxidants that create H202 (hydrogen peroxide), from peroxide provided from the food source (cellulose, hemicellulose, or glucose) (1). Lignin Peroxidase, Manganese- peroxidase and laccase break apart the h202 into h20 and a free radical oxygen atom. Once the enzymes start to “break open” lignin, it creates a backdoor access for these free radical oxygen molecules to sneak in and bounce around randomly stealing electrons from lignin’s phenol rings and side chains until the structure has been degraded into carbon dioxide, ammonia, chlorides, and water. This
same free radical oxidation is the same mechanisms that cause rusting of metals, browning on apples, and the patina on copper. What makes this free radical oxidation mechanism so incredible is that they are nonspecific non-stereo selective and effective against a broad spectrum of aromatic compounds (11). This means that any molecule that is close to lignin and/or cellulose, are able to be broken down by fungi.

The most common chemicals that one might fungi into that fungi have the incredible ability to break down are: Persistent Organic Pollutants (POPs), Polychlorinated Biphenyls (PCBs), Dioxins and Furans, Dichlorodiphenyltrichloroethane (DDT) and other pesticides (herbicides, insecticides, and fungicides), Volatile Organic Compounds (VOCs), Benzene, Ethylbenzene, Toluene, Xylene, Trichloroethylene (TCE), Polycyclic Aromatic Hydrocarbons (PAHs), Radiation, Dyes, Nitroaromatics, Bisphenol A (BPA), Chromated Copper Arsenate (CCA), Dimethyl Methylphosphonate (DMMP), and industrial wastewater (Dairy, slaughterhouses, tanneries, silage, breweries, distilleries, and fruit processors, olive mills, oil sands).

**Persistent Organic Pollutants (POPs)** – Decoding by the name, POP’s are biological composites that persist in the atmosphere for an extensive period, biomagnifying by means of food webs then bioaccumulation in wildlife and people. POPs can travel over wind, air, soil, and water. They are located everywhere on the universe roaming far afield. POPs come about as of existing or former pesticides, insecticides, plus the manufacturing methods of creating drugs, thinners and polyvinyl chloride to name just a few. Despite several bans in the late twentieth century in a lot of republics, POPs persistency in the environment makes these a mark for remediation specifically in nations where there were no bars ordered. These pollutants have an impact on the endocrine, immune, the skin, neural, nervous, liver as well as the reproductive system, making one more prone to cancer. A little contact has been responsible for complications like birth defects as well as sterility. These pollutants are broadly categorized e.g., furans, Polychlorinated Biphenyls (PCBs), Dichlorodiphenyltrichloroethane (DDT), Dioxins besides other pesticides. (1,6)

**Polychlorinated Biphenyls (PCBs)** – PCBs find their way into the atmosphere by means of any electrical tool, capacitors, coolants and lubricants in transformers. Despite the USA and Canada implementing bans on them in the late 1970’s, PCBs are still leached from ancient goods produced before the ban. Examples of these goods are electrical equipment holding PCB
capacitors, ancient luminous light equipment, plastics, hydraulic tools, caulking agents, microscopes, hydraulic oils, and rubber products in addition to plasticizers in paints. Following the ban, a lot of people replaced the use of PCB’s with Polybrominated diphenyl ether, which additionally remain in our bodies for a extended periods and may lead to impairment of the brain as well as nerves. (1,6)

**Furans and Dioxins** – These are the byproducts of the manufacturing of timber that is treated with chlorine, industrial processes and combustion plus burning of fuels in automobiles with leaded gasoline, herbicides, casting of metals, the chlorine bleaching of the soft wood tissue for paper at pulp mills, burning garbage in the open, public as well as medical waste burning, fires caused by failing electrical equipment as well as wildfires, burning of PVC plastics, production of cement, papermaking in addition to other pesticides. What makes these toxins so dangerous is that they are so portable in the atmosphere and have a tendency to hold on to soil plus residues. Not only are furans and dioxins mobile but also they last in the environment for decades being very hard to break down. (1,6)

**Dichlorodiphenyltrichloroethane (DDT) and other pesticides – as of the late twentieth century,** DDT was banned in Canada as well as the USA. This was done since DDT is the most notorious and well known pesticides/insecticides having well known toxicity. DDT and other pesticides get released into the atmosphere by means of outflows from manufacturing plans as well as storage tanks, overflow from grounds that have been sprayed, agronomic spraying as well as dumping. There are over 250 pesticides currently used throughout the world, around 150 of those are herbicides. (54) Over 95% of herbicides and insecticides reach a destination other than their target. Other pesticides to put on the radar are Aldrin, alpha-hexachlorocyclohexane, Endrin, Beta-hexachlorocyclohexane, Hexachlorobenzene (HCB), Chlordane, Mirex, Chlordecone, Toxaphene, Dieldrin, Lindane, Endosulfan and Heptachlor. Commonly sprayed pesticides that fungi have been shown to degrade include Alachlor, Aldrin, Atrazine, Chlordane, DDT, Heptachlor, Lindane, Mirex, 2-4-D, and 2,45-T (The last two combined in equal parts make agent orange). In addition to having a terrible effect on humans they also have an overwhelming impact on the pollinator populace. The leaching of pesticides makes the agriculture industry the number-one polluter in the U.S. (55)

Other industrial chemicals and byproducts that are POP’s to also put on the radar would be short-chain chlorinated paraffins (SCCPs), Hexachlorobutadiene, , Pentabromodiphenyl ether
(penta-BDE), Polychlorinated naphthalene (PCN), Pentachlorobenzene, Octabromodiphenyl ether as well as Perfluorooctane sulfonate (PFOS). (1,6)

Volatile Organic Compounds (VOC’s) – Numerous VOCs are composites from dry cleaning agents, fuels, hydraulic fluids, paint thinners, as well as solvents. Judging by the name, volatile means that these compounds evaporate into the air very easily making them able to travel by air and wind. High exposures to Volatile Organic Compounds affects the heart, nervous, as well as neurological systems, and are a lot of the time carcinogenic. (1,6)

Benzene – it is a share of plastics, crude oil, dyes, gasoline, drugs, rubbers, pesticides, lubricants in addition to detergents. It is similarly used in manufacturing sceneries in the oil conduits, rubber industry, shoe manufacturers, oil refineries, coke and chemical industries besides gasoline-associated plants. It is also found naturally in erupting mountains as well as wild fires. It is a notorious compound that can lead to an infamous type of kidney cancer, leukemia and additional cancers of the blood. Inhaling Benzene can lead to lethargy, faintness, pains, body shakes, rapid head rate, mix-ups, mental fog, oblivion or even death. Consuming the compound through drinks and edibles may lead to nausea, stomach irritation, faintness, drowsiness, seizures and even death. It damages the bone marrow, reduces the red blood cells plus may lead to anemia. Benzene may additionally lead to bleeding, and may weaken someone’s immunity. Benzene can also lead to birth defects like anencephaly as well as a spina bifida, delivering underweight babies, slow formation of bones besides damage to the bone marrow. (1,6)

Ethyl Benzene – it is present in petroleum in addition to coal tar. Ethylbenzene is used as a solvent, an integral of tar, naphtha, artificial rubber, carpet glues, coats, inks, fuels, polishes, tobacco goods as well as pesticides. Contact with the compound may lead to sweltering of the skin, defatting, irritation to the mucosal film, eye, nose, upper respiratory area plus gullet, soreness, drying, dermatitis as well as constriction of the chest. Ethyl Benzene can also cause headache, dizziness, fatigue, and lack of concentration, effects to the respiratory systems, central nervous system, plus impacts on the liver, kidneys as well as eyes. (1,6)

Toluene – it is present in crude oil, gasoline plus additional fuels counting jet fuel from crude oil and in the development of coke from coal. It is also used to make coats, paint solvents, nail polish, glosses, glues, and rubber plus in some printing as well as leather processes.
Exposure to Toluene might lead to weariness, mix-up, faintness, drunken-type actions, amnesia, vomiting, and loss of appetite, hearing as well as color apparition. It additionally has an effect on the cardiovascular plus nervous systems and may even cause unconsciousness and/or death. (1,6)

Xylene – it is present in petroleum as well as coal tar, is highly flammable releasing it into the atmosphere. It is also found in airplane fuel, gasoline, paints, paint thinners, varnishes, solvents, cleaning agents, and in the printing, latex, and rawhide plants. Contact with the compound may lead to impairment of the liver, the central nervous system besides any additional body system. It can cause headaches, exhaustion, tetchiness, lethargy, vomiting, tenderness of the face, anorexia, a feeling of amplified body temperature flatulence, irritation of the eyes, gullet in addition to the nose, problems with mechanical synchronization besides poise, flushing, amplified salivation, body shocks, faintness, mix-up plus cardiac irritability. Increased contact with the compound might lead to dermatitis, mucosal outflow, central nervous system depression, anemia, conjunctivitis, dehydration of the nose, gullet & skin, bone marrow hyperplasia plus impairment to the kidney & liver. (1,6)

Trichloroethylene (TCE) – Trichloroethylene is a degreasing compound for metal and electronic fragments, for taking out oils, fats as well as waxes, metal cleaners plus polishes, a solvent for cellulose esters besides ethers, carpet-cleaning fluids, a cleaning fluid, spot removers, refrigerant as well as exchange of thermal energy fluid, typewriter rectification fluid, chemical for suffocating pests within, carrier agent in coats as well as glues, coat, a scouring for fabrics and as feedstock for producing biological elements.

Trichloroethylene exposure via breathing may lead to depression of the central nervous system, impairment of the kidney plus liver, pains, faintness, mix-up and then oblivion. It may also cause non-Hodgkin Lymphoma, kidney as well as liver cancer, leukemia, and other hereditary heart complications. (1,6)

Polycyclic Aromatic Hydrocarbons (PAHs) – This is a set of more than a hundred diverse partly explosive organic composites that come about in the incomplete combustion of organic elements like coal, fuel, garbage, tobacco and charbroiled meat. These structures are completely made up of carbon plus hydrogen in ringed structures in linear, angular, or clustered arrangements lacking any branching structures. It is similarly present in roofing & coal tar,
creosote, crude oil, incinerators, coke ovens, asphalt and sometimes found in some medicines, dyes, plastics and pesticides. The US Environmental Protection Agency has identified sixteen elements to be “priority pollutants.”

2-Ring: Naphthalene
3-Ring: Anthracene, Acenaphthene, Phenanthrene, Fluorene, Acenaphthylene
4-Ring: Benzo(a)anthracene, Fluoranthene, Chrysene, Pyrene,
5-Ring: Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene,
Dibenzo(a,h)anthracene
6-Ring: Benzo(g,h,i)perylene
7-Ring: Indeno(1,2,3-cd)pyrene

The two most common PAHs are benzo(a)pyrene and naphthalene. Two and three ring PAHs are very easily volatilized and degraded by bacteria, however higher weight PAHs are less water soluble, bind to clays and other exchange sites in soil where they will persist in the environment for years. Fungi possess a fantastic ability to degrade these higher weight PAHs into things like hydroxyl derivatives and quinones that tend to be less toxic than their parent compound(s) and can be fully mineralized to water and carbon dioxide by bacteria and other fungi.

Nevertheless, the breaking down of Benzo[a]pyrene by Pleurotus ostreatus is heavily aided through the occurrence of heavy metal cations plus mediators like 2,2’-azinobis-(3-ethylbenzothiazoline-6-sulfonate) in addition to vanillin (a breakdown product of lignin). A 15 mM concentration of copper was found to greatly boost the process of deteriorating chemically (74.2%), which gradually deteriorated as the clustering of Copper augmented. The extent of deteriorating chemically was augmented to 83.6 % the minute 5 mM of vanillin was introduced in the medium (Bhattacharya et al., 2014). A prospect is presented, consequently, that the occurrence of vanillin may boost the course of mycoremediation by means of white-rot fungi in real eld-applications. (10)

Polycyclic Aromatic Hydrocarbons are Mutagenic, tumorigenic, and carcinogenic. Exposure to it may lead to impairment of the red blood cell thus causing anemia,
suppression of the immune system, cataracts, kidney and liver damage, jaundice, cancer, lower IQ, childhood asthma, deliver of underweight babies and early deliveries in addition to heart deformities in children. PAHs are lipophilic meaning they can absorb into the fats of humans and other animals. Some even bind to DNA, RNA and proteins causing cell damage. (1,6)

**Radiation** – Radiation is from the atomic business by means of its mining processes, power industries as well as waste discarding (e.g. iodine, uranium, cesium, plutonium, tritium and strontium). Another source is by the military where weapons are made, tested and used. Metals that emit radiation are similarly used in some products like electronics. Radiation can also be put into the ground during oil and gas drilling operations. Exposure to radiation can lead to blood, lung plus thyroid cancer and ailments affecting the digestive system, bones, intestines, muscles, and nervous system. These effects last for years and can be passed down generation to generation as complications in delivery, malignancies as well as additional health complications. Initial symptoms include nausea, vomiting, diarrhea and fatigue. The second set of symptoms may be loss of hair, permanent skin blackening, anemia, fiery sensation in the body, bleeding spots beneath the skin, shortness of breath, dry cough, inflammation of the esophagus plus buccal cavity, waning of tooth and gum sickness, heart aches, fast heartbeat, plus death. (1,6)

**Dyes** - Over 700,000 tons of synthetic dyes are produced per year for industries including the textile industry, the cosmetic industry, the paint industry, ink industry and plastic industry. Compounds including, Orange 2, Azure B, Disperse Yellow 3, Tropaeolin in addition to Congo Red, make their way abundantly into the water supplies. When they infiltrate the water supplies they suppress the growth of phytoplankton limiting the food supply of organisms that rely on them for food. They are also carcinogenic and mutagenic. (1,6)

**Nitroaromatics** - This group is a group of aromatic rings with one or more nitro functional group (NO3) attached. Examples include 2,4-dinitrotoluene, 2,4-dichloro-1-nitrobenzene, 2-amino-4,6-dinitrotoluene, 1,3-dinitrobenzene, 1-chloro-3,4-dinitrobenzene in addition to 2,4,6-trinitrotoluene (TNT). (1,6)

**Bisphenol A (BPA)** – BPA is used in the production of softer plastics. When products made with this are heated, BPA is released and is an endocrine disruptor that mimics the hormone estradiol, causing hormonal imbalances in humans and animals. (1,6)

**Chromated Copper Arsenate (CCA)** - This element is a highly antimicrobial compound used to protect and preserve wood, which is highly comprised of heavy metals
chromium, copper, and arsenic. Over time this wood leaches out these toxins into the soil and waterways. When this wood is burned these toxins get released into the air. Studies have found that Copper oxalate produced by copper-tolerant fungi presents an alternative disposal strategy. (1,6)

**Dimethyl Methylphosphonate (DMMP)** – This compounds in used in the production of flame-retardants, plasticizers, and anti-foaming agents and historically in the manufacturing of several chemical weapons including the nerve agents VX, Soman, and Sarin. All of these compounds contain phosphorus, so using species like *Psilocybe* that require phosphorus for their growth are a good candidate for remediating these toxins. (1,6)
Microbes:

Some common pathogens in our world:

Bacillus spp.
Enteroviruses
Escherichia coli
Listeria monocytogenes
Mycobacterium tuberculosis
Plasmodium falciparum
Pseudomonas aeruginosa
Legionella
Staphylococcus aureus
Streptococcus pneumoniae
S. pyogenes

**Bacillus spp.** - They are gram-positive bacteria with cylindrical and rod like shapes.

Most bacillus spp. are harmless but there are a few that are harmful. *B. cereus* causes food spoilage which leads to food poisoning, similar to staphylococcal food poisoning. *B. subtilis* is a common contaminant of laboratory cultures, and is useful in creating antibiotics. *B. anthracis* causes anthrax in humans. (11)

**Enteroviruses** - small viruses such as polioviruses, echoviruses, and coxsackieviruses that live inside of your intestines. These can cause a wide variety of diseases from gastroenteritis to meningitis. (12)

**E. coli** - Causes cramps, nausea, diarrhea, headaches, urinary tract infection, respiratory, illness, pneumonia, and more. These symptoms are more severe for people with weak immune systems, elderly people, young children and infants. (13)
*Listeria monocytogenes* - gram-positive bacterium - caused 2,161 illnesses and 210 deaths in the European Union in 2014. (14)

*Mycobacterium tuberculosis* is a pathogenic bacterial species that is responsible for tuberculosis. (15)

*Plasmodium falciparum* is a protozoan parasite carried by female Anopheles mosquito that causes malaria in humans. (16)

*Pseudomonas aeruginosa* - Gram negative rod shaped bacterium that is multidrug/antibiotic resistant. It is opportunistic as it will infect people with existing diseases or conditions like cystic fibrosis and traumatic burns. (17)

*Legionella* - thrives in warm waters. if in a shower of air-conditioning system this causes it to be aerosolized and if inhaled may result in a type of pneumonia called Legionnaires disease. (18)

*Staphylococcus aureus* - gram positive, round-shaped bacterium causes skin infections such as skin abscess, respiratory infections such as sinusitis and food poisoning. Also causes life-threatening diseases such as pneumonia, meningitis, osteomyelitis, endocarditis, toxic shock syndrome, bacteremia, and sepsis. (19)

*Streptococcus pneumoniae* - gram positive pathogenic bacterium which is a major cause of pneumonia. Also causes meningitis, bronchitis, rhinitis, acute sinusitis, otitis media, conjunctivitis, meningitis, sepsis, osteomyelitis, septic arthritis, endocarditis, peritonitis, pericarditis, cellulitis, and brain abscess. (20)

*Streptococcus pyogenes* - Gram positive bacteria that - pharyngitis (Strep throat), impretigo, erysipelas, cellulitis, necrotizing fascitis, scarlet fever toxic shock syndrome, and rheumatic fever. (21)
There is one strong study out there (22) that has very strong data on using *Stropharia Rugoso-annulata* (SRA) for filtering E. coli. E. coli is 50% protein by weight aka lots of food for the fungi. Fungi can stun E. coli and use them as a nitrogen source. If you look under an electron micrograph at mycelium one can see these cells are about .5-2 microns thick. When the mycelium links up into a huge network spanning up to miles long they create a perfect net or filter. *Vibrio Cholerae*, a gram-negative bacteria, binds to chitin, the substance that mycelium is made out of.

Species in the Stropharia genus have very ropey tenacious mycelium, being able to support 30,000 times their weight (24). Paul Stamets talks about in his book *Mycelium Running* how he was able to reduce an E. Coli contaminated waterway by 100 fold in a year despite doubling the amount of animals he had on his land. Zhu Ling (*Polyporus umbellatus*) was 100 percent effective in vitro in inhibiting the malarial parasite *Plasmodium falciparum* according to research conducted by Lovy and others (1999) (24)

### Indigenous biome

Once you know what is going on in your soil/water it’s really important to isolate the contamination as quickly as possible. Toxins can travel very quickly and it’s super important to make sure they are contained and are not being distributed far and wide.

Once the contamination is contained look around at your site and notice if there is any local mushrooms or plants growing. Take spore prints of these mushrooms to get new genetics that are more adapt to this toxic environment. Isolate mycorrhizal fungi from the area and clone plants. Take handfuls of soil and put them in compost teas to expand indigenous microbes that are adapted to the contaminant(s).
With the indigenous fungi along with the other organisms it’s time to run trails. In addition to the local fungi there are a lot of other fungi that are powerful tools in the tool belt.

**SPECIES SELECTION**

If I had to pick three different kind of fungi to recommend for beginners to use for remediation I would go with *Pleurotus ostreatus, Lentinula edodes, and Stropharia rugoso-annulata*. Not only are they incredibly easy to cultivate, but also since they are the mycelium or spent mycelial blocks can be acquired in bulk with much simplicity. They are also very potent species for remediation. Oysters and stropharia are the easiest mushrooms to grow and they are one of the best for remediation, which makes them go to’s for beginners. Oysters are great for chemical remediation and water filtration; stropharia is great for filtering *E. coli* from water. Shiitake is great for chemical remediation and water filtration. Old oysters and shiitake blocks that don’t fruit as much as before are often thrown away at most mushroom farms, which can absolutely be recycled and used in mycoremediation projects. This means that someone without access to a lab or without much or any cultivation skills can easily help remediate a site using “waste” from a mushroom farm who have already gone through the steps of growing the mycelium for you. The simple chart below is to show the wide variety of fungi that have mycoremediation abilities. So keep an open eye when you walk through the woods and see the biodiversity of fungi, that most of them can be used as not only medicine for your body but also medicine for the earth. As one gets more advanced with lab skills and cultivation the species in a remediator’s tool belt expands eventually to the whole kingdom of fungi! Start small at first! Ally with the three mushrooms I listed above first and then expand it out further to *Lentinus tigrinus, Trametes versicolor, Ganoderma lucidum*, other types of oysters like *P. pulmonarius, P. eryngii*, and then to Bjerkandera spp, Phanerochaete chrysosporium, and beyond!
<table>
<thead>
<tr>
<th>Name of Fungi</th>
<th>Pollutants Addressed</th>
</tr>
</thead>
</table>
| **Agaricus Spp.**     | **Metals:** Rabinovich et al. (2007) found supplementing copper and zinc at four hundred parts per million to mycelium increased copper content by 449 times and zinc by 163 times. Also shown to hyperaccumulate cadmium. (Yesil et al. 2004,) Meisch et. al. (1986) actually found that cadmium stimulated its growth in laboratory conditions. A finding that is apparent with many mushroom species. (10)  
**Chemicals:** Contains laccase and manganese peroxide that helps lignin degradation. This means they have potential to degrade a wide range of chemicals that are closely related to Lignin. (Bonnen et al. 1994; Trejo-Hernandez et al. 2001) Also potentially oxidate endocrine disrupters like nonylphenol and bisphenol A. (10)  
**Biological:** Also shown active against Streptococcus pneumoniae, E. coli, Salmonella species (Dornberger et al. 1986, Bernardshaw et al. (2005), Helicobacter pylori (Kim, D.-H. et al. 1996), Bacillus subtilis, (Rana et al. 2008), Biomphalaria glabrata, Aedes aegupti (Keller, C. et al. 2002), Staphylococcus aureus (Atkinson 1946; Nano et al. 2002; Suay et al. 2000) tuberculosis and sinusitis. The implications of this fungi being effective against these effective against these strains of bacteria and viruses is that is can be used as a water filter. (10) |
| (E.g. Button Mushroom, Field Mushroom, Portobello, etc.) |  
| **Agrocybe Spp.**    | **Chemical:** Produces laccases. This means they have potential to degrade a wide range of chemicals that are closely related to Lignin. Also potentially oxidate endocrine disrupters like nonylphenol and bisphenol A. Also shown to produce peroxidases that oxidize aryl alcohols, such as veratryl and benzyl alcohols in |
| (e.g. spring agrocybe, pioppino, black poplar) |
| **mushroom** | *aldehydes and then acids at neutral pH.* (Ullrich et al. 2004) (10) |
| **Biological:** Shown to be active against five bacteria including *E. coli*, *Streptococcus aureus*, *Bacillus cereus*, *B. subtilis*, and *Salmonella typhimurium*. Also shows antiviral activity against tobacco mosaic virus (Ngai et al. 2005) (10) |
| **Albatrellus Spp.** | *Biological:* Shown to inhibit *Staphylococcus aureus* and *Bacillus subtilis* as well as *Mycobacterium avium*, *M. phlei*, *bacillus cereus*, *B. subtilis*, *E. coli*, and *salmonella typhimurium* (Hirata et al. 1950) (10) |
| (E.g. Crested polypore, sheep polypore, confluent polypore etc.) | Sheep polypore excretes esterase, protease and amylase enzymes. Esterases such as lipase and carboxyl esterase are important in food processing, fats and oleo chemicals, cosmetics, leather, dairy, and tea processing, as well as sewage treatment, pulp and paper, oil degradation and biodiesel production. So not only can enzymes produced from this fungus break down oil but it can create new oil as well. (10) |
| **Alnicola Melinoides** | *Biological:* Hervey (1947) found that this fungus was effective against *Staphylococcus aureus* on an agar plate. This means this fungus is also probably effective against other kinds of bacteria as well. (10) |
| (e.g. Brown alder Mushroom) | |
| **Amanita muscaria** | **Metals:** Shown to not be affected by being exposed to even 50 parts per million of cadmium. Also tolerant of mercury. (Willenbrog et al. 1990) Seeger and Schweinshaut (1981) showed thorium is also accumulated. (10) |
| (e.g. Fly Amanita, fly agaric) | **Chemicals:** Braun-Lullemann et al. (1999) found that these fungi can degrade 50 percent of phenanthrene, 35 percent of chrysene. *A.* |
*excelsa* removed the same amount of benzopyrene in four weeks.

