Wood Pellet Ash as a Soil Amendment in the Northwest Territories

Research Study

Prepared by Ecology North

For the Territorial Farmers Association

March 2014

This study into the options for using wood pellet ash as an agricultural soil amendment in the NWT was commissioned by the Territorial Farmers Association in 2014 with funding from the Canadian Agricultural Adaptation Program. This report was researched and written by Alex Cool-Fergus, research intern at Ecology North, Yellowknife, Northwest Territories.

The Territorial Farmers Association (TFA) represents the interest of Northwest Territories Farmers and gardeners at local, territorial and national levels. TFA actively promotes northern agriculture and supports relevant research related to growing local food.

Ecology North is an environmental non-governmental organization founded in 1971 in Yellowknife. Ecology North works on subjects relating to public environmental awareness and education, climate change and sustainable living. With a mission to bring people and knowledge together for a healthy northern environment, it has staffed offices in Yellowknife and Hay River and works in partnership with communities across the territory.

For more information or to access copies of this report, please contact the Territorial Farmers Association (www.farmnwt.com) or Ecology North (www.ecologynorth.ca).

ABSTRACT

Samples of fly ash and bottom ash from wood pellet boilers and stoves were analyzed to determine their fertilizing potential as well as physical characteristics and concentration of elements or compounds that could be toxic or limiting to plant growth. Wood pellet ash is rich in potassium and certain micronutrients. It is also highly alkaline and has high acid neutralizing values. The author found that wood pellet ash added safely to compost at a maximum of 5-15% of total compost weight can enrich it in a variety of nutrients. Ash can be a valuable addition to compost especially during the early decomposition stages. Wood pellet ash must be monitored in compost in order to avoid alkaline shock and reduced productivity.

EXECUTIVE SUMMARY

The amount of wood pellet ash is increasing in the Northwest Territories (NWT) as biomass heating systems are developed. Wood ash from cordwood is used in southern Canada as a liming material for acidic agricultural soils. Other jurisdictions currently use wood pellet ash as an amendment for forested soils to recycle nutrients and increase forest regrowth. This study aims to fill the knowledge gap about the use of wood pellet ash as a soil amendment to increase garden productivity. The goal is to assemble information about the properties of wood pellet ash produced in the Northwest Territories and how ash could contribute to vegetable production in this jurisdiction.

Samples of fly ash and bottom ash from wood pellet boilers and stoves were analyzed to determine the amount of nutrients and content of potential toxic or limiting materials. Results show that wood pellet ash is rich in potassium and certain micronutrients. It is also highly alkaline and has high acid neutralizing values.

Gardeners in the Territory must create their own garden soils with compost or bagged soil because of unfavourable local soil conditions. Because soils are created, acidity is generally not a problem, and the acid neutralizing value of wood pellet ash is not required. However, some nutrients found in wood pellet ash, such as potassium, are commonly lacking in garden soils in the NWT. According to literature, the best practice for using pellet ash to amend these nutrient deficiencies without overly increasing soil pH is to add the ash to compost.

Analysis results found that wood pellet ash can be added safely to compost. The trace metals in ash tested from NWT wood pellet boilers and stoves are within maximum acceptable concentrations recommended for soil amendments in Alberta and CCME guidelines, except for boron that is higher than control limits. Literature concludes that ash can be a valuable addition to compost especially during the early decomposition stages. However, wood pellet ash must be monitored in compost in order to avoid alkaline shock and reduced productivity. Authors find that a maximum of between 5 to 15% of total compost weight can safely enrich compost in a variety of nutrients without accumulating trace metals or micronutrients to toxic concentrations or negatively modifying the composting cycle.

Trial testing is a necessary further step to confirm the conclusions made in this study.

Table of Contents

List of Tables and Figures

ACKNOWLEDGEMENTS

Many thanks are due to a variety of people without whom this study would never have taken place. First of all, thanks to the entire EN staff, especially Christine Wenman. Shannon Ripley was instrumental in developing the research and contributing advice and review throughout its development. Our sincere gratitude also to those who contributed ash (Arctic Energy Alliance, Publics Works and Services of the City of Yellowknife, and several Yellowknife homeowners: John MacKay, Craig Scott, Dwayne Wohlgemuth and Gerald Enns). This research was supervised by an advisory committee that oversaw its development and provided expertise and peer review. Enormous thanks to Shannon Ripley, Bryan Pelkey, Jackie Milne, Christine Wenman. Funding was provided by Agriculture and Agri-Food Canada's Canadian Agricultural Adaptation Program (CAAP) through the Territorial Farmer's Association. Design and layout for the plain language accompaniment piece was provided by Jazmine Gardner at Soaring Tortoise Graphic Design.

