Powell River Incinerator Site Restoration Project

By Zachary Luck

In partial fulfillment of the Restoration of Natural Systems Program
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Acknowledgements

The Restoration of Natural Systems program has been an amazing opportunity to combine my passions for Chemistry and Environmental Studies at the University of Victoria. I am grateful for all the amazing professors, TA’s, students, guest lecturers and everyone who has made the journey memorable. It is with great nostalgia that I will hand in the final piece of my Diploma program.

A huge thanks to Dr. Val Schaefer for introducing me into the program, his teachings, and his support in pursuing a project related to my future career and research interests. Many thanks to Diana Wood, Lauritz Chambers and Mike Wall for their help and hospitality during my stay in Powell River.

Many thanks to Dr. William Hintz and Paul Delabas for their help selecting, culturing and wisdom regarding fungi. Their generosity in letting me use their lab and equipment has been crucial to the success of the project.
Abstract
In 2012, former RNS student Ian Browning conducted a case study about the feasibility of bioremediation to help restore an old incinerator/landfill site in Powell River BC. Unfortunately, Ian’s work ended just as a preliminary study and was never able to visit Powell River or test any of his ideas. Now, two years later, I had the opportunity to visit Powell River and meet with the Regional District and Botanical Garden Society. It was concluded that at this time, the best way for myself and the University to help both parties involved was to take a sample of Ash from the site and conduct some early studies involving the use of fungi to compost woodchips and ash to create a substrate in which a botanical garden may one day be able to take root. Four species of Fungi are currently being cultured they are as followed: Schizophyllum commune (1), Phanerochaete gigantea, Pleurotus cystidiosus, Schizophyllum commune (2). The success of the project will be determined using bioassays and studying the success of growing species such as Lettuce and Sunflowers using the various composted mixtures. The goal is to use the results and outcome of these studies as a pilot project for further research into bioremediation of the bottom-ash present in Powell River.
1.0 Objective
Mycoremediation is an exciting and emerging field with new opportunities arising faster than ever. To date, there has been extensive research on using various species of fungi to remediate petroleum hydrocarbon spills and by-products (Valentin et al, 2013). Although petroleum waste is a major concern throughout the world, there are extensive contaminated sites laden with heavy metals. The intent of this project was to begin a pilot study looking at the use of various species of fungi to create feasible growing conditions from an ash-woodchip mixture for a botanic garden in Powell River.

2.0 Introduction
British Columbia is riddled with old, forgotten contaminated sites across the province. Once world renowned for the pulp and paper industry, many of BC logging towns were also home to massive incinerators that produced thousands of cubic meters of polluted ash for decades. These incinerators often saw thousands of work hours, and just about every piece of garbage and waste possible. In the past, this ash and was dealt with by simply piling it into enormous piles and locking the gate access to the site. Nowadays the attitude is changing. The severity and harm of leachable substances is being realized, and the attitude towards creating waste is improving. However, the question remains as to what to do with the existing tons of ash waste from the result of decades of burning. The purpose of this research was to study the feasibility of mycoremediation of the ash found on an incinerator site in Powell River, BC.

In the sleepy town of Powell River BC, a few dedicated community members and the Powell River Regional District are teaming up to find a progressive solution to the +28,000m³ of heavy metal laden ash on an old incinerator site. The final fate of the site is still up for debate and won’t likely be settled within the immediate future.
3.0 Site Assessment

3.1 Location

The site is approximately 10 hectares of municipal land that was once used as a gravel pit previous to a landfill. The site is located at 4800 Marine Drive, Powell River, to the North of Westview (the main drag of Powell River) towards the pulp mill and the historical district, as seen below. According to Google Earth, the site is located 389886.62 m E, 5523275.47 m N in UTM co-ordinates. West of the site, is the Strait of Georgia, a world renowned area for salmon fishing.

Figure 1. Location of Site
3.2 General Assessment

A detailed site map was made by Sperling Hansen for the Closure plan, as seen below.

As seen above, the dark brown piles are ash from the incinerator. Currently, these piles are massively overgrown with over 30+ years of blackberry growth as seen in Figure 3.

On the largest pile to the East, a few alders have even managed to take root in the surface layer of blackberry debris.
The largest bright brown pile was originally woodchips, however after 30 years, no one is certain how degraded the woodchips are.