**Biological:** A. caesarea has shown activity against *bacillus subtilis* and *Staphylococcus* *(Yamax and Bilgili 2006)*

**Insecticide:** the compound that attracts flies is called 1,3-diolein and the main isoxazole toxin, iboten acid stuns and kills them. House flies are strongly suspected of transmitting at least 65 diseases to humans, including typhoid fever, dysentery, cholera, poliomyelitis, yaws, anthrax, tularemia, leprosy and tuberculosis. This is huge for countries with these epidemics.

| **Auricularia** (e.g. wood ear, tree ear) | **Biological:** Effective against *Bacillus cereus, E. coli, Proteus vulgaris, and Staphylococcus aureus.* *(Gbolagade and Fasidi 2005)*

| **Bjerkandera** (e.g. Smoky Polypore) | **Chemicals:** *B. adusta* has been shown to transform organophosphorus pesticides *(Jauregui et al. 2003).* Also has been demonstrated to degrade three phenylurea-based herbicides. *B.adusta* tested the best out of 100 fungal strains being able to degrade 98% of chlortoluron, 92 percent of diuron, and 88 percent of isoproturon in two weeks *(khadrani et al. 1999)*

Yuxin Wang et at. *(2003)* found that with the absence of manganese, there was a higher increase of oxidation of polycyclic aromatic hydrocarbons (PAHS). Demonstrated degrading anthracene by 99.2% in only twenty-eight days *(field et al. 1996)*

Also another study demonstrated 56 percent reduction of fluorene and 38 percent reduction of anthracene after a mere three days of incubation!
Also has been shown to mineralize phencyclidine (PCP) with Oyster mushrooms doing a better job. (Ruttimann-Johnson and Lamar 1997)

Been shown to decolorize Poly R-478 (field et al. 1992; Kotterman et al. 1998)

Polychlorinated biphenyl (PCB) is another chemical that *Bjerkandera* spp. Has been shown to be an active degrader of. (beaudette et al. 1998.)

*Pleurotus ostreatus* and *B. adusta* has been shown to almost completely degrade styrene in just 48 hours with the addition of lignocellulosic materials (Braun-Lullemann et al. 1997)

*Bjerkandera* spp. Were effective against degrading nonylphenol (an endocrine disrupter) by 98.7% in soils after five weeks of incubation. (10)

**Wastewater:** Kornillowicz-Koralska et al. (2005) found that *B. adusta* was able to degrade cytostatic byproducts from the postproduction of daunomycin a chemotherapy medication.

In the presence of humic acid from brown coal, it was noted a huge increase in the synthesis of laccase and lipase. (Belcarz et al. (2005).

This has potential for treating humic acid in treated water. Humic and fulvic acids, when present in treated drinking water, can react with the chemicals used in the chlorination process to form disinfection byproducts such as dihaloacetonitriles, which are toxic to humans. (Oliver, Barry G. (1983); Peters, Ruud J.B.; De Leer, Ed W.B.; De Galan, Leo (1990)) (10)

**Boletopsis**

Pleurotin, also found in *Pleurotus ostreatus* was found mildly inhibitory to *S. aureus, Bacillus mycoides, and B. subtilis.* (10)
<table>
<thead>
<tr>
<th></th>
<th><strong>Oxyporus spp.</strong></th>
<th><strong>Calocybe</strong></th>
<th><strong>Calvatia</strong></th>
<th><strong>Ceriporiopsis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(e.g. Kurokawa, Kurotake, Gray Polypore)</td>
<td>Biological: <em>O. corticola</em> shows antifungal, and antibacterial activity including activity against <em>Staphylococcus aureus</em>. (10)</td>
<td>Biological: Keller, c. et al. (2002) showed activity against <em>Bacillus subtilis</em> and <em>E. coli</em>. (10)</td>
<td>Biological: Mosaic puffball (Handkea utriformis) showed activity of inhibition against <em>Bacillus subtilis</em>, <em>E. coli</em>, <em>Klebsiella pneumonia</em>, <em>Pseudomonas aeruginosa</em>, <em>Salmonella typhimurium</em>, <em>Staphylococcus aureus</em>, <em>Streptococcus pyogenes</em>, and <em>Mycobacterium smegmatis</em>. Dulger (2005) made a 60 percent methanol extract and demonstrated its inhibition relating to the antibiotic gentamycin. Studies at University of Oklahoma showed that spores from Giant Puffballs (<em>Calvatia gigantea</em>) were shown to be active in vitro against <em>Staphylococcus aureus</em>, <em>Streptococcus pneumonia</em>, <em>Proteus</em>, and <em>Pseudomonas</em> species. (10)</td>
<td>This fungus excretes novel enzymes that break down wood chip lignins prior to biomechanical pulping that results in energy savings</td>
</tr>
<tr>
<td>(e.g. Noble polypore, Fuzzy Sandozy)</td>
<td>Chemical: Shown to degrade three different types of phenyl urea based pesticides. (Khadrani et al. 1999) (10)</td>
<td></td>
<td>Phytoremediation: Use the spores of these puffballs to create mycorrhizal connections in plants used on toxic sites. (10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(e.g. Pink Calocybe, St. george's Mushroom)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(e.g. Checkered Puffball, Mosaic Puffball, Giant puffball, Warted/gem puffball, western lawn puffball, meadow puffball etc)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of 40-48%. (Masood Akhtar 1994)
Also is a good biological devulcanizer of rubber which recycles spent tie rubber into forms that can be used again. (Sato, S. et al. 2004) (10)

| Cerrena  | Biological: Activity against *Staphylococcus aureus* (Hervey 1947) (10)  
|          | **Chemical:** Laccase levels were found as high as 22% when the fungus was grown in tomato juice (Michniewicz et al. 2005) They were also found increased by twenty-fold when using cellobiose instead of avicel as a carbon source.  
|          | High levels of manganese peroxidase were found by Gray Polypore on wheat bran, on ethanol production wastes.  
|          | *C. Maxima* demonstrated degrading up to 50% of atrazine in five days and 80-90% in forty days. (10) |

| Chlorophyllum  | Biological: Moderate activity against *Staphylococcus aureus* (Suay et al. 2000)  
|                | The green-spored parasol (*Chlorophyllum molybdites*) tested positive against the poliomyelitis virus  
|                | According to Paul Stamets, this mycelium is used by ant colonies to protect them from parasitic diseases. There is potential to use this mycelium to protect humans from parasitic diseases as well. More research is needed. (10)  
|                | **Metals:** It has been shown to myco-accumulate arsenic, lead, mercury, and copper. (10) |
| **Chroogomphus** | **Biological:** Acetone extracts of the fruiting body showed activity against *E. coli*, *Enterobacter aerogenes*, *Salmonella typhimurium*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Bacillus subtilis*. Ethanol extracts showed activity in most of these cases. (Yamac and Bilgili 2006) (10) |
| **Clavaria** | **Biological:** Antibiotic activity has been noted against *Bacillus tubercle* (Tuberculosis) when fermenting purplish clavaria (*Clavaria zollingeri*). Also has shown activity against *Staphylococcus aureus* and *Bacillus subtilis* and weak activity against *E.coli, Enterobacter aerogenes*, and *Salmonella typhimurium*. (Yamac and Bilgili 2006) (10) |
| **Climacodon** | **Biological:** Moderate activity found against *Staphylococcus aureus* and *E. coli*. (Robbins et al. 1945) (10) |
| **Clitocybe** | **Biological:** Mountain avens *Clitocybe* contains clitocybin that may be effective in resisting pulmonary tuberculosis and has been effective against both gram positive and negative bacteria. (10) *C. nebularis* has been found effective against five bacteria: *Bacillus cereus, B. subtilis, Streptococcus aureus, E. coli*, and *Salmonella typhimurium*. Yamac and Bilgili (2006) found that *G. geotropa* showed activity against *Staphylococcus aureus, Bacillus subtilis* and *Saccharomyces cerevisiae.* *C. infundibuliformis* (10) |
| **Coprinopsis spp.** | **Biological:** *C. plicatilis* has shown inhibition against *Bacillus cereus and B. subtilis*. (Bianco and Giardino 1996) *C. micaceus* has shown activity against poliomyelitis. |
(E.g. Smooth inky cap, Japanese parasol, woolly inky cap, etc.)

Activity against *Corynebacterium xerosis and Staphylococcus aureus* from the sterol produced by this fungi, Micaceol, were identified by researchers at the University of Winnipeg.

*C. Picaceus* contains pacacic acid with weak activity against *Staphylococcus aureus*, *S. typhi*, and *Streptococcus pyogenes*. Corpinol with is a cuparene isolated by wood loving strains of *Coprinus spp.*, shows activity against penicillin-resistant *pneumococci*, methicillin- and quinolone-resistant *staphylococci*, vancomycin-resistant *enterococci*, and *staphylococci* (Johansson et al. 2001) (10)

**Chemical:** Acts as a good alternative to horseradish peroxidase for aqueous phenol treatment of phenol with a wide range of pH activity. (10)

**Wastewater:** Ikehata et al. (2005) proposed to use these fungi as a useful candidate for treating industrial wastewater. (10)

<table>
<thead>
<tr>
<th><strong>Coprinus Comatus</strong> (Shaggy mane, Lawyer’s Wig, Inky Cap)</th>
</tr>
</thead>
</table>

**Biological:** Contains coprinin, which is a natural antibiotic. It has shown activity against *Aspergillus niger*, *Candida albicans*, *E. coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and various *Bacillus* species. It is been shown to be active against multi-drug-resistant gram-positive bacteria (Johansson et al. 2001) (10)

**Chemical:** Related *C. cinereus* contains iron peroxidase, which Dr. Joel Cherry at Novo Nordisk Lab in Davis California discovered that it can be a solution to neutralizing white clothes that have been tinted by others in a washing machine. The incredible thing about this is that it will only work on the dyes leached into the wash water and not work on the dyes in the clothes themselves.
Researchers have found a 37% decrease in nitrocellulose in liquid cultures (Auer et al. 2005).
Both *C. cinereus*, and *C. macrorhizus* contain peroxidases and other enzymes capable of degrading phenols. (Al-Kassim et al. 1994) (10)

**Metals:** Hyperaccumulator of heavy metals including mercury by twenty seven times, arsenic by twenty-one times, and cadmium by eight times. (10)

<p>| <strong>Craterellus</strong> | <strong>Enzymes:</strong> The horn of plenty lives up to it’s name with its abundant array of enzymes. Goud et al. (2009) tested a variety of 50 basidiomycetes for production of enzymes and only four tested positive for excreting all five enzymes: protease, amylase, phytase, carboxyl esterase, and lipase. These enzymes have various commercial applications and the application for mycoremediation needs to be further researched and addressed. These enzymes can be used for food, alcohol, paper, leather, pharmaceutical industries and have potential for the biodiesel industry and also for petrochemical degradation. (10) |
| <strong>Cyathus striatus</strong> | <strong>Chemicals:</strong> <em>C. stercoreus</em> was shown to be the quickest of four species to degrade and detoxify TNT (10) |
| (Ribbed splash cup, Striate bird’s nest, Fluted bird’s nest, Dung loving bird’s nest, Jellied bird’s nest) | |
| <strong>Daedaleopsis Confragosa</strong> | <strong>Chemicals/dyes:</strong> This fungi is a degrader and decolorizer of synthetic dyes (Sasek et al. 1998) (10) |
| (Thin Walled Maze) | |</p>
<table>
<thead>
<tr>
<th><strong>Polypore, Blushing Bracket)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elaphomyces granulatus</strong></td>
<td><strong>Metals/Radioactive waste:</strong> It has been noted that this fungus can hyperaccumulate cesium at 25,600 becquerels per kilogram. Post Chernobyl we need solutions like this to hyperaccumulate radioactive isotopes of Cesium - Cesium-137. (10)</td>
</tr>
<tr>
<td>(Common deer truffle)</td>
<td></td>
</tr>
<tr>
<td><strong>Fomes fomentarius</strong></td>
<td><strong>Biological:</strong> Shown to inhibit <em>herpes simplex</em>, <em>Pseudomonas aeruginosa</em> and <em>Serratia marcescens</em>. (Suay et al. 2000) and Paul Stamets showed complete inhibition of <em>E. coli</em>. (10)</td>
</tr>
<tr>
<td>(Tinder fungus, Amadou)</td>
<td></td>
</tr>
<tr>
<td><strong>Fomitopsis officinalis</strong></td>
<td><strong>Biological:</strong> Effective against: cowpox, measles, vaccinia, shows promise against smallpox, influenza B, H1N1 (swine flu), H3N2, and H5N1 (avian flu) strains; yellow fever; West Nile, arenaviruses such as tacaribe and pichinde, and punta toro, drug resistant tuberculosis strains, <em>Staphylococcus aureus</em> and <em>E. coli</em>. (10)</td>
</tr>
<tr>
<td>(Quinine conk, White agaric, Agarikon)</td>
<td></td>
</tr>
<tr>
<td><strong>Funaila trogii</strong></td>
<td><strong>Chemicals/Dyes:</strong> Shown to be an active source of laccase and shown to decolorize various red and orange textile dyes (Yesilada et al. 2002) (10)</td>
</tr>
<tr>
<td>(Trog Trametes, Deer Trametes)</td>
<td></td>
</tr>
<tr>
<td><strong>Ganoderma applanatum</strong></td>
<td><strong>Biological:</strong> Activity against: <em>Bacillus cereus</em>, <em>Corynebacterium diphtheriae</em>, <em>E. coli</em>, <em>Pseudomonas aeruginosa</em>, <em>Streptococcus pyogenes</em> (A. Smania et al. 1999), and <em>Mycobacterium phlei</em> (Florey et al. 1949) (10)</td>
</tr>
<tr>
<td>(Varnished Conk, Artist's conk, varnish</td>
<td></td>
</tr>
<tr>
<td><strong>Ganoderma Lucidum</strong> (Reishi, Ling Zhi)</td>
<td><strong>Biological:</strong> Activity against: <em>Bacillus, Micrococcus, Streptococcus, Staphylococcus</em> (Yoon, S. Y. et al. 1994) <em>E. coli, Aspergillus niger,</em> and <em>Trichoderma viride.</em> (10)</td>
</tr>
<tr>
<td><strong>Gloeophyllum sepiarium</strong> (Rusty Gilled Polypore, Polypore de poutres)</td>
<td><strong>Chemicals:</strong> Rusty-gilled polypore mycelium excretes quinone reductases that break down toxic wood preservatives. <em>G. trabeum</em> breaks down telephone poles, bridge structures and even automobile woodwork. (10)</td>
</tr>
<tr>
<td><strong>Gomphidius glutinosus</strong> (Slimy pegs)</td>
<td><strong>Metals/radioactivity:</strong> Dr. Solomon Wasser et al. found wild specimens in Ukraine hyperaccumulating cesium up to 17,117 kBg/kg. Other research has found it can hyperaccumulate up to ten thousand times concentrations of radioactive cesium making it a good candidate for cleaning up toxins from nuclear plants and other radiation sources. (10)</td>
</tr>
<tr>
<td><strong>Gomphus clavatus</strong> (Pig’s ears, wooly chanterelle, scaly chanterelle)</td>
<td><strong>Enzymes:</strong> This fungi was another fungi screened along with the Horn of Plenty by Goud et al. (2009) for the extracellular hydrolytic enzymes: protease, amylase, phytase, carboxy esterase, and lipase and they found significant activity. These enzymes can be used for food, alcohol, paper, leather, pharmaceutical industries and have potential for the biodiesel industry and also for petrochemical degradation. (10)</td>
</tr>
<tr>
<td><strong>Polyporus umbellatus</strong></td>
<td><strong>Biological:</strong> Effective against: <em>E. coli, Staphylococcus aureus.</em> (10) Research by Lovy et al (1999) found that strains of <em>Zhu ling</em> 100 percent effective against <em>Plasmodium falciparum,</em> the parasite that...</td>
</tr>
<tr>
<td>Supplier</td>
<td>Biological: Activity against:</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>--------------------------------</td>
</tr>
</tbody>
</table>
| **Hygro
cophorus Camarophyllus**               | *Staphylococcus aureus*, twice as effective as the drug against *S. epidermidis*, and *Bacillus subtilis*. Also active against: *Enterobacter aerogenes*, *Salmonella typhimurium*, *Saccharomyces cerevisiae* and *E. coli*. | This has potential to remediate toxins at much lower temperatures than most other species. Paul Stamets suggests in his book *Mycelium Running* that this species along with *Flammulina velutipes* and other cold tolerant species can be used to decompose munitions at temperatures below risk for spontaneous combustion. |
|                                             |                                | (24, 10) |
| **Inon
utus tomentosus**                    | *Staphylococcus aureus* (Robbins et al. 1945) | This fungus along with *Trametes versicolor* degraded humulones and lupulones from spent hops in only thirty six hours when exposed to light and in four days in the dark. |
<p>|                                             | (10)                           | (10)     |
|                                             | <strong>Chemical:</strong>                  | This fungus along with <em>Trametes versicolor</em> degraded humulones and lupulones from spent hops in only thirty six hours when exposed to light and in four days in the dark. |
| <strong>Hypsizygus Ulmarius</strong>                      |                                | (10)     |
|                                             | <strong>Chemicals:</strong>                 | Produces strong cellulases that might be useful for remediating paper products, dioxins, and wood preservatives. Mycelium grows best between 70-80 degrees fahrenheit. |
| <strong>Laccaria laccata</strong>                         | <strong>Phytoremediation:</strong>          | Laccaria species were the most frequently observed ectomycorrhiza associated with pine and poplar in |</p>
<table>
<thead>
<tr>
<th>(Orange laccaria, common laccaria, the deceiver, etc)</th>
<th>reclaimed oil sands in northern Alberta (Bois et al. 2005) (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals:</strong></td>
<td>Purple <em>Laccaria</em> is a bio-accumulator of arsenic, up to 146.9 milligrams per kilogram (10)</td>
</tr>
<tr>
<td><strong>Chemicals:</strong></td>
<td>Richter et al (2003) found that <em>laccaria bicolor</em> and <em>L.laccata</em> show a very high tolerance to creosote. (10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><em>Laetiporus sulphureus</em></th>
<th>Biological: Lovy et al. (1999) presented data on activity against <em>Plasmodium falciparum</em>. It also has been shown activity against: <em>Staphylococcus aureus, Bacillus subtilis, E. coli, Serratia marcescens</em>. (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Chicken of the woods, Sulfer shelf)</td>
<td>Chemical: Wunch et al. (1997) found this fungus decolorized 68 percent of polymeric R-478 dye. Mineralization of phenanthrene and pyrene compounds has also been noted. (10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Shiitake)</td>
<td>Chemicals: Shiitake is a great candidate for remediation proving to break down PCBs, PAHs, PCBS, and more. Also removing heavy metals and industrial dyes from waterways (Robert Rogers, 2011). KO, G. H et al (2005) conducted studies on enzymes secreted by spent shiitake blocks showing activity in alpha amylase (229 nano katals per gram), cellulase (759 nano katals per gram), beta glucosidase (767 nano katals per gram). (10)</td>
</tr>
</tbody>
</table>
Research that I have conducted on the mycoremediation of PAHs in cigarette butt waste showed that with the application of enzymes from *Pleurotus ostreatus* and *Lentinula edodes* there was 100% reduction in 1-Methylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Fluoranthene, Fluorene, Naphthalene, and Phenanthrene in under 12 days.

Hatvani and Mecs (2003) did research on the myco-absorption ability of shiitake for heavy metals and how manganese peroxidase degraded synthetic dyes and how these abilities are very important for remediating waterways contaminated with heavy metals and other xenobiotics. Duran et al (1994) demonstrated shiitake removing 73 percent of color of effluent in five days without an additional carbon source. When Duran et al. pre-irradiated the mycelium for ten minutes in the presence of photocatalyst, ZnO the decolorization was noted in forty-eight hours. (10)

Charles Lee (2005) determined the structure of Xyn11A, a gene instruction for the formation of xylanase from shiitake, which has incredible application for biofuel production. (10)

Okeke et al. 1997 conducted incredible research on using hydrogen peroxide to enhance the activity of the degradation of pentachlorophenol (PCP) and Delor 106 in soil that was degraded by 24 percent in six weeks.

D’Annibale et al. (1999) showed that total phenols could be eliminated by 67 percent in twenty-four hours (10)

<p>| <strong>Lepista nuda</strong> | <strong>Biological:</strong> Activity against <em>E. coli, Staphylococcus aureus</em> (Hervey 1947) (10) |</p>
<table>
<thead>
<tr>
<th>(Blewit etc)</th>
<th><strong>Metal:</strong> Blewits have been shown to hyperaccumulate mercury a hundred times or more. A great easy cultivable candidate for mining sites. (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marasmius troyanus</strong></td>
<td><strong>Chemical:</strong> Wunch et al. (1997) at Tulane University studied this rare mushroom noting its activity against PAHs, TNT, and other contaminants. A U.S. Patent (6,204,049) was created for encapsulating fungi spore in beads to use on contaminated sites. (10)</td>
</tr>
<tr>
<td><strong>Morchella esculenta</strong></td>
<td><strong>Metals:</strong> If you have ever been Morel hunting in apple orchards I’m sure you have been warned about how they hyperaccumulate heavy metals like lead arsenic. <em>Morchella</em> species hyper accumulate lead from seventy to one hundred times (10). Shows incredible abilities to detoxify metal ridden environments but it’s a pity it’s such a delicious mushroom.</td>
</tr>
<tr>
<td>(Yellow morel, Sponge morel, Black morel, etc)</td>
<td><strong>Chemicals:</strong> Paul Stamets identified this mushroom as being able to break down chemical and biological warfare neurotoxins. (24)</td>
</tr>
<tr>
<td><strong>Mycena chlorophos</strong></td>
<td><strong>Chemicals:</strong> Poison Paxillus has been shown to degrade PAHs and transform TNT after three days of incubation in axenic cultures. Blackroot Paxillus was found to bioaccumulate radioactive cesium up to twelve hundred times. (10) This has potential for remediating nuclear sites.</td>
</tr>
<tr>
<td>(bioluminescent mushroom)</td>
<td><strong>Biological:</strong> Active against: <em>bacillus subtilis</em>, <em>Staphylococcus aureus</em> (Robbins et al. 1945), <em>Bacillus subtilis</em>, <em>Staphylococcus epidermis</em>, <em>Enterobacter aerogenes</em>, and <em>Salmonella typhimurium</em>. (Yamax and Bilgili, 2006) (10)</td>
</tr>
<tr>
<td><strong>Paxillus involutus</strong></td>
<td><strong>Biological:</strong> Active against: <em>bacillus subtilis</em>, <em>Staphylococcus aureus</em> (Robbins et al. 1945), <em>Bacillus subtilis</em>, <em>Staphylococcus epidermis</em>, <em>Enterobacter aerogenes</em>, and <em>Salmonella typhimurium</em>. (Yamax and Bilgili, 2006) (10)</td>
</tr>
<tr>
<td>(Poison paxillus etc)</td>
<td><strong>Chemicals:</strong> Poison Paxillus has been shown to degrade PAHs and transform TNT after three days of incubation in axenic cultures. Blackroot Paxillus was found to bioaccumulate radioactive cesium up to twelve hundred times. (10) This has potential for remediating nuclear sites.</td>
</tr>
</tbody>
</table>
**Phanerochaete Spp.**

(Velvet crust, Yellow crust, Giant crust, giant Yellow crust)

This is one of the most well noted white rot species for mycoremediation potential along with *Trametes, Pleurotus and Bjerkandera*

**Chemicals:** Has been shown to decolorize azo dyes up to 100 percent and breaking them down to nitrogen and a phenol compound. (10)

The Yellow Crust (*P. chrysosporium*) has been found to degrade benzopyrenes, pentachlorophenol, TNT, aldrin, DDT (dichlorodiphenyltrichloroethane), triphenylmethane, heterocyclic, azo, and diazo dyes. (10) also shown to degrade Chlorobenzene, xylenes, toluenes, and ethylbenzene. (Yadav and Redy 1993)

Herbicides based on 2,4-dichlorophenoxyacetic and 2,4,5-trichlorophenoxyacetic acid; and insecticides such as chlordane, heptachlor, lindane, dieldrin, and mirex. (Kennedy et al. 1990; Ryan and Bumpus 1989; Yadav and Reddy 1993)

Novotny (1997) did research on the breakdown of polychlorinated biphenyl (PCB) by this fungus. Delor 106, a commercial PCB mixture was degraded by 25 percent in three weeks. Other studies show that PCP, in a mixture of creosote, can be degraded by 80% in six weeks. (10)

---

**Phlebia tremellosa**

(Trembling phlebia, Trembling merulius, Jelly Rot)

**Chemicals:** De Jong and Field (1997) showed that *Phlebia* spp. Along with *Bjerkandera, Trametes, and Hericium* are highly effective at degrading chlorinated pollutants. Trembling phlebia has been recommended to decolorize textile effluent and transform alachlor (Ferry et al. 1994)

It has also been found to degrade trinitrotoluene and isolated MnP mineralized dinitrotoluene compounds. (Van Aken et al. 1997,
Robert Rogers describes in his book *Fungal Pharmacy* (2011) that this fungus secretes lignin peroxidase, manganese peroxidase, and laccase in pulp wastewater and pulp mill wastewater meaning that it is a good candidate for industrial wastewater treatment. (10)

