Waseug

wa · su · ek (Gold Flower)

USING GOLDENROD PLANTS AS A SCIENTIFIC AND ARTISTIC TOOL TO EXPLORE THE HISTORY AND IMPACTS OF LEGACY GOLD MINE TAILINGS IN NOVA SCOTIA

By
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ABSTRACT

Using Goldenrod Plants as a Scientific and Artistic Tool to Explore the History and Impacts of Legacy Gold Mine Tailings in Nova Scotia

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The purpose of this project is to use the concept of Etuaptmumk Two-Eyed Seeing to discuss the history and impacts legacy gold mine tailings have on the environment. This was done through a plant bioaccumulation study, the outputs of which was simultaneously woven into a bio-art work output. The outcome of the bioaccumulation plant study revealed that goldenrod plants consistently bioaccumulated mercury and arsenic in the treatments. The flower buds having the lowest concentrations. By interweaving two seemingly separate fields of work, I am able to break down the barriers of Western thinking and show that incorporating different elements and views to a project is an important facilitator of conveying not only knowledge pertaining to an issue but also invoking a deeper understanding through visual outputs that can reach a larger audience and create a deeper connection to the topic.

April 17, 2019

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Poqji Atugwei
bock·gee·a·took·way
(I am going to tell you a story)

Gold mining in Nova Scotia has deep cultural and historical roots that spread all over the province, its remnants creating open toxic landscapes which should be home to flourishing flora and fauna. It is important to share the history of these activities in this province, as well as the negative side effects that came from them. By presenting this topic through bio-art, disciplinary lines are blurred through transdisciplinary research, as bio-art goes beyond the borders of the neat boxes that Western science has created for fields of study.

To explain this concept of bio-art, I will introduce the idea of *Etuaptmumk* Two-Eyed Seeing, coined by Elders, Albert Marshall, and Murdena Marshall, and Cheryl Bartlett. Although this idea has been expressed elsewhere in the world and by different names, (Brodnig and Mayer-Schönberger, 2000., Huntington, 2000., Colorado, 1998) this concept also defies the labelled boxes around knowledge systems of the Western world. While this concept is referred to by many different names and without one single definition, Marshall and colleagues explain it as "*Etuaptmumk- Two-Eyed Seeing adamantly, respectfully, and passionately asks that we bring together our different ways of knowing to motivate people, Aboriginal and non-Aboriginal alike, to use all our understandings so we can leave the world a better place and not compromise the opportunities for our youth through our own inactions."*

This project consists of two main components that are interconnected, with its final outcomes being a research paper and a bio-art work depicting the findings outlined within the research paper.

While this way of thinking has come naturally to Indigenous cultures around the world, the idea of a transdisciplinary approach to learning is becoming more integrated into post secondary education. By integrating art into learning, it opens new avenues of how we think about objective fields of study such as math and science. It allows for subjective thoughts with the integration of metaphorical communication, or visual representations outside of the usual scientific communication (Marshall, 2014). Barbara Clark introduces the concept of STEM: Sustainability Transdisciplinary Education Model. She believes that by exploring environmental issues through artistic lenses we can think more critically about our day to day sustainable choices. Art has the ability to close the gap between sustainability and scientific thinking (Clark, 2011).

Being a student within the Bachelor of Environmental Studies program, I have learned many components of the field of the environment, from core science classes to cultural geography. Throughout my academic career I have had a lot of interest in the Etuaptmumk Two-Eyed Seeing concept, as it allows for the incorporation of different perspectives on a topic. I had never heard the term 'bio-art' before beginning this project, but once the concept was introduced to me, I knew it was something I wanted to pursue. Being surrounded by colleagues of a science background as well as new colleagues of the arts, this project fell together nicely and the incorporation of Etuaptmumk Two-Eyed Seeing came naturally.

With any project, especially ones that relate to the natural environment, it is important to acknowledge the history of the landscape. Indigenous knowledge is a key component to understanding and appreciating the landscape. There have been many inputs and collaboration with people from many different backgrounds for this project, an important message to the future of study in the field of the environment, and beyond.

Overview

It is important to note that while it seems as though there are two aspects to this project- a growth experiment and an art component- these two are not separate. Both elements grew and were shaped together. The plant growth experiment influenced the bio-art piece and the materials were interwoven. The bio-art shows the journey of this project, incorporating knowledge shared with me from key influencers, data directly taken from the plant growth experiment and knowledge I have learned about the land that has been directly influenced by legacy gold mines. While I will speak to these elements separately, it is important to note that these elements are all one within a single project.

For the first component of this project I conducted an ecotoxicology and contaminant bioaccumulation growth experiment using giant goldenrod (*Solidago gigantea)* in different treatments (fig. 1); one control group with regular garden soil, one control with garden soil and a sodium selenate additive. One experimental group with tailings from Montague, and one with the addition of the sodium selenate additive to the Montague tailings. One experimental group with tailings from Muddy Pond and one with the addition of the sodium selenate additive to the Muddy Pond tailings. This component's intent was to build on Dr. Linda Campbell and Dr. Emily Chapman's previous experiments which assessed plants grown in tailings treated with a selenium additive. Dr. Campbell and Dr. Chapman's study shows us that the interactions between selenium, mercury, and arsenic are very complicated (Chapman et al, 2016). It has been hypothesized that selenium can counteract the toxic effect of mercury. (Yoneda and Suzuki, 1997). Selenium has also been seen to modify the distribution of mercury within plants (Culvin & Furness, 1991). However, some studies suggest that one does not influence the other. This could be due to the interaction between specific chemical forms (Cuvin-Aralar and Furness, 1990). At very low doses of Se, this relationship may be difficult to monitor. It is known that there is a high binding affinity between mercury and selenoenzymes, giving selenium protective effects against mercury toxicity at a 1:1 ratio (Qiu, et al., 2019). Perhaps at higher concentrations, Se can be effective at governing Hg toxicity (Ralston, et al., 2012).