LIST OF ACRONYMS

NWT	Northwest Territories
EN	Ecology North
CAAP	Canadian Agricultural Adaptation Program
GNWT	Government of the Northwest Territories
PAH	Polycyclic Aromatic Hydrocarbons
CSB	Combined Services Building
dS\m	Decisiemens per metre
SAR	Sodium Adsorption Ratio
EC	Electrical Conductivity
CCE	Calcium Carbonate Equivalent
ANV	Acid Neutralizing Value
$CaCO_3$	Calcium Carbonate
CCME	Canadian Council of Ministers of the Environment
CaO	Calcium Oxide
Zn	Zinc
Cu	Copper
Fe	Iron
Mn	Manganese
B	Boron
Ca	Calcium
K	Potassium
N	Nitrogen
P	Phosphorus
C	Carbon
Mg	Magnesium
Cd	Cadmium

INTRODUCTION

Rising fuel prices and environmental concerns have spurred rapid uptake in the installation of biomass heating systems in the Northwest Territories (NWT), most notably wood pellet boilers and wood pellet stoves. With the help of initiatives such as the Alternative Energy Technologies Program[1] and the Energy Efficiency Initiative Program[2], many institutions and home-owners are converting from using fossil fuels to installing commercial or multiple residential boilers as their primary source of heating. Across the NWT, wood pellet biomass systems produce approximately 90 tonnes of wood pellet ash per year (Pelkey, 2014). As the NWT Biomass Strategy is implemented and wood pellet stoves and boilers become more common in homes and institutions across the Territory, this number is projected to increase. Presently, wood pellet ash is discarded to NWT landfills, adding to the growing amount of garbage and resulting in management costs for businesses, residents and municipalities. However, there are many potential ways to reuse this waste material.

Wood pellets are made by compressing the woody by-products from sawmills and wood into highly uniform pellets of dried wood. They contain no additives or glue. Wood pellet stoves and boilers have long been used in Northern European countries to reduce the use of fossil fuel-based heating systems that are costly to operate and environmentally damaging. Wood ash, which has many similar physical and chemical properties to wood pellet ash, has a large variety of uses that make it a valuable product in many jurisdictions. It is commonly used as a liming material to increase soil pH on agricultural or forest soils. Wood ash is also used as a cover on mine remediation sites, or as an additive to concrete.

The use of wood ash in agricultural soils is by no account a new phenomenon. Wood ash has been used for centuries as a liming material to increase the pH of acidic soils and as a source of plant micronutrients. Adjustment of soil pH to an optimum range for growing plants is a critical component to ensuring plants can access essential nutrients in the soil. This study focuses specifically on the potential to use ash produced during the combustion of wood pellets in stoves and boilers in the NWT as a local agricultural soil amendment.

[1] The Alternative Energy Technologies Program offers funding for small, medium and large-scale renewable energy projects in the Northwest Territories. More information can be found at: http://www.enr.gov.nt.ca/_live/documents/content/128-AETP%20Guidelines%202011_web.pdf

[2] The Energy Efficiency Initiative Program offers rebates for homeowners who purchase alternative heating appliances, including wood pellet stoves. More information can be found at: http://aea.nt.ca/programs/energy-efficiency-incentive-program

NWT soils lack certain elements that are readily available in wood ash, suggesting that wood ash may be a valuable resource to gardeners and farmers. As NWT soils generally have low fertility, wood pellet ash could potentially become an appropriate soil amendment and could be diverted from the waste stream while contributing to local food production.

This study aims to collate and document relevant information relating to wood pellet ash as an agricultural soil amendment elsewhere in order to inform NWT practice. The study further aims to test a representative selection of wood pellet ash from NWT residential and commercial boilers for a suite of parameters that will determine if it is an appropriate soil amendment for agricultural purposes. Ultimately, this report will assist decision-makers and individuals in identifying the most value added method to divert wood pellet ash from NWT landfills. Detailed results from laboratory analysis of wood pellet ash samples from NWT boilers and stoves present the nutrient concentrations as well as the physical and chemical properties of the ash. These results are then contextualized within the knowledge drawn from the literature review in order to develop recommendations for the use of wood pellet ash as a soil amendment in local food production and agriculture throughout the NWT.

1. METHODOLOGY

This study addresses the need for specific information on the chemical and physical properties of wood pellet ash.

Although studies of the use of biomass ash as a soil amendment have been carried out in Europe and other parts of Canada, ash was mostly studied in regards to its use as a liming agent or as a fertilizer for forest soils. No previous research had been conducted on wood pellet ash as a soil amendment for northern agriculture. The combined growth of the wood pellet biomass sector and small-scale gardening and farming in the NWT created a demand for this type of investigation. This project aims to identify best-practice in the reuse of wood ash across Canada and other northern jurisdictions so as to inform individuals and decision-makers about the uses and limitations of ash as an amendment to agricultural soils. This study provides a base of information, which can be used to further develop wood pellet ash management strategies in the NWT.

An advisory committee consisting of experts in the fields of soil science, northern farming, biomass systems, centralized compost and waste reduction was established to guide project work. The committee assisted the author with research and writing of the report including determination of NWT soil needs, ash sampling and review of ash laboratory analyses. The NWT Biomass Energy Strategy 2012-2015 (GNWT, 2012) was used to provide a portrait of ash produced in Northwest Territories, as it both quantified the resource in different NWT communities and projected future growth in wood pellet use. The lead author met with commercial, residential and institutional wood pellet boiler and stove owners to discuss their various needs in regards to ash collection and disposal. As Territorial farmers and gardeners currently import mineral fertilizers over long distances, sourcing soil amendments locally would reduce both their capital costs as well as their environmental footprint. Staff from the City of Yellowknife and Ecology North, who collaborate to manage the Yellowknife centralized composting program, have also expressed interest in study conclusions in order to know if wood pellet ash is an appropriate addition to Yellowknife's centralized compost piles, and if so, in what quantity and with what treatment.