<table>
<thead>
<tr>
<th><strong>Piptoporus betulinus</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Razor strop, Birch conk, Birch Polypore)</td>
</tr>
<tr>
<td><strong>Biological:</strong> Activity against: <em>Staphylococcus aureus</em>, <em>Enterococcus faecalis</em> (Schlegel et al. 2000), <em>Micrococcus pyogenes</em>, <em>Bacterium racemosum</em>, (Ying 1992) <em>B. subtilis</em>, <em>Bacillus megaterium</em> (Suay et al. 2000), <em>E. coli</em> (C. Keller et al. 2002). Paul stamets said this fungi should be trialed against anthrax (<em>B. anthracis</em>) (10)</td>
</tr>
<tr>
<td><strong>Enzymes:</strong> Birch Polypore secretes the highest level of cellulases out of any fungi. These enzymes are useful for industrial purposes like detergents, textiles, food, preparation, and animal feed. Cellulase are used for denim bleaching and decolorizing recycled paper by de-inking. (10)</td>
</tr>
<tr>
<td><strong>Metals:</strong> This fungus is also good at hyperaccumulating metals, being able to grow at 250 micromoles of cadmium. (10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pisolithus tinctorius</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dead man’s foot, Bohemian truffle, dye maker's puffball, Dog turd fungus)</td>
</tr>
<tr>
<td><strong>Phytoremediation:</strong> This puffball grows a lot in disturbed areas and has been noted to break through concrete to be able to spread its spores. That right there is a green flag for use with mycoremediation. It associates with Pine trees, which Hendrix et al. (1985) found pine seedlings transplanted on a coalmine site that has this mycorrhizal association were twice the height and stem diameter compared to those that did not have this symbiosis. (10)</td>
</tr>
<tr>
<td><strong>Metals:</strong> It has been shown that these mushrooms could tolerate two thousand parts per million concentrations of aluminum. This was</td>
</tr>
</tbody>
</table>
increased when calcium and magnesium concentration was increased. (Egerton-Waterton and Griffin 1984) (10)

**Chemical:** It has also been noted that Dead man’s foot can transform TNT after only three days of incubation and it shows hope in transforming 1-naphthalene acetic acid. (10)

<table>
<thead>
<tr>
<th><strong>Pleurotus Ostreatus</strong></th>
<th>Paul Stamets says “If one mushroom can steer the world on the path to greater sustainability, fighting hunger, increasing nutrient return pathways in ecosystems, destroying toxic wastes, forestalling disease, and helping communities integrate a complexity of waste streams, oysters stand out… Oyster mushrooms are well positioned to lead the way for rebalancing vast waste streams that currently overload our ecosystems. “ (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Oyster mushrooms)</td>
<td>Biological: Active against: <em>Aspergillus niger</em>, (Gerasimenta et al. 2001) <em>Micrococcus luteus, Staphylococcus aureus</em> and <em>Bacillus mycoides</em>, (Poyendinok et al. 1999) (10)</td>
</tr>
<tr>
<td></td>
<td><strong>Chemical:</strong> <em>Pleurotus ostreatus</em> is probably the easiest most effective fungi that a mycoremediater can ally with. It is incredibly easy to grow and it packs a punch. It has been shown to treat wastewater from the pulp and paper industry, pesticide-contaminated waste like chlorinated biphenyls, aromatic hydrocarbon, dieldrin, atrazine, the fungicide benomyl, and also PCP. After the oil tanker <em>Coco Buscan</em> leaked fifty-eight thousand gallons of bunker crude into San Francisco Bay, a group called Matter of Trust remediated plots with Pleurotus Ostreatus and found that several months later the petrochemicals were significantly reduced. (10)</td>
</tr>
<tr>
<td></td>
<td>Research that I have conducted on the mycoremediation of PAHs in</td>
</tr>
</tbody>
</table>
cigarette butt waste showed that with the application of enzymes from *Pleurotus ostreatus* and *Lentinula edodes* there was 100% reduction in 1-Methylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Fluoranthene, Fluorene, Naphthalene, and Phenanthrene in several months. Enzymes from *Pleurotus ostreatus* were able to remediate PAHs by 100% in fewer than 2 weeks. There is however other research out there by Jauregui et al. (2003) that describes the transformation of a variety of organophosphorus pesticides and that some intracellular origin of the transformation activity takes place, rather than simply being an enzymatic effect. More research definitely has to go into this for developing a better understanding of how mycoremediation works.

Sesek et al. found that oyster mushrooms degraded fluorine 41 to 67 percent, phenanthrene 24 to 42 percent, anthracene 29 to 49 percent, fluoranthene 29 to 57 percent, pyrene 24 to 42 percent, chrysene 0 to 42 percent, and benzanthracene 0 to 13 percent at two contaminated industrial sites.

Has shown to decolorize a commercial blue dye along with *P. citrinopileatus* and *P. pulmonarius*. (10)

*P. pulmonarius* (*Phoenix Oyster*) has been shown to degrade naphthalene, phenanthrene, and benzopyrene (Law et al. (2003)

This is another incredibly easy mushroom to cultivate that is very aggressive. This species has been shown to be effective against dioxins and TNT and is known to hyperaccumulate cadmium, mercury and copper. Shown also to decolorize a commercial blue dye. Mycelium grows best around 75 degrees fahrenheit.

King Oyster (*Pleurotus eryngii*) most notably known for breaking down 2,4-dichlorophenol, the base agent for Agent Orange, among
other toxins. Mycelium grows best around 75 degrees fahrenheit. (10)

**Metals:** It has been shown to hyperaccumulate cadmium, mercury, silver, gold. Mercury has been shown to concentrate in substrates up to 140 times (Bressa et al. 1988) This technology can be incredibly useful for mining precious metals and using sodium bicarbonate to remove the metals afterward. Pleurotus ostreatus has evolved overtime to take in metals it might need for nutrition and then can exchange it for hydrogen ions.

I did research on the hyperaccumulation heavy metals from cigarette butt leachate by *Pleurotus ostreatus* and found that the mushrooms hyper accumulated, lead, nickel, zinc, copper, aluminum, iron, and manganese. The levels of copper were 23.9 mg/Kg and the levels of iron were 185 mg/Kg being way too toxic to consume. This means that people should air on the side of caution when using this mushroom for remediation sites as it not only produces tasty mushrooms but these mushrooms can be toxic/fatal if eaten and if small animals feed on these mushrooms, the heavy metals can be transferred in food chains. (10)

<table>
<thead>
<tr>
<th><strong>Stropharia Rugosoannulata</strong></th>
<th><strong>Biological:</strong> One of the most tenacious aggressive mushrooms and highly adaptive to many substrates. This is another easy to cultivate super effective fungi that every mycoremediator should keep in their tool belt. This species has a symbiotic relationship with bacteria and grows better in it’s presence. Because of it’s thick tendril mycelium and it’s affinity for bacteria, this is a perfect candidate for filtering bacteria in waterways. In bench scale tests there has shown an incredible inhibition of E. coli but in field application the results are varied. This more has to do with the design on the filter and weather</th>
</tr>
</thead>
</table>
conditions (e.g. flooding) than it has to do with the mycelium doing its job. There needs to be a simple effective design for implementing these water filters into streams, creeks, and rivers. The design that Paul Stamets lays out in his book has been duplicated many times throughout the world and sometimes it works and sometimes the mycelium dies because of poor design and the E. coli actually use the bunker as a place to reproduce and when a flood comes there is a huge surplus of E. coli washing downstream. We need smart designers and hydrologists working on better solutions to this. (10)

**Chemical:** Known for molecular disassembly of hydrocarbons. Extracellular manganese peroxidase from this fungus have been found to convert and breakdown the toxic explosive amino nitrotoluenes. (10)

Steffen et al. (2002) demonstrated that this mushroom can degrade benzopyrene, polycyclic aromatic hydrocarbons, and other toxins in six weeks especially in the presence of manganese, which stimulates the production of manganese peroxidase exhibited above. (10)

This is also an important mushroom for soil health as it traps and kills nematodes and also attracts earthworms to keep the soil healthy.

**Psilocybe spp.**

**Chemicals:** Found to convert high molecular mass polycyclic aromatic hydrocarbons. Also shown effective against Dimethyl methylphosphonate (VX, Soman, Sarin) and persistent organophosphates. Since they uptake phosphorus to turn it into psilocybin they can also mine phosphorus compounds from Dimethyl methylphosphonate (DMMP) a surrogate for neurotoxins. (10)
| **Rhizopogon vinicolor**  
(False Truffle) | **Biological:** Active against: *E. coli, Saccharomyces cerevisiae, Bacillus subtilis, Enterobacter aerogenes, Pseudomonas aeruginosa,* and *Staphylococcus aureus.* (Yamac and Bilgili 2006) (10)  
**Chemicals:** Has been found to degrade 2,4-D when supplemented with one mM nitrogen concentration (Donnelly, P.K. et al. 1993) Also been shown to break down herbicides like atrazine and 2,4D. (10) |
| **Schizophyllum commune**  
(Split Gill) | **Biological:** Active against: *Pseudomonas aeruginosa,* *Staphylococcus aureus,* *E. coli,* and *Klebsiella pneumoniae.* (10)  
**Chemical:** is efficient at de-colorization of mill effluent in the pulp and paper industry. In one study by Belsare and Prasad (1988) they found that this fungus removed nearly 80 percent of the color in five days. (10) |
| **Serpula lacrymans**  
(Dry Rot Fungus) | **Chemicals:** Active against chromated copper arsenate and polycyclic aromatic hydrocarbons. (10) |
| **Stereum Spp.** | **Chemicals:** Lee, S. -M. Et al. (2005) showed that *Stereum hirsutum* fully degraded bisphenol A in culture in seven to fourteen days. (10)  
**Enzymes:** *S. subtomentosum* secretes protease, amylase, phytase, carboxyl, esterase, and lipase enzymes proving to have potential wide range applications in many industries. (10)  
I foresee that this group of fungi along with *Trichaptum biforme* is going to have a wide range of applications in many industries and for breaking down a wide range of chemicals very well. When I am walking in the woods around the northeast US, any time of year I see *Stereum ostrea, Stereum complicatum, and Trichaptum biforme* everywhere I turn. Since these fungi are so abundantly breaking down lignin left and right and apparently so aggressively doing so, they must pack some powerful enzymes that I feel have mighty potential. They also look so similar to turkey tail (often being mistaken for turkey tail by beginner mycologists), which you will read later has quite the extensive list of mycoremediative abilities! |
| **Strobilurus spp.** | **Chemicals:** According to Robert Rogers in his book *Fungal Pharmacy* Strobilurus species are apparently one and a half to three times more powerful than *Trametes versicolor* when it comes to lignin degradation. This means it is definitely a species that deserves more research, and has a lot of potential. (10) |
| **Suillus** | **Biological:** Active against: *E. coli, Enterobacter aerogenes, Salmonella typhimurium, Staphylococcus aureus, S. epidermidis, Bacillus subtilis, Candida albicans, and Saccharomyces cerevisiae*. (10) |
Chemical: Shown to remove benzo pyrene by 50% in four weeks (Braun-Lullemann et al. 1999)
Also shown to degrade TNT under nitrogen-deficient conditions. 
*Suillus granulatus* completely metabolizes catechol, 3,4-dihydrobenzoic acid and vanillic acid. It has also been shown to transform para-cresol in five hours. (10)

Metals: Woolly pine bolete is shown to hyperaccumulate lead by sixty-seven times and accumulate mercury by up to six times. (10)

**Trametes**
(Turkey tail, anise polypore, sweet trametes, hair turkey tail, velvet talk, cinnabar red polypore, etc.)

Biological: Active against: Enterobacter aerogenes, Saccharomyces cerevisiae (Yamae and Bilgili 2006) Plasmodium falciparum (Silva et al. 2009) *Staphylococcus aureus*, *S. albus*, *Streptococcus salivarius*, *E. coli*, *Klebsiella pneumoniae*, *Vibrio cholerae*, *Shigella paradysenteriae*, *E. coli*, *Listeria monocytogenes*, *Candida albicans* and *Pseudomonas aeruginosa*. (10)

Chemical: Goud et al. (2009) demonstrates that laccase production for *T. pubescens* is best stimulated by xylidine, and also produces high rates of lipase which has a wide uses in oleochemical, petrochemical, and biodiesel applications.
Some think Turkey Tail is the most powerful degrader of 3,4-dichloroaniline, dieldrin, PCP, lignin and chlorine-containing effluent and phenanthrene. This fungus has demonstrated that it is great at breaking down polycyclic aromatic hydrocarbons including anthracenes, pyrenes, fluorene, methoxybenzene, and styrene. Also shown ability breaking down dibenzyl sulphide to benzyl alcohol and benzyl mercaptan. Also shown to break down triarylmethane, indigoid, azo, Chicago Sky Blue dye, anthraquinone dyes, DDT, chlorophenols, aldrin, dieldrin, lindane, and heptachlor. (10)
Fragoeiro and Magan (2008) showed that turkey tail was able to
Researchers like Pointing et al. (2000) found that laccase levels were increased by added apramycin sulfate, ABTS, and twenty micromoles of xylidine. (10)

**Metals:** Red Polypore (*T. sanguineus*) has shown to hyperaccumulate more than 90% of lead, copper, and cadmium from water. (10)

<table>
<thead>
<tr>
<th><strong>Trichaptum biforme</strong></th>
<th><strong>Chemical:</strong> has been shown to be a cold weather remediation of PCPs. More research is needed with this fungi (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Purple toothed polypore)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tyromyces chioneus</strong></th>
<th><strong>Chemicals:</strong> Sasek et al. (1998) shows that this fungus is a great remediation for degrading synthetic dyes. (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(White cheese polypore)</td>
<td></td>
</tr>
</tbody>
</table>

| **Xylaria polymorpha**  | **Biological:** Activity against *Plasmodium falciparum* (Tansuwan et al. 2007) (10)  
**Enzymes:** Has shown to produce laccase in tomato juice and peroxidase in soybean meal. (10) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dead man’s fingers)</td>
<td></td>
</tr>
</tbody>
</table>
**Bench Scale**

Before remediating a 12-acre site it is important to do bench scale tests to figure out what fungus to use, at what inoculation rate, if the fungus can handle that concentration of the toxin or if it needs to be diluted and/or treated off site.

The most basic bench scale test one can conduct would be the using petri plates inoculated with the toxin and different strains of fungi. This is a perfect test to follow to see what strains of fungi are the best to use to combat the contaminant you are dealing with. On the plate you have tickets to a time machine portal, which brings you to a roman gladiator match between a fungus and a contaminant. If you're testing this with bacteria it will either climb towards the fungi and try to fight or it will run away to the other end of the dish while the fungus slowly pulses its tendril hyphae towards the bacteria throwing up deadly free radical exudates able to bring the gladiator match to an end. If one is working with chemicals the mycelium will creep up like an octopus stalking its prey. Once the hyphal tips get close enough the mycelium will sense a contaminant ahead. The commander will send commands to the spitzenkorper in the hyphal tip to start excreting very potent fungal enzymes to combat the chemical. These enzymes include cellulases, ligninases, peroxidases, and laccases, which combine with free radical oxygen molecules to infiltrate and break apart these chemicals like lego sculptures. “ARRRRRGH! — YOU CURSED BRAT! LOOK WHAT YOU'VE DONE! I'm MELTING! Melting! Oh — what a world, what a world! Who would have thought a good little girl like you could destroy my beautiful wickedness?! ARRRRRGH! I'm gone! I'm gone! I'm going!... [is fully melted]” - *(Wicked witch of the west, Wizard of Oz, 1939)*

Similarly one-mix dilutions of the chemical/toxin in the agar media and try inoculated different strains of fungi of the series of dilutions. This will show how well each fungus does at each dilution. Also one can also germinate fungal spores on the series of dilutions. Since spores are genetically variable, the ones that germinate are tolerant to the toxin. One can produce a super fungal strain that is super adapted to a toxin by continuing to germinate spores generation after generation on higher dilutions of the toxin. This is also a great technique to do if one finds a mushroom growing on or near a contaminated site. These spores will carry genetic variations
that favor the toleration of this contaminant. Combine this with genetic engineering to really create super cleaning mushrooms.

(Pleurotus ostreatus mycelium growing on agar infused with dirty cigarette butts)

This same test can be done with liquid cultures that have a chemical added to it. Tests can then be done of how much this chemical has been degraded while in the liquid culture.

Once one finds out the best strains to work with it is best to get the conditions of the site you are remediating (temperature, humidity, moisture level, ph, etc) and then replicate them as best as possible to do small scale tests with bulk substrate seeing what strain cleans up a small sample of the site the best. This test can also be done on site if applicable. These small tests can be done in mason jars, buckets, bins or small piles.
(Image: Ja Schindler flowing e coli contaminated water through stropharia and ganoderma mycelial filters during a 5 day mycoremediation workshop.)

If one is working with a water filtration project one should construct a water filtration bench scale prototype. Any test requires a container with holes at the bottom to hold the myceliated substrate, water with the contamination in it, and then after the water is passed through the myceliated filter, a container to collect the filtered water.
This is talked about in Tradd Cotter’s book *Organic Mushroom Growing and Mycoremediation* (Chelsea Green 2014). This three tiered plastic drawer unit is great to use for a filter. One can start with one drawer and if it still needs to be filtered more they can tests a double filter by using both drawers. This can also be used for harvesting enzymes that are excreted from the mycelium and washed into the bottom base of the unit)

Whatever unit you are using these prototypes test rate of flow, biomass needed and the efficiency of the fungal species.

On your bench scale tests you can test for many things:

- Inoculation rate
- Species selection
• PH (let’s you know if you need to change the pH of the site)
• Temperature (let’s you know what time of year is best to work on the site and if you need to add shade to cool it down, or maybe remediate the site off site in a warmer condition)
• Substrate/nutrients/supplements added (biochar, micro amounts of heavy metals, compost, chicken/worm poop, hydrated lime, H2o2, gypsum, straw/sawdust/coffee grounds etc)
• Type of inoculation (layer, just on top, on the bottom, or all mixed up)
• Multiple species (bacteria, enzymes, mycelium, plants, worms etc)
• And so much more!

When conducting tests try to follow the scientific method and limit as many variables as possible. When you get results publish them and share them with the community to get as much data on myco/bioremediation out there as possible. There is definitely not enough information about mycoremediation in this world, and therefore people don’t trust using it on big plots because frankly it hasn’t really been done. So we need everyone to be tested this and getting as much data as possible in many different conditions. We need people replicating tests in different places in the world. And we need people to be trying out new tests that no one has ever tested before to change the game of mycoremediation and figure out new better ways to remediate toxic waste.
Pilot tests

After you have done some preliminary tests it’s time to do a pilot test. The pilot test is going to be a lot bigger than your bench scale tests. The pilot test is going to be a test on the site that shows direct application of the biotechnology. But sometimes it’s not as big as the full remediation of the entire site. For the pilot project it’s going to cost a lot more money and it’s great to have the community involved and updated. Connect with the town and the mayor, get volunteers from the community if the site is not that toxically dangerous. Take lots of pictures and videos to track your updates.

There are so many factors that control the success of your pilot project. A lot of the questions laid out in the beginning of this chapter are good ones to ask like: where are the contaminants on the sites? What is the hydrology of this site? What is the soil like? The temperature? The weather? What are the politics of this site (is it tied up in a lawsuit? Is it located on someone else's land? Etc.

LAND:

1. Lay mycelium on top of soil to let enzymes rain down on contaminated soil.
2. Depending on how big the plot is and how manageable you could dig up some of the soil and do layers of soil and mycelium with a food source for the mushroom like (straw sawdust, cardboard etc.) You could always do this off site or to the side in piles, or in containers.
3. The last method is windrow composting. This method has great results with facultative bacterial teas like the IOS-500 blend invented by Robert Rawson.
This bacterial tea is grown in a White Knight™ inoculator system.

(Image credit: Robert Rawson)

Then it is sprayed on windrow compost piles which are more than 4 feet high and more than 12 feet long. Heavy machinery is needed to move these piles to create aeration and prevent them from overheating.

**Enzymes:**

Although never done yet from my knowledge, one could easily add white rot enzymes into the mix of a facultative bacteria mix or compost tea and use the same method. A great way to crudely extract enzymes is:

- The method of the drawers system from Tradd Cotter’s book, laid out in the bench scale section

- Make friends with a commercial mushroom farm and ask if you could poke holes in the corner of some of their bags where some of the “juice” has collected and hold a collection unit under it. This is very easy to do for something like Oyster mushrooms that grow in the bag but it’s a lot harder to collect for something like
shiitake unless you ask before they take the blocks out of the bags, or lay down a big bin below where they are ripping open bags and hope enough enzymes call into the bin. I have done this method with shiitake before and it took well over 100 five-pound bags to almost fill a quart sized mason jar. These bags were also sitting for a while as well creating more enzymes than a bag that is a lot newer. With the mister systems in grow room; it does a great job of falling into the holes of bags and washing the secondary metabolites or enzymes into a pool at the bottom of the bag.

- Use a conical fermenter or something of the sorts that allows you to pour water through mycelium that is packed in the container and collect the enzyme's dripping from the bottom like this one here:

To make this extraction continuous you want to add a bin at the bottom with a pump leading back to the top to continuously run the same liquid through the mycelium. One could even take a handful of the contaminated soil, make an indent on the top part of the mycelium wait a couple days and then run water through. This will make the mycelium react to the contaminants and release more enzymes to counteract the toxins. You could have many of these collectors or a giant one. It all depends on how much contaminants you are dealing with. In terms of how much enzymes you need per square foot, this has not been studied, but the more the merrier. The benefit of using enzymes is that they are the things produced by the mycelium to
break down these toxins anyways. If we can “milk” them out in a sense and mass spray them on a site, it would save a lot more time, money, energy and make a lot more sense. Cut the middleman, go straight to the source. Another benefit is that bacterial teas are used a lot already in industrial remediation so the combination of these enzymes with the bacterial tea spray would be crucial. These enzymes are able to break down higher weight molecules that sometimes bacteria can’t break down. This would mean a higher remediation percentage and probably a faster remediation time as well!