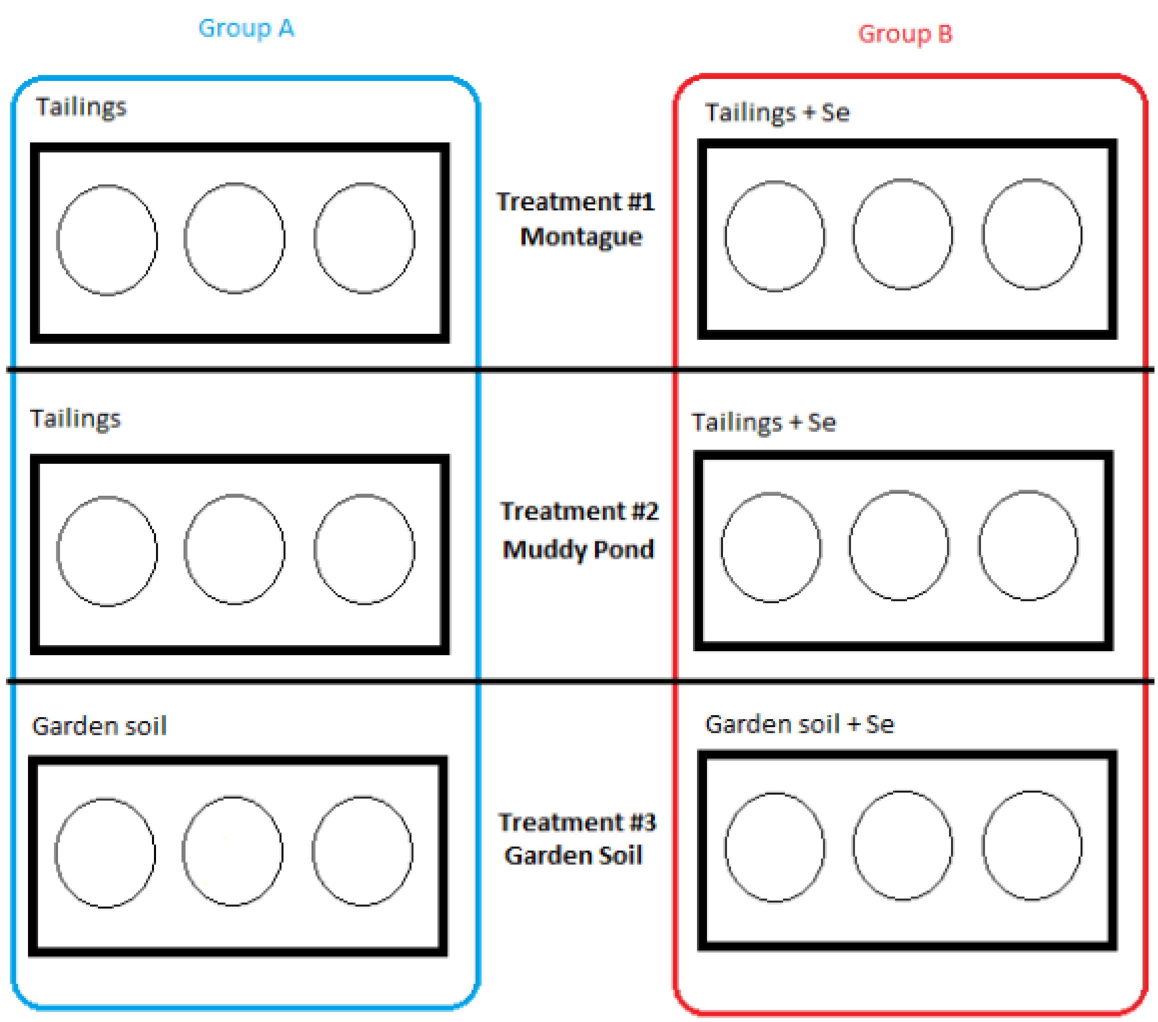

Figure 1- Experimental design of plant growth experiment

Selenium has also been noted to reduce arsenic toxicity in plants. Lower bioaccumulation of As with Se additions to the soil has been found for lower plants, but not much work has been done on the influence selenium has on arsenic in higher plants. Malik et al., (2012) concluded that at certain concentrations, selenium has the ability to reduce the uptake of arsenic in mung bean plants, thus lessening the arsenic toxicity (Malik et al, 2012).

The purpose of this plant growth experiment was to determine if hardy native plant species such as goldenrod can be successfully transplanted directly into tailings and continue to grow and flourish with and without low dose sodium selenate additions. Bioaccumulation of contaminants will also be assessed to determine contaminant concentrations in different parts of the plant. If goldenrod plants can grow well in tailings without accumulating high concentrations in above ground portions of the plant, this type of plant has the potential be used to revegetate gold mine tailing sites across Nova Scotia for the purpose of mitigating environmental risks associated with exposure to contaminants.

The second component of this project takes the findings from the plant growth experiment, as well as the natural pigments of the goldenrod plants to create an interactive visual representation of the data collected from the plant-growth experiment as well as some of the materials used in the process, in the form of bio-art.

By displaying this information through bio-art work, it allows the audience a broader understanding of the environmental issues at hand. It communicates and educates the impacts that century-old gold mines have left on the province, the damage they are causing to our environment, ecosystem health and the food chain. Touching on these issues through the creation of a bio-art work, will open up the conversation not only to a wider range of people but also to invoke different emotions and responses, and provoke critical questioning.

CHAPTER 2
Literature Review

Gold Mining History in Nova Scotia

Gold mining in Nova Scotia began in the early 1860's, came in waves and the major rushes ended in the 1980's. The first discovery of gold which lead to the first gold mine district was in Mooseland, located on the Eastern Shore of the province. Gold continued to be discovered along the Eastern Shore and new districts popped up in many places in the 1860's. By the end of the major rushes in Nova Scotia, the number of districts reached 64 (fig. 2) across the province (Bates, 1987). Gold was located in quartz veins and harvested through the crushing of ore in a stamp mill. The grainy, naturally high in arsenic (Parsons, et al., 2012) material that came from crushing the ore was then amalgamated with mercury. Through this process, it is estimated that for every 1 oz. of gold recovered, 1 oz. of mercury was used in the process (Bates, 1987). This mixture was then heated, the mercury evaporated and collected for re-use. (Little, et al., 2015). Gold was then separated from the mixture and melted down into bars. (Bates, 1987). This process was replaced by a more efficient extraction method called cyanidation in some districts as early as 1898, at the beginning of the second rush. Gold was dissolved in lime and cyanide. With the addition of zinc to the liquid, the gold settles and can be extracted.

Cyanidation is currently the preferred gold extraction method globally (Bates, 1987).