The Government of the Northwest Territories (GNWT) Department of Public Works and Services, City of Yellowknife Department of Public Works and Engineering as well as several residences and commercial entities provided ash from their pellet stoves and boilers for analysis. A complete list of wood ash sources examined in this study is detailed in Table 1: Ash Sampled.

Based on the results of the lab analyses conducted on the wood pellet ash, documented best practice and specific details about local ash quantities and soil needs, conclusions and recommendations are developed. A short plain-language document summarizes the main results from this research and provides information for the general public. This document can be obtained by contacting the Territorial Farmers Association or Ecology North.

Ash was analyzed from wood pellet boilers and wood pellet stoves. The differences between the two types of biomass technologies are that stove ash does not separate fly ash and bottom ash, whereas boilers collect the fly ash in a cyclone situated behind the combustion chamber. Wood pellet stoves also have a higher likelihood of containing matter that is not fully combusted because of their lower combustion temperature.

The fly ash and bottom ash from wood pellet boilers were analyzed separately because of probable chemical variations in the ash. This information will help determine whether uniquely the fly ash or the bottom ash should be used in agricultural soils, or whether it is possible to mix both. Stove ash was also collected from wood pellet stoves and analyzed separately from the wood pellet boiler ash.

Because most of the pellet market in the NWT consists of La Crete pellets and because Pinnacle pellets are not sold in bulk, the analysis was done solely with ash produced from La Crete pellets. According to literature review there should not be a significant difference between ash from the two brands because they are both composed of softwood trees. Chemical differences are mainly found between softwood and hardwood species used as biomass.

The 9 ash samples were collected in various locations around Yellowknife. Every sample consisted of 450 mL of wood pellet ash collected from different parts of the ash pile. Samples were immediately stored in plastic Ziploc bags and refrigerated. Two additional samples were taken (one from bottom ash and one from stove ash) and stored in a glass jar to avoid contamination from plastic for the polycyclic aromatic hydrocarbon (PAH) analysis. No ash was sampled from outside of Yellowknife because of time and travel constraints. The ash was tested at Exova Laboratory in Edmonton for most parameters and the polycyclic aromatic hydrocarbons (PAHs) were tested at Taiga Lab in Yellowknife in March 2014.

Table 1: Ash Sampled

Type of Ash	Collected from	Boiler or stove size
Wood Pellet Stoves	Household 1	Residential stove
	Household 2	Residential stove
	Household 3	Residential stove
Wood Pellet Boilers, Fly Ash	Combined Services Building (CSB)	540 kW
	Legislative Assembly	300 kW
	Yellowknife Arena	750 kW
Wood Pellet Boilers, Bottom Ash	Combined Services Building (CSB)	540 kW
	Legislative Assembly	300 kW
	Yellowknife Arena	750 kW

Parameters were chosen in compliance with analysis requirements from *Alberta Standards and Guidelines for the Use of Wood Ash as a Liming Agent on Agricultural Soils* (Alberta, 2002) and the *Code of Practice for Soil Amendments* (British Columbia, 2008) under the BC Environmental management act. These documents provided the required analyses in both jurisdictions and were compared in order to determine the elements to be analysed for the purposes of this study. No guidelines or standards currently exist in the NWT regarding wood ash as a soil amendment.

1.1 Parameters Measured

The tested and analyzed parameters listed in this section are determining factors in the decision to use wood pellet ash as a compost additive or soil amendment. The following parameters were measured:

Electrical conductivity (EC) is an indirect measurement of the amount of dissolved salts in soils. It measures both the advantageous salts (potassium, calcium, magnesium, ammonium and nitrates) and the salts that can precipitate toxicity in the soil such as sodium and chloride (A&L Laboratories, 2005). Too much salt can have a negative impact on plants uptake of nutrients. Generally, crops aren't impacted by dissolved salt levels under 2 dS\m (decisiemens per metre) (Brady and Weil, 2002).

The ***Sodium adsorption ratio (SAR)*** compares the sodium to calcium and magnesium cations in the soil. This ratio provides a portrait of the salinity of the soil that takes into account the presence of calcium and magnesium which moderate the impact of the sodium (Brady and Weil, 2002). High sodium levels can impact plant roots by creating a "burn" that reduces their water and nutrient uptake (A&L Laboratories, 2005). Higher SARs indicate that the soil is prohibitively saline. Most crops thrive at SAR lower than 4, and SAR between 4 and 8 only induce moderate limitations for plants (Alberta, 2002).

Expressed as a ***Calcium carbonate equivalent (CCE)***, the ***Acid neutralizing value (ANV***) measures the capacity of a material to raise the pH of soil. Materials rich in cations such as calcium, magnesium and potassium have a high ANV. It is a ratio of the alkalinity of ions contained in a material over the neutralizing capability of calcium carbonate ($CaCO_3$), which is considered to have a neutralizing value of 100%. Higher ANV or CCE can help neutralize overly acidic soils but can also create soils that are too alkaline, which has an impact on the capacity of plants to absorb many crucial nutrients (Alberta, 2002) and (Brady and Weil, 2002). Demeyer et al. conclude that wood ash rapidly modifies soil pH following application, but its alkaline effects are short-lasted and micronutrients that are more readily available in acidic soils increase in mobility after the effects of the wood ash decrease (Demeyer et al., 2001).