Other significant piles include a large pile of roofing adjacent to a pile of gyproc to the East below the ash pile. The dark blue polygon is a large pile of glass waste. To the North end there are significant piles of yard waste (1,200m³), tires (100m³), and tree stumps (2,000m³). Spread around the site is various small piles of asphalt and road surface material (2,100m³). Pictures taken in late September 2014 can be seen in Appendix 1.

The entire site falls within the CWHdm coastal biogeoclimatic zone. The soil throughout the site drains well as it is very sandy due to its proximity to the ocean nearby. However, a large portion of the site is paved or compact for vehicles. Although the site itself resembles hardly anything remotely expected, outside of the site lies a more typical temperate rainforest. Douglas-fir (Pseudotsuga menziesii) is the most commonly found tree due to the proximity to the ocean, other species such as hemlock (Tsuga heterophylla) and Western redcedar (Thuja plicata) can also be found. Common shrubs found in the area include Salal (Gaultherion shalal), Tall Oregon grape (Mahonia aquifolium), and Dulll Oregon grape (Mahonnia nervosa).

Due to the decades of disturbance, much of the site is barren to trees, however Red Alders (Alnus rubra) can be seen amongst the wetter areas of the site. The very northern tip of the site has become home to an invasive population of Scotch Broom (Cytisus scoparius).
3.3 Stream Assessment

There is a naturally occurring creek that runs almost through the middle of the site as seen in Figure 2 as the bright blue line. The condition of the creek previous to the use of the site of the gravel pit is not well documented, if at all (Wall, 2014). Currently, the creek is slowly regenerating on its own natural path. Evidence of natural succession in the upper portion of the creek can be seen by the older, taller Alders providing shade and nitrogen fixation for the water loving species below such as Sword fern (*Polystichum munitum*) and Western redcedar saplings. Other species such as Horsetails (*Equisetum*), Cattails (*Typha*), and more can be seen recolonizing the wetter parts of the creek. This is a good indicator of creek health, moisture retention, and the presence of nitrogen. The soil in the stream was found to be very rich, and very wet leading to the site series of Western redcedar, skunk cabbage. Many of the expected species were found at the site, however, no skunk cabbages were present. The presence of skunk cabbage usually infers that the area has been a wetland for an extended period of time, as a result the creek has only likely been relatively healthy for a short period of time. The emergence of cedar saplings is also a good indicator of stream health and regeneration as the Cedars will likely take the place of the Alders over time. Photos taken from late September 2014 can be seen in Appendix 1. Due to extreme disturbance over the years, the entire outer rim of the creek habitat is lined with a thick layer of Himalayan Blackberry (*Rubus armeniacus*).
The middle portion of the creek as defined as reach 2 in red will require significant bank restoration. Currently, there is no defined creek bed at reach 2, the stream simply flows freely over a hardened road surface as seen in Appendix 2.

The last portion of the creek (reach 3) will also require significant bank restoration and re-shaping, although currently natural regeneration is underway similarly to reach 1.
3.4 Methods of Assessment

Due to the sheer size of the site, and given that the site will look vastly different once the inorganic materials are either capped or hauled off, only a brief qualitative assessment was conducted during my limited time in Powell River. The maps and plans were made by Sperling Hansen and released by Mike Wall from the regional district for purposes of this study. A brief site history and walk-around was conducted with Mike Wall outlining the various piles of waste and issues with the site.

The general site analysis and stream analysis was conducted using the following guides:


Background information was obtained from a former RNS student (Ian Browning) report, available through Dr. Val Schaefer.
4.0 Future of the Site

The future of the 10+ hectare site is still up for debate. Currently, there are three feasible outcomes for the site. The outcome of the site is dependent on a number of factors primarily the toxicity of the soil and ash, and meeting a budget set by the municipality. To date, the ash and soil has had very limited testing for contaminants, after a more thorough test is completed, the waste on site may have to be classified as ‘special waste’ that will need to be hauled away to special facilities for cleaning and storage. This option is likely to take years, create a huge mess, and be the most expensive. The remaining two options are outlined as followed.

4.1 Powell River Regional District Closure Plan

Developing a ‘Closure Plan’ for the site has fallen to Mike Wall of the Powell River Regional District. A map of the Closure plan can be seen below.