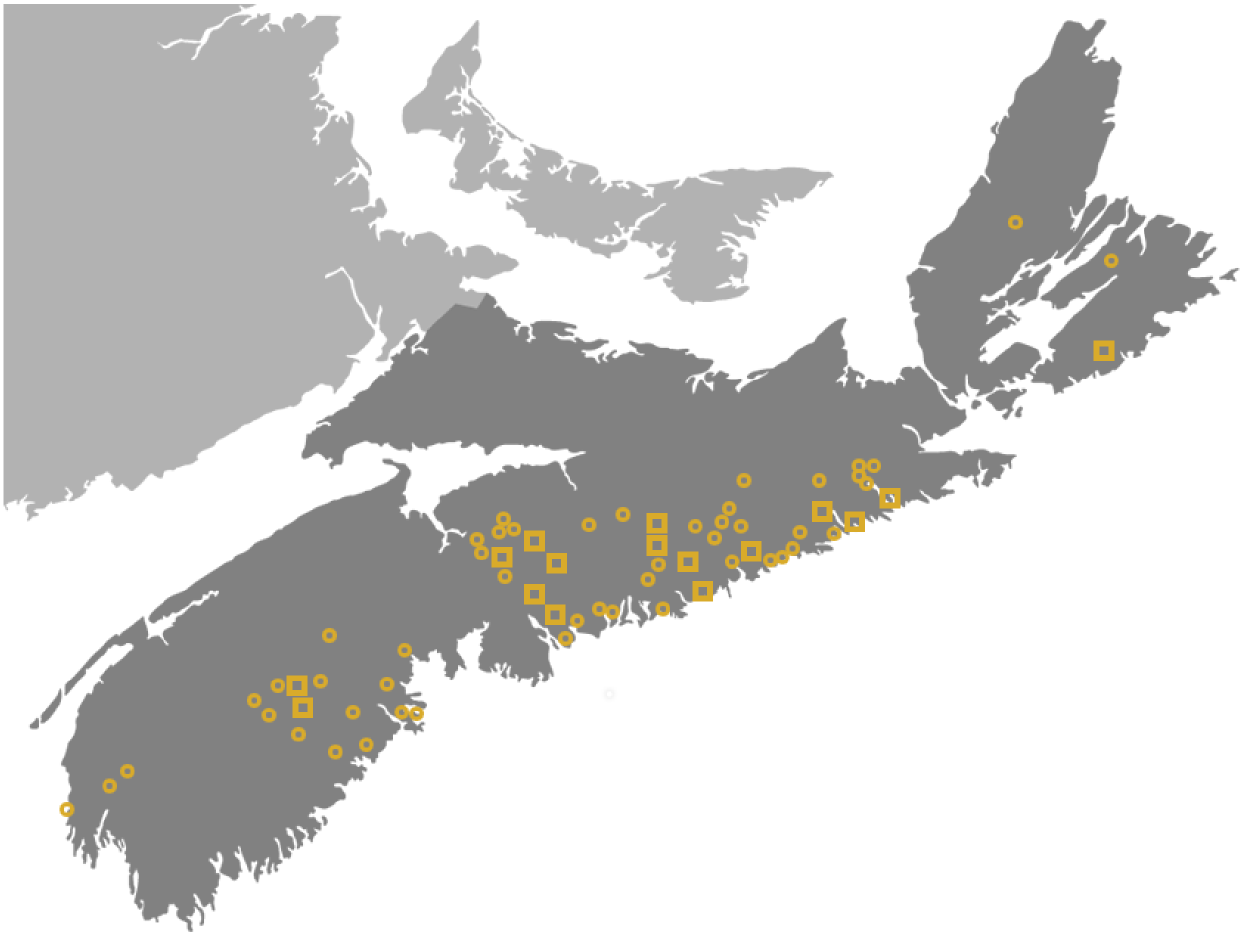

Figure 2- Map of Historical Gold Districts in Nova Scotia Photo retrieved from Nova Scotia Gold website: http://novascotiagold.ca/theme/exploitation_de_lor-mining/carte_dor-gold_map-eng.php

In the beginning, the waste or 'tailings' from these operations were dumped nearby or transported into larger tailings ponds. This dumping causing considerable impacts on the environment. In the 1970's, studies began regarding the effects of gold mine remnants on human health following the death of a man living near a closed mining site. His death was due to arsenic intoxication from leaching in his well water. (Hindmarsh et al., 1977). A study conducted by Brooks et al., (1982) in the Montague gold mine district, now an extensive tailings pond, investigated arsenic in sediments, streams, aquatic organisms and plants. The results showed that the degree of arsenic contamination was extensive.

Figure 3- Tailings located in an intertidal zone in Nova Scotia. Photo retrieved from Atlantic Geology: https://journals.lib.unb.ca/index.php/ag/article/view/22930/28102

In 2004, studies were conducted in intertidal zones along the Eastern Shore (fig. 3). Samples were taken from water, sediment, and mollusc tissue. These samples were tested for their arsenic and mercury content which were then compared to the Canadian Council of Ministers of the Environment (CCME) environmental quality guidelines. Many of the water, sediment and mollusc samples reported Hg concentrations below the CCME guidelines while the arsenic content was found to be extremely elevated (Doe, 2017).

It is clear that the tailings from century-old gold mines in Nova Scotia are causing significant negative impacts to the areas where they were deposited and beyond through transfer of contaminated water and air, bioaccumulation in primary producers and possibly throughout the food chain. Earlier this year a request for proposals was sent out by Nova Scotia Lands looking for a closure plan for two historic gold mine sites in Nova Scotia, the Montague gold mine and the Goldenville gold mine. Both sites are located in areas close to communities and see a lot of human activities, as both sites are used recreationally. Until this point, risk management strategies have been limited to signage (NS Lands, 2018).

Remediation Strategies

Due to its toxicity and potential risks, the remediation of contaminated soil and sediment high in As and Hg is not a new concept. Currently, the most common method for contaminated soil or sediment remediation is excavation or dredging of the contaminated material. This ensures that contaminants are removed from the site, but it comes at a high cost, is disruptive to existing ecosystems, and can sometimes lead to remobilization of contaminants when they are disturbed. Other options for remediation includes solidification and stabilization (s/s). This method solidifies the waste material and then stabilizes it with a binding agent, inducing a chemical change of As and Hg, making them less likely to leach and have a toxic effect. There are a range of binding agents that can be used, such as cement, or a mixture of combustion products (fly ash) and stone (Wilk, 2018). This method can be done in-situ and has been seen to lessen the potential impact to plants and animals. While lessening potential impacts, the risk of leaching is still very high (Alam, et al., 2001).

Geopolymerization, which is the activation of alkali chemicals within certain raw materials which can generate inorganic polymers (geopolymers), has been another technique put forward in the stabilization of potentially toxic metalloids due to its low cost and ability to be done in-situ. For the purpose of remediating gold mine tailings, this method does not seem to be a viable option as studies have shown that this method does not effectively immobilize arsenic (Kiventera, et al., 2018).

Selenium has an affinity to mercury and arsenic and the ability to lessen the bioavailability of these contaminants to plants. We have seen this through a study conducted by Wang et al. (2014). In this study it was found that with Se additions, lower levels of mercury accumulated in brown rice, while enriching the crop with selenium, a micronutrient, necessary in our diet (Wang et al., 2014). Selenium has also been found to limit the uptake of arsenic in plants. When Mung bean plants were grown in As rich soil with 5μM of Se l, selenium restricted the uptake of As while allowing the plant to absorb small amounts of selenium (Malik et al., 2011).

Because tailing ponds are composed of potentially toxic elements, have poor nutrient status and poor organic carbon content, it is not the ideal home for plants (Young, et al., 2012). This is why some tailing ponds to this day are still open, empty pits. At some sites, limited plant growth is present. This life usually comes from years of plant debris falling and slowly building up on top of the tailings (Young, et al., 2012). If selenium has the ability to limit the toxicity of Hg and As in the environment, could Se be used as a way to reduce the environmental risks of old gold mine tailings? This was a question proposed by Chapman et al (2016) at Saint Mary's University. In this study, researchers grew a grass seed mix in tailings. Tailings were divided into six treatments with varying amounts of selenium for a total plant exposure time of 28 days. The outcome was a positive correlation between the added selenium at concentrations up to 3 mg/kg and biomass, root length and number of emerging plants. Less chlorosis was also observed in plants exposed to 3 mg Se/kg tailings, compared with plants growing in untreated tailings.

Goldenrod in Contaminated Soils

Although wild goldenrod and other plants tend to grow around the tailing sites rather than within them, it is possible for plants to grow within the toxicant rich tailings as we have seen with the Chapman et al (2016) study. A study conducted by Zhang et al, at Zhejiang University compared two plant species grown in Pb-contaminated soil; *Solidago canadensis*, a native plant to Nova Scotia (Keen, et al., 2004), but invasive to Asia, and *Kummerowia striata*, which is a native plant Zhejiang, China. *S. canadensis* was able to grow virtually unaffected by higher concentrations of Pb. It was theorized that *S. canadensis* has the ability to be selective in what it absorbs. This raises the question if *S. canadensis,* or a closely related sub-species has the ability to flourish at sites that have been contaminated by other toxic elements, such as the unproductive tailings ponds left from century old gold mines in Nova Scotia.

While goldenrod (*Solidago spp.)* is a native species to Nova Scotia, it is widely viewed as invasive because goldenrod species can grow and flourish very rapidly, suffocating surrounding plants (Keen et al., 2004). *Solidago spp.* is a very versatile species that has the ability to grow in both moist and dry climates, depending on the subspecies (Tilford, 1997). The whole plant is edible and has many different medicinal purposes. Goldenrod flowers used to be ground and used to cover wounds as a styptic on the battlefield in Europe. Tea made from flowers has been used as a remedy for the symptoms associated with the common cold and used as a tonic for the kidneys (Tilford, 1997). On a related medical note, the common misconception about goldenrod flowers being associated with fall hay fever allergies is a myth. Most hay fever sufferers are actually allergic to pollen from ragweed (*Ambrosia)* genus which blooms around the same time and has much less showy flowers compared to goldenrod (Leitner et al 2012).

Goldenrods Natural use in Art

Goldenrod can also be used to create a beautiful golden dye that can change to various shades of yellow, brown and green depending on how the fabric is treated and what the plant dye is being transferred to. An issue with natural plant dye is that a large amount of the plant material must be used to dye fabric (Leitner et al., 2012). We do not see natural plant dyes used in modern dye houses due to the unpredictability of the colour outcome.