Alkalinity and acidity are measured by pH, which is a scale that goes from 1 to 14 pH (1 being most acidic and 14 highly alkaline). The availability of micronutrients such as zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) are strongly influenced by pH and are less soluble in soils higher than 7 pH. Iron and zinc especially can become deficient in alkaline soils. Adding these elements via fertilizers do not generally resolve the deficiencies and gardeners must sometimes resort to spraying micronutrients onto foliage to ensure their absorption by plants (Brady and Weil, 2002). Modification of compost pH significantly alters the structure and nutrient availability during the decomposition process and in the end product. Micronutrients must be carefully monitored in alkaline soils to avoid deficiencies. High pH also limits the mobility of some elements such as aluminum, iron, zinc and manganese (Demeyer et al., 2000 and Estevez, 2006).

Additionally, the forms of iron, manganese, zinc and copper found in wood ash generally have a low solubility and rate of leaching (Steenari et al., 1999). Small quantities of these minor elements are necessary for plant growth, although if the dosage is too high, they become toxic for plants and soil life (Breton and Hébert, 2008).

The availability of boron (B) also depends on soil pH, as it is tightly bound to organic material and will not become available in alkaline soils. Boron is one of the most commonly deficient micronutrients in the soil (Brady and Weil, 2002). However, liming soils that are high in organic materials may encourage their decomposition, which liberates available B (Havelin et al., 2005).

Calcium (Ca) is a nutrient with acid neutralizing properties. It is essential to plant cell structure and plays a role in N metabolism. Ca regulates cation uptake, notably potassium uptake in plants. Calcium is important for the transportation of nutrients and carbohydrates in plants, which helps form stronger tissues in fruits and vegetables (Havlin et al., 2005).

Plant-available potassium (K) is often very deficient in soils, especially in the Canadian northwest. However, this essential nutrient plays an important role in photosynthesis, influences enzymes that participate in the nitrification process and assists plants in absorbing water. Because non-exchangeable K is slow to degrade towards exchangeable K, supplementing soils through potassium-rich fertilizers is a good option for increasing it in soils (Havlin et al., 2005). The K found in wood ash is nearly as available as in synthetic fertilizers (Demeyer et al., 2001). The potassium (K) efficiency of ash is estimated at 100% (Breton and Hébert, 2008).

Nitrogen (N) is a highly valuable and often deficient element in soils. Plant uptake of plant-available N (as NH4+) is optimal at neutral pH soils and decreases in acidic soils. Because N is typically absent from wood ash, any fertilizing plan that uses wood ash as the main fertilizer must also determine an alternate source of N (Demeyer et al., 2001).

Phosphorus (P) is a nutrient that is crucial for plant growth, although if too much is applied it can oversaturate a soil. While less mobile than N, phosphorus can be transported by surface runoff and degrade local water quality. The primary plant-available form of P in the soil is better absorbed by plants when the pH is lower than 7.2 (British Columbia, 2008). Research shows that the P contained in wood ash has a very low solubility, which makes it a poor source of phosphorus (Demeyer et al. 2001). The efficiency of phosphorus is determined by the amount of total P that is plant-available. Studies have found that the P efficiency of ash is of approximately 50%, which indicates that half of the total P from ash will have an effect on soil composition and plant growth.

Carbon (C) is one of the most essential elements for plant growth. It is an energy source and the main building block of all organic materials (A&L Laboratories, 2005). The amount of organic matter in the soil is measured by its total carbon content.

Magnesium (Mg) assists with the photosynthesis reaction and increases nutrient uptake in plants, especially phosphorus. An Austrian study found that the Mg in wood ash has a low leaching rate (Steenari et al., 1999).

Sulfur is measured as sulphate, which is crucial for plant structural development and an essential part of the chlorophyll production (Havlin et al., 2005).

Chloride is a trace element that plays a role in reducing certain plant diseases. Chloride also suppresses nitrification, which leads to a decrease in pH. It can be present at toxic levels in the soil, although this generally only occurs when too much potassium chloride (a common fertilizer) is applied. In that case, the buildup of chloride can be harmful for some plants (Brady and Weil, 2002).

Zinc is a minor element that plays an important role in photosynthesis. It tends to be deficient in soils that are lower than 6.8 pH. Over-saturating soils with P fertilizer can create a Zn deficiency (Estevez, 2006).

Iron (Fe) helps plants create chlorophyll and protein. Soils with a high pH and calcareous soils with low organic matter tend to be Fe deficient. However, Fe deficiency in soils is common and even acidic soils tend to be too deficient in Fe for plants. Iron becomes accessible to plants mostly by bonding with cheleates (soluble organic compounds created by microbial activity and degradation of organic matter).

Therefore, adding organic material contributes to the availability of Fe in the soil, although in many cases it is not enough to fully meet plant requirements (Havlin et al., 2005).

Copper (Cu) is involved in protecting plants against disease, photosynthesis, respiration and creating lignin. It is closely tied to organic matter, as plant roots absorb organically bound, cheleated Cu. Soil solution and plant-available Cu increase with decreasing pH. This micronutrient is commonly deficient in excessively leached, coarse-textured soils. Crops such as beets, carrots, lettuce and spinach are highly sensitive to copper deficiency in soils (Havelin et al., 2005).

Cadmium (Cd) is not currently recognized as being valuable to plants or humans and is therefore considered a strict contaminant (CCME, 2005).