Another method that has shown great success (Stoilove, I et al. (2010)) is by making a huge liquid culture broth of the fungi you want to cultivate. In the sugary broth the mycelium is secreting extracellular enzymes, which the cultivator can then pour onto a contaminated plot. The most common enzyme extracted from liquid cultures from white rot fungi is laccase, which is most notably used to decolorize dyes. One could always use some of the liquid culture for inoculating substrate for food and medicine production, and then use the rest for remediation. One could also filter off the mycelium from the rest of the liquid broth, dry it out powder it and use it in medicinal preparations. There are lots of notable medicinal compounds found in liquid culture broths including LEM, LAP, Schizophyllan, PSK, PSP, AB-FP, Cordycepin and more. These compounds can be isolated using Soxhlet extraction, ethanol concentration, fractional precipitation, acidic precipitation with acetic acid, ion-exchange chromatography, gel filtration and/or affinity chromatography. One could strain the mycelium from the liquid portion first. This method can both be done to treat solid and liquid contaminants. One could add various nutrients like glucose to act as a peroxide (\( \text{O}_2^{-2} \)) for low-molecular-weight oxidants (mediators) like glyoxal oxidase to create \( \text{H}_2\text{O}_2 \) which is then broken up into \( \text{H}_2\text{O} \) and a free radical oxygen to bounce around and steal electrons on the given toxin aiding in its complete mineralization. Enzymes from fungi are extracted all the time in big 10-30 foot high fermentation reactors.
<table>
<thead>
<tr>
<th>Enzymes</th>
<th>Species</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amylase</td>
<td><em>Aspergillus niger, Aspergillus oryzae</em></td>
<td>Brings about the hydrolysis of starch to dextrin and sugars. Starch processing and food industry, used in the preparation of adhesives and sizings, digestive acids and to clarify fruit juices.</td>
</tr>
<tr>
<td>Alpha-galactosidase</td>
<td><em>Aspergillus niger</em></td>
<td>Breaks down the galactose that many people can’t metabolize causing it to ferment in our guts, causing gas. The active ingredient in “beano” a product designed to prevent flatulence when beans or brassicas are eaten.</td>
</tr>
<tr>
<td>Chymosin</td>
<td><em>Aspergillus niger</em></td>
<td>Food industry</td>
</tr>
<tr>
<td>Cellulase</td>
<td><em>Trichoderma viride, Trichoderma reesei</em></td>
<td>Hydrolyze cellulose to cellobiose. Bio Finishing agent in textile industry, improvement of beatability, drainage and solubility of pulp, deinking and dewatering for paper industry, dehydrated foods, food processing, Clarify fruit juices and form jams, brewing, detergent, Ethanol production, baking, animal forage and feed to increase digestibility</td>
</tr>
<tr>
<td>Cellbiohydrolase</td>
<td><em>Trichoderma viride, Trichoderma reesei</em></td>
<td>Textile, pulp, and paper industry</td>
</tr>
<tr>
<td>Glucoamylase</td>
<td><em>Aspergillus phoenicis, Aspergillus oryzae</em></td>
<td>Starch processing industry</td>
</tr>
<tr>
<td>Glucose isomerase</td>
<td></td>
<td>Manufacture of high fructose syrup and high sweetness</td>
</tr>
<tr>
<td>Glucose oxidase</td>
<td><em>Aspergillus niger, Aspergillus oryzae, Penicillium spp.</em></td>
<td>Oxidizes glucose to gluconic acid. Textile industry, biosensing, removes glucose from eggs before they are dried and oxygen from canned food, soft drinks and beer. Used in making test papers for use by diabetics.</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Source</td>
<td>Application</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hemicellulase</td>
<td></td>
<td>Baking, brewing, bioconversion of lignocelluloses to sugars, production of xylitol and ethanol, clarifying fruit juices, increasing the nutritional value of silage and fodder</td>
</tr>
<tr>
<td>Laccase</td>
<td><em>Trametes versicolor</em></td>
<td>Textile, pulp, paper industries, used as bio transformers to remove nonionic surfactants</td>
</tr>
<tr>
<td>Lipase</td>
<td><em>Aspergillus niger, Aspergillus oryzae, Rhizopus</em></td>
<td>Hydrolyzes lipids to glycerol and fatty acids. Used in degradation of particulate organic matter. Used in the food and detergent industry. Improves the flavour of some processed foods, and boosts the cleaning action of detergents.</td>
</tr>
<tr>
<td>Pectin Lyase</td>
<td><em>Trichoderma reesei</em></td>
<td>Food industry,</td>
</tr>
<tr>
<td>Peroxidases</td>
<td><em>A lot of white rot fungi</em></td>
<td>Removal of pollutants by precipitation</td>
</tr>
<tr>
<td>Proteases</td>
<td><em>Aspergillus niger, Aspergillus oryzae, Rhizopus delemar, Rhizopus oligosporus</em></td>
<td>Usually a mixture of enzymes that break down proteins Food, detergent, soaking baiting, dehairing, and tendering for the leather industry, meat tenderizer, cheese manufacturing, Chill proofing for beer, generation of flavors and aromas, digestive acids, making of liquid glues, as stain removers in detergents, and used in biomedical applications.</td>
</tr>
<tr>
<td>Phytase</td>
<td><em>Aspergillus niger, Aspergillus oryzae</em></td>
<td>Food industry</td>
</tr>
<tr>
<td>Rennin</td>
<td><em>Mucor miehei</em></td>
<td>Food industry, cheese manufacturing</td>
</tr>
<tr>
<td>Xylanases</td>
<td><em>Trichoderma reesei, Trichoderma koningii, Aspergillus niger</em></td>
<td>Textile, pulp, paper, and bakery industries</td>
</tr>
<tr>
<td>Amyloglucosidase</td>
<td><em>Aspergillus niger</em></td>
<td>Starch syrups, dextrose, foods</td>
</tr>
<tr>
<td>Invertase</td>
<td><em>Saccharomyces cerevisiae</em></td>
<td>Catalyses the hydrolysis of sucrose to glucose and fructose.</td>
</tr>
<tr>
<td>Enzyme/Enzymatic Activity</td>
<td>Organism(s)</td>
<td>Industry/Process Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Alcohol Dehydrogenase</td>
<td><em>Saccharomyces cerevisiae</em></td>
<td>Ethanol assay</td>
</tr>
<tr>
<td>Lactase</td>
<td><em>Kluyveromyces lactis</em></td>
<td>Dairy industry</td>
</tr>
<tr>
<td>B-Glucanase</td>
<td><em>Aspergillus niger</em></td>
<td>Brewing</td>
</tr>
<tr>
<td>Pecintase</td>
<td><em>Aspergillus spp.</em></td>
<td>Fruit juice clarification and forming jams, also used in the retting of flax preparatory to the making of linen, and used in the manufacturing of yogurt, fermentation of coffee bean</td>
</tr>
<tr>
<td>LDSs</td>
<td>P. chrysosporium, Inonotus dryophillus, T. versicolor,</td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>Lignin peroxidase (LiP)</td>
<td>*P. chrysosporium, Coriolopsis polyzona, Pleurotus ostreatus, Nematolona frowardii, T. versicolor, *Chrysonilia sitophila</td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>Peroxidases</td>
<td>Horseradish, several microorganisms</td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>tryrosinase</td>
<td><em>Agaricus bisporus</em></td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Bacteria/Species</td>
<td>Function</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Permethrinase</td>
<td><em>Agrobacterium, Pseudomonas sp., Flavobacterium sp.</em></td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>Parathion hydrolase, 2-4-Pentanedione esterase, Alkaline protease</td>
<td><em>Nocardia sp, Bacillus cereus, Pseudomonas vericuliris.</em></td>
<td>Remediation of pollutants</td>
</tr>
<tr>
<td>Esterase</td>
<td><em>Curvularia senegalensis, Corynebacterium, Comamonas acidovorans.</em></td>
<td>Polyurethane degradation</td>
</tr>
</tbody>
</table>

(1, 29, 30, 31, 32, 33, 34, 35, 36, 37, 52)

**Extract enzymes from spent or fresh spawn**

**Materials:**
- Fresh or spent spawn
- Ammonium sulfate ((NH₄)₂SO₄)
- Water
- Ice bath
- Vinegar
- Baking soda
- Stirring chemical dialysis system

1. Soak spawn in water for 4 hours dissolving the enzymes (notably laccase) into the water
2. Add ammonium sulfate at 70% solution in an ice bath to form sulfate anions and ammonium cations, which bring to laccase lowering the enzymes solubility causing it to precipitate out of the water.
3. Centrifuge the solution.
4. Resuspend in a 100mM (8.2 grams per liter of water) sodium acetate buffer (pH 5) made from the vinegar and baking soda.
5. Run this solution through a stirring chemical dialysis system to remove the ammonium sulfate from the laccase.
6. Store the dialyzed solution at 4 degrees Celsius until use.

(1)
With this method the enzymes are still pretty unstable even in a buffer. Enzyme immobilization is widening the scope of enzyme application allowing improvement of costs, enzyme performance under optimal process reaction conditions (e.g. higher activity and stability at extreme pH’s, elevated temperatures or in organic solvents). Immobilized enzymes have an increased thermostability, and resistance to chemical agents and/or harsh reaction conditions, making them more shelf stable and create a wider application window. Laccases have been successfully immobilized on various carriers, such as nanoparticles, chitosan, poly (GMA/EGDMA) beads, alginate, and nylon membrane. There are various ways to bind the enzyme to the support including physical and chemical. It’s always a compromise between high stabilization at the expense of activity and matrix derivatization and then the other way around. Nutrient levels, culture conditions, culture mediate, developmental stage, and the addition of a wide range of inducers influence synthesis and secretion levels of fungal enzymes. This technology is paramount for the biosensing and biofuel cell industries as well with the emerging mycoremediation industry. A crude laccase extract was made from *Pleurotus ostreatus* and was immobilized in copper-alginate beads. This concoction attained high levels of laccase production and was packed in a fixed bed bioreactors employed for the continuous decolorization of RBBR. 70% of the RBBR was decolorized after 20 cycles. (Palmieri et al. 2005, Phetsom et al. 2009). There are dozens and dozens of studies exhibiting the ability for crude extracts of fungal enzymes from various fungi that demonstrated the ability to decolorize a wide variety of dyes. I foresee many industries coinciding with the creation of massive fermenters of liquid cultures, making room for spawn for culinary mushrooms, medicinal mushrooms, medicinal extracts, cancer drugs, new antibiotics, biofuel, biosensors, mycoremediation, brewing, denim bleaching, paper industries, and much much more! Laccase extracts can even be combined with myco-material companies like ecovative to integrate antimicrobial or antioxidant properties for functional packaging materials (Kuganda et al. 2010). The potential is extraordinary. (11, 38)

With the addition of solid state mycelium and enzymes to soil based toxins, one can also add some other things like supplements, compost tea, plants and mycorrhizal fungi and more.

**Compost tea:**

**Materials:**

- Five-gallon bucket (clean!)
- Non-chlorinated water (best is well water, rain water, pond water) if your tap has chlorine, leave it uncovered for 24 hours to off-gas any chlorine.
- 1 cup of inoculant (worm castings or aerobic compost)
- ¼ cup of food: comprised of equal parts of unsulphured molasses, fish hydrolase, kelp and 1 tablespoon of humic acid.
- 1 compost tea bag/stocking
- Air pump with tube and air stone
- Stocking or mesh bag
- Plastic watering can or backpack sprayer (one that’s clean!)

Steps:

1. Take your compost inoculant and add humic acid fish hydrolase, or soaked oats to it in a shallow tray and mix it up well. Leave it out for two or three days to encourage fresh microorganism growth.
2. Fill a bucket with “good” water that has a temperature of 55-80 degrees fahrenheit.
3. Put the airstone at the bottom of the bucket and plug in the air pump. You are looking for a churning or rolling boil of water not simply light bubbles.
4. Put inoculant and food in the stocking or mesh bag, tie off the end and add it to the bucket. This stocking or mesh bag must be at least 400 micrometers.
5. Let the brew bubble between 24-36 hours but no more no less!
6. Strain the tea, and apply it to your site. A minimum of 1 gallon of tea for 1,000 square feet of contaminated land. Wait two weeks between applications.

Or you can simply purchase compost tea bags, compost tea brewing systems and/or EM (efficient microorganisms) which is a shelf stable blend of 8-12 microorganisms that are usually facultative which means they can survive in a lack of oxygen. A lot of times these commercial blend of microorganisms are specific strains that are highly efficient at what they do and are much more powerful than a homebrew of microorganisms.

You can also use bioventing in combination with compost tea and enzymes to aerate the soil and also allow these liquids to enter deeper into the soil. Bioventing is the use of fans and pipes to blow oxygen, and sometimes nutrients deep in the soil to feed the bacteria. This can be combined with drip irrigation and pipes with holes in them drilled into the soil to not only aerate the soil but also a means to apply your enzymes/compost tea deeper into the soil.
Phytoremediation:

Before adding plants on your site you want to make sure your soil health can sustain them. Consult a soil expert on the health of your soil. Adding lots of compost, compost tea, and fungal material down will create rich soil to add plants to create more of a biodiversity of life. Great soil = great biodiversity. Other amendments would be biochar, worm castings/worms, chicken poop, and more! Highly recommend either making friends who make these products or make them yourself! Raising chickens, worms, and making biochar are very simple fun things to do but also tackling a contaminated site with all the other stressors of life can also be a little overwhelming so limiting the amount of projects you are doing at one time is always a plus!

If you realized there are heavy metals on your site and the soil is not healthy enough for plants to be added to hyperaccumulate the heavy metals, adjusting the pH with the addition of say lime will raise the pH and lower the solubility of metals like aluminum, iron, magnesium, lead, cadmium, and others from flowing into the soil and groundwater. There is also the product Chitosan which is a water soluble, biodegradable product made from modified shrimp shells that readily binds to heavy metals that one could also add to their soils in the meantime.

Once the soil is ready for plants you want to check what metals you want to hyperaccumulate and match them to your contams. Below is a chart modified from the book Earth Repair by Leila Darwish. (6) If you want more information about phytoremediation you should definitely buy her book. It’s a go to resource for any grassroots bioremediator.

<table>
<thead>
<tr>
<th>Lead</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alpine pennycress (Thlaspi caerulescens)</td>
</tr>
<tr>
<td></td>
<td>Sunflow (helianthus annuus)</td>
</tr>
<tr>
<td></td>
<td>Brown mustard (Brassica juncea)</td>
</tr>
<tr>
<td></td>
<td>Geranium (pelagrium spp)</td>
</tr>
<tr>
<td></td>
<td>Corn (Zea mays)</td>
</tr>
<tr>
<td></td>
<td>Tomato (Solanum lycopersicum)</td>
</tr>
<tr>
<td></td>
<td>Buckwheat (Erigonium spp)</td>
</tr>
<tr>
<td></td>
<td>Willow (Salix spp)</td>
</tr>
<tr>
<td></td>
<td>Alfalfa (Medicago sativa)</td>
</tr>
<tr>
<td></td>
<td>Wheat (Triticum aestivum)</td>
</tr>
<tr>
<td></td>
<td>Water hyacinth (Eichornia crassipes)</td>
</tr>
<tr>
<td></td>
<td>Sheet fescue (festuca ovina)</td>
</tr>
<tr>
<td></td>
<td>Honey locust (gleditsia triacanthos)</td>
</tr>
<tr>
<td></td>
<td>Bald cypress (taxodium distichum)</td>
</tr>
<tr>
<td></td>
<td>Vetiver Grass Vetiveria zizanioides)</td>
</tr>
<tr>
<td></td>
<td>Alyssum (Alyssum wulfenianum)</td>
</tr>
<tr>
<td></td>
<td>Quaking aspen (populus tremula)</td>
</tr>
</tbody>
</table>

(6)
<table>
<thead>
<tr>
<th>Metal</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>● Chinese brake or ladder brake ferns (Pteris vittata)</td>
</tr>
<tr>
<td></td>
<td>● Bentgrass (Agrostis castellana)</td>
</tr>
<tr>
<td></td>
<td>● Marsh fern (Thelypteris palustris)</td>
</tr>
<tr>
<td></td>
<td>● White lupine (Lupinus albus)</td>
</tr>
<tr>
<td></td>
<td>● Poplar (Populus spp)</td>
</tr>
<tr>
<td></td>
<td>● Douglas fir (Pseudotsuga menziesii)</td>
</tr>
<tr>
<td></td>
<td>● Rice (Oryza sativa)</td>
</tr>
<tr>
<td>mercury</td>
<td>● Sunflower</td>
</tr>
<tr>
<td></td>
<td>● Poplar</td>
</tr>
<tr>
<td></td>
<td>● Cottonwood (Agrostis castellana)</td>
</tr>
<tr>
<td></td>
<td>● Rapeseed (Brassica napus)</td>
</tr>
<tr>
<td></td>
<td>● Water lettuce Pistia statioes</td>
</tr>
<tr>
<td></td>
<td>● Hydrilla</td>
</tr>
<tr>
<td></td>
<td>● Water hyacinth</td>
</tr>
<tr>
<td></td>
<td>● Willow</td>
</tr>
<tr>
<td>Zinc</td>
<td>● Alpine pennycress</td>
</tr>
<tr>
<td></td>
<td>● Tomato</td>
</tr>
<tr>
<td></td>
<td>● Bladder campion (Silene vulgaris)</td>
</tr>
<tr>
<td></td>
<td>● Sunflower</td>
</tr>
<tr>
<td></td>
<td>● Brown mustard</td>
</tr>
<tr>
<td></td>
<td>● Common duckweed (Lemna minor)</td>
</tr>
<tr>
<td></td>
<td>● Red clover (Trifolium pratense)</td>
</tr>
<tr>
<td></td>
<td>● Reed canary grass (Phalaris arundinacea)</td>
</tr>
<tr>
<td></td>
<td>● Wheat</td>
</tr>
<tr>
<td></td>
<td>● Water hyacinth</td>
</tr>
<tr>
<td></td>
<td>● Willow</td>
</tr>
<tr>
<td>Nickel</td>
<td>● Alyssum (Alyssum lesbiacum)</td>
</tr>
<tr>
<td></td>
<td>● Yellow Tuft (Alyssum murale)</td>
</tr>
<tr>
<td></td>
<td>● Sunflower</td>
</tr>
<tr>
<td></td>
<td>● Mustards</td>
</tr>
<tr>
<td></td>
<td>● Milkwort (Glaux L.)</td>
</tr>
<tr>
<td></td>
<td>● Alpine pennycress</td>
</tr>
<tr>
<td></td>
<td>● Reed canary grass</td>
</tr>
<tr>
<td>Cadmium</td>
<td>● Mustard</td>
</tr>
<tr>
<td></td>
<td>● Cabbage (Brassica oleracea)</td>
</tr>
<tr>
<td></td>
<td>● Willow</td>
</tr>
<tr>
<td></td>
<td>● Field chickweed (Cerastium arvense)</td>
</tr>
<tr>
<td></td>
<td>● Miner’s lettuce (Claytonia perfoliata)</td>
</tr>
<tr>
<td></td>
<td>● Wild chives (Allium schoenoprasum)</td>
</tr>
<tr>
<td></td>
<td>● Common duckweed</td>
</tr>
<tr>
<td></td>
<td>● Hydrilla</td>
</tr>
</tbody>
</table>

(6)
<table>
<thead>
<tr>
<th>Element</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>Water hyacinth, Sunflower, Tomato, Tape and eel grass (vallisneria spp), Alfalfa, Alpine pennycress, Common yarrow (Achillea millefolium), Purple foxglove (Digitalis purpurea), Northern starwort (stellaria calycanthus), Holly (ilex spp)</td>
</tr>
<tr>
<td>Copper</td>
<td>Brown mustard, Goat willow (Salix caprea), Basket willow (Salix viminalis), Birch (Betula spp), Smooth water hyssop (Bacopa monnieri), Water hyacinth, Sunflower, Tape grass, Alpine pennycress, Creosote bush (larrea tridentata), Lodgepole pine (pinus contorta), Gray alder (alnus rubra), European alder (Alnus glutinosa), black cottonwood (Populus balsamifera L. ssp. trichocarpa)</td>
</tr>
<tr>
<td>Selenium</td>
<td>Two-grooved milk-vetch (astragalus bisulcatus), Rapeseed, Barley (Hordeum vulgare), Desert prince's plume (stanleya pinnata), Willow</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Alpine pennycress (6)</td>
</tr>
<tr>
<td>Element</td>
<td>Plants</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Alpine pennycress (6)</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Barley</td>
</tr>
<tr>
<td></td>
<td>Fava bean (Vicia faba var. Equina Pers.)</td>
</tr>
<tr>
<td></td>
<td>Hairy goldenrod (Solidago hispida)</td>
</tr>
<tr>
<td>Silver</td>
<td>Brown mustard</td>
</tr>
<tr>
<td></td>
<td>Rapeseed</td>
</tr>
<tr>
<td></td>
<td>Willow</td>
</tr>
<tr>
<td>Cesium</td>
<td>Red Maple (Acer rubrum)</td>
</tr>
<tr>
<td></td>
<td>Larch (larix Mill.)</td>
</tr>
<tr>
<td></td>
<td>Spruce</td>
</tr>
<tr>
<td></td>
<td>Redroot amaranth (Amaranthus retroflexus L.)</td>
</tr>
<tr>
<td></td>
<td>Amaranth (Amaranthus spp)</td>
</tr>
<tr>
<td></td>
<td>Tulip tree (Liriodendron L.)</td>
</tr>
<tr>
<td></td>
<td>Monterey pine (pinus radiata)</td>
</tr>
<tr>
<td></td>
<td>Ponderosa pine (pinus ponderosa)</td>
</tr>
<tr>
<td></td>
<td>Coconut palm (Cocos nucifera)</td>
</tr>
<tr>
<td></td>
<td>Cabbage</td>
</tr>
<tr>
<td></td>
<td>Beans (Phaseolus spp)</td>
</tr>
<tr>
<td></td>
<td>Spiderwort (Tradescantia L.)</td>
</tr>
<tr>
<td></td>
<td>Reed canary grass</td>
</tr>
<tr>
<td></td>
<td>Brown mustard</td>
</tr>
<tr>
<td></td>
<td>Beet (beta spp.)</td>
</tr>
<tr>
<td></td>
<td>Quinoa (Chenopodium quinoa willd)</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td>Sunflower</td>
</tr>
<tr>
<td></td>
<td>Russian thistle (Salsola L.)</td>
</tr>
<tr>
<td></td>
<td>Field chickweed</td>
</tr>
<tr>
<td></td>
<td>Tall fescue (Schedonorus arundinaceus)</td>
</tr>
<tr>
<td></td>
<td>Perennial ryegrass (Lolium perenne)</td>
</tr>
<tr>
<td></td>
<td>White clover (Trifolium repens)</td>
</tr>
<tr>
<td>Plutonium</td>
<td>Red maple</td>
</tr>
<tr>
<td></td>
<td>Tulip tree</td>
</tr>
<tr>
<td>Uranium</td>
<td>Sunflower</td>
</tr>
<tr>
<td></td>
<td>Cabbage</td>
</tr>
<tr>
<td></td>
<td>Redroot amaranth</td>
</tr>
<tr>
<td></td>
<td>Oak (Quercus spp)</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td>Black spruce (picea mariana)</td>
</tr>
<tr>
<td></td>
<td>Juniper (Juniperus spp)</td>
</tr>
<tr>
<td></td>
<td>Bladder campion</td>
</tr>
<tr>
<td>Strontium</td>
<td>Monterey pine</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td></td>
<td>Ponderosa pine</td>
</tr>
<tr>
<td></td>
<td>Forest red gum (Eucalyptus tereticornis Sm.)</td>
</tr>
<tr>
<td></td>
<td>Sunflower</td>
</tr>
<tr>
<td></td>
<td>Water hyacinth</td>
</tr>
</tbody>
</table>

This list doesn’t include the range of chemicals that can be remediated by plants. For the full list, consult Liela Darwish’s book *Earth Repair*!

**Physiological mechanisms of metal remediation by plants:**

- Mobilization - release of organic acids (citric acid, maleic acids), phytosiderophores or chelators etc to solubilize and facilitate uptake

- Uptake and sequestration into roots - adsorption on root surface or absorption- active uptake through membrane transporters, transport and sequestration into vacuoles in root cells

- Transport through xylem and phloem - root to shoot transport, either through transpiration pull or active transport through xylem and phloem loading

- Unloading and tissue distribution - unloading of metals from xylem or phloem and distribution through phloem or cytoplasm

- Sequestration or hyperaccumulation - through endogenous vacuolar transport system like glutathione conjugate pumps (GCPs) or cytosolic metalloenzymes

- Molecular mechanisms: induction of gene transcripts and synthesis of proteins or enzymes that regulate all these physiological mechanisms
**Mycorrhizal Fungi:**

With all plants you want to add mycorrhizal fungi. Truly all Fungi are symbiotic in one way or another depending on the perspective and scale you look at it. One of the incredible ways fungi can be marked as symbiotic is through mycorrhizal relationships, which are split further into two main groups: ectomycorrhizal and endomycorrhizal fungi. “myco” meaning mushroom and “rhizal” meaning roots. The ectomycorrhizal mushrooms will create an exterior sheath covering the roots of plants. The Endomycorrhizal mushrooms will invade the interior of these roots.

The ectomycorrhizal fungi are able to produce mushroom fruiting bodies like chanterelles, boletes, amanitas, morels, and more! The endomycorrhizal do not produce mushrooms but have a connection with approximately 95% of plants. These fungi work extremely well symbiotically with plants, increasing the plant’s absorption of nutrients, nitrogenous compounds, and essential elements. Mycorrhizal fungi are considered the Internet of the forest, transferring data from plant to plant and helping pass along information including nutrients. The ectomycorrhizal fungi act as a separate root system that attaches onto the existing plant root system that carries further nutrients to the plant roots. Plants with mycorrhizal associations can resist diseases far better, and can actually use these mycorrhizal connections to signal to other plants underground to start producing enzymes to build its immunity to the given incoming infection, disease, parasite etc. Mycorrhizal fungi can also transfer nutrients from for example a tree that is getting a lot of nutrients to trees that might not, or from a tree that is in the sun to trees that are in the shade. In addition to helping the plants overall health it also plays a
huge role in mycoremediation. Mycorrhizal fungi can also secrete enzymes to break down toxins and also sequester heavy metals in their network and immobilizing them taking the load off of the plants. Either attaching onto the outside of the mycelium, or absorbing into the network. (40)

There are various ways to cultivate mycorrhizal fungi to use on your plants for your site. The easiest way would be:

    Buy mycorrhizal inoculum online or at a store and follow the instructions on the back. They will either come in a liquid, a gel, a powder or tablets. Most common is in a powder. You can dilute this powder in water and germinate your seeds in it. You can also water your baby seedlings in it. You can dip your baby seedlings bare roots in it. You can apply mycorrhizal fungi any time of the plant's life cycle but to ensure that the plants accepts the mycorrhizal connect you want to add it as young as possible. When the plant matures it usually figures out a way to get what it wants and will often reject a new partnership. Another tip for growing mycorrhizal fungi is not to fertilize your plants with phosphorus because mycorrhizal fungi mine phosphorus naturally and give it to the plants so if you are already giving the plants phosphorus they wouldn’t have a need to form a relationship with this fungi to add more phosphorus into it’s life.
Water Remediation

Water is everywhere is a huge carrier of toxins. Every day, 2 million tons of sewage and industrial and agricultural waste are discharged into the world’s water. The UN estimates that the amount of wastewater produced annually is about 1,500 km³, six times more water than exists in all the rivers of the world. (UN WWAP 2003) (42). In some regions, more than 50% of native freshwater fish species are at risk of extinction, and nearly one-third of the world’s amphibians are at risk of extinction. (Vié et al. 2009) (42). Unsafe water causes 4 billion cases of diarrhea each year, and results in 2.2 million deaths, mostly of children under five. This means that 15% of child deaths each year are attributable to diarrhea – a child dying every 15 seconds. In India alone, the single largest cause of ill health and death among children is diarrhea, which kills nearly half a million children each year. (WHO and UNICEF 2000) (42). Just recently there was a crisis in Flint Michigan where detected lead levels were as high as 13,000 parts per billion. The level of concern is 5 ppb, and the level where the epa advises the town/city to take steps to reduce the waste and change pipes etc is 15 ppb for lead. We are constantly seeing oil spills leaking into rivers and even on a higher frequency fertilizers, bacterial coliforms, heavy metals and more seeping into most every water way on planet earth. We are at an edge where we are making it near impossible to live in a biodiverse healthy clean environment anymore.
Here are some of the water mediums in which toxic waste can be carried.