Within the flower of the goldenrod there are two different types of natural dyes, quercetin and kaempferol (Casselman, 1993). As goldenrod extracts are flavonoids the use of a mordant to "fix" the dyeing extracts are necessary to allow the dye to hold on to the cloth fibres. Mordants are usually metallic or mineral salts, and depending on the type of mordant you use you can adjust the shade of the outcome colour (Casselman, 1993).

The goldenrod plant with its golden flowers and naturally golden dye acts as a metaphor for the land it has the potential to revegetate after the damage created by the extraction of gold. It is important to convey these environmental issues outside of text to reach a greater audience and evoke emotion around the subject. This can be accomplished through bio-art.

Examples of Bio-art

Bio-art is a transdisciplinary practice that breaks the barriers between the subjects of art and science (Yetisen et al., 2012). The materials used for bio-art are those of a living source, this can be done with plants and animals or on a microscopic scale to bacteria or DNA (Stracey, 2009). We can trace the origins of bio-art back to the discovery of penicillin. Alexander Fleming was a bio-artist who enjoyed creating bacterial paintings on paper. Through this process he discovered that bacteria were being killed by fungi on the paper, leading to the unearthing of our much relied on antibiotic (Yetisen et al., 2012). Since then, bio-art has shaped and evolved into an array of bio-art forms.

Dan Barber, a farmer and food chemist at Blue Hill Farms, took to modifying the eggs of chicken by feeding them hot peppers. Chickens have very few taste buds, allowing them to eat the peppers with ease. The chickens would then lay eggs with a vibrant red and spicy yolk: beautiful bio art creation with which chefs can create interesting dishes. Bio-art does not always have to be in the form of a physical piece. In 1970, Hans Haacke bought a group of endangered turtles and released them into the wild as a form of a performance piece to bring awareness to the illegal pet trade happening globally (Yetisen et al., 2012).

What makes bio-art such an interesting form of expression is that it brings forth a form of Etuaptmumk Two-Eyed Seeing that we do not typically use in the western world, although this concept is beginning to obtain the recognition it deserves, as we are starting to see this concept and similar concepts used in science and education. Bio-art allows another avenue of expression through scientific research. Having this extra output allows a deeper connection and understanding of the information it is attempting to convey.

CHAPTER 3

Amaltaqawi'gas'g

a·mal·ta·hka·wii·ga·sek

(Mixed designs)

As much as this project required independent learning and working, much of it also required interaction with people and the environment. These aspects are all part of the journey that comes with working through a project. The interactions along this journey are a key component to understanding the importance of the work that is being contributed to society and to the betterment of the landscape. Conducting a project that takes into consideration many different perspectives and disciplines, allows for a greater understanding of the information, and allows the communication of that information in a currently unconventional way. Perhaps with this communication, soon it will not seem so unconventional.

My guides for this journey came in the form of a professor of environmental science whose knowledge and passion towards the land is communicated in every interaction and her ecological health research group, who, hand picked, follow her moral compass. One of those members, a meticulous scientist, became my objective voice of reason. An artist who doesn't allow titles or boundaries to define her. A museum curator, whose connections to the land extend further than the artifacts he handles, and the spaces we have travelled to, in order to exchange knowledge.

Plant Growth Experiment

Solidago canadensis was chosen for this project as it is native to Nova Scotia, is naturally occurring at both of the selected mining sites, and carries beautiful, golden flowers that bloom in the later months of the summer reflecting the traces of gold that could be present in the soil it grows in. Yet, it holds another purpose. This project assessed the potential of goldenrod plants for revegetation of tailings to manage risks of contaminants left in the century-old gold mine districts scattered across the province. Goldenrod has many species and a wide global distribution that has been illustrated in Fig. 4. *S. canadensis* can only be found on the eastern side of North America, and is abundant in all of the Maritime Provinces.

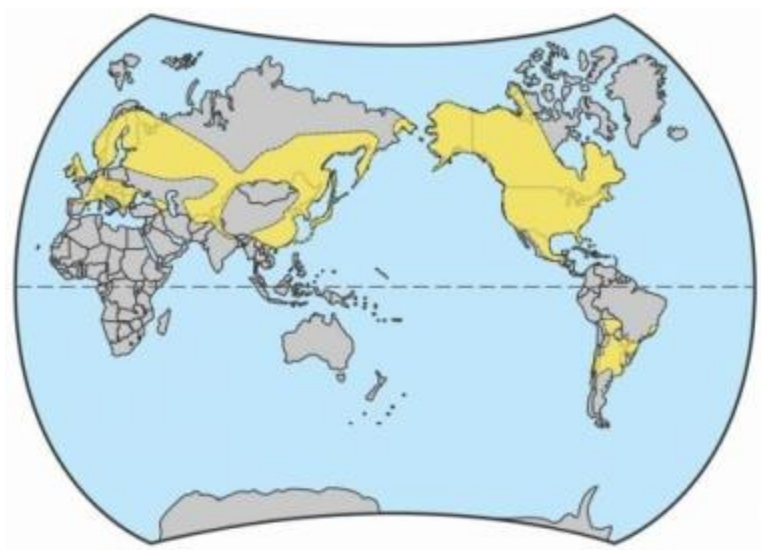

Figure 4- Global distribution of goldenrod. Photo retrieved from University of Waterloo: https://uwaterloo.ca/astereae-lab/research/goldenrods

With the addition of a selenium additive as a treatment to tailings that meet the CCME agricultural guidelines, we predict the selenium will lessen the uptake of As and Hg to the goldenrod plants. If this outcome is successful, goldenrod could be used as a revegetation technique of century-old gold mine tailing sites. By revegetating tailings with goldenrod, this also has the potential to lessen the spread of potentially toxic elements by wind and other environmental factors. Over time, the accumulation of plant material will superimpose the tailings.

Solidago canadensis plants (100) were ordered from Peel's Nursery in Mission, British Columbia. The plants came individually in 10 cm pots containing 3-5 stems per pot. Where

Solidago canadensis is a perennial plant that does not flower in its first year, it was important to obtain plants that had already been growing for over a year (Pors & Werner, 1989). These plants were expected to first flower between August and October, 2018. The plants arrived on May 30th 2018 in very poor condition. They were transported by truck, packed sideways and layered into two boxes. Due to this treatment during transport, the plants were damaged, sun-deprived and with many soggy, rotting leaves.

The plants were transplanted on June 1st into Miracle Grow soil in larger pots and damaged stems were tied to support poles. A few days' post-transplant, many of the plants recovered and looked as though they might be able to be used in the experiment, or at the very least they would be suitable as extra flowers for dyeing with. With these plants arriving in such a poor state, it was deemed risky and impractical to transplant them into the tailings material as they would most likely not survive.

Back-up options for obtaining plants that were discussed included finding a group of the same species of *Solidago spp.* in the wild and transplanting them into the treatments. One of the drawbacks of this method is that the success rate of transplanted wild plants versus plants grown in a nursery may be different. It could also be difficult to be certain that all of the plants collected are of the same species. Another option would be to find a different species of goldenrod at a local nursery that can be ordered in bulk. Unfortunately, it is likely that the species available at local nurseries would not be found in the natural environment in Nova Scotia, which would put flaws in the data. A third option would be to find a completely new species that is easily obtainable and present in the wild in Nova Scotia and around tailings areas. Possibilities include lupines or knapweed, which are abundant in Nova Scotia. However, neither is native to Nova Scotia, nor would be an environmentally friendly option.

We decided that the first option was the most attainable. Two locations were found to have an abundance of *Solidago gigantea* a close relative to *Solidago canadensis.* Plants (100) of roughly the same size and health were collected from the perimeter of Bisset Park, in Cole Harbour (fig. 5).