Polycyclic Aromatic Hydrocarbons (PAHs) are carcinogens found in materials that have gone through an incomplete combustion (Alberta, 2002). Literature consistently describes fly ash as undergoing a complete combustion. The risk of PAHs forming in the bottom ash and stove ash is higher; therefore for the purposes of this study only the bottom ash and stove ash were tested for this parameter. According to the Alberta guidelines, the limit for PAHs in agricultural soil is 4 mg\kg of benzo(a)pyrene and naphthalene, respectively. The Canadian Council of Ministers of the Environment (CCME) guidelines recommend testing feedstock that has could have potentially elevated levels of PAHs before integrating the materials into compost (CCME, 2005).

Moisture content should be over 1% to promote the conversion of oxides found in ash to hydroxides, which then adsorb carbon dioxide and become carbonates. This prevents the pH from becoming excessively high and creating alkaline shock (Breton and Hébert, 2008).

Chlorinated organic compounds such as dioxins and furans were not tested for the purposes of this study. These compounds are produced from materials that are combusted with chlorine-containing compounds (Alberta, 2002). This was deemed highly unlikely for wood pellet ash because the wood pellets are composed uniquely of wood by-products and are not mixed with any chlorinated compounds (Dinwoodie, 2014).

Table 2: Laboratory Analysis of Parameters and Values

Parameter	Alberta Guidelines*	British Columbia Guidelines	CCME** Final Compost Contents
Moisture content	Minimum 1%		
Calcium Carbonate Equivalent			
pH			
Electrical conductivity	≤2 dS\metre		
Total Organic Carbon			
Sodium Adsorption Ratio (SAR)	≤4 ideal		
Copper		2 200 mg\kg	400 mg\kg
Zinc	5500 mg\kg	1 850 mg\kg	700 mg\kg
Boron (hot-water soluble)	43 mg\kg		
Cadmium	46 mg\kg	20 mg\kg	3 mg\kg
Benzo(a)pyrene	4 mg\kg		
Naphthalene	4 mg\kg		
Nitrate			
Phosphorus- Plant available			
Potassium-Plant available			
Sodium			
Calcium			
Magnesium			
Sulfur			
Manganese			
Chloride			

*Alberta guidelines are based on the *Alberta Tier I Criteria for Contaminated Soil Assessment* (1994)
**CCME (Canadian Council of Ministers of the Environment) guidelines are for final compost, not for the feedstock (in this case feedstock would be wood pellet ash).

2. BENEFICIAL REUSE OF WOOD ASH IN OTHER JURISDICTIONS

Previous studies that have investigated the properties of wood ash and its use in agriculture and small-scale food production were reviewed. Some studies that have examined other uses for wood ash are also presented, although the goal of this study was to determine recommendations regarding the uses of wood ash specifically in a food-production context. This information and the analysis of NWT wood pellet ash will help design useful application guidelines for gardeners and farmers across Northwest Territories. It must be noted that most of the studies reviewed in this section pertain to the characteristics of wood ash, most of which was sourced from cord wood, which has different properties than wood pellet ash. Some of the studies evaluated ash from hardwood pellets or from logs containing bark, which has a significantly different chemical composition than debarked wood. Therefore the conclusions drawn from this review could differ from the final results of the testing done for the purpose of this study.

There are various beneficial uses for wood ash such as the following: covering landfills and mine tailings; remediating groundwater and acid mine drainage; constructing roads; and as herbicide (Wood Ash Industries, 2014). In areas such as Scandinavia, where the forestry industry and wood biomass systems coexist, wood ash is often returned to the forest soil to complete the mineral cycle and increase tree regeneration (Sweden, 2006). As an agricultural amendment, wood ash is most commonly used for its liming properties in soils that have a pH of 7 or lower (Majeau, 2013). The increase in soil alkalinity from wood ash is intense but short-lasting as the potassium and sodium responsible for its acid neutralizing value are water-soluble and therefore non-persistent in the ground (Demeyer et al.,2001). For soils that do not need alkaline amendments, but would benefit from the nutrients found in wood ash, studies have found that it is possible to reduce the alkalinity in wood ash by exposing it to moisture and air (Hébert, 2014). Wetting and aging the ash transforms its oxides into hydroxides, which adsorb atmospheric carbon dioxide. The process is simple: small amounts of water are added to the ash, which is then exposed to air for a determined amount of time before application onto the soil. This process creates carbonates that reduce the pH level of the final product and prevent leaching of nutrients, especially calcium (Steenari et al., 1999). Low leaching rates for phosphorus, magnesium and iron were observed in an Austrian study looking at the leachate of wood ash after application to soil (Steenari et al. 1999). Through this wetting and aging process, ash is converted into a less-alkaline fertilizer that retains its nutrients without affecting microbial soil life (Sweden, 2006 and Majeau, 2013).

There are two different categories of biomass ash in wood pellet boilers: bottom ash is collected directly from a grate and/or tray in the bottom section of the boiler and fly ash is removed from the flue cleaner system. The relative proportions and composition of fly ash vary greatly in different boilers, although there is generally much more bottom ash than fly ash. Fly ash tends to have a finer texture and is richer in volatile metals than bottom ash, which increases its toxicity (Sweden, 2006). As opposed to wood pellet boilers, wood pellet stoves do not have fly ash.