For almost all these scenarios it’s a lot easier to remediate biological toxins like bacterial coliforms than it is to remediate chemicals in water. Heavy Metals are also easy to filter out but then it gets tricky when one has to figure out how to dispose of the heavy metals in a safe way. Chemicals take days to months to break down where bacteria can just be trapped in the filter of mycelium and the water is then filtered. Bacteria is most commonly found in waterways where fecal matter from animal farms wash into the waterways.
Runoff from a parking lot/construction site:

One of the basics for water managements is to slow it down, capture it and store it so it seeps into the environment. When we put asphalt and pavement over our earth and destroy the soil beneath us, water tends to run faster and faster picking up all the toxic wastes on it’s way. Apart from building soil we need to capture it. Parking lots are a notorious everyday toxic collection space that more often than not when it rains washes a cocktail and chemicals and heavy metals down a slope into the groundwater and into local creeks, streams and rivers.

- Build a swale on contour. A swale is basically a ditch where water can run into and have enough time to seep into the soil. By adding plants inoculated with mycorrhizal fungi and other amendments, you can filter the water and increase absorption and remediation. Another thing you can add would be either bunker spawn (a burlap sack filled with woodchips and mycelium), or just lay woodchips as mulch for the plants and inoculate it with mycelium. The benefit of the bunker spawn is there are easier to manage considering they are already in neat bags and also they create a higher barrier for water to pass through. The benefit of just putting down wood chips is that a lot of people already put down wood chips to mulch their plants, and it looks aesthetically pleasing. You can also achieve a wider surface area by spreading a layer of inoculated wood chips too. It’s best to use fungi like turkey rail, reishi, lentinus tigrinus, or stropharia, which have very strong ropey dense mycelium that won’t wash away easily from water running down a slope. The mycelium is able to grip to the surrounding earth and hold it’s ground.
Lentinus tigrinus is also salt resistant so it is a good candidate for a site that is by a road or parking lot that has salt running off of it.

Creeks and streams

- You first want to test the water too see what kind of contaminant is present in the water. See what happens to the waterway when it rains, and when it’s very dry. This will give you information on how big to make the filter and how to prepare for drought events.
- Once you know what contaminant you are dealing with you can make it to the fungi you are dealing with. The most common one for dealing with bacteria in creeks and streams is Stropharia rugoso-annulata
- You can either buy sawdust spawn or make your own and then expand it onto wood chips in burlap sacks. These sacks you can get cheaply or free from most coffee shops. Wood Chips you can get cheaply or free if you call around to landscaping companies. There is also a great website called chipdrop.in where you can sign up to have wood chips dropped off at your house for free or for a little optional tip.
- After the inoculum is added to the wood chips, it is important to run a hose on the bags to give the wood chips and mycelium some moisture. These bags can then be placed in a shady spot between 50-70 degrees Fahrenheit. After a few weeks the mycelium should have established itself onto the wood chips and it will be ready to install into your waterway.
- If the water is flowing pretty fast one can set up a metal or mesh net across the waterway or a series of posts in the ground to prevent the myceliated burlap bags from washing
away. Then one could easily stack these bags across the waterway to make a check dam which water can still flow through this myceliated filter. It is important to run tests on the water before and after the check dam to see what is happening with these pollutants.

- Depending on how fast the water is running it is important to change these bags once every 6-18 months to make sure this filter is operating at full capacity. The old bags can then be composted since all/most of the pathogenic microbes have been “eaten” by the mycelium. But just to make sure it’s better to hot compost it. If there are heavy metals present you may have to dispose of the mycelium as you would toxic waste.

- Incase of a drought it’s important to monitor the bags to make sure the mycelium is staying alive. You may have to replace the bags in that case. Also in terms of flooding, it’s important to have safety measures in store like extra bags to throw down incase that does happen.

- Placing the bags in a metal cage that can be dragged in and out of the creek and stream will make this process a whole lot easier

**River**

Rivers are one of the trickier things to remediate. Most of the time you want to prevent the toxins from entering the river in the first place. Rivers are big and fast moving - very hard to control the situation.

- If the river is small it might be possible to do the same as you would do for a creek or a stream, but unlikely.

- Another option would be to construct a dam with inlets to allow the water to pass through. In these inlets there would be mycelium that water would have to pass through. Depending on how much water per minute flows through your inlets depends on how
deep you want the dam and how many inlets, and how big of inlets you want. Consult a hydrologist and an architect for this.

(Idea inspired by Tradd Cotter)

A lot of pollution that gets dumped into rivers comes from industries. It’s important to set up relationships with these industries and make a plan to remediate their wastewater. This requires a lot of engineering and technical knowledge that far surpasses my expertise. The use of enzymes and facultative bacteria in bioreactors is a common technique here. This can either be done in batch-fed fermentation systems where the polluted water is transferred into a sealed vessel and sterilized and then inoculated with microorganisms. The vessel is oxygenated and the mycelium, enzymes, and/or bacteria work to break down the contaminants. This is done in a lot of scientific studies with small bioreactors that are 0.8-1.5 L to test the efficiency of strains, concentration of contaminants, supplements, and rate of remediation. The other method is continuous fermentation, which requires elaborate expensive tricky equipment and engineering to make possible.
Cascales Project:

The organization Corenewal that I am apart of is working on remediating a river system in Cascales Ecuador using Robert Rawson’s IOS 500 mixture. Amazon mycorenewal’s co-founder and bacteriologist Robert Rawson, president of International Wastewater Solutions and patent holder of the IOS-500 bacteria. With over 40 years experience in wastewater management and over 30 years experience in bacterial bioremediation of petroleum contaminated soils, Rawson has been a pivotal player in the development and implementation of bioremediation solutions on the municipal level in the city of Cascales, Ecuador. The same bacteria that is cultivated on-site at the Cascales landfill are the same species that Rawson has had international success using in bacterial remediation of petroleum contaminated soils and waters.
Image 1. Blueprint of Treatment Plant of Residual Solids, Municipality of Cascales, Ecuador (image credit: 45)

In Image 1., the city’s sewage settling tank (#1) was already in place, collecting black waters from the city's population of 14,000 inhabitants without any type of filter before discharging into the river. CoRenewal implemented sand and rock physical filters (#2) that then pass the leachates on to the IOS-500 biological bacteria nursery tanks (#3), where the nutrients and pathogenic bacteria are digested, and then passed through the final touch of a physical biochar filter before entering the river. The leachates leaving the landfill (#7) are exposed to the IOS-500 bacteria at the revision box (#4). To increase retention time and oxygen these combined leachates are passed through a settling tank (#5), re-pumped over a biological trickling filter (#6), and passed through the final touch of a biochar filter before entering the river. (45)

In Image 1., filters 2, 3, 5, 6, 8 and 10 have all been designed and constructed on site with the collaboration of CoRenewal members and the engineers of the Municipality of Cascales between the months of November 2015 and February 2016. Operation manuals for each point are in process to elaborate on the process, and train locals on function, maintenance, and troubleshooting for each station. Stations are numbered on the map for on-site applications of the IOS-500 bacteria (#2) to treat the sewage water (#1), butcher pits (#11), landfill leachates (#7), as well as formulate a rich and healthy organic compost product (#9). (45)
With our proposals, the Municipality of Cascales has a pending order to buy an industrial wood chipper to provide a carbon source to the high nitrogen butcher pits full of blood and carcasses, as well as sell mulch and woodchips as a side product. To take it even further, what were once waste products are now used as nutrient rich food to augment the bacterial populations of the IOS-500. CoRenewal members have taught the municipality how to make Biochar on-site to provide the final filtering touch on all discharge tubes. Biochar can also be a selling product for home water filters. Maintenance suggestions have also been provided for the city to create its own fertile, organic compost from city organic waste separation. (45)

Moreover, the municipality of Cascales is on its way in a competition to become “the most ecological city in Ecuador.” The mayor hopes to achieve this title with a landfill that will last longer in duration, by producing various useful products from waste, and with its education campaigns to replicate these projects other municipalities throughout Ecuador. After our first meeting and proposal to the mayor, he expressed the objective to make the landfill of Cascales a tourist attraction with beautiful paths to show native plants grown by their on-site organic compost, with little to no trash in the landfill, highlighting and educating the various processes of recycling and repurposing. The mayor himself hopes that this project can become a training center for other municipalities and schools to follow. (45)
Image 3. CoRenewal members alongside Mayor of Cascales and Manager of landfill inside the Municipality of Cascales (image credit: 45)

The applications of the IOS-500 bacteria that are now being produced from the landfill leachates are numerous. International Organic Solutions Inc, with the leadership of CoRenewal board member Robert Rawson, has used these bacteria for wastewater management, bacterial remediation of petroleum, and many agricultural applications in many countries. More information can be found at [http://ios500.com/](http://ios500.com/). (45)

This system and systems like it could definitely be improved with additions of mycelium and immobilized enzymes.

**PONDS:**

- One could transfer some of the water into bioreactors like talked about above
- One should also filter water going into the pond
- One could also use bacterial teas and enzymes to spray onto the top of the pond
Another great thing to do is to create floating islands

(Image credit: William Padilla-Brown)

This is my friend William Padilla-Brown who hosted a workshop on making these floating islands which he inoculated the straw with *Lentinula tigrinus* (tiger sawgill) which is a salt resistant fungi.

Instructions modified from Scott Kellogg’s book: Toolbox for Sustainable City Living.

Materials needed:

- Lots of floating plastic bottles
- A roll of plastic construction fencing
- Zip ties
- Water plants: irises, bulrush, pickerel rush, arrowhead, duckweed, and watercress are great choices
- Anchor and rope or mooring.

1. Roll the plastic fencing in a tube with a diameter of at least a foot. Zip Tie it closed along the side and at one end. However long you make your tube it how big in diameter you want to make your floating island.

2. Fill the tube with plastic bottles. Make sure the bottles have caps so they don’t fill with water and sink the island!

3. Bend the tube into a circle and zip tie it together.

4. Stretch plastic fencing along the center and zip tie that in place as well.

5. Fill the inside with myceliated sawdust, wood chips or straw with a good portion of it outside of the water to it doesn’t suffocate. Plants can be weaved into this mixture and through the holes of the fencing. The plants can provide shade for the mycelium to flourish.

6. You want to anchor this island by tieing it to a cement block or two and dropping it to the bottom of the pond.

These floating islands can also be placed in rivers, streams, lakes, and possibly even the ocean. Solar powered air pumps can be added to float below the floating islands to reverse the process of eutrophication where there is excess nutrients in the body of water, algae bloom and die off and then bacteria come and deplete the oxygen in the water. (46)

**Lakes:**

- One should follow the same protocols as for ponds.
● One could make even bigger floating islands like the Aztecs used to do with building chinampas. These floating islands were 300 feet long and 30 feet wide with space in between them for canoes to go down. They were anchored at the corners by willow trees and were able to grow vegetables like corn, beans, squash, tomatoes and peppers. This incredible feat of engineering spanned 22,000 acres of Lake Texcoco. (47) Similar systems can be put in place adding mycelium and remediative water plants to clean a lake.

● These floating islands/rafts can even be pulled behind a boat/canoes.

Oceans -

We want to minimize/eliminate toxins before they reach the ocean. So focusing on land contamination, and contamination in streams, creeks, rivers, ponds, lakes, and industrial/residential wastewater before it reaches the ocean is paramount. Two big pollutants that are wreaking havoc on our oceans are floating islands of trash and oil spills.

● Floating islands of trash

There is a floating island of trash in our oceans as big as the state of Texas! These can be skimmed up and then possibly exposed to UV light and then inoculated with a slew of genetically engineered white rot fungi enzymes, and genetically engineered bacteria. A group of researchers from Yale discovered that an endophytic fungi from the ecuadorian amazon rainforest, Pestalotiopsis microspora, can not only use polyurethane
plastic as it’s primary food source and degrade it but can also do this in the presence or in the absence of oxygen. This is huge if we want to degrade our huge toxic landfills filled with plastic. (49) There needs to be more research into this fungus and others with the potential to degrade plastic. There especially needs to be more research into the genetics and DNA of these fungi to possibly swap genes that allow a fungus to degrade plastic and to survive without oxygen into easily cultivated fungi like oyster.

**Oil Spills:**

Oil spills happen from:

- Tankers leaking, colliding or running aground
- Blowouts
- Pipelines leaking or bursting
- Tanker trucks carrying fuel colliding or rolling over and spilling
- Leaks from refineries
- Corporate negligence and irresponsibility
- Foul play/sabotage
- Disposal of brine and wastewater

There are many different types of oil

Light: gasoline, kerosene, heating oil, diesel,

Medium: Bunker A, Fuel Oil No. 4, Lubricating oils, medium crudes

Heavy: Bunker B and C, Fuel Oil No. 6, weathered crudes and bitumen. (6)
Things to consider:

- Type of oil
- How much
- Weather conditions/temperature
- How long it's been there
- Are there animals in danger
- Is it close to land (what is the ecology of the land)
- How many resources you have ($, time, boats, supplies, materials, people etc)

Light type oils are easier to remediate because they will float on the surface of the water. When the oil becomes heavier it becomes near impossible to remediate because it will sink to the bottom of the ocean.

**Industrial remediation techniques of oil spills in water:**

**Booms:**
- Booms are floating pieces that attached to the sides or in the back of boats on a cable/chain. It's made of three parts: the freeboard, the skirt and the cable/chain.
- Freeboard = is above the water line and prevents it from splashing over the top
- Skirt = hangs below the surface and prevents the surface oil from being pushed below the boom and prevent it from being collected.
- Cable/chain = pulls the freeboard and skirt and stabilizes everything. (6)

**Skimmers**
- Skimmers essentially suck up the oil like a vacuum cleaner into a container. It sounds great but it clogs easily and doesn’t work well on large spills or when the water is rough. (6)
Sorbents

- Sorbents are any material that can suck up the oil like a sponge, either by adsorption or absorption. Materials like straw have a coating on the outside that will bind to oil particles on the outside (adsorption). Whereas hay or vermiculite will actually suck up oil. Luckily for us, fungi grow really well on these materials. For a lot of beginner mushroom cultivators, straw and a combination of vermiculite and brown rice flour two easy starting points to learn how to grow mushrooms with ease. This means that after the oil is sorbed the material can be put in a pile/container and inoculated with mycelium like *Pleurotus ostreatus*. Remediators can also apply bacteria and enzymes to this mix as well and also hot compost it aswell. (6)

- **Fires** - just...No.

- **Dispersants** - This is a tricky substance that works almost like soap does where it breaks all the oil molecules into tiny balls where they will sink down below surface and hopefully natural microorganisms will continue the degradation process. Boats or aircrafts drop these dispersants. There are a lot of cases of oil workers getting sicker after being exposed to dispersants. They are also used in excess by oil companies to “hide their mess”. It’s a quick way to dispose of their problems. Burning the oil makes HUGE plumes of black smoke and looks terrible. Other methods take a while. Dispersants push the oil underwater and from the surface it looks like the problem has been solved. Once it goes underwater it’s unclear on how fast this oil is being degraded or what the effects on the combination of salt water,
oil and dispersant have on marine life. Some people believe this is a great method for saving a flock of migrating birds from being entrapped in the oily mess, to push it under water before it gets to them. But there is an unknown trade off of how many birds it saved to how much marine life it negatively affected. (6)

- **Floating Dummies, Balloons, water cannons, buoys and horns** - another method to saving wildlife like birds from an oil spill in the use of these listed things to try and scare them aware. This is a humble approach that not always works. (6)

- **High-pressure hoses and vacuums** - When oil washes up onto shore, an alternative to sorbing it would be either spraying it with a high-pressure hose which I feel like is not helping at all, it's just washing it away from the beach and moving it somewhere else. This can also push the oil deeper into the sand. Another method is to vacuum it up into a truck. This sounds great but isn't always the most efficient and also leaves the question - What do you do with it after you sucked it up with the vacuum? (6)

This is where bioremediation comes in:

- Either the oil is sorbed (from the back of a boat or sorbed on a beach) and inoculated with fungi on a location on land.

- And/or enzymes and/or genetically engineered bacteria are sprayed onto beaches as is. It is important to add nutrients like phosphorus and nitrogen to increase their growth and also encourage indigenous microbes to join in on the feast. In places where there is frequent oil spills like in the Gulf of Mexico there are microbes that have evolved to degrade oil more easily and efficiently. These microbes should be
captured, cultivated, and researched. The same applies for toxins on land. Microbes adapt and evolve very quickly. Isolate, study, engineer, and cultivate them to help degrade the massive quantity of toxins on Planet Earth.

Do your research. Establish yourself with smaller experiments and projects first and network and build yourself up. Get a degree, training and certifications. Link up with the EPA, get yourself some grants. Do your own unique research, publish unique data. Become a contractor/consultant/spawn supplier/volunteer/assistant. Stay humble, stay curious.
How to work with fungi? There are some great resources in the resources section that I highly recommend checking out! The basic steps to cultivation are as follows:

These steps have been adapted from the book *Radical Mycology*:

1. A small amount of mycelium or spores is added to agar mix in a dish or a sugary water broth called a liquid culture.
2. 7-21 days later this small amounts of the agar or liquid culture can be transferred into jars of sterile grains (e.g. rye grain)
3. 10-21 days later these grains are then fully colonized and ready to be transferred onto the final pasteurized or sterile substrate (usually sawdust based)
4. A few weeks to months later the mycelium should fully colonize this bulk substrate and it is ready to either fruit mushrooms and then use on a mycoremediation project or go straight ahead to use in a mycoremediation project.

(1)

Fungi need a few basic things to grow:

These steps have been adapted from Tradd Cotter's book: *Organic Mushroom Farming and Mycoremediation*

1. **Fungi need lots of good water, but not too much**
   They are made of 90% water!

2. **Fungi need a healthy diet**
   The substrate you give them depends on the mushroom you are growing.
   Some require more sterility than other, some like a more manure based substrate, some like to grow on wood chips, some species like oysters can basically grow on anything while others are...
pickier! Get to know the dietary restrictions and allergies of your fungi before you feed them a meal!

3. Fungi need to breathe
Just like us, they breathe in oxygen and let out carbon dioxide

4. Fungi need warmth
There are some cold weather strains but most fungi like it warm around 70 degrees F. Nothing above 105 degrees F.

5. Mushrooms need a proper fruiting surface
- Some mushrooms like to grow vertically (up trees, logs), some like to grow horizontally (on the forest floor). Some don’t really care and seem to do both.

There are of course always exceptions to the four steps of cultivation. Some fungi like *Stropharia rugoso-annulata* and *Pleurotus ostreatus* can be grown entirely from little bits of the mushroom right onto cardboard/wood chips, without much sterile technique to then use in remediation projects. This is what makes *Stropharia rugoso-annulata* and *Pleurotus ostreatus* favorites among grassroots remediators and cultivators worldwide. Not to mention they are powerful remediators and produce delicious mushrooms that are also medicinal.
How To Make Cardboard Burritos:

- Source cardboard (free of oils, grime and a lot of ink writing) and take all the tape off.
- Rip this cardboard into strips about the size of a standard piece of paper
- Soak these pieces into water that you just boiled
- Once these pieces are taken out you can easily strip them apart revealing the wavy corrugated part
- Take your mycelium (stem butt, myceliated woodchips/sawdust/dowel) and place them onto the wet cardboard
- Roll up your cardboard so the mycelium is in the inside
- Place this rolled up cardboard burrito in a plastic bag that’s only slightly open
- Wait until you see the white mycelium engulf the cardboard.
- This cardboard can be used to inoculate more cardboard which can then be used to inoculate substrates like coffee grounds, straw, sawdust mixes, woodchips etc.

Expanding from cardboard burritos
If one wants to get more advanced and start doing some techniques in the lab I highly recommend some valuable equipment.

Tools/equipment I highly recommend for any beginner are:

- Glovebox/flow hood
- Pressure cooker(s)
- Lots of isopropyl alcohol
- Agar ingredients and plates
- Lots of mason jars (the more the merrier)
- Polyfill (pillow stuffing)
- Access to hardwood woodchips and sawdust
- Rye grain
● Friends with someone who has a mushroom farm
● Polypropylene grow bags
● Syringes
● Plastic totes and five gallon buckets

If you want to get into mycology you want a laboratory to do your crazy experiments in. The most basic set-up in a glove box which is basically just a plastic tub with holes for your arms to go in where you can do clean semi sterile work. The upgrade to this would be a laminar flow hood, which sucks air and pushing it through a micron filter filtering out any contaminants (mold/fungal spores, bacteria, etc.). This air pushes in front or on top of your workspace making sure there is nothing in the air going to land and contaminate your work.

**ASSEMBLING A GLOVE BOX:**

I recommend any beginner just learning lab techniques to start in a glove box. This is portable, light, cheap, and can be taken anywhere. These instructions are adapted from Ja Schindler’s instructions he gives out at his five day mycoremediation course.

**Glove Box without the Attached Gloves.**

Pros: cheaper and easier to build. You can flame sterilize things outside the box easily. Whereas if you had the attached gloves it would be impossible to flame sterilize your tools.
Cons: increase susceptibility for contamination coming from the open holes.

**Glove Box with the Attached Gloves**

Pros: Increased sterility
Cons: more expensive, takes longer to build, cannot flame sterilize your tools outside the box.
Materials:

- A clean clear large plastic tote with a tight snap on fitting lid. (all clear/see through)
- A pair of chemical handling gloves or elbow length waterproof gloves from the hardware store (optional)
- Hose clamps or zip ties (optional)
- Two pieces of 4 inch diameter PVC pipe that are each 2-3 inches long (optional)
- Sealant (optional)
- Sharp knife

Steps:

1. If you are using the attached gloves place the 4-inch diameter PVC against the box, draw a circle on the box and cut out the circles with the sharp knife being careful not to cut yourself. If you’re not using the gloves find a circular object around 4 inches in diameter and use that as a guide.

2. If you are not attaching the gloves you have just made your very own glove box! If you are using the gloves, slide in the pieces of PVC into the holes and use a strong glue/sealant to seal them to the box.

3. After the glue has dried stick the gloves into the holes, wrap the ends around the outside of the PVC pipe and zip tie them. Use of glue/sealant to seal the gloves to the PVC is optional.

It’s your choice of whether you want to use the glove box with the lid facing up or the lid facing down. Another benefit to not attaching gloves is that you can always choose what feels better to you.
BUILDING A LAMINAR FLOW HOOD:

If the glove box worked out for you and you got down a few basic skills and are looking to upgrade, this is the next best place to go. A laminar flow hood is a lot more expensive but is an essential piece of equipment for any mycoremediator or mushroom cultivator. $300-600 DIY, $600-1,600 or more to buy.

Once you go Flow Hood you never go back.

(Homemade Flowhood donated to Sterling College while assisting Tradd Cotter’s 4-day workshop)

Materials:
- 4’ by 4’ (1.2 x 1.2 m) sheet of ¾” (2 cm) oak plywood
- 1” by 1” (2.5 x 2.5 cm) furring strip
- 1” (25 cm) edge trim, 8’ (2.4 m) long
- 1 ½” (3.8 cm) wood screws
- 1” (2.5 cm) nails
- Roll of ⅜” (9 mm) weather stripping
- All-purpose silicone sealant
- 400-500 cfm blower
- 12” x 24” x 5 ⅜” (30 x 61 x 15 cm) HEPA filter, efficient to 0.3 microns (This is important to get a true HEPA filter which offers 99.99 percent efficiency at 0.3 microns)
- Power strip with on/off switch

<table>
<thead>
<tr>
<th>Filter Size</th>
<th>Blower Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>12” x 24” (30 x 61 cm)</td>
<td>400-500 cfm</td>
</tr>
<tr>
<td>24” x 24” (61 x 61 cm)</td>
<td>800-1000 cfm</td>
</tr>
<tr>
<td>36” x 24” (91 x 61 cm)</td>
<td>1200-1400 cfm</td>
</tr>
<tr>
<td>48” x 24” (122 x 61 cm)</td>
<td>1600-200 cfm</td>
</tr>
</tbody>
</table>
Steps:

1. Begin cutting out the chap of the box. If your filter is not the size in the materials you will have to adjust accordingly the size of the box and aso the cfm’s of the blower.
2. Top and Bottom - 25 ½“ x 16 ¾”
3. Two sides - 16 ¾” x 13 ½“
4. Back - 24” x 15 ¼“
5. Drill pilot holes (easier to insert screws so they don’t crank wood)
6. Measure depth of your filter and install the furring strips that distance, plus the thickness of the weather stripping, back into your box. This is the barrier that holds the filter in place from the back.
7. Install the weather stripping facing out the front of the box. This ensures a tight seal.
8. Measure the opening of your blower and cut that measurement into the top of your box between the furring strips and the back.
9. Using silicone sealant, seal all the joints on the backside of the box.
10. Lay a small ring of silicone around the hole where the blower will go.
11. Install the blower and screw it in.
12. Slide the filter into the front opening.
13. Tack several nails into the sides to hold it in place
Vectors of Contamination

When growing mushrooms, contamination is a very real part of the learning experience. It keeps you humble. Never lose hope when you get contamination, just tighten up your clean technique and be mindful of potential vectors of contamination!