[Diagram: Powell River Regional District Closure Plan]
As seen above, the general idea is to turn the majority of the site into a botanical garden and compost facility. To complement the compost facility, Mike Wall hopes to design a recycling facility where residents can drop off all of their compostable “green” waste in an attempt to reduce waste sent to the Powell River landfill and increase the City’s sustainability. The large area in Pink is of large concern. This area is where all the current piles of ash, glass, tires, and other waste will be “Capped” (Mike Wall, personal correspondent, 2014).

In brief, Capping refers to a strategy where an enormous pit is dug and lined with a non-permeable membrane. The waste is then wrapped a geomembrane then buried underneath clay and dirt. There are numerous benefits to capping such as: the waste does not need to be transported, less material handling and less exposure to surrounding communities (United States Environmental Protection Agency, 2012). However, there are numerous drawback to capping primarily the risk of the membrane being breached leading to leaching of contaminants into surrounding water ways and soils (United States Environmental Protection Agency, 2012). Furthermore, this option is not a real solution to dealing with contaminated wastes, it is merely a temporary measure of mitigation to prevent further leaching of contaminants.

As seen in Figure 5, there is small portion reserved for the creation of an area for an educational facility/area to study bioremediation and ecology. The Regional District hopes to draw funding from the provincial government to help offset the estimated $4.6 million cost of the project.
4.2 Powell River Botanic Garden Society Vision

The Powell River Botanic Garden Society was incorporated in 2012 by founding and current president Diana Wood. The Society currently has over 100 members, 9 of whom sit on the board of directors. The Society was created to push for Powell Rivers’ very own Botanical Garden near the heart of Powell River. The society aims to create a location where food can be grown locally and both residents and visitors can enjoy an arrangement of ornamental and local plant species. The society also hopes to create an area for composting for residents, as well as an area that can serve as a research and/or educational reasons such as bioremediation. Through these goals they hope to work toward their overall vision (Powell River Botanic Garden Society, 2014).

“That plant diversity will be cherished and preserved in an increasingly polluted world for all life on earth”

The society’s vision is similar to that of the regional districts’ except much larger and expansive beyond the original site. The society would like to use the current 10 hectare site for just an educational facility, composting, and bioremediation. The society would like to have their garden outside of the site so that fruit and vegetables that are harvested from the garden can be safely eaten. A drawn out map of the society’s vision can be seen below.
This plan expands far beyond the original area (outlined in red) adjacent to marine drive. The estimated cost of this project is placed around $10 million.

Due to massive cutbacks in the pulp and paper industry, Powell River now receives a fraction of the revenue from taxes that it used to from the pulp mill. These cutbacks make a project this size nearly impossible.

**Figure 6. Powell River Botanic Society Vision**
4.3 Common Ground

Although the two main plans are drastically different in terms of scale, there are a few similarities. The major similarity is the goal to develop an area/facility for studying bioremediation. Powell River is in the process of switching gears from primarily a pulp and paper town, to more ecotourism based industry. Both the regional district and the botanic society agree that a botanical garden would greatly benefit local tourism as well as increase sustainability if fruits and vegetables could be grown for local peoples. As a result, the outcome of my time in Powell River was to focus on finding a species of fungi that could potentially be used for mycoremediation of the bottom ash-woodchip mixture into some sort of soil that could potentially be used to grow an ornamental garden or used for further studies in soil chemistry/biology.
5.0 Mycoremediation

In recent decades the use of fungi and bacteria to rehabilitate contaminated sites has been a hot topic. It is well known that there are various strains of fungi capable of breaking down various petroleum products and hydrocarbons. The use of fungi to remediate sites laden with heavy metals is less established.

5.1 Challenges

There are two main challenges associated with the use of mycoremediation of the ash:

1) The carbon sources are already broken down

2) Metals are toxic and unable to break down into anything simpler.

Fungi which use petroleum hydrocarbons as a carbon source obtain their energy by breaking carbon-carbon bonds which have a large dissociation energy. Petroleum products are made up many different molecules of varying carbon-carbon bond chains lengths (alkyl chains). The fungi obtain their energy from breaking these chains, a process known as biodegradation. The issue with bottom incinerator ash is that most of the carbon chains have been broken down into a simpler form by the time it leaves the incinerator.

Another large problem with bottom incinerator ash is the presence of heavy metals throughout the mixture. Metals in their most basic form cannot be broken down any further. Many metals are also highly toxic to various species of fungi and bacteria.
5.2 Species of Fungi

For this study, woodchips were chosen as the organic substrate due to its well-known properties as a both a carbon source and its ability to retain moisture and heat. When selecting species of fungi for study, one of the most crucial properties had to be the species use of wood as a substrate. Four species of fungi were chosen at the recommendation of Dr. William Hintz, a table summarizing their properties can be seen below.