Both fly ash and bottom ash have fairly high amounts of calcium (Ca) and magnesium (Mg), which are important structural agents for the soil. Wood ash is also rich in many trace elements that are necessary for plant growth and can increase plant immunity against illness in organic production (Breton and Hébert, 2008). Wood ash alone can replace most mineral fertilizers with the exception of nitrogen (N), which is fully lost from wood pellets during combustion (Sweden, 2006). Because wood ash has a high quantity of potassium (K), it could be a free, locally-generated source of that nutrient for garden soils in the Northwest Territories, which are typically potassium-deficient (Milne, 2014). However, the application of wood ash on soils to amend potassium levels must be monitored to avoid over-concentration of other elements (Weil and Duval, 2009), and to ensure that pH is maintained at suitable levels for plant growth. For example, some micronutrients such as iron, copper, manganese and zinc, which are mainly plant-available in slightly acidic soils, can become deficient in soils supplemented by highly alkaline wood ash, if pH levels become too elevated (Havlin et al., 2005). It is very important to test wood ash prior to using it as a soil amendment, and to test the receiving soil, so proper application rates can be determined.

Different varieties of wood pellet energy systems may produce wood pellet ash with varying characteristics, and therefore varying potential end uses. Factors such as combustion temperatures, boiler size and separation or mixing of fly and bottom ash create different end products with varying characteristics (Sweden, 2006).

In Scandinavia, where wood ash is used as a fertiliser for forest soils, compaction and granulation systems have been put in place to slow the decomposition and release of the ash in the soil. In this way the effects of the wood ash are gradual and consistent over the growing season. In agricultural systems, it is preferable to apply larger, more compact granules of wood ash rather than directly applying fine ash. Particle size directly influences the effects of wood pellet ash, and the compaction process tends to make wood ash slower to degrade, which reduces the chances of provoking alkaline shock or salinization of the soil (Sweden, 2006).

Because compaction is done mechanically by compressing ash mixed with water or binding agents, it requires specific equipment and knowledge. A 2006 Swedish compaction plant estimated the cost of pelletization to be between $10-15 per tonne, plus capital investment that varied between $5-13 per tonne processed by the plant (Sweden, 2006). Because of large distances between communities, and the relatively small quantities of wood pellet ash produced, compaction technology would likely be cost-prohibitive in the NWT.

As the needs of local food growers and farmers in the Northwest Territories are significantly different than those of Scandinavian forestry managers, other application techniques need to be considered. In this study, direct and indirect application methods are evaluated and compared in the context of NWT agriculture.

Most typical fertilizing equipment is not suitable for use with ash, although it is possible to use certain equipment, such as screw spreaders and pendulum spout spreaders. These types of spreaders are attached to the back of tractors and distribute the fertilizer material evenly on agricultural soil. Direct application with such pieces of equipment creates dust and should not be carried out in inhabited areas. Wetting the ash can make it a lot easier to deal with and prevent the expulsion of dust when handled. However, wet ash can become more compact, which could make it difficult to consistently apply the material (Sweden, 2006). Some studies have found that direct application of wood ash is less effective than incorporating the ash into soil, although direct application has the advantage of gradually providing nutrients over time (Nader and Thompson, 2013). The machinery required to directly apply ash or incorporate ash on agricultural land is labour-intensive and unlikely to be viable in most NWT communities. Mixing wood ash with manure is highly inadvisable as the ash stimulates nitrification which leaches the nitrogen from manure (Orbenberger and Supancic, 2009).

A number of studies have explored options for mixing wood ash with compost. Mixing wood ash with compost is advantageous as it can be added directly to the compost without being sifted or hydrated. In addition, positive chemical interactions between ash and compost can increase the nutrient value of the final product. Adding ash to compost can accelerate the decomposition process, improve oxygenation, create higher pH and higher temperatures, absorb excess humidity and smother certain unpleasant odours. Ash has been proven to modify soil texture, mineral content and aeration. Generally, wood ash admixture has positive impacts on soil microbes because of improved chemical and physical properties. (Demeyer et al., 2001).

If wood ash is mixed with compost at 20% or less of the total compost weight, the final result can be compost enriched in potassium, phosphorus, calcium, magnesium and trace minerals (Majeau, 2013).

If the compost typically receives low levels of nitrogen-rich food scraps or yard clippings during the winter, it is advisable to reduce the amount of wood ash added to the compost until the spring. If the ratio of ash to green residues is too high, the ash can inhibit the microbial activity necessary for the decomposition of organics. Ash should either be kept separate from the compost until spring, at which time green residues become more readily available, or added into the compost in very small quantities during the winter and in slightly larger quantities in summer. Adding small proportions of ash to compost simultaneously with nitrogen-rich green residues such as freshly cut grass or leaves can create a well-balanced fertiliser that contains all the macro- and micro-nutrients needed by plants (Sweden, 2006). Replacing conventional inorganic fertilizers with fertilizers made from residual materials such as wood ash can result in important long-term agricultural and economic benefits (Nader and Thompson, 2013).

One study that explored the addition of wood ash to compost in Austria found that between 5 and 16% of the total weight of the compost pile can be added as wood ash, if the mixture is to be applied on agricultural soils (Orbenberger and Supancic, 2009). Another study from Québec concluded that ash can be sustainably added at a ratio of up to 20% of the total weight of compost (Majeau and Hébert, 2008). Exceeding these ratios can be harmful to microbial life and reduce the benefits of the resulting compost.

The low cost and relative ease of adding ash to compost are important factors to consider when planning a strategy for the use of wood ash, especially in small to medium-scale projects like those that would potentially take place in the NWT. The use of wood ash as a soil amendment can be an ecologically responsible and cost-effective way of transforming a potential waste material into a locally produced fertilizer. As well as the obvious benefits of reducing garbage in landfills, the use of wood pellet ash as a fertilizer could also reduce the amount of chemically-created or non-renewable mineral fertilizers that are presently transported to the NWT.