Here is a basic list of the seven vectors of contamination:

**The Cultivator** - Make sure to take a shower and change into clean clothes before working in the lab. Wash your hands and under your fingernails (wearing gloves is the best) some people put on full plastic suits but for most applications that it not necessary. It is recommended to wear a facemask to limit the bacteria coming from your mouth. You mouth is one of the most bacterial rich places on your body, so limit talking, coughing, laughing and breathing out of your mouth into your workspace. Some people where a hair net and possibly a beard net. You can never be too clean when working with mycelium in the lab. The more the merrier. You will be grateful you did. It’s easy to contaminate hours and hours of work that costs money too because you were being careless and dirty in the lab. Make sure you keep spraying your arms with alcohol, especially if you touch anything outside of the workspace!

**The Air/Environment** - fungal spores and bacteria usually float in the air. The best workspace has a HEPA filter blowing clean air. If you get really serious you can have a special room that has a fan attached to a hepa filter blow clean air into the room creating positive pressure, pushing out any dirty air under the cracks of the doors. Be sure not to make any rapid movements and create wind current that carries contaminants. Don’t work in a room with rugs, plants, pets, dirty kids or any surfaces/objects that will create contaminant floating in the air. The room you are working in should be as clean as possible. A lot of people working low budget work in their bathroom after they bleached it down. It is also good to mist the air with 70-80% alcohol, 10% bleach or lysol disinfectant 2-5 minutes prior to working and if you have a laminar flow hood with a hepa filter, turn that on in the room 15 minutes to an hour or so before you start working.
The Substrate - Whether you are working with agar, liquid culture, grains, bulk substrate or something else, make sure it is properly sterilized otherwise it will carry contaminants.

The Inoculum - Along the same lines make sure that whatever you are inoculating with is also as clean as possible. If you are transferring from a petri plate or grains that has mold growing through or on it, most likely the thing you are transferring to will then have that mold. Pay close attention! Know what mycelium looks and smells like! Check your liquid culture on agar before you use it mass scale. Carefully check your grain jars to make sure that there isn’t a couple grains that have been infected by the blue green mold Trichoderma that are hiding from you.

The Tools - Make sure that whatever tools you are using to work with are preferably stainless steal and you sterilize them before, during and after your work. Having an electrical transfer tool sterilizer is the most efficient way of sterilizing your tools. It heats up your tools until they get red hot. Another method is to have an alcohol lamp and sterilize you tools.

Pests - insects, pets, other humans, rodents, etc can all be carriers of contaminants. Make sure you keep your windows closed or with screens. Tell everyone in your house or the place you are working not to disturb you for a little bit.

Technique - Practice slow mindful techniques. Place everything in the workspace in an ergonomical organized way.
Lab Techniques:

Everyone mushroom grower should gain comfortability in these techniques:

- Making Agar
- Preparing grain
- Preparing bulk substrate
- Making lids for grain jars and liquid culture jars
- Making a spore print
- Preparing liquid culture
- Cloning a mushroom (store bought, home grown, or wildcrafted)
- Spore print to agar
- Agar to agar
- Agar to liquid culture
- Agar to grains
- Grain to grain
- Grain to liquid culture
- Grain to agar
- Grain to bulk substrate
- Liquid culture to agar
- Liquid culture to grains
- How to make a master slant
Making a spore print:

Take a mushroom, separate the cap from the step of the mushroom and place it gills, pores, or tubes down onto a clean square piece of aluminum foil that is at least twice as big as the mushroom. This is best done in a clean room, in a glove box, or in a flow hood, but spore prints can be made anywhere. Place a clean jar on top of the mushroom cap lying on the aluminum foil and wait overnight. After the allotted time, take the glass jar off and quickly fold the aluminum foil
Preparing agar

Preparing agar plates are one of the most important skills for mushroom cultivators. These are just a handful to start working with. My favorite is malt extract agar. But recipes are agar is endless. A bigger list that is worth checking out is in the back of *Radical Mycology*. There is an even bigger list that Aloha Medicinals has in a big binder with hundreds of different recipes. You can be creative.

Some basic recipes are below:
All recipes start with 500ml of water and 10 grams of agar

<table>
<thead>
<tr>
<th>Malt extract agar (ME)</th>
<th>Dry, light malt (barley) extract - 10g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malt-yeast extract (MYA)</td>
<td>Malt - 10mL</td>
</tr>
<tr>
<td></td>
<td>Yeast - 1mL</td>
</tr>
<tr>
<td>Malt Extract with Activated Carbon (MEAC)</td>
<td>Malt- 10g</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td><strong>Activated Carbon</strong> - 1 g</td>
<td></td>
</tr>
</tbody>
</table>
| **Malt Extract with Peptone (MEP)** |  ● Malt -10g  
                           |  ● Peptone - 1 g |
| **Malt Extract with Yeast and Peptone (MYAP)** |  ● Malt -10g  
                           |  ● Yeast - 1 g  
                           |  ● Peptone - 1g |
| **Malt Extract with Yeast, Peptone, and Activated Carbon (MEPYAC)** |  ● Malt -10g  
                           |  ● Peptone - 1g  
                           |  ● Yeast - 1g  
                           |  ● Activated carbon - 1 g |
| **Potato Dextrose Agar (PDA)** |  ● Diced or boiled potatoes - 150g or  
                           |  ● Potato starch - 10g  
                           |  ● Dextrose - 7g  
                           |
|                              | In 500 mL of water boil 150 g of potatoes. Strain out the solids, bring the solution back to 500 mL with water, and then add remaining ingredients. Five grams of potato flakes can be used as a substitute. |
| **Potato Dextrose Agar (PDA)** |  ● Dextrose or Honey/Corn syrup - 7g or  
                           |  10 mL  
                           |  ● Diced potatoes - 150 g |
| **Potato Dextrose yeast agar (PDYA)** |  ● Dextrose or Honey/Corn Syrup - 7 g or  
                           |  10 mL  
                           |  ● Diced potatoes - 150 g  
                           |  ● Yeast 1 g  
                           |
| Spore Germination Agar #1 | • Cornmeal - 10 g  
|                         | • Dextrose - 1 g  
|                         | • Yeast - 0.5 g   |
| Spore Germination Agar #2| • Cornmeal - 10 g  
|                         | • Dextrose - 3.5 g 
|                         | • Sucrose - 5 g   
|                         | • Yeast - 0.5 g   
|                         | • KH₂PO₄ - 0.5 g  |
| Spore Germination Agar #3| • Cornmeal - 10 g  
|                         | • Malt 0.8 g     |
| Spore Germination Agar #4| • Cornmeal - 10 g  
|                         | • Glucose - 1 g   
|                         | • Sucrose - 1.5 g 
|                         | • Yeast - 0.5 g   |

(1)
Petri plates just filled with agar

Cloning mushrooms onto agar

Fully colonized petri dish
Once you got a recipe, combine these materials in a small mouth glass vessel like in the previous picture. Cover the hole with tin foil and stick it in your pressure cooker or autoclave for at least 20 minutes. Let it cool for 2 hours. This is the point where you want to use it right away or else it will solidify on you. Make sure you have your petri dishes out ready to pour the liquid into them. It’s better to have more petri plates out than not enough.

Continuously stir the glass vessel with the agar liquid in it in circular motions to keep the liquid from solidifying between pours. Have an alcohol lamp burning so you can heat up the lip of the glass container between pours.

Fill the plates up only to the point where you see the liquid touch all the edges of the dish.

I like to stack the petri plates in a stack and fill them from the bottom up.

Once you have all your plates poured have the option of letting the plates solidify over night or waiting around for a little bit for the plates to solidify and then use them right away.

**Spore print to agar:**

Working in a glove box or flow hood… unwrap your aluminum foil spore print. Take a scalpel and scrape some of the spores onto the agar dish. Some people like to squirt a tiny bit of sterilized water onto the aluminum foil with a syringe to disperse some of the spores into the water to make them easier to transfer. Since the technique of taking a spore print isn’t sterile, one needs to keep track of the mycelium growth on the dish. Once one sees some mycelial growth it’s best to take a cutting of that and transfer it onto another dish. There could have been some contaminants that were transferred onto spore print foil that were then transferred onto the agar. It’s now important to try and get only mycelium growing on the agar dish, this could take a few rounds of transfers until you get a completely clean plate.

**Cloning Mushrooms onto Agar:**

You can either clone wild harvesting mushrooms, store bought mushrooms, or mushrooms you grew. Depending on the mushroom, the technique changes. For a fleshy mushroom like an oyster mushroom or a shiitake mushroom you want to spray the outside with alcohol and then rip the
mushroom in half exposing the inside which has never been exposed to the outside air. You can see a part that is different in color and is the “meat” of the mushroom, which is the sweet spot between the stem and the edge of the cap. This is the part that you want to clone from. Take your scalpel and cut out a triangle from this meaty part and scoop out that piece with grace. Quickly and fastidiously open the lid of the petri dish and plop the bit of mushroom onto the center of the agar dish. For bracket fungi and hardier species you need a metal tool with a pick to finley scrap off some chunks of it at the bottom where it was attached to the tree. This can be a lot more difficult to do. After you have done this take your parafilm, and holding the first edge down with your dominant forefinger, stretch the parafilm around the dish. Keep pressing your forefinger down to hold it and stretch the parafilm around until you run out of film. Press down firmly, and then right your information about the culture onto the dish. I normally do it like this:

After 7-12 days, your agar dish should be fully colonized and be ready to be either transferred onto more petri dishes, into grain or into a liquid culture. Make sure you put your petri dish in the refrigerator before the mycelium reaches the edge of the dish. This will slow down the growth of the mycelium and make sure it doesn’t run out of food from the agar and sinense meaning it will be less powerful and productive.
**Petri to petri**

Unwrap the parafilm from the dishes and with your sterilized scalpel cut a little square of triangle out of the agar at the edge where the mycelium is growing out. Scoop it out with the scalpel and then plop it onto the center of your agar plate. Wrap it in parafilm, label it and wala!

![Diagram of Petri to petri](image)

**Petri to grain**

Unwrap the parafilm from the dishes and with your sterilized scalpel cut crescents into the agar and then cut those crescents into four sections as pictured below.

![Diagram of Petri to grain](image)

You want to scoop up one cresent per jar. This gives 4 different points where the mycelium jumps off of. It might be tricky at first to get all four segments onto the scalpel at one time. With practice and finesse you should get the hang of it. When you shake your jars the agar will most
likely stick the glass above the grain line. When this happens obviously the mycelium will not jump off onto the grain so a remedy is just knocking the bottom of the jar onto a semi soft surface like a rolled up towel on a table, a bicycle tire, the back of a cushioned chair to create force to knock the agar back down into the grains.

**Petri to liquid culture**

There are two ways to go about transferring mycelium from a petri dish into liquid culture form. The first would be getting a metal blender, or autoclavable blender lid for a mason jar. In your lab space either your flow hood or glove box, cut up your colonized petri dish and transfer it to the blender container filled with sterilized liquid culture broth or water. With the sterilized water mixture you can then pour little bits of that into grain jars or straight into bulk substrate bags. With the liquid culture mix you can let the mycelium expand out and use that to inoculate more agar, grain, more liquid culture and you can keep it in the fridge for years. The water mix is more short term while the liquid culture has some food for the mycelium in the liquid mix to keep it for long term.

**How to make liquid culture**

**Materials:**
- Mason jars (or equivalent)
- Drill
- 3/16 and 5/16 inch drill bits
- High temperature (RTV) silicone
- Polyfill (pillow stuffing)
- A marble, a coin (nickel or quarter), or metal screw
1. The first step is to take your metal lids of your jars and drill two holes on opposite sides, one that is 3/16” and the other 5/16”
2. Blop a big glop of high-temperature RTV silicone on the front and backside of the 5/16” hole. Let it dry for at least 24 hours.
3. Once the RTV silicone has dried, twist some polyfill and stick it into the 3/16” hole, cutting off any excess.

After you have your lids it’s time to make your liquid culture. There are a few recipes as follows. Each recipe calls for 500ml of water and a pinch of gypsum (optional).
<table>
<thead>
<tr>
<th></th>
<th>Complete LC</th>
<th>Honey LC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>● Malt - 10 g</td>
<td>● Honey - 2 tsp or 10 g</td>
</tr>
<tr>
<td></td>
<td>● Peptone - 1 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Yeast - 0.3 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Vegetable oil - 5 drops</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Ground grain 1 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Light malt extract - 2 Tbsp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Corn Syrup - 2 tsp or 10 g</td>
<td></td>
</tr>
</tbody>
</table>

(1)

1. Prepare the media in a pot on a stove top on low heat and mix until the ingredients have dissolved.
2. Pour this liquid in your jars.
3. Plop a marble (works the best), nail, screw, quarter, or nickel at the bottom of the jar.
4. Close the lids and cover them with tin foil
5. Pressure cook at 15 psi for 20 minutes
6. Let cool in pressure cooker over night.

There are several ways to inoculate liquid culture with mycelium;
From a fresh mushroom, from a spore syringe, or from another liquid culture.
Simply inject through the dried RTV. Once you have inoculated the liquid cultures jars, you want to swirl the jar around every day to create a vortex to break up the mycelium colony. Be very careful not to get the polyfil wet as bacteria can travel in through the wetness of the polyfill and contaminate your jar. After 10 days you should see a thick cloud of white mycelium floating
in the liquid. Place this jar in the fridge and use whenever you see fit. It’s great to buy new luer lock syringes and in a glove box or flow hood take them out of their plastic and tilting the liquid culture jar to the side where there is RTV and avoiding the polyfill side, suck up liquid into your syringe. If you are using old syringes, wrap them in aluminum foil and pressure-cook them for 20 minutes on 15 psi. These syringes can inoculate agar, grain jars or more liquid culture.

**Liquid culture to agar:**

Always test your liquid culture with agar plates so you can see if any contamination got into your liquid culture. Always shake your liquid culture syringe to distribute the mycelium before using. Squirt less than 1 cc of liquid onto each plate

**Liquid culture to liquid culture**

This can be done on your kitchen counter but it’s best to be done in front of a flow hood or in a glove box.

- Wipe alcohol on the RV lid,
- Flame sterilize your needle
- Cool it down with alcohol soaked paper towel
- Push your needle into RV, inject 1-3 cc’s
- Let colonize for 10 days was stirring it every day
- Place in fridge

**Liquid culture to grain**

You can go straight from liquid culture to grain.

You can either use the lid tek for the liquid culture or use a lid technique with just polyfill. Drill a 5/16” hole in the center of your lids and push poly fill into the hole. From there you can push the syringe needle through the poly fill and in 1-10 cc’s of liquid culture. Or use the liquid culture lid and push it through the RTV.
Grain

Use the lid tek from above.

You can use most grains but the most popular grains to use are rye grain, sorghum, millet, popcorn, and birdseed.

1. Know that the grains will expand double in size after you soak and sterilize them and you want your grain to fill up ⅔ to ¾ of your jar. For quart-sized jars I normally use 1 cup of grain and one pinch of gypsum per jar.
2. Figure out how many grain jars can fit into your pressure cooker(s)/autoclave and measure out that many cups of grain. Fill a large pot or one or a couple colanders. If you are using a large pot, fill it with water until you see dirty water rise above the grain line. Pour this water out being careful not to pour out the grains. Repeat this water until you see the water is clear. If you are using a colander just run water through until you see clear water. You want to rinse your grains to rinse off dirt and such and prevent them from sticking together so much later.
3. Fill the pot with clean water, cover the lid and let sit for 12-24 hours.
4. After this allotted time, put the pot on the stove and bring to a boil for 5-10 minutes.
5. Drain the water off the grains and put the grains into big bowls, or trays. Shift the grains around every 5-10 minutes and let them steam off.
6. Keep shifting the grains around until you can press a dry paper towel or your dry hand onto the grains and don’t pick any grains up.
7. Once they are at this point you can now fill your jars ⅔rds to ¾ths full and cover them with the lid. After you put on the lid, cover it with aluminum foil and put them into your pressure cooker(s) or autoclave.
8. Pressure-cook your jars for 60-90 minutes at 15 psi.
9. Let them cool in the pressure cooker/autoclave preferably overnight.
After you have your grain jars you can inoculate them with liquid culture, spore syringe, agar, or other grain jars. After you inoculate them, they should take 7-14 days to fully colonize. When they are about 30% colonized, shake the jar and wait until they are fully colonized, this will speed up the process. Only shake it once or else it will significantly slow the growth process or stop growing altogether. After they are colonized you can inoculate more grain jars with the inoculated grain jars. With one quart sized jar you can inoculate 7-14 other quart sized jars in a flow hood or glove box.
Pressure Cookers

This is essential for sterilizing agar, tools, grain, liquid culture, jars, bulk substrate, etc. Getting to know how to use and be comfortable with a pressure cooker is essential. For the first couple months of using a pressure cooker I was using it wrong. A few months after that I was still terrified it would blow up.

Your pressure cooker is your best friend.

Be sure to read the instructions on how to use your pressure cooker and do some research online before using your pressure cooker.

The times in which you need to pressure-cook your items change depending on what elevation you are at.

But the basic times you will use is:
<table>
<thead>
<tr>
<th>Time Duration</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 minutes at 15 psi</td>
<td>Liquid culture, tools,</td>
</tr>
<tr>
<td>60-90 minutes at 15 psi</td>
<td>Grains</td>
</tr>
<tr>
<td>90 minutes at 15 psi</td>
<td>Sawdust based bulk substrates</td>
</tr>
</tbody>
</table>

Tips:

- Always let pressure cooker cool completely before opening the lid
- Release steam before putting weight on
- Be in the same room as your pressure cooker while it’s cooking
- Set a timer
- Make sure you have enough water at the bottom
- Know the temperature to set it at to keep a steady rock on your weight
PASTEURIZATION

There is also the wonderful world of pasteurization which is killing off most bacteria, fungi etc.

that inhabit a substrate but not to a stage where it is completely sterile.

1. **Hot water** - 160 degrees F (71 degrees C) for 1-2 hours then drain to desired moisture content - *Mechanism of action = Heat*

2. **Hot steam** - between 160-212 degrees for 4-16 hours depending on how much substrate you are sterilizing

3. **Hydrated lime bath** - make a saturated solution with grade “S” hydrated lime so all the lime dissolves in cold water, about 2-4 lbs of lime (Calcium Hydroxide) to every 50 gallons of water. Soak substrate submerged for around 12 hours at 8.5-13 pH. Drain, and inoculate when desired moisture content is achieved. - *Mechanism of action - pH change*

4. **Bleach** - 3-4 cups of bleach (Sodium hypochlorite) to 50 gal. Of water. Soak for 4-12 hrs, and inoculate with an aggressive species, such as *Pleurotus pulmonarius* AX. -- *Mechanism of Action = disinfectant.*

5. **Soap** - use 2-3% dilution of soap & water, and soak for 6-24 hrs. Drain to desired moisture content then inoculate. - *Mechanism of action - Change in Osmotic Pressure*

6. **Hydrogen Peroxide** - Use 2 liters of 3% Hydrogen peroxide for every 5 gallons of water. Soak for 4-8 hours. Stir. grain to desired moisture content then inoculate. -- *Mechanism of actions - Alteration of cell wall.*

7. **Tri-Sodium Phosphate** - Dilute 240g of TSP for every 200L of unchlorinated water. Soak 6-12hrs. Drain to appropriate moisture content and inoculate. -- *Mechanism of Action - pH*

8. **Wood Ash** - Fill a 200-liter (55 gal.) drum with 150 liters (40 gal.) of unchlorinated water. Add 4.25 kilos (10 lbs) of sifted wood ash to the solution and stir. Add 10 kilos (5-6 lbs) of straw, and soak for 12-24 hours. Drain to desired moisture content, and inoculate. -- *Mechanism of action = pH*

9. **Natural Fermentation** - Clean a plastic or metal 55 gal. drum or other vessel and fill with 8-10 lbs of dry chopped straw. Add water until straw is submerged. Let this mixture
sit as 70 degrees Fahrenheit for 5 days. The mixture will smell foul, ammonia like. Drain the straw to field capacity and inoculate. -- Mechanism of Action - fermentation

10. **Yeast Fermentation** - use *Saccharomyces cerevisiae* propagated in 50 gal. of water with 1-5% sugar broth. Ferment solution for 2-3 days at 75 degrees F. soak substrate in solution for 48 hours. Drain to desired moisture content and inoculate. -- Mechanism of Action - fermentation

11. **High-pressure Extrusion** - a complex pasteurization method reducing the size of the substrate 6:1 via pelletizing - Mechanism of Action - Dramatic change in size and pressure.

My favorite methods of pasteurization methods would be steam, hydrated lime, and natural cold-water fermentation. But it all depends what materials you have available and what you want to experiment with. Whatever works for you.

**Cold water fermentation:**

1. Fill a container (like a trashcan, or a 55 gallon drum) with the substrate you are using (chopped straw, hardwood sawdust, etc). It makes it easier to put them in burlap sacks or something to easily move the substrate around.

2. Fill the container with preferably non-chlorinated water, or better yet well water. If you do not have either simply leave out your tap water in the sun for a day and the chlorine will evaporate off. Fill the water until it’s fully covering the substrate.

3. Place a weight on the substrate to keep it submerged.

4. Wait 7-10 days

5. At this point it should smell very strongly. This is a good sign! Dump the water out and drain and dry your substrate until it’s at the desired moisture content (field capacity)
Hot Steam pasteurization:

Materials:

- 55 gallon metal drum with lid
- Propane tank
- Propane burner
- Support bricks
- Probe thermometer
- Burlap bags
- 6 inch bricks at the bottom of the drum with a metal screen to fit over them
- Water

1. Set up the propane burner preferably on a concrete surface.
2. Build supports for the drum
3. Place the drum on the supports and make sure it’s stable. Place 6 inches of support bricks in the bottom of the drum. Lay screening material on top of the bricks and fill the water up to ½ inches from the screen.
4. Ignite the flame
5. Fill the burlap sacks with the substrate and once you notice the drum starting to fill with steam it’s time to load the drum with the substrate.
6. Once the internal temperature has reached 160 degrees F it is time to start timing.
7. After the allotted time it is time to turn off the heat source and let your barrel cool down.
8. Remove the lid and remove the bags being consciousness of the hot material.
When your substrate is pasteurized or sterilized its time to add spawn.

- Plug spawn
- Grain spawn
- Sawdust/coffee spawn
- Cardboard spawn
- Slurry
- Woodchip spawn

At this point a sterile environment is not needed and can be done outside depending on what you’re inoculating and what you’re inoculating with. With advancements in mushroom growing...
in the last couple decades we have pushed how dirty and low tek we can grow a wide variety of mushrooms successfully. As long as we understand how fungi grow and what they need, anything is possible. If you don’t want to go through all the hassle, don’t have the time, the resources to grow the entire mycelium link up with your local mushroom farm and get their waste mushroom block stream. This is not a valuable product for them but it’s super valuable for a bioremediator. The waste mushroom blocks still produce a cocktail of enzymes and can still be used as a water filter in a stream or waterway. Also these blocks will still produce mushrooms if put in the right conditions. The reason that mushroom farms get rid of these blocks and throw them in a compost pile is because they don’t produce the same amount of mushrooms as when they first put them in fruiting conditions. For this reason the mushroom farmer makes more money per square foot by making new blocks and putting them into the fruiting environment. Take advantage of this valuable resource. It will turn into soil anyways so pick up these blocks, fruit some more mushrooms for food and medicine, clean some toxins with the mycelium and then make soil with it.

Learn these valuable skills, and master the art of working growing and being a steward for fungi. With these skills one can clone a mushroom from the wild, run experiments in the lab, grow enough edible mushrooms and medicinal mushrooms to heal and feed their city and beyond, find new antibiotics, and the ability to bulk up on enzymes and spawn to clean up toxic waste in our world. If you think that is amazing, that’s just the beggening! This is truly powerful information. Take the power in your own hands and ally with one of the most powerful and underrecognized organisms on earth!
Case Study: Mycoremediation of Cigarette Butts

For anyone looking to start to delve into the wild world of mycoremediation it’s super important to start small. Look around in your local community and look at potential sources of pollution that can be remediated by fungi. For me, I used to smoke cigarettes and eventually quit. I saw cigarette butts on the ground everywhere I went, no matter where in the world I was. It’s a toxin that is super familiar to everyone and is abundant and accessible to everyone everywhere. A perfect place to start to someone who wants to experiment and generate conversations around this topic.