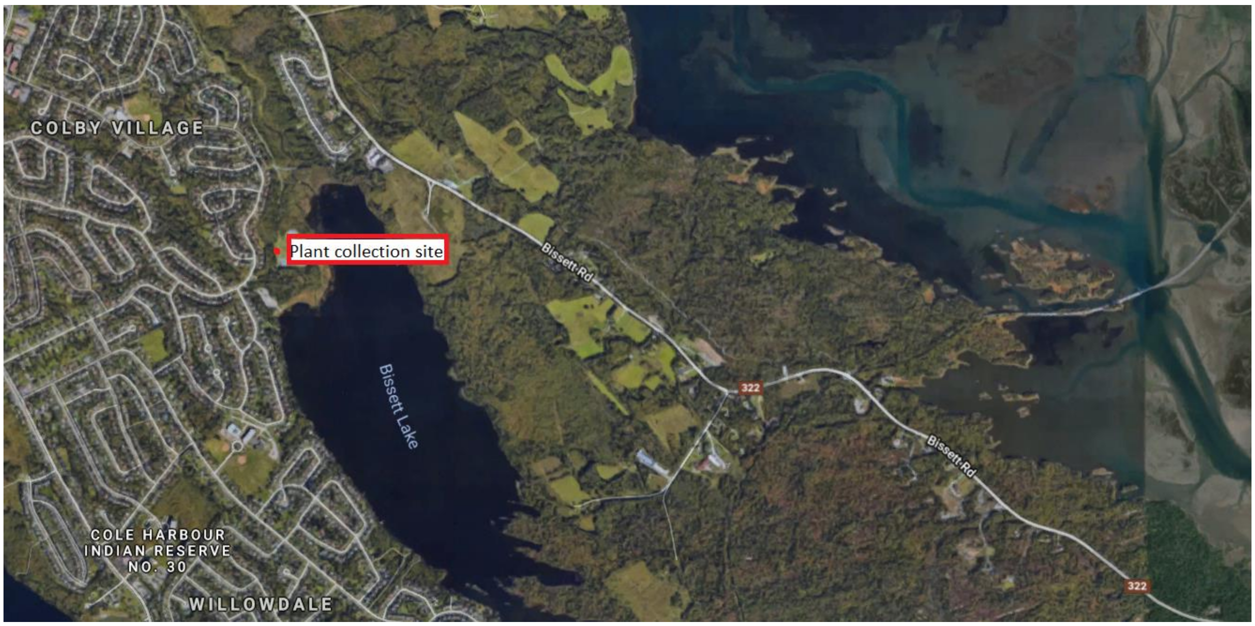

Figure 5- Experimental plant collection site Bisset Park (Cole Harbour)

Gold mine tailings were collected from two areas in Nova Scotia, the first being Montague gold mines, located in Dartmouth and the second being Muddy Pond, located in Waverley (fig. 6). A total of approximately 10 gallons of tailing material from the top 30 cm of tailings was collected from each site by shovel. Once the material was collected it was transferred onto a tarp, on site, where the tailings were mixed and homogenized by hand. To minimize exposure to the toxic waste we chose a day for sampling when the wind was low. Respirators were worn as well as full coverage clothing and gloves. Once mixed, the tailings were transferred into tightly sealed buckets and transported to the lab. The control soil for the experiment was Miracle Gro® potting soil, which is a mix of sphagnum peat, aged bark fines, perlite, coconut coir and plant food.

Figure 6- Tailings collection sites: Montagues (Dartmouth) and Muddy Pond (Waverley)

We had two treatments for each 5-gallon bucket of tailings; untreated with no additivities and treated with a low-dose selenium additive. Tailings and the control soil were tested for their water holding capacity as well as their moisture content (see appendix). Based on this information, the amount of sodium selenite to be added to each soil type to reach 1 mg Se/kg (dry weight) was calculated. This concentration of selenium was selected as it is also the CCME soil guideline value.

Tailing material and control soil were each inserted into fabric growing pots. Each treatment group was separated into its own containment tray to ensure no cross contamination. Within each of these containment trays three fabric pots were placed, containing 3-5 juvenile goldenrod plants each with 3-5 stems per plant. Tailings in pots were covered using a geotextile fabric and rocks to prevent tailings blowing outside of the pots. A hole was cut in the fabric big enough for the plant stems to fit through. All excess water was collected regularly from the trays for disposal. Water was collected at the end of the test (4 weeks) from each tray for analysis of total and dissolved Hg to determine if the leaching of Hg changed with the Se additive. A portion of each water sample (for dissolved Hg analysis) was filtered through a 0.45um filter. This filtered sample, as well as the unfiltered samples were preserved with 1% v/v ultrapure nitric acid. As the plants grew within each treatment, they were monitored and data was collected regarding their growth rate and colour. Data was collected in the form of written observations, photos and videos (see appendix).

The plants were removed from their respective pots on August 21st 2018. Plants in control soil were removed first to make sure there was no cross contamination between plants or treatments. The plants were carefully cleaned with tap water and separated into roots, stems and buds and rinsed again with RO water. Plant samples were then dried at 50°C overnight and ground to a fine powder using a Retsch mixing mill. Tailing and soil samples were also obtained from each treatment, dried at the same temperature and ground by means of mortar and pestle within a fume hood to limit exposure. The prepared samples were sent to Bureau Veritas Mineral Laboratory in Vancouver, BC for total metal(loid) analysis (ICP-MS).

Total Hg concentrations for each plant sample was determined at Saint Mary's University using DMA 80.3 in a HEPA-filtered cleanroom laboratory. The samples were run through the direct mercury analyzer by placing ~250g of material in quartz boats. Quality assurance was conducted through the use of blanks between samples to eliminate cross contamination as well as through the use of liquid mercury standards followed by in-house and certified reference materials. Between sample runs, the quartz boats were thoroughly cleaned through a 5% acid bath as well as a boat burn through the DMA. Plant samples were also prepared and sent to Analytical Services Unit (ASU) at Queens University for the analysis of As and Se concentrations (ICP-MS).

Bio-Art Work

Components

The bio-art work component takes into consideration materials and outcomes from the plant growth experiment and creates an interactive output based on this information gathered. It also incorporates artifacts and history pertaining to Nova Scotia and the gold mining industry and the effects it has had on the environment, water systems and Indigenous peoples. I created all of the components of the piece, except for the incorporation of photos retrieved from the Nova Scotia Museum.

The piece begins with 2 framed full-size giant goldenrods that were harvested from the Muddy Pond tailings site. These two plants were first cleaned, vacuum sealed and stored in a cool room. They were checked regularly for punctures until they were ready to be preserved. The plants were released from their vacuum sealed bags and left to air for a few hours. The leaves and roots were removed from each plant. The stems were stapled to the frame and the buds were glued down using Loctite© general purpose quick set rubber instant adhesive. The structure was then sprayed with several coats of Varathane Clear Matte© Polyurethane Spray and left to set.

While the structure was drying, the removed leaves were place in a water bath to regain some of their moisture and structural integrity. The roots were picked apart, discarding the main root and saving the lateral and root hair structures. These were left to dry. The leaves were taken out of their bath and patted dry. They were then carefully placed along the stem of the plant, mimicking their natural placement. The leaves were glued down and sprayed with Varathane© every 30 minutes for 3 hours to ensure preservation.

This section connects at a 90-degree angle to a flat piece of plywood. This piece has an enlarged map of the historic Sipekne'katik Shubenacadie canal system stemming from Sipekne'katik Shubenacadie Grand Lake to Halifax Harbour, along with the surrounding lakes. The two tailing sites that were used in the plant-growth experiment are outlined on this map, including enlargements of the areas with materials embedded into them which allude to the activities carried out in each area.