Table 1. Species of Fungi used for the test mixtures.

<table>
<thead>
<tr>
<th>Name</th>
<th>Substrate</th>
<th>Location Isolated</th>
<th>Notable Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Schizophyllum commune</em></td>
<td>Hay</td>
<td>Calgary, Alta.</td>
<td>Biodeteriogen/biodegradation</td>
</tr>
<tr>
<td><em>Schizophyllum commune</em></td>
<td>Log of Aspen <em>(Populus tremuloides)</em></td>
<td>Elk Island National Park, Alta</td>
<td>N/A</td>
</tr>
<tr>
<td><em>Pleurotus cystidiosus</em></td>
<td>Cultivated edible mushroom</td>
<td>Aldergrove, BC</td>
<td>Edible mushroom</td>
</tr>
<tr>
<td><em>Phanerochaete gigantea</em></td>
<td><em>Pinus contorta</em> (lodgepole pine)</td>
<td>Alberta</td>
<td>Brown pigment</td>
</tr>
</tbody>
</table>
5.3 Methods of Culturing and Inoculation

The fungi were obtained through the University of Alberta’s Microfungus Collection and Herbarium through the Faculty of Agricultural, Life & Environmental Sciences available through URL:
https://secure.devonian.ualberta.ca/uamh/searchcatalogue.php. The fungi arrived as spores are were initially cultured on regular TSA (Trypticase soy agar plates). The cost breakdown can be seen in Appendix 3.

To date (December 16th 2014), the cultures are still growing on the plates. Once fully grown, the cultures will be moved into a flask to form what is known as a Rye Grain Spawn.

Preparation of the Spawn mixture is comprised of the following ingredients

- 250 ml Volumetric flasks
- 50 ml beaker level full of rye grain
- ½ tsp. of calcium carbonate (lime)
- ¼ tsp. of calcium sulfate (gypsum)
- 60ml of warm water

The mixture is then autoclaved for 35 minutes at 121° C. This helps break down the starches to be more available for the cultures, as well as sterilizes the cultures prior to inoculation of the target species. After being autoclaved, the mixture is inoculated with the target species of fungi and the spawn begins to grow. The spawn is then left to allow the mycelium to completely grow through the rye grain. This process is done sealed, room temperature, and takes roughly 1-2 months. Once the mycelium has entirely grown through the mixture, the spawn will be ready for inoculation of the compost.
For each species of fungi there will be 4 test mixtures, 4 control mixtures, and 4 blanks. The test mixture will comprise of a 50/50 by volume mixture of sifted incinerator ash and hardwood woodchips, then inoculated with ~20ml of spawn. The controls will be just woodchips with ~20ml of spawn. The blanks will just be woodchips left to see what will grow without any ash or spawns. Each mixture will be separated in approximately 1.0 liter containers and left sealed in a reasonably temperature controlled room.

6.0 Methods of Analysis & Success
Since this project is a pilot study for the ash found in Powell River, any indication that the ash can be composted will be taken as a positive outcome for future studies. The success of the fungi will be carefully documented for future studies.

6.1 Bioassays
Once the mixtures are done composting (time not yet determined), each of the mixtures will be analyzed using one or two bioassays. Common lettuce (Lactuca sativa) will be used as it is fast growing and success can easily be measured by visual health of plant and biomass. Furthermore, lettuce is cost effective and can be grown in damp, cool places such as in BC during the fall and spring. Further studies may include attempting to growing sunflowers during the summer months as sunflowers have proven to be metal resistant ornamental species for a botanical garden.
7.0 Recommendations

7.1 Stream Restoration

A more detailed study and restoration plan should be developed once the massive overhaul for the remainder of the site has been completed. If the materials on site are going to be capped, the process will likely be another great disturbance event and the stream will likely see physical damage, sediments, and debris. Once the materials are capped, restoring the creek should be high on the priority list as it is an excellent spot for pioneer plants to take hold and begin to propagate.