Cigarette butts are one of the most littered objects in the world with estimates of 4.5 billion cigarette butts weighing in at 1.7 billion pounds are being thrown into the environment and into landfills every single year. Cigarette filters are made out of cellulose acetate plastic, fungi that break down lignin-cellulose are able to break down cellulose acetate plastic, formerly thought to be either non-decomposable or take at least take up to 10-15 years before beginning to break down. Cellulose acetate is made of cellulose (the structural component of green plants), wood pulp that has been plasticized through the process called acetylation, which is when an acetyl functional group is transferred to one molecule. Cellulose acetate was once considered non-biodegradable, but further research has concluded that it all depends on the degree of substitution, which is the number of substituent groups attached to a base group. These cigarette filters go through this process to create structure, to prevent combustion and to prevent fungal and bacterial spoilage (Fischer et al., 2008, Talio et al., 2012). The toxins that leech from cigarette butts include pesticides, herbicides, insecticides, fungicides and rodenticides. Additionally, over 4000 chemicals may also be introduced to the environment via cigarette particulate matter (tar) and mainstream smoke, over 50 of which are known to be carcinogenic to
humans. Also heavy metals such as Al (aluminum), Ba (Barium), Cr (Chromium), Cu (Copper), Fe (iron), Pb (lead), Mn (manganese), Ni (nickel), Sr (Strontium), Ti (Titanium) and Zn (Zinc) seep out of cigarette butts and become toxic to fish and microorganisms. White Rot Fungi like *Pleurotus ostreatus* (oyster mushrooms) break down Lignin (the complex 3 dimensional structure that gives plants their rigidity) in nature by exuding extracellular lignolytic oxidative enzymes like - Manganese Peroxidase, Lignin Peroxidase, and Laccases along with free radical oxygen molecules to break apart some of the most complex molecules on this planet. For this experiment I am seeing how fungi and bacteria can influence the breakdown of 16 polycyclic aromatic hydrocarbons that are on the EPA’s priority pollutant list over the course of 2 weeks, 4 weeks, and 6 weeks. These PAHs are Naphthalene, Acenaphthene, acenaphthylene, Phenanthrene, Fluorene, Anthracene, Benz[a]anthracene, Chrysene, Pyrene, Fluoranthane, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene, Indeno[a,2,3-cd]pyrene, Benzo[ghi]perylene, Dibenz[a,h]anthracene. The results give hope to better implementation of natural biological remediation technologies especially for our sewer systems.

“1) There are 1.1 billion smokers in the world today, and if current trends continue, that number is expected to increase to 1.6 billion by the year 2025.

2) China is home to 300 million smokers who consume approximately 1.7 trillion cigarettes a year, or 3 million cigarettes a minute.

3) Worldwide, approximately 10 million cigarettes are purchased a minute, 15 billion are sold each day, and upwards of 5 trillion are produced and used on an annual basis.

4) Five trillion cigarette filters weigh approximately 2 billion pounds.

5) It's estimated that trillions of filters, filled with toxic chemicals from tobacco smoke, make their way into our environment as discarded waste yearly.” -

(1)
In fact in one study they dropped one single cigarette butt in one liter of water for 24 hours and the chemicals leached out were toxic enough to kill 50% of the saltwater and freshwater fish if they were exposed to them for 96 hours. (2)

“Later experiments identified that the key mechanism for degradation is an initial deacetylation step by chemical hydrolysis and acetyl esterases, thereby allowing the degradation of the cellulose backbone with cellulase. “ - (5)

I did my own experiments on the mycoremediation of cigarette butts. The first test was to see if I could train a fungal mycelium to colonize a dirty cigarette butt. The second test was to see if the mycelium would colonize a dirty cigarette butt more efficiently after it was trained to colonize a clean/unsmoked cigarette butt. This was inspired by the work of Peter McCoy who demonstrated that mycelium was more efficient at colonizing dirty cigarette butts after it was exposed to unsmoked ones. These tests were done in plastic petri tubes with agar slants in them inoculated with *Pleurotus ostreatus* from a liquid culture. The results were consistent with Peter’s in that I found the mycelium was able to colonize the dirty cigarette butts fully only after I was exposed to clean cigarette butts. The slants that were not exposed to the unsmoked cigarette butts first and directly given the dirty butts right away had a hard time growing.

In later studies I made agar infused with cigarette butts, both clean and dirty. I transferred mycelium from agar dishes colonizing clean cigarette butts onto the dirty cigarette butt agar, and noticed it colonized all the way to fruiting on the petri dish. I then took a five-gallon bucket and put in a sawdust block of *Pleurotus ostreatus*. After the mycelium was put into the five-gallon bucket, unsmoked clean cigarette butts were added to the top of the mycelium. After a week or so the mycelium climbed over the cigarette butts and was ready for dirty ones. Dirty cigarette butts were collected, dipped in water and put on top of the mycelium. Since the mycelium was trained on the clean cigarette butts first, the mycelium was able to colonize the dirty ones with ease. About a month later I started noticing fruit bodies forming from the cigarette butts. I collected the fruit bodies and sent them into a lab to get them tested for a series of heavy metals. It is known that there are heavy metals in cigarette butts and that mushrooms hyperaccumulate.
heavy metals. The test was to see if the metals were too toxic for human consumption. After reviewing the results:

1. YES there are heavy metals present in the mushrooms

2. Most of the heavy metals are in safe ranges except for Iron, which are in toxic ranges! (Toxic effects begin to occur at doses above 10–20 mg/kg of elemental iron. Ingestions of more than 50 mg/kg of elemental iron are associated with severe toxicity.) There is the same amount of aluminum as 1-2 tablets of buffered aspirin. Copper was also way too high at 23.9 mg/kg. The results of three single exposure studies suggest that the threshold for gastrointestinal symptoms is between 4 and 6 ppm, which is equivalent to doses of 0.11 mg/kg and 0.017–0.018 mg Cu/kg. (6)
I also conducted studies on the mycoremediation of Polycyclic Aromatic Hydrocarbons. Particularly the 16 polycyclic aromatic hydrocarbons that are on the EPA’s priority pollutant list. These PAHs are Naphthalene, Acenaphthene, acenaphthylene, Phenanthrene, Fluorene, Anthracene, Benz[a]anthracene, Chrysene, Pyrene, Fluoranthène, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene, Indeno[a,2,3-cd]pyrene, Benzo[ghi]perylene, Dibenz[a,h]anthracene. Polycyclic Aromatic Hydrocarbons are mutagenic, tumorigenic, and carcinogenic. According to research by A.B. Azizi et al. they found that mycoremediation with the combination of bacteria from worm castings could degrade PAHs by 99.99% (7)! I have conducted experiments using mycelium of *Pleurotus ostreatus*, a compost tea, harvested enzymes from *Pleurotus ostreatus*, a combination of mycelium and compost tea, a combination of the enzymes and compost tea and two controls (one with substrate without mycelium, and one with just water).
I took 14 quart sized mason jars and filled the first three with 60.99 grams of oyster mushroom mycelium. The second three I filled with 60.99 grams of mushroom mycelium and 50 ml of compost tea. The third set up three jars I filled with 50ml of compost tea, and the fourth set I filled with 50 ml of crude extracted enzymes from oyster mushrooms mycelium. With two remaining I filled one with 50 ml of water, and the other with 60.99 grams of substrate (50% sawdust, 50% cotton seed hulls).

This was all done in a flow hood with brand new materials. The jars were retrofitted with a hole in the top and stuffed with polyfill. This was done so the microorganisms could exchange oxygen and co2 while in the jar and prevent other organisms from entering the jar.

Enzymes were collected from commercial blue oyster mushroom blocks from a local mushroom farm, Fungi Ally, owned and operated by Willie Crosby in Hadley Massachusetts.
These secondary metabolites were used that day.

The compost tea bags were bought off amazon. The company was called Malibu compost. This compost tea was brewed with an aquarium pump for 5 hours with the addition of 60g of worm castings made by a friend in PA.

Willie Crosby of Fungi Ally in Hadley Ma also supplied the mycelium and the substrate.

New cigarettes were purchased and then their filters were broken off and allowed to absorb DI water in a petri dish. An equal amount of cigarette filters were added to each jar and allowed to sit for a week. This gave time for the microorganisms to get accustomed to a less toxic version of the contaminant before being introduced to the full toxic load.

Cigarette butts were collected from various community members in jars like these. There was attention to separate the cigarette butts by the person who smoked it and what kind of cigarette they were smoking to have uniformity throughout the tests.
After the cigarette butts were collected they were laid out and counted to make sure that each jar would get the same amount of cigarettes from each variety. The cigarette butts were then dipped into a dish of water and placed into the jars.

Starting point samples were then sent in to ALS environmental lab in Florida for testing:

- The mycelium
- The substrate without the mycelium
- The compost tea
- The enzymes
- And the cigarette butts themselves (both smoked and unsmoked)

All the following did not pick up any PAHs (Polycyclic Aromatic Hydrocarbons) besides the cigarette butts themselves.

Here is the data for the cigarette butts:

<table>
<thead>
<tr>
<th>Analyte Name</th>
<th>Result</th>
<th>PQL</th>
<th>Dil.</th>
<th>Date Analyzed</th>
<th>Date Extracted</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Methylanthanthrene</td>
<td>260</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>2-Methylanthanthrene</td>
<td>289</td>
<td>61.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>161</td>
<td>125</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>125 U</td>
<td>125</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Anthracene</td>
<td>183</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Benz(a)anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Benzo(ghi)pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Benzo(b)fluoranthenone</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Benzo(e,h,i)pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Benzo(k)fluoranthenone</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Chrysene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Dibenzo(a,h)anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Fluorene</td>
<td>92.3</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>178</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Indeno(1,2,3-cd)pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Naphthalene</td>
<td>333</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>188</td>
<td>125</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
<tr>
<td>Pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>1</td>
<td>03/08/17 17:56</td>
<td>3/7/17</td>
<td></td>
</tr>
</tbody>
</table>

Surrogate Name                  | % Rec. | Control Limits | Date Analyzed | Q   |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Fluorobiphenyl</td>
<td>38</td>
<td>30 - 118</td>
<td>03/08/17 17:56</td>
<td></td>
</tr>
<tr>
<td>p-Terphenyl-d14</td>
<td>42</td>
<td>41 - 146</td>
<td>03/08/17 17:56</td>
<td></td>
</tr>
</tbody>
</table>

The PQL is the lowest detectable level limit. The results in bold are the ones that were able to be detected. The results are in parts per million.
Since there were three jars per substrate, with the same environmental conditions one jar could be tested every two weeks. The exception was the two control jars, which were tested on day one and on day 42.
Mycoremediation of PAH's from Cigarette Butts by Pleurotus ostreatus

<table>
<thead>
<tr>
<th>Result day 1</th>
<th>PQ1</th>
<th>Result day 14</th>
<th>PQ1</th>
<th>Result day 28</th>
<th>PQ1</th>
<th>Result day 42</th>
<th>PQ1</th>
</tr>
</thead>
<tbody>
<tr>
<td>260</td>
<td>63.4</td>
<td>105 U</td>
<td>105</td>
<td>63.7 U</td>
<td>63.7</td>
<td>63.7 U</td>
<td>63.7</td>
</tr>
<tr>
<td>200</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>63.7 U</td>
<td>63.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>160</td>
<td>52.3</td>
<td>210 U</td>
<td>210</td>
<td>63.7 U</td>
<td>63.7</td>
<td>125 U</td>
<td>125</td>
</tr>
<tr>
<td>25</td>
<td>125</td>
<td>210 U</td>
<td>210</td>
<td>125 U</td>
<td>125</td>
<td>125 U</td>
<td>125</td>
</tr>
<tr>
<td>183</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
<tr>
<td>24</td>
<td>62.4</td>
<td>105 U</td>
<td>105</td>
<td>62.7 U</td>
<td>62.7</td>
<td>62.7 U</td>
<td>62.7</td>
</tr>
</tbody>
</table>
Extraction of PAH's from Cigarette Butts by Oyster Mushroom Mycelium (Pleurotus ostreatus) and Corr
Mycoremediation of PAH's from Compost Tea

<table>
<thead>
<tr>
<th>suit day</th>
<th>PQL</th>
<th>results day 14</th>
<th>PQL</th>
<th>results day 28</th>
<th>PQL</th>
<th>Results day 42</th>
<th>PQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>260</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>209</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>161</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>5 U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>186</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>923</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>178</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>333</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>188</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
<tr>
<td>A U</td>
<td>62.4</td>
<td>25 U</td>
<td>25</td>
<td>2 U</td>
<td>2</td>
<td>2 U</td>
<td>2</td>
</tr>
</tbody>
</table>
ediation of PAH’s from Cigarette Butts by Enzymes from Oyster Mushroom Mycelium (Pleurotus osti...
# Mycoremediation of PAH's Control Liquid

![Graph showing the decrease in detectable PAHs over time.]

<table>
<thead>
<tr>
<th>PAH</th>
<th>Result day 1</th>
<th>PQL</th>
<th>Results day 42</th>
<th>PQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Methylnaphthalene</td>
<td>260</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>2-Methylnaphthalene</td>
<td>289</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>acenaphthene</td>
<td>161</td>
<td>125</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>acenaphthylene</td>
<td>125 U</td>
<td>125</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>anthracene</td>
<td>183</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>benz(a)anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>benz(a)pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>benzo(b)fluoranthene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>benzo(k)fluoranthene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>chrysene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>Binenz(a,h)anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>92.3</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>fluorene</td>
<td>178</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>indeno[1,2,3-cd]pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>naphthalene</td>
<td>323</td>
<td>62.4</td>
<td><strong>3.72</strong></td>
<td>2</td>
</tr>
<tr>
<td>phenanthrene</td>
<td>188</td>
<td>125</td>
<td>2.00 U</td>
<td>2</td>
</tr>
<tr>
<td>pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>2.00 U</td>
<td>2</td>
</tr>
</tbody>
</table>
# Mycoremediation of PAH's Control Solid

![Graph showing the reduction of detectable PAHs over 42 days.](image)

<table>
<thead>
<tr>
<th>PAH</th>
<th>Result day 1</th>
<th>PQL</th>
<th>Results day 42</th>
<th>PQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Methylnaphthalene</td>
<td>260</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>2-Methylnaphthalene</td>
<td>289</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>161</td>
<td>125</td>
<td>175 U</td>
<td>125</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>125 U</td>
<td>125</td>
<td>175 U</td>
<td>125</td>
</tr>
<tr>
<td>Anthracene</td>
<td>183</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benz[a]pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benz[b]fluoranthene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benz[g,h,i]perylene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Chrysene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Benzen[a,h]anthracene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>92.3</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Fluorene</td>
<td>178</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>323</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>188</td>
<td>125</td>
<td>175 U</td>
<td>125</td>
</tr>
<tr>
<td>Pyrene</td>
<td>62.4 U</td>
<td>62.4</td>
<td>87.6 U</td>
<td>62.7</td>
</tr>
</tbody>
</table>
This data is profound. It shows that *Pleurotus ostreatus* mycelium can be used to remediate PAHs from toxic cigarette butts by almost completely below detectable limits in less than two weeks. This is also true for bacterial rich compost tea, a combination of compost tea and mycelium, and enzymes from *Pleurotus ostreatus*. The controls also showed amazing potential. If I were to do this study again I would definitely test the controls every two weeks. The PQL in the data set kept changing because of human error on the lab side, but the data is all accurate. The reason that there was more PAHs present after 4 weeks compared to after 2 weeks with the mycelium combined with the compost tea, and then for the jar with the enzymes was for the fact that the jar tested at 2 weeks was different than the jar after 4 weeks. This doesn’t change the overall results that the PAHs were dramatically to totally decreased in a matter of days to weeks. What’s incredible about having the crude extracts of the enzymes be able to degrade these toxins is that there is huge potential to harvest a lot and make a spray to spray over a large contaminated site. Imagine a fire truck hooked up to a pressurized tank filled with crude extracts of a multitude of different enzymes from white rot fungi and also a cocktail of effective microorganisms being sprayed onto a brownfield, superfund site or a huge oil spill. Industries already use airplanes to drop dispersants onto oil spills in the ocean. Imagine the potential. For the future, applying a combination of crude enzymes and bacterial tea together on a contaminated site is the projected goal. The potential is astounding.
Suggested Projects

Cigarette butts -

- Experiment with growing mycelium on cigarette butts and remediating toxins from them. If you are a heavy smoker create a five-gallon bucket cigarette butt-munching machine. Layer the bottom with *Pleurotus ostreatus* spawn and lassana cigarette butts and layers of spawn. Give it some water to hydrate the butts. Be careful not to dip the cigarette butts in water with your bare hands, as you will absorb a lot of toxins into your skin. It’s much better to pour/spray a little water on it after you put it in the bucket. If you wanted, you could buy a pack of cigarette tubes (cigarettes that don’t have tobacco in it) soak them in water and add it to the mycelium first to let the mycelium adjust to this new food before adding the dirty butts. Try and get a fruit and take spore prints to keep developing a culture. Once your bucket is filled you can keep it as an inspirational tool to show your friends/family/community members and/or dispose of it as it is filled with heavy metals from the cigarette butts. Install these buckets around your local community where a lot of people smoke. Get people actively involved with remediating their own handheld toxic waste sticks! This is a great experiment to start with because a lot of people can relate to cigarette butts. A lot of people smoke cigarette butts, most every human on this planet has been surrounded by people who smoke, and have seen cigarette butts littered everyone on the ground.

Chicken coop:

If you have chickens, you know that sometimes their coop smells pretty bad. You also probably know that chickens carry lots of bacteria and to wash your hands after dealing with them. Luckily fungi secrete antibiotics to help deal with this problem. Tradd Cotter lays this out really well in his book and was actually awarded one of the best smelling chicken coops around by doing this exact method. You want to place a wire screen a foot or two above the floor for the chickens to walk on. When they poop it will drop down through the wire holes and land in their straw/wood shaving bedding, which is inoculated with King Stropharia. It is important to add a way where you can replace the bedding once and awhile.
Cat poop:

- 4 cups of cat litter
- 4 cups water
- ⅓ cup guinea pig food
- ¾ cup oyster spawn

Combine this in a container

Compost toilet

Instead of just pouring sawdust into your compost toilet, add spent sawdust spawn. The mycelium secretes antibiotics, which can break down the fecal coliforms present while also adding carbon to the n-c ratio.

Agar dish-
Experiment with adding toxins to petri dishes and watching the battle between different strains of fungi.

Dripping car oil on cardboard-
If you notice that a car is dropping oil, place cardboard underneath to soak it up. Once you have the soaked cardboard, place this in a five-gallon bucket and layer the cardboard pieces with mycelium spawn.

Bike grease - same thing can be done with bike-greased rags.

(Photo credit: Daniel Reyes)

Diapers - Experiment with breaking down diapers (dirty or not)
In a five gallon bucket or a larger bin inoculate diapers with oyster spawn and some more carbon material like paper scraps, straw, cardboard etc.
**Water filtration unit** - Build the 3 tiered drawer water filtration unit. Test out different contaminants and species of fungi while using it. Use it to extract crude enzymes.

**Floating island** - Build a floating island and install it

**Parking lot filtration** - Install wood chip spawn or bunker spawn to filter parking lot runoff. Extra points for building a swale.

**Creek restoration** - Cultivate some bunker spawn and place it in a creek/stream. Test before and after and publish your results

**P. Microspora** - get your hands on *P. microspora* and see if you can get it to colonize polyurethane.

**Crude enzymes** - Extract crude enzymes and apply it on some toxins

**Purified enzymes** - purify some enzymes, start with laccase, and use it on some toxins. Test before and after and publish your results.

**Enzyme assays** - Learn how to run fungal enzyme assays

**Design your own experiment** – Curious about something? Design your own experiment. Look at the data and research already out there and design your own experiments and add data to this field!

**Learn how to sequence DNA of fungi** - Learn how to run a PCR and get DNA sequences of fungi that are apt at remediation

**Teach** - teach a workshop, record a video, make a blog/social media post, hold a conversation about mycoremediation to spread that word.

**Plant disease protection** - One can take a diseased part of a plant, blend it up. Then streak the blended disease plant matter on an agar plate and then test different mushroom species to see what will attack and overcome this disease. Once you find one that overcomes the disease you can inoculate matchsticks/toothpicks with the fungi and drill it back into the plants.
**Salt-water tolerance** - Look for mushroom growing on the beach or near salt water. This means that the mushroom is salt tolerant and would be a good candidate for cleaning up oil spills in the ocean, or next to roads/parking lots where lots of salt is used. Culture this mushroom and keep it in your library for when not if it will come in handy. This protocol should also be done for mushrooms found on pesticide sprayed lawns, near spilled oil, downstream of a parking lot, or near a site that you want to remediate. It’s also very important to clone mushrooms that are doing weird stuff like growing on trees that are not their normal fruiting substrate. This means that they had a mutation and they are releasing different enzymes to break down a food that they normally do not break down. This is important for mycoremediation because the main purpose is to get fungi to do weird stuff and break down food that they normally don’t digest.

**Clone and grow your own mushrooms** – Go out into the wild, clone a mushroom and grow it! You can even train this fungus to be able to better degrade a toxin!

**Create a culture library** - Build a culture library of many different kinds of fungi and wild cultures around your area. More specifically build a mycoremediative culture library of cultures you have trained or cultures you have found near onr on toxic sites.
Great Resources for Inspiring Mycoremediators:

Courses:

- **Ja Schindler of Fungi for the People 5 day mycoremediation course in Eugene Oregon around $750**
  Longest course on strictly mycoremediation currently out there!
  https://fungiforthepeople.org

- **Tradd Cotter’s mycoremediation course:**
  He usually offers one a year. He also is offering live seminars on his website
  http://mushroommountain.com/p/mm-university $60 for the replay of the live session

- **Telluride Mushroom Festival $275 in telluride Colorado mid August**-
  Have classes on mycoremediation there!
  http://www.telluridemushroomfest.org

**Mycoremediation (and other fungal) workshops with Alex Dorr**-

Stay posted for workshops around the country with me, Alex Dorr. Prices, dates, durations, and topics vary!

- **Princeton groundwater pollution and hydrology course**
  The registration fee is $1,595 and is payable in advance
Princeton Remediation Course:

Course Fee: US$1,595
Course fees cover all course materials and refreshments breaks.

BONUS COURSE:

5.5-hr. Optional Hands-on Computer Modeling of Contamination and Remediation Engineering and Design

HAZWOPER 40-hour Course -

HAZWOPER 40-hour is required for workers that perform activities that expose or potentially expose them to hazardous substances.

This course is specifically designed for workers who are involved in clean-up operations, voluntary clean-up operations, emergency response operations, and storage, disposal, or treatment of hazardous substances or uncontrolled hazardous waste sites. Topics include protection against hazardous chemicals, elimination of hazardous chemicals, safety of workers and the environment and OSHA regulations. This course covers topics included in 29 CFR 1910.120.

BOOKS:

- Radical Mycology – Peter Mccoy
- Mushroom Cultivation for Mycoremediation Zine – Peter Mccoy
- Mycelium Running – Paul Stamets
- Organic Mushroom Growing and Mycoremediation – Tradd Cotter
- Earth Repair - Leila Darwish
• *Mycoremediation* – Harbhajan Singh
• *Fungi in Bioremediation* – edited by G.M. Gadd
• *Fungal Pharmacy* - Robert Rogers
• *Toolbox for Sustainable City Living* - Scott Kellogg
• *Fungal Enzymes* - editors: Maria de Lourdes T.M. Polizeli, Mahendra Rai
• *Medicinal Mushrooms* - Christopher Hobbs
• *Medicinal Mushrooms: A Clinical Guide* - Martin Powell

And more!

**Organizations:**

• Amazon Mycorenewal Project
• Corenewal
• Mycoalliance
• Mushroom Mountain
• Fungi for the people
• Radical Mycology
Conclusion:

- Experiment with the list of suggested projects above

- Get connected to everyone in the mycelial network. Make friends with everyone who is interested to any degree in mycology. This will build a network of people that you can share resources knowledge and have extra helping hands to help you with projects and you can help other people with projects as well.

- This includes making friends with your local mushroom farm(s) to get access to spent mushroom blocks.

- Join your local mycological association.

- Get acquainted in or make friends who have knowledge in fungal physiology, biochemistry, enzymology, ecology, genetics, molecular biology, engineering, and several related disciplines. We need people skilled in phytoremediation, plant propagation and cultivation, fundraising and grant writing, soil science and soil testing, hydrology, chemistry and contaminants, permaculture design, irrigation, biology and ecology, microbial remediation and microbiology, compost making, vermi-composting, compost tea making, mycoremediation, mushroom cultivation, water filtration and treatment, public outreach and community engagement/community organizing, government and/or company relations (proposal writing, lobbying), environmental regulations and law, remediation regulations and standards, health and safety, disaster response, oil spill response, and alternative healing modalities as preventative protection and medicine for chemical and toxic exposure.
● Build a library of books about mycology and all these topics listed above.

● Build a culture library of many different kinds of fungi and wild cultures around your area.

● Learn the basics and get comfortable with lab skills and cultivating mushrooms.

● Walk in the woods and observe the natural habitat of fungi, what conditions they are growing in, what they are growing on, what species grow around you, etc.