Most aspects of this piece is represented through the use of clay and paint, but where possible, goldenrod that I had grown was incorporated. It was used to represent trees within the enlarged tailing sites. Pieces of goldenrod buds along with red beads were used as well to show data points of As concentrations in the treated and untreated tailings pots. This sections also displayed the CCME As soil guidelines. In nature, many reds and yellows are used as a warning sign to other species that they can be harmful if bothered. These species do not need the safety of camouflage to stay safe from prey, thus the reasoning for the red beads showing the elevated As concentrations. More neutral colours such as greens and browns show the data points that are below the CCME guidelines.

Cement and wood ash was mixed together to mimic the look of the tailings at the Montague site. The tailings from the Muddy Pond site were created by mixing cement, paint and Mod Podge® to create a paste. Beside each mounted plant three swinging infographics can be pulled out to show the data collected from the experiment plants displaying the uptake of Hg for each section of the plant.

Dye Extraction

According to Karen Leigh Casselman in her book *Craft of the Dyer*, the best method for dye extraction from plants is conducting the extraction as soon as the plants are harvested, just before the plants are in full bloom and/or after a morning dew. This way, the colours extracted will be more vibrant. When plants are frozen prior to extraction, the dye will be darker, and if the plants are dried prior to dye extraction, the colours will be paler. Because the first half of this project involves testing the content and uptake of the plants, it was necessary to freeze the plants prior to dye extraction. Since there will be backup plants for dyeing purposes, dyes extracted from these plants could be added to the dyes extracted from the experimental plants, for a truer dye colour.

A large amount of material is needed for natural dyeing, as the actual dye stuff within a plant is a very low percentage (Leitner, P., et al. 2012). For every ounce of textile to be dyed, the same amount of dyestuff is required, even more-so if the plants are first dried. Where goldenrod is classified as adjective dye stuff (meaning it requires the use of a mordant to help the flavonoid dyes attach to the material being dyed), iron or aluminum salt mordants would be a necessary component of the dyebath (Casselman, 1989). The specific flavonoid dyes that are found in the goldenrod flowers are quercetin (C.I. Natural Yellow 10) and kaempferol (C.I. Natural Yellow 13,10) (Bechtold, et al, 2007).

Upon harvesting the experimental plants, there was not enough budding to test the contents of the buds as well as use them for dyeing. Instead, the back-up plants that were continually harvested throughout the growing season were used in the dyeing process. These plants were vacuum sealed and frozen to ensure freshness, and thawed for 24 hours prior to dyeing.

The material to be dyed was 100% organic wool yarn (fig. 7) It is vital that the material being dyed be very clean. Any excess oil or dirt on the material and the dye may not stick. The yarn was brought to a boil in a mixture of water and Palmolive dish soap and left to simmer for an hour. It was then strained and rinsed. The pot was refilled and the dyestuff was added as well as an alum mordant (Casselman, 1980). The ratio of plant material to water was 1:10. It is important that the dyebath have a neutral pH so that the colours are not affected (Casselman, 1989). In order to ensure this, tap water was used and the pH levels were tested to ensure neutrality. The water in the dye bath was heated to 95°C; once to a boil the heat was reduced to a simmer and the plant was occasionally stirred for two hours. Upon extraction, the mixtures were filtered through a cloth to eradicate the extracted plant material.

Figure 7- Wool dyed with goldenrod buds that were grown on the green roof at Saint Mary's University

CHAPTER 4
Na'mset
Nah·um·set
(person is finished)

An interesting aspect of this paper is that due to its collaborative nature, the language used throughout, weaves between storytelling from the humanities perspective and scientific report writing. This is important to acknowledge, as it is actively showing the relationship between the different elemental outputs. The creators of the Etuaptmumk Two-Eyed Seeing concept, over the years developed a list of "Lessons Learned" which "facilitate the talking, and walking togetherness of indigenous knowledge and western science" (Bartlett, et al., 2012). These lessons are:

1. Acknowledge that we need each other and must engage in a co-learning journey;
2. Be guided by Etuaptmumk Two-Eyed Seeing;
3. View "science" in an inclusive way;
4. Do things (rather than "just talk") in a creative, grow forward way;
5. Become able to put our values and actions and knowledges in front of us, like an object, for examination and discussion;
6. Use visuals;
7. Weave back and forth between our worldviews;
8. Develop an advisory council of willing, knowledgeable stakeholders, drawing upon individuals both from within the educational institution(s) and within Aboriginal communities

The outputs of this project and the weaving of knowledge, in my opinion successfully facilitated many of these lessons learned.

Goldenrod Bioaccumulation

In regards to the plant growth experiment, the outcome was not consistent with the predictions of reduced mercury and arsenic bioaccumulation for goldenrods planted in Se-treated soils. Due to the CCME guidelines for agricultural use, the acceptable limit for selenium in soil is 1 mg/kg. Where tailings material is a waste product from mining operations, it is not considered soil, but over the past few decades due to accumulation of organic material from surrounding plants, has become a growing matrix where terrestrial plants and invertebrates have established themselves, thus justifying the soil guidelines. Where this experiment was meant as a possible remediation strategy for legacy gold mine tailings, it was important to not exceed those guidelines as selenium can become toxic at higher concentrations.

The plants from the Montague tailings material and control soil treated with the selenium additive had lower Hg concentrations in the buds and roots of the plants (fig. 8), but increase in concentrations the stems compared to those from untreated Montague tailing material and control soil treatments. The plants sampled within the Se-treated Muddy Pond tailing treatments all had slightly higher Hg concentrations in all plant parts compared to those plants from Muddy Pond tailings materials not treated with selenium.