7.2 Soil Composition

One of the largest concerns for the site is how much lead and other heavy metals have leached from the enormous piles of ash and other waste found around the site. The site naturally slopes towards southwest towards the ocean and after 30 years of extreme coastal rain, it is uncertain how much metal remains in the ash piles, or in the groundwater throughout the site. A preliminary study on the concentration of metals in the ash was conducted in 1996 by Pottinger Gaherty Environmental Consultants Ltd., the official results can be seen in Appendix 4. New studies should be conducted to provide a more accurate concentration of metals in the ash piles, streams, and general site.

7.3 Bioleaching

Future studies involving the mycoremediation of the ash could possibly involve searching for native fungi that could be used for bioleaching. Bioleaching is a process where fungi produce acids from reduced sulfur compounds to create acidic environments that solubilize desired metals for recovery (Willey et al., 2014). This approach can be used to recover metals from substrates where the concentration of the metal is too low to be smelted such as in mine tailings.
Conclusion
The dedicated community member in Powell River along with the Regional District have a long, expensive, and arduous task ahead of them. The site will require significant re-landscaping and movement of waste. A botanical garden will be difficult given the increasing presence of invasive Blackberry and Scotch broom, however, upon completion the garden will undoubtedly be one of the most beautiful and fruitful on the coast of British Columbia. The culturing of the fungi is still underway and results will likely not be obtained until about May 2015. Other methods of mycoremediation, phytoremediation and bioremediation should be investigated.
References


Appendix

Appendix 1. General Site Assessment
Appendix 2. Stream Assessment Photos

Appendix 3. Provided Information on Fungi used and Receipt for Cultures
Slants: Loosen caps upon arrival.

Medium: Potato Dextrose Agar (PDA)

Please confirm receipt of package by email to cgibas@ualberta.ca

Please note that the UAMH accession number should be cited in patent(s), GenBank records, or publications arising from the use of these strains. Reprint(s) would be appreciated.

For GenBank deposits, include the UAMH number in the DEFINITION field and/or include it under SOURCE information as follows:

/culture_collection="UAMH:xxxx" This format is used for collections listed in the Registry of Biological Repositories. http://www.biorepositories.org/

UAMH 6328  Schizophyllum commune  Date Accessioned: 2/14/1989
Isolation Data: heavy growth on hay Calgary, Alta. A. Flis
Sender: Schulz, J.
Strain Characters: biodetergogen/biodegradation. Culture conditions produces clamps, spicules and basidioecarps.

UAMH 7376  Phanerochaete gigantea  Date Accessioned: 7/25/1993
Isolation Data: ex Pinus contorta Alberta R. Bourchier 25 Jun 1954
Sender: Hutchison, L. NOF 131
Strain Characters: pigment brown. Mesophilic NG @ 37C.

UAMH 8021  Pleurotus cystidioua  Date Accessioned: 6/7/1995
Isolation Data: cultivated edible mushroom from B. Chalmers, Western Biologicals Aldergrove, B.C.
Sender: Davies, S. FC-408
Strain Characters: edible mushroom.

UAMH 9034  Schizophyllum commune  Date Accessioned: 9/17/1997
Strain Characters: biodetergogen/biodegradation white rot. Culture conditions produces clamps, spicules and basidioecarps.
Microfungus Collection
University of Alberta, Devonian Botanic Garden
Edmonton, AB T6G 2R3
Ph 780-987-4811 Fax 780-987-4141
Connie Gibas, Acting Curator
e-mail: cgibas@ualberta.ca
http://www.uamh.devonian.ualberta.ca

INVOICE

Customer
Name: Beverley Scheurle/ Dr. W. Hints U Victoria
Address: 3800 Finnerty Road, Patch Bldg, Room 168
City: Victoria
Phone: 250-721-8852

Date: 10/14/2014
Order No.: SS01351
Rep: CG
FOB: 

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PROFORMA INVOICE

SubTotal $360.00
Taxes
GST $16.00
TOTAL $378.00

Payment Details
☐ Cash
☐ Check
☒ Credit Card MC or VISA

Name
CC #
Expires

Office Use Only

Please make check payable to Microfungus Collection
and mail to address above

GST Registration Number R108102831; US IRS # 98-6001254
Appendix 4. Concentrations of Metals in the Ash from 1996

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<th>CanTest No.</th>
<th>Description</th>
<th>Pb (µg/g)</th>
<th>Zn (µg/g)</th>
<th>Cu (µg/g)</th>
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<td>1670</td>
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<td>Coarse Slag</td>
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