● We need more people who are myco-literate and we need to start teaching about myology in elementary and middle schools to start raising a new generation myco-literate humans.

● Teach workshops in your community

● Tell your friends and family about this work and the wonderful potential of using fungi to clean up toxic waste.

● Attend any workshops about topics that relate to learning skills that aid in bioremediation.

● We need to bridge the gap between the scientific community and everyone else. If you are part of a university and have access to research papers that everyone else doesn’t, share this access.

● We need more research on using white rot + brown rot together

● We need more research on efficiently and cost effectively harvesting enzymes and applying them large scale

● We need more research on enzyme combinations and their use in mycoremediation
● We need more research on the use of enzymes with bacteria in large-scale application sprays.

● We need people who can readily make large quantities of compost tea, mushroom spawn, enzymes, phytoremediation seedlings etc.

● We need a system of government that respects the use of sacred sacraments in the form of psilocybe mushrooms and other sacred plant/fungal medicine. We need places where people can go to work with these medicines to break down and transform any destructive traumas, patterns, conditioning we have so we are not perpetuating the destructive tendencies that cause chaos and suffering outside of ourselves.

● We need more funding to be reverted from military spending and towards the EPA to help remediate toxic sites that can be used for medicinal and food forests to provide free food and medicine for our people. Peace, healing+nourishing+Love> murder, hate, war, destruction

● We need to replace golf courses with these medicine and food forests. And then take all the golfers and give them mycelium seed balls to shoot onto brownfield/superfund sites with white rot enzymes and facultative bacterial tea sprinkler systems water it all. Maybe it’s not nessisary, but it’s an idea.

● We need better open sourced replicable modular remediation systems that can be designed and shared to empower community members living in a toxic zone. Right now a lot of these systems and technology is patented and kept from the public. Technology that cleans toxic waste should not be kept from the public who the toxins are affecting.

● We need an online database that houses all resources, data, and information on mycoremediation. An online plateform that remediators cannot only get access to information and education but also jobs, and connect with other remediators.
• We need more people bioprospecting new fungal species for mycoremediation, but also for new enzymes. A good start would be in thermophilic fungi found in extreme environments. These organisms might also be a great resource for new antibiotics as well!

• We need to create a new system of government that is beneficial to all and doesn’t encourage exploitation, systematic oppression, and extractivism leading to environmental and community destruction.

• We need to create a new Bible to put in all the hotel rooms everywhere. Where the Old Testament is how to remediate and break down old toxins/paradigms. And the New Testament is how we create new sustainable systems. We have been worshipping and creating an allyship with fungi for 7,000+ years and then longer for our worship and allyship with the earth and all it’s inhabitants for longer. It makes sense to create a guidebook that points the way for people to remember. This will be a guide to work around floods, earthquakes, tsunamis, hurricanes, viruses, droughts, fires, financial crisis, food shortages, oil spills, meteorites, disease, world war 3, desertification, fish dying, colony collapse of bees, Amazon Rainforest being destroyed etc.

• We need to come to terms of where we are and where we are going if we keep up these systems at play. We need to come together as a team and pull all our strengths together to turn ourselves around.

• We need to build a team that is ready on call for when disaster strikes.

• Stay Humble, stay loving, be here now, do the best you can, and may the spores be with you.

Moving forward as a whole we need to protect the biodiversity of Life itself especially fungi by limiting our involvement in logging, fossil fuels, the cattle industry, the soy industry, mining, pesticides, etc. Just as we are finding species of Fungi in the Amazon Rainforest able to degrade
plastic, crude oil spills and help fight and defend our bodies against cancer, we are destroying the Amazon just as quick. “Pinning down exact numbers is nearly impossible, but most experts agree that we are losing upwards of 80,000 acres of tropical rainforest daily, and significantly degrading another 80,000 acres every day on top of that. Along with this loss and degradation, we are losing some 135 plant, animal and insect species every day—or some 50,000 species a year—as the forests fall.” – (Scientific American) We need to ally with some of the great mycologists and organizations out there today doing great work including the Amazon Mycorenewal Project cleaning up oil spills left by Chevron/Texaco in the Sucumbios region of Ecuador, Peter McCoy author of Radical Mycology: A treatise on seeing and working with fungi Founder of Radical Mycology, educating people on low tek assessable radical mycological methods to give the skills needed for this paradigm shift to everyone, conducting extensive research on mycoremediation (for example on Pleurotus ostreatus degrading cigarette butts), Ja Schindler of Fungi for the People educating people on mycoremediation, hosting week long courses and implementing various studies and installations around the west coast, Paul Stamets who is doing some of the top of the line research on everything fungi including some great studies on mycoremediation and implementing lots of projects all over the west coast, Daniel Reyes Owner and Founder of Myco Alliance which is an organization based in Austin Texas which strives to bring the Fungi Kingdom to the forefront of research in the fields of bioremediation, urban hydrology, and sustainable agriculture, Leila Darwish the incredible author of the book Earth Repair: A Grassroots Guide to Healing Toxic and Damaged Landscapes, G.M. Gadd the editor of the book Fungi in Bioremediation, Harbhajan Singh the author of Mycoremediation: Fungal Bioremediation, Tradd Cotter author of Organic Mushroom Growing and Mycoremediation founder of Mushroom Mountain provides knowledge, workshops, education and low tek methods for everyone interested in mycoremediation, myco permaculture, urban mycofarming and more. These are just a handful of the great mycologists or projects out there. Look around your area and reach out to your local mushroom producers, your local mushroom foragers, go to your local bookstore and buy all the books about mycology and join your local mycological association. We need more people who are myco-literate and we need to start teaching about myology in elementary and middle schools to start raising a new generation myco-literate humans. We need to start culturing all the fungi around us and create culture banks to store the genetics incase of their eminent extinction from anthropogenic causes.
We need to start training these fungi to excrete enzymes able to break down the xenobiotic pollutants we are putting out into the environment and into our bodies. We need to ally with these powerful organisms and ask for help with using their enzymes to help us heal the planet and our people. We need a greater knowledge of fungal physiology, biochemistry, enzymology, ecology, genetics, molecular biology, engineering, and several related disciplines. We need people skilled in phytoremediation, plant propagation and cultivation, fundraising and grant writing, soil science and soil testing, hydrology, chemistry and contaminants, permaculture design, irrigation, biology and ecology, microbial remediation and microbiology, compost making, vermi-composting, compost tea making, mycoremediation, mushroom cultivation, water filtration and treatment, public outreach and community engagement/community organizing, government and/or company relations (proposal writing, lobbying), environmental regulations and law, remediation regulations and standards, health and safety, disaster response, oil spill response, and alternative healing modalities as preventative protection and medicine for chemical and toxic exposure. We need a plethora of important white rot fungi spawn on deck at as many locations around the world as possible. We need to start stockpiling these incredible organisms to prepare for when a natural disaster occurs like an oil spill. We need grassroots operators, along with serious funding from the government and various beneficiaries. We need to start investing into the future by investing NOW before it’s too late. We need to have low-tek mycological methods spread around the world and handbooks (ie oil spills 101) sent out in case of natural disasters like oil spills that educates people in how easy it is to use fungi to degrade, disassemble, decompose, transform, and filter these xenobiotic pollutants, and also use medicinal mushrooms to even protect and cleanse our own human bodies from the ill effects of these pollutants that are often toxic, mutagenic, tumorigenic and carcinogenic. Finally, we need a whole global paradigm shift on the our association of Fungi and in the same way fungi transform waste into life we need to change our mental outlook on fungi being gross, dangerous, fearful, to being the KEY to not only the survival of our species but the manifestation of a world THRIVING with biodiversity of LIFE for seven generations ahead. The key is fungi. The time is NOW.
Terms

**Bioremediation** - This term is either an umbrella term to encompass using plants, bacteria, and fungi to remediate toxic wastes or it’s used to describe the remediation of toxic waste using just bacteria.

**Mycoremediation** - The use of fungi to remediate toxic anthropogenic waste.

**Fungi** - Eukaryotic organisms that include yeasts, molds, and mushrooms.

**Mushroom** - The fruiting body of some fungi

**Hyperaccumulation** - Taking up materials such as heavy metals into the cell walls of the organism.

**Hyphae** - Each of the branching filaments that make up the structure of mycelium. The fingers to a hand.

**Compost tea** - A tea made from compost which is teeming with microbial activity.

**BMP** - Best management practice

**Recalcitrant compounds** - In environment any compound or molecule that persists in nature for long time and resist degradation.

**Xenobiotic** - Relating to or denoting a substance, typically a synthetic chemical, that is foreign to the body or to an ecological system.

**Anthropogenic** - (chiefly of environmental pollution and pollutants) originating in human activity.

**In Vivo** - (of a process) performed or taking place in a living organism.
**In Vitro** - (of a process) performed or taking place in a test tube, culture dish, or elsewhere outside a living organism.

**In Situ** - in its original place.

**Ex Situ** - Outside, off site, or away from the natural location.

**Sorption** is a physical and chemical process by which one substance becomes attached to another.

**EEA** - Extracellular Enzyme Activity

**Enzyme activity** - moles of substrate converted per unit time = rate × reaction volume. Enzyme activity is a measure of the quantity of active enzyme present and is thus dependent on conditions

**Enzyme Assay** - laboratory methods for measuring enzyme activity

**Buffer solution** - Buffer solutions are used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications

**Enzyme** - Enzymes are simple or complex proteins composed of chains of amino acids linked together by peptide bonds, which are produced by all living cells. Enzyme catalyze or accelerate chemical reactions. They are the biocatalyst, which alters the rate of reaction without undergoing any permanent change in themselves. All enzymes are proteins but not all proteins are enzymes. Only a small quantity of enzymes is needed to bring a large amount of reaction product.

**Agar** - a derivative of seaweed used as a gel usually in a sterile petri dish to cultivate bacteria, fungi, and plants

**Bacteria** - single-celled microorganisms that are abundant in a diverse number of ecosystems throughout the world noted for their biochemical and pathogenic activities.

**Basidiomycete** - A group of fungi that produce spores on structures called basidia
**Brown Rot** - Fungi that are capable of metabolizing cellulose, leaving behind mostly brown woody tissues

**Culture** - a collection of living tissue comprising the basic building blocks of cells that is capable of exponential expansion

**Fruit body** - reproductive structure of fungus made up of mycelium - aka mushroom

**Germination** - When the spore initiates reproduction, extending a thread of mycelium into the surrounding environment to find a compatible spore to join with and initiate a fruiting cycle.

**Total Maximum Daily Load** - total sediment, pathogens, nutrients, metals, dissolved oxygen, temperature, PH, pesticides, mercury, organics etc. that companies can dump every day.
Appendix 1:

- *Life Cycle of a White Rot Basidiomycete*

When people hear about fungi they immediately only think of the fruit body, or the actual mushroom, but they are unaware of the inner workings. One way to think about mushrooms is as an apple tree; the apple tree is the mycelium and the apples are the mushrooms. Except that the apple tree is completely buried underground and the apples pop up above ground, reproducing through spores instead of seeds. These spores are one celled almost microscopic libraries filled with half of the genetic material necessary for the production of a species. One single mushroom has the ability to release billions of spores a day, only a few will find a suitable environment for germination the other half of the genetic material needed. For basidiomycetes fungi, these spores are housed on structures called basidia. On these basidia are generally four peg like structures called sterigmata with one spore on each peg. There has been much debate on the dispersal mechanisms of basidiomycetes. The most viable theory is that the spores get released through a surface tension catapult mechanism. (*Ballistospory* McLaughlin, et al. 1985)

The spore is hydrophilic meaning it attracts water, especially at one point forming a ball of water called the buller’s drop. Research has found that this ball of water doesn’t come from the spore or the sterigma, but is collected from humidity in the air. It is unsure what triggers the next phenomena but all of a sudden the buller's drop is released and makes it’s way rapidly down the surface of the spore, and is forcefully ejected from the sterigma, launching the spore into the air to send off its genetic information into the universe.

Once a spore lands in an environment suitable for germination, it sends out a filamentous cell called a hypha or mononuclear monokaryotic mycelium, which continues to extend mitotically. Each hyphal strand comprises cytoplasm, organelles and one or more nuclei. Tubular cell walls and septa surround the cell. It takes hundreds of thousands of individual hyphal strands
to form a network thick enough for the human eye to see. In fact, a single teaspoon of good garden soil may contain several meters of fungal hyphae that are invisible to the human eye. Once two compatible hyphae meet each other they come together and fuse genetic material to create binucleate dikaryotic mycelium, which continues to branch out and expand mitotically in search of nutrients and water. Once the mycelium comes in contact with a food source it interweaves around and inside its substrate, secreting enzymes and acids that break down lignin-cellulose complexes into simpler compounds, which the fungi and other organisms can consume.

Vacuoles are intracellular storage bubbles filled with water and powerful enzymes that help destroy and build molecules. They regulate the amount of water and the PH levels in the cell, they store and isolate harmful materials, and they allow nutrients and other substances to move in and out of the cell. Specialized vesicles, lysosomes, are used in lysis, the breakdown or death of cells. They form when smaller vesicles merge and serve to contain and neutralize harmful molecules that would damage or kill the fungi if released into the cellular cytoplasm. Peroxisomes are enzyme-filled vesicles used in breaking down long fatty acid chains, which is important for creating metabolic energy. They are also involved in breaking down amino acids and decomposing hydrogen peroxide (H2O2) a byproduct of digestion that is harmful to fungal organelles.

While growth is occurring in the apical zone, at the other end of the hypha the older parts things are deteriorating. The cells undergo autolysis or self-destruction. What can be reused is moved toward the hyphal growing tip, while the nutrients contained in the rest of the decaying fungus become available to other organisms in the soil food web. In addition, hyphae leave behind a system of microscopic tunnels in the soil through which air and water can flow, contributing to soil structure and health. The enzymes needed for digestion are released there after being assembled in the Spitzenkörper.

Fungi are more similar to humans than plants in the way they consume food rather than making it through photosynthesis. Fungi are heterotrophic – incapable of converting carbons into sugar to produce their own energy. However, they are different from humans in the sense that they digest their food externally and then consume it rather than consuming and then digesting internally. In the process of digesting their food, they are creating enriched soil and food for all of life. This vegetative growth state of mycelium running across its substrate is one of the longest stages in the fungi life cycle.
Mycelium will continue to grow until it runs out of food and/or it reaches physical boundaries or encounters a biological competitor. At this stage the mycelium will enter a stasis in which heat and carbon dioxide evolution will decline and nutrients will be amassed in storage vessels in the cells. This combined with the environmental factors of water and humidity, light, drops in temperature, and a reduction in carbon dioxide will trigger the mycelium into the next phase of the fungal life cycle: mushroom production. This stage starts with the formation of primordia, which are tiny dense mushrooms, which continue to grow at a rapid continual pace given that the outside factors are suitable (high humidity, light, air flow etc.) This mushroom will continue to grow and produce spores, which are housed on the surface of structures called gills, teeth, or pores, which will then be released in mass clouds to repeat the life cycle once again. The process in which mycelium breaks down its food is of great interest for researchers looking to break down pollution in our environment.

Appendix 2:

Fungi Roles in Our Environment

Fungi fill many roles and niches in our ecosystems. These roles can be split up into three different categories: saprophytic, parasitic, and symbiotic.

Unlike plants, fungi are heterotrophic, meaning that they are unable to make their own food via photosynthesis. Fungi, like animals must rely on other mechanisms to receive their nutrients. One of the ways fungi do this is by breaking up organic material and injecting the nutrients from it. If the organic material is already dead or decomposing, these fungi are called saprophytic fungi. Saprophytic fungi are the decomposers of the forest. They are the main recyclers and janitor clean up stewards of the forest. Without them, the forest would be stacked hundreds of feet high with piles of dead trees. The mycelium interweaves between and through
the cell walls of plants and excretes enzymes and free radical oxygen molecules, which degrade these large complex molecules into simpler ones. The end result is the return of carbon, hydrogen, nitrogen, and minerals back into the ecosystem in which plants, insects and other organisms can use to create life. These decomposers are split into three categories: primary decomposers, and secondary decomposers. Primary decomposers are the first fungi that nature sends out on the job. These primary decomposers are fast growers and send out their ropy strands of mycelium to attach to and decompose plant tissue. Most of these decomposers attack wood, but have developed specific sets of enzymes to break down lignin-cellulose, the structural components of most plant cells. Once the primary decomposers have broken down the lignin-cellulose to it’s full potential, then other saprophytic fungi go in to finish the job. This is where secondary decomposers come in. The secondary decomposers thrive on composted material and thrive with actinomycetes, bacteria, and yeasts to break down this compost into beautiful nutrient rich soil. The byproducts of this composting process are heat, carbon dioxide, ammonia and other gases.

The next group of fungi is called parasitic mushrooms, which also feed off organic material but this time, living organisms. These have been seen as the bane of the forest and very hostile to the long-term health of the ecosystem. With more research though, these fungi are now considered beneficial, by increasing the diversity of plant communities by making changes in the composition and succession in the forest. Another benefit is that they make hollow logs, which are homes to some wildlife. Also with human’s creating huge tracts of monoculture agriculture and ruining biodiversity and destroying the soil, parasitic fungi often come in to try to restore balance. The most well known edible parasitic mushroom is the honey mushroom. “One of these Honey mushrooms, known as Armillaria gallica made national headlines when scientists reported finding in Michigan a single colony covering 37 acres, weighing at least 220,000 pounds, with an estimated age of 1,500 years! Washington State soon responded with reports of colony Armillaria ostoyae covering 2,200 acres and at least 2,400 years old. With the exception of the trembling Aspen forests of Colorado, this fungus is the largest known living organism on the planet. And, it is a marauding parasite.” Another incredible and probably one of the strangest parasitic fungal feats would definitely have to go to the
Cordyceps mushroom which invade insects using their insides as nutrients and grows a mushroom right out the insect's body.

The spores of this fungi land on the insect and germinate. The hyphae drill into the chitinous layer of the insect body and makes it’s way up the central nervous system and affects the brain. This action performs a sort of brainwashing by which the for example an ant will literally turn into a some sort of zombie under mind control and climb it’s way to the highest point possible before having mushrooms rip open from it’s dead carcass and spread spores from the highest point possible that the ant just climbed. Incredibly many insects including the bullet ants have learned to point out if any other insects in their colony that are acting funky and will literally pick up and carry these brainwashed disoriented ants as far away from the colony as possible. Once they get as far away as possible they act as martyrs and bury not only the infected ants but also themselves in fear that they also got infected.

The next group of mushrooms is symbiotic. Mycorrhizal has been described and touched on in the above sections. Other symbiotic relationships with fungi include symbiotic relationships with insects. Studies have found that in the neotropics about 18-20% of the above ground leaf mass a year is recycled by leaf cutter ants (Fonicidae: Atta Spp.) (Berish 1986). Travelling great distances, Atta ants collect leaf cuttings to bring back to their colonies to use to
cultivate fungal gardens underground as a food source for their colonies (Kendrick 2000) Atta Spp. are considered a keystone taxon in their habitats (Nadkarni 94, lugo 73) and are a dominant feature in soil ecology and nutritional status of the soil, vastly increasing the organic matter content (Kendrick 2000). In the fall of 2015 I spent a few months in Ecuador studying different ecosystems, their biodiversity and the anthropogenic effects on them. During my travels I did independent research on Atta Ants. In this study we conducted research on the Atta spp. to determine their daily total harvested leaf mass through a series of observational studies at areas surrounding Tiputini and Yasuni research stations located in and around Yasuni National Park in Orellana Province, in Ecuador’s lowland Amazon Rainforest. We ended up finding that the average weight of a leaf bit these ants were carrying weighed .0295 grams. We also found out these ants can workday or night by averaged 11-hour work days. From our data we collected we extrapolated that the average amount of leaf biomass from nests we measured in Tiputini was 624.46 (g) per day and 502.58 pounds per year. The average for nests at Yasuni was 765.99 (g) per day and 616.49 pounds per year. The average for nests at both locations was bringing in 712.92 (g) per day and 573.77 pounds per year. Whereas our biggest colony was bringing in 1907.28 (g) a day reaching a grand total of 1535.03 pounds of leaves a year!

Other symbiotic relationships with insects include that with termites, bees, beetles, fungus gnats, and snails. We also see this symbiotic relationship with fungi with other animals including cows, squirrels, fish, bears, and more! One of my favorites is the symbiotic relationship with fungi and humans. Now is time to make friends and allies with the organisms around us and chose to learn from all their wisdom.
Introduction: The Role of Fungi in Our World


3. Ja Schindler


PART 1: Basic overview

What is Mycoremediation, Why Does it Matter?


History of Mycoremediation

Examples of Successful Mycoremediation


The Potential of Mycoremediation

**PART 2: Considerations**

**Intersectionality**


**Why/When Mycoremediation Can be Harmful**


5. Synergistic Toxicity of Macondo Crude Oil and Dispersant Corexit 9500A® to the Brachionus Plicatilis Species Complex (Rotifera)." (n.d.): n. pag. Web.

**How to Protect Yourself**


Medicinal Mushroom List


<https://blog.mycology.cornell.edu/files/2010/02/Paul_Stamets_with_Agarikon1.jpg>.


List of Herbs, Plants, Foods, Vitamins, Nutrients to Contradict Toxins


PART 3: How to Apply Mycoremediation


Factors That Affect Mycoremediation


Testing


Heavy Metals


Microbes


19. "Staphylococcal Infections". MedlinePlus [Internet]. Bethesda, MD: National Library of Medicine, USA. Skin infections are the most common. They can look like pimples or boils.


Remediating on Land


Enzymes


29. Ravalason, Holy; Jan, Gwénaël; Mollé, Daniel; Pasco, Maryvonne; Coutinho, Pedro M.; Lapierre, Catherine; Pollet, Brigitte; Bertrand, Frédérique; Petit-Conil, Michel; Grisel, Sacha; Sigoillot, Jean-Claude; Asther, Marcel; Herpoël-Gimbert, Isabelle (2008). "Secretome analysis of Phanerochaete chrysosporium strain CIRM-BRFM41 grown on softwood". Applied Microbiology and Biotechnology. 80(4): 719–733. doi:10.1007/s00253-008-1596-x. ISSN 0175-7598. PMID 18654772.


36. M., Kissi; M., Mountadar; O., Assobhei; E., Gargiulo; G., Palmieri; P., Giardina; G., Sannia (2001). "Roles of two white-rot basidiomycete fungi in decolorisation and detoxification of olive mill waste water".


Phytoremediation

Mycorrhizal


Water Remediation


Runoff From Parking Lots/Construction Sites


Creeks/Streams


Rivers

Cascales Project

**Ponds**


**Lakes**


**Oceans**


**Oil Spills in Water**


**Industrial remediation techniques**


**PART 4: Cultivating Fungi**

**Steps of Cultivation**


**What Fungi Need**


**Cardboard burritos**

**Glovebox**


**Laminar Flow Hood**


**Cold Water Fermentation**


**PART 5: Spore Forward**

**Case Study: Mycoremediation of Cigarette Butts**


Suggested Projects

Resources for a Mycoremediator

Conclusion

Terms

Appendix 1: Life Cycle of Basidiomycetes


Appendix 2: Fungi Role in Environment


Back pages:

Alex Dorr is a student and Mycophile who graduated from Hampshire College with a bachelor's degree focused in mycology with a hyper focus on mycoremediation. He has dedicated the last four years to learning as much as possible about Fungi. Alex worked with Fungi Ally for the last couple years, a local gourmet mushroom and spawn producer and education hub in Hadley Massachusetts. Currently working with Amazon Mycorenewal Project, Corenewal and Fungi Ally. Alex received his commercial spawn production and cleanroom certifications from Aloha Medicinals, the world’s largest organic medicinal mushroom producer. Alex completed independent research with fungi in Ecuador. He has also created many mushroom installations and taught dozens
of workshops around the pioneer valley in Massachusetts, Vermont, Pennsylvania, New York, Colorado, Utah, Texas and more! Travelling all around the world, teaching and growing mushrooms in countries like Mexico and Ecuador. Dedicated to the mission of using fungi to clean up the earth’s pollution.
We are reaching a point of no return with our accumulation of toxic waste on Planet Earth. One solution that we have is mycoremediation - the remediation of toxic waste with fungi.

Alex Dorr, a graduate of Hampshire College with a BA in Mycology with a focus on Mycoremediation wrote this book as a beginning exploration to how to clean up toxic waste with fungi and create an allyship with this powerful organism. From cleaning up oil spills, to pesticides, to cigarette butts. From brownfield sites to super fund sites to your own backyard. Learn how to cultivate mushroom and prepare your own medicine for your body and the body of the earth. This is a wake up call and a guidebook giving practical solutions on healing yourself, your community, and the world we live in. We have a duty to protect the biodiversity of life on this planet. We are stewards of this earth, it's time to step up and use the tools mother nature provides. Welcome to a training of mycoremediation. Prepare to clean up our mess.

Praise for Mycoremediation Handbook:
Tradd Cotter - "Alex is truly a mycowarrior! Others enlist or be attacked by cordyceps!"