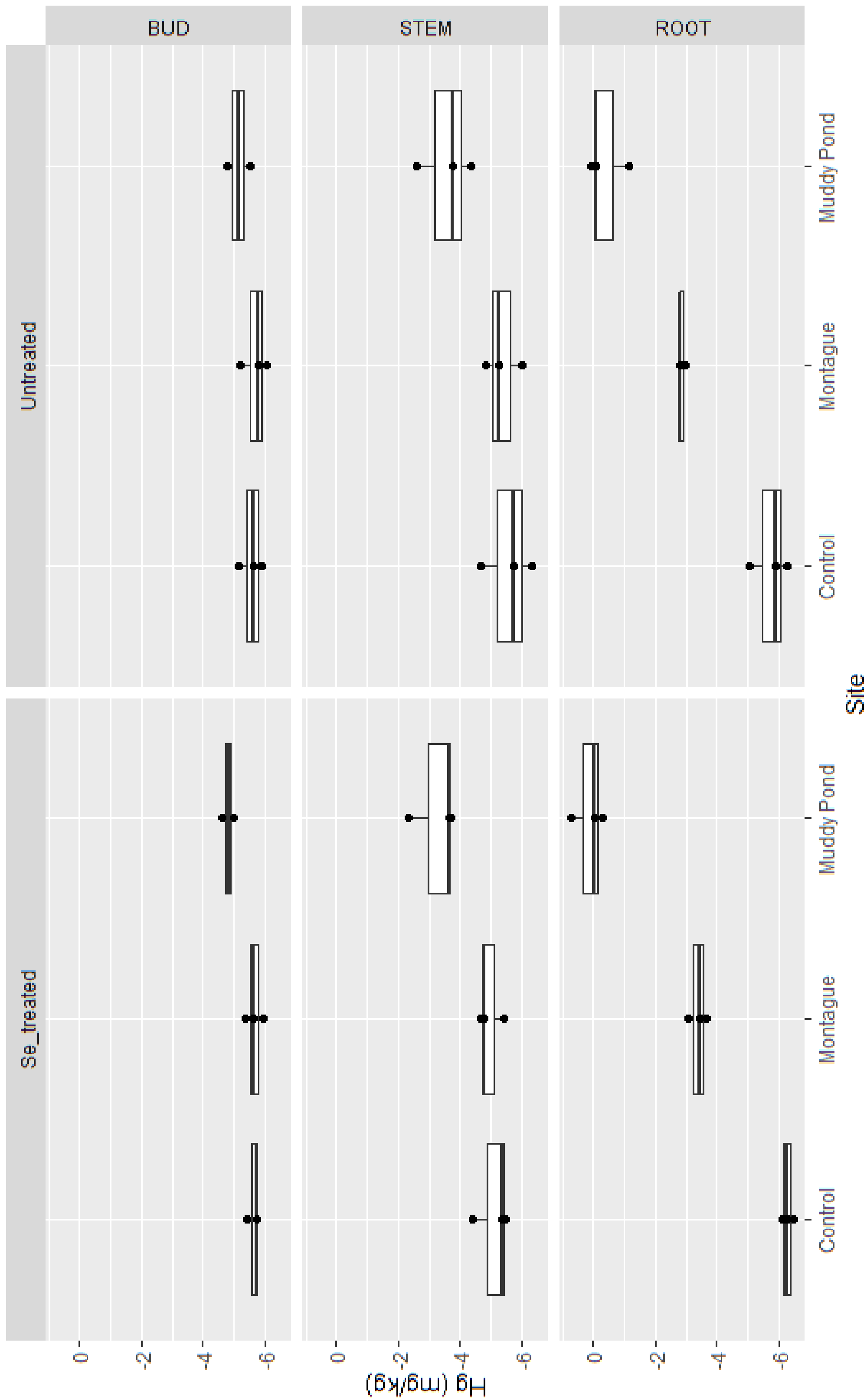

Figure 8- Hg concentrations separated by treatment, site, and plant part in logarithmic scale

Many of the values indicating the uptake of As in different parts of the plant had levels below instrumental detection limits, as indicated by <0.5 values in Table 1. However, plants appear to accumulate lower As concentrations in the Se-treated tailings than in the Untreated tailings. All Se treated pots had a reduction in As uptake compared with their untreated counterparts. These roots also had a significant increase in the concentrations of Se compared with their untreated counterparts.

Table 1- Relationship between Se and As concentrations in roots

	Se mg/kg	**As mg/kg**
Control +Se Roots	0.13	0.68
	0.12	0.95
	0.19	1.1
	0.146	**0.91**
Control Roots	<0.05	1.3
	<0.05	2.6
	<0.05	1
	<0.05	**1.633**
Muddy Pond +Se Roots	3.2	440
	4.7	210
	3.6	240
	3.83	**296.66**
Muddy Pond Roots	<0.05	200
	<0.05	250
	<0.05	560
	<0.05	**336.66**
Montague +Se Roots	0.17	180
	0.13	190
	0.31	270
	0.203	**213.33**
Montague Roots	<0.05	450
	<0.05	320
	<0.05	420
	<0.05	**369.66**

A tailing/soil sample was taken from each pot per treatment, at the end of the experiment. It was analyzed and tested for the amount of Hg, As and Se (Table 2). Where 1 mg of Se per kg was added to each treatment, the only significant change that can be observed was the difference in the amount of selenium between the Montague values and the Montague plus selenium values. The selenium treated Montague tailings had double the amount of selenium in the tailings of the untreated Montague tailings. All other outcomes between the selenium treated and non-treated pots had no significant differences.

Table 2- concentrations of Hg, As and Se within soil/ tailing

Sediment sample	Hg ppb	As ppm	Se ppm
Control 1	46	22.3	0.6
Control 2	61	42	0.8
Control 3	47	10	0.8
Control +Se 1	51	7.8	0.9
Control +Se 2	37	4.3	0.8
Control +Se 3	60	11.5	0.8
Muddy Pond 1	2180	2630.7	<0.1
Muddy Pond 2	2220	2834.3	<0.1
Muddy Pond 3	1999	2571.9	<0.1
Muddy Pond +Se 1	2217	2559.8	0.5
Muddy Pond +Se 2	2062	2793.1	0.5
Muddy Pond +Se 3	2234	2498.6	0.4
Montague 1	2896	>10000.0	0.8
Montague 2	2627	>10000.0	0.6
Montague 3	2724	>10000.0	0.7
Montague +Se1	2776	>10000.0	1.6
Montague +Se 2	2707	>10000.0	1.7
Montague +Se 3	2630	>10000.0	1.3

Please *Do* Touch the Art Work

Because the bio-art output incorporates living material from the plant growth experiment, it allows for it to have a lifespan (fig. 9). I encourage those who are viewing the piece to interact with it. Play with the clay pieces, swing the graphs around, touch the plants. Doing this also aids in the degradation of the piece. All things must come to an end. I wanted this bio-art piece to reflect that, further mimicking the birth and decline of the gold mining industry in Nova Scotia. While all components of the piece will not degrade naturally, some needing human influence to dispose or recycle, so too, will we have to interfere with aspects of gold mining that could not degrade themselves, such as the tailings left behind.

Figure 9- Completed bio-art piece. A) Framed goldenrod plants obtained from Muddy Pond tailing site. B) Graphs depicting the Hg concentrations beside the part of the plant the graph is representing. C) False roots made from dyed goldenrod. The red beads depict the As concentrations within the roots of the plants. D). The different landscape colours represent the different rock formations within this part of Nova Scotia. E) Two enlargements of the sampled tailing sites, Montague (below), Muddy Pond (above). The sculptures scattered throughout the landscape piece represent landmarks of those areas.

Future Work

Plant Bioaccumulation Experiments

A similar study could be conducted with adding additional Se treatment concentrations to the experimental design to allow for a more in depth analysis of how Se treatments to tailings can affect the uptake of metal(loids) to plants. Chapman et al. (2016), found that 3 mg Se/kg, while higher than the CCME guidelines, allowed for improvement in plant growth within the tailings. Having a larger design model, with more replicates, would allow for more data to be collected and analysed. In this study, the minimum amount of replicates (3) required for statistical purposes were used.

By starting the plants from seeds rather than transplanting would allow the plants' total exposure to be limited to the experimental environments. Starting from seeds would also allow a longer exposure time, as goldenrod plants do not flower until their second year of growth. With a longer exposure time and the ability to monitor the plants full growth cycle, more physical differences and outcomes could be monitored.

Creating a similar experiment with goldenrod, and including other native plant species that may be found in areas near gold mine tailings could show different results. Different species interaction could show an interesting outcome as different species require different nutrients. This experiment, conducted with different amounts of selenium could be a great starting point for finding a reclamation strategy for legacy gold mine tailings, using native species.

Bio-Art Work

The bio-art piece I created for this project was quite big, needed to be installed in parts, and could not be easily moved. I think it is a great stepping stone to something bigger. By creating something physical that people can interact with, allows the person experiencing the piece to create a deeper emotional connection to the message being conveyed. It may not be feasible to bring many people to the tailing sites as permission is needed and exposure can be dangerous. Instead, it may be interesting to create a walk-through installation that explores components outlined in my bio-art piece, at all full-room level.

Onsite visits could be possible, if permission was granted and proper PPE was worn. I think this could be an effective tool. By bringing key stakeholders to the tailings sites to share knowledge and stories, exposing them to the open mostly lifeless sites, this could create a deeper connection to the environmental damage tailing ponds have created.

There can never be too much collaboration, especially when it comes to the environment. We only have one home, and it is home to all of us. We must speak for those who cannot speak for themselves. The more collaboration and the more out reach you create, the greater the knowledge you incorporate and share with the community.