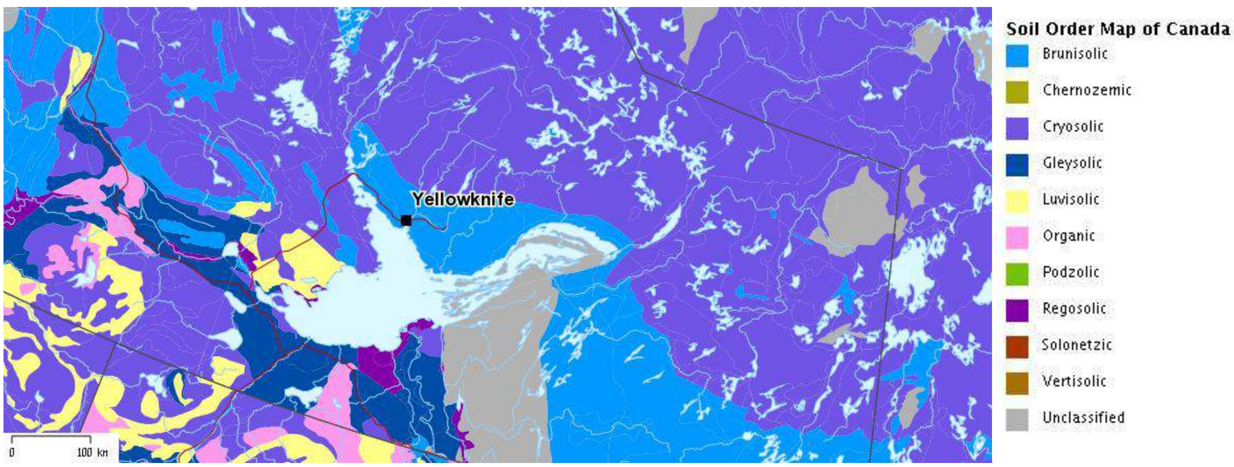
Overall, wood ash can affect soil or compost positively or negatively by modifying pH-related parameters such as nutrient absorption or inhibition, stimulating or impeding microbial activity and increasing nutrients and metals. The results from this review of best practices conclude that ash is a safe soil amendment, especially when added to compost. Recommended dosages of ash vary between 5 and 20% of total compost weight, as too much ash can impede healthy compost decomposition.

Additionally, ash should be tested before application into compost or garden soils to determine any potential hazards it may pose to human health or the environment. The main parameter to monitor in wood-ash amended soils is the alkalinity, which can become too elevated.

3. SOILS IN THE NWT

As represented in Figure 1, the soils in and around Yellowknife are of the Dystric Brunisolic order. This type of soil tends to be acidic (under 5.5 pH) and lacking in a well-developed mineral or organic surface horizon (Canada, 1998 and Agriculture Canada, 2010).

Table 3: Soil order map of North and South Slave regions



Reference: Soil Orders of Canada, Agriculture and Agri-foods Canada (2010)

Hay River has Gleysolic soils, which indicate current or previously high levels of water saturation. These soils are typically shaped under anaerobic (oxygen-free) conditions, which mobilize iron (Fe) and manganese (Mn) (Agriculture and Agri-foods Canada, 2010 and Soil Classification Working Group, 1998).

Most other regions of the NWT have Cryosolic soils, which are characterized by the proximity of permafrost to the thin mineral surface. This type of soil is prohibitive for agriculture: any food production must be in boxes and requires human-made earth such as compost (Soil classification working group, 1998 and Agriculture and Agri-foods Canada, 2010). Most NWT soils are rated as ill-suited to agriculture. This is measured by plant hardiness, which is based on soil, climate and plants that are typically grown in a region. On these scales, NWT rates 0a in most regions, which is the harshest possible growing climate found in Canada (Natural Resources Canada, 2001).

Yellowknife has a centralized composting program that recycles approximately 200 tonnes/year of organic materials into finished compost. This program is in the process of expanding to divert further organic waste resources. Finished compost is sold to local residents for use in gardens and yards. The compost facility produces Grade A compost, rated according to compost quality standards established by the Canadian Council of Ministers of the Environment (CCME). Hay River is developing a municipal compost program, and other communities such as Fort Simpson are beginning work on the implementation of organic waste recycling (Ripley, 2014).

Over the past decade, small-scale subsistence farming and gardening has been increasing in the Territory, with community gardens, greenhouses and farming education programs being created to provide local food and support for food production. As interest in farming and gardening grows, so does the need for locally-sourced fertilizers. However, depending on a variety of factors and parameters, every garden soil has different needs. For this reason, it is difficult to determine general fertilizer application rates. Ideally, gardeners will test their soil for major parameters such as pH, nitrogen, phosphorus and potassium concentrations, as well as the presence of calcium and magnesium. The results will provide a clear picture of what is present or lacking in the garden, which can then suggest courses of action.