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APPENDIX

Height of Goldenrod during Bioaccumulation Experiment

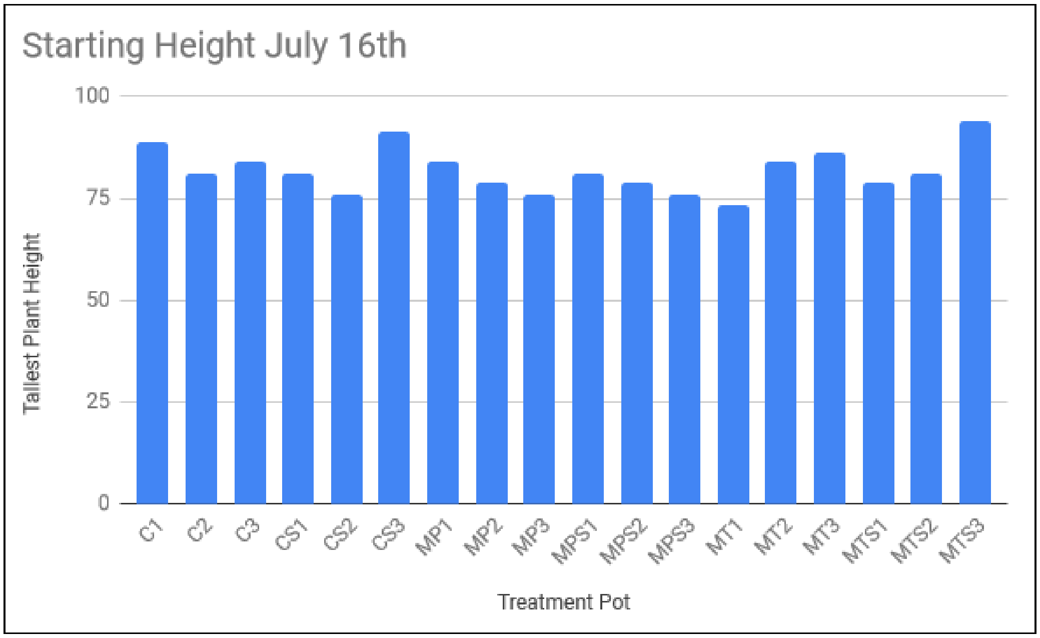

Figure A. 1: Goldenrod maximum plant height on day one of bioaccumulation experiment

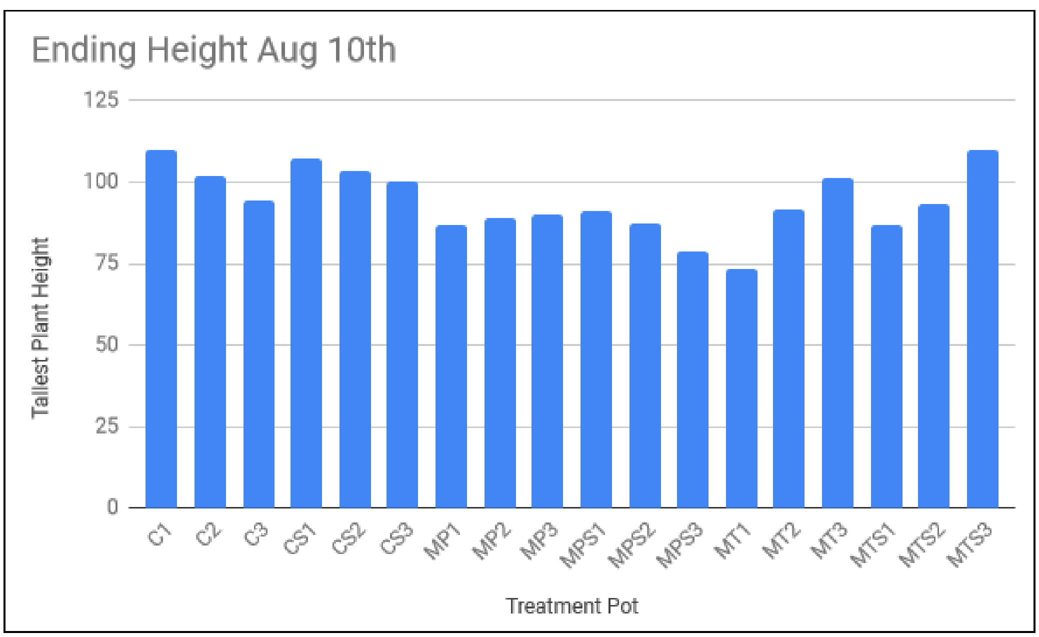

Figure A. 2: Goldenrod maximum plant height per pot at the end of the bioaccumulation experiment

Sodium Selenate Calculations

Se Calculations

Molar mass of Sodium selenite: Na_2O_4Se= 188.94g/mol
Molar mass of Se= 78.96g/mol
% Se in Sodium selenite = 78.96/188.94= 0.4179= 41.79%

Montague: 6.389mg sodium selenate /128mL= 0.04988mg/mL
0.04988*1000= 49.9mg/L – make at least 500 mL
so, **24.94mg/ 500mL**
Muddy Pond: 5.7668mg sodium selenate /128mL= 0.04505mg/mL
45.05mg/L or **22.53mg/ 500mL**
Control: 0.512mg sodium selenate/128mL= 0.004mg/mL
4mg/L or **2mg/500mL**

Figure A. 3: Calculations for Se additive based upon the water holding capacity of each tailing/soil

Wet-Dry / Dry *100
Montague moisture % = 6.914-5.397=1.517/5.397=0.281*100=28.108%
Muddy Pond moisture % = 13.434-10.901=2.533/10.901=0.232*100=23.236%
Control moisture % = 2.629-0.782=1.847/0.782=2.362*100=236.189%

Figure A. 4: Moisture content for each group

pH levels

	pH	**Temperature**
Montague	6.39	21.3C
Muddy Pond	6.87	21C
Control	4.51	20C
c w. added CaCO3	6.25	

*CaCO3 added to soil to make less acidic

Figure A. 5: pH levels for each soil/tailings

Water Holding Capacity

<u>Water holding capacity</u>

	weight soil	Wet filter paper	Dry filter paper + soil	water holding capacity
Control (1)	1.512g	7.746g	16.168g	457.01
Control (2)	1.901g	7.584g	20.749g	592.53
Control (3)	1.594g	7.788g	18.332g	561.48
averages	**1.669g**	**7.703g**	**18.416g**	**537.01**

	Dry weight soil	Wet filter paper	Dry filter paper +	holding capacity
Montague (1)	15.657g	8.163g	30.358g	41.76
Montague (2)	17.435g	7.835g	34.234g	51.41
Montague (3)	18.560g	8.081g	36.420g	
averages	**17.217g**	**8.026g**	**33.671g**	

	Dry weight	Wet filter	Dry filter paper + soil	water holding capacity
Muddy pond	16.497g	7.808g	30.189g	183.00
Muddy Pond	16.162g	8.052g	28.816g	178.29
Muddy Pond	16.819g	7.967g	30.100g	178.96
averages	**16.493g**	**7.942g**	**29.716g**	**180.08**

Figure A. 6: Water holding capacity for each group pot

Weight of Soil/Tailings

Empty fabric pot: 0.06 kg Montague + pot= 3.48 – pot = **3.42 kg** Muddy Pond + pot= 3.03 kg – pot = **2.97 kg** Control + pot = 0.78 kg – pot = **0.72 kg**

Figure A. 7: Weight of soil/tailings in pot

Figure A. 8: Each bead represents a data point for the As concentrations within the roots. The left is plants living within the Montague tailings and the right is the plants living within the Muddy Pond tailings. The green and brown beads at the bottom represent the CCME guidelines for As soil concentrations.