4. WOOD PELLET ASH IN THE NORTHWEST TERRITORIES

Approximately ninety percent of wood pellets shipped to the Northwest Territories are La Crete brand pellets, consisting mostly of spruce with some aspen wood products. These wood pellets are produced in La Crete, Alberta. La Crete is currently the only provider of bulk pellets in the NWT (Arctic Energy Alliance, 2009). The other ten percent of pellets are provided by Pinnacle Pellets, and some other brands. The majority are made with sawdust from spruce, pine and fir wood (Pinnacle Renewable Energy Group, 2011). Apart from La Crete bulk pellets, all other wood pellets are sold in bags and are therefore mostly used for residential pellet stoves. Both La Crete and Pinnacle pellet brands produce less than 1% ash after combustion (Manuilova and Johnston, 2011).

An estimated 29 tonnes of ash were produced in 2013 in the NWT from commercial and institutional buildings, with a projected increase to 84 tonnes/year by 2016 (Pelkey, 2014). As biomass becomes a more popular heating alternative, the increase in ash will create a significant waste material requiring management.

Using wood pellet ash as a soil amendment can be particularly beneficial in the NWT. An ash collection system could potentially create an opportunity to produce a local soil amendment and stimulate the production of local produce in areas where fresh food is expensive. Additionally, businesses and institutions recycling ash may be able to reduce their waste management costs. It is difficult to quantify the savings gained from replacing conventional fertilizers with wood pellet ash because of the variability in fertilisation needs and the effects of local climate on garden soil requirements. However, because wood pellet ash is a free product and conventional fertilizers entail high transportation costs, the savings could be large, especially in remote communities.

5. SAMPLING AND ANALYSIS OF NWT WOOD PELLET ASH

The following section documents the analyzed contents of wood pellet ash. The tables indicate result values from certain important parameters.

Table 4 Fly Ash Content

Parameters Measured in mg\kg unless otherwise indicated	Nitrate (N)	Calcium (Ca)	Phosphorus (P)	Potassium (K)	Zinc (Zn)	Boron (B)	Moisture (%)	CCE (%)	pH	Electrical Conductivity (dS\m)
Combined Services Building	2500	108000	1900	129000	1100	178	0.2	96.1	12.7	14.1
Legislative Assembly	810	1400000	3100	68500	108	85.2	0.1	90.9	12.7	11.7
Yellowknife Arena	980	127000	2700	66100	261	98.1	0.2	88.6	12.7	11.9

Nutrient levels are high in fly ash, especially calcium (Ca), potassium (K) and phosphorus (P). Fly ash is the most nutrient-rich component of wood pellet ash; however it also has the highest concentration of heavy metals. There are advantages and disadvantages to using fly ash to supplement compost and agricultural soils; although it closes the nutrient cycle, it can also pose a potential threat to soil and plant health if applied incorrectly.

Moisture levels for the fly ash samples are below ideal control limits. Moisture levels under 1% could react with oxygen to create calcium oxide (CaO), which is a highly caustic element that can endanger plant and human health. However, when weathered, the moisture levels should increase significantly and the Calcium Carbonate Equivalent (CCE) should be reduced (Havlin et al., 2005).

Fly ash pH is highly alkaline: all fly ash samples had a pH of 12.7. Such a strong alkalinity has the potential to incur important damage to soil and plants. The Acid Neutralizing Value (ANV) as measured by the CCE is fairly high in all fly ash samples, with an average CCE of 91.8%. The CCE measures the relative alkalinity of materials by comparing them to calcium carbonate, which has a neutralizing value of 100%. With such high CCE, fly ash can be considered an efficient liming agent.

The electrical conductivity (EC), which measures the amount of dissolved salts in a material, largely exceeds the control limits in all fly ash samples and is considered strongly saline. However, the dilution of ash in compost should bring the EC of the final product to safe levels.

Only one fly ash sample had available data on the Salinity Adsorption Ratios (SAR), as the data for this parameter in all other samples are otherwise non-available. With insufficient information from which to draw conclusions, SAR will not be taken into account for the purposes of this study. Polycyclic Aromatic Hydrocarbons (PAH) levels were not analyzed for the fly ash samples as the fly ash was considered to be fully combusted and therefore would not contain any PAHs.

The fly ash analyzed in this study is below control limits for most metals except for boron (B): all samples had significantly more boron than the recommended level. Because B can be liberated when in the presence of organic materials, this parameter should be monitored in compost.

Table 5: Bottom Ash Content

Parameters Measured in mg\kg unless otherwise indicated	Nitrate (N)	Calcium (Ca)	Phosphorus (P)	Potassium (K)	Zinc (Zn)	Boron (B)	Moisture (%)	CCE (%)	pH	Electrical Conductivity (dS\m)
Combined Services Building	810	97300	140	55300	22.4	41.6	0.3	94.5	12.6	10.6
Legislative Assembly	30	135000	2200	10500	≤5	111	0.3	103	12.7	11.8
Yellowknife Arena	270	28000	1000	44000	7	42.1	0.4	97.6	11.8	2.1

Bottom ash is not as nutrient-rich ash fly ash. Calcium (Ca, potassium (K) and phosphorus (P) are less present in bottom ash than in fly ash.

Samples analyzed show that Polycyclic Aromatic Hydrocarbon (PAH) levels are far under the control limits.

Bottom ash pH is highly alkaline and greatly resembles the pH of fly ash. The calcium carbonate equivalent (CCE) is generally higher than fly ash CCE, which means that the acid neutralizing value of bottom ash is higher than that of fly ash.

Moisture content in the bottom ash is below the recommended 1% of moisture for wood ash. As with fly ash, this means that the ash could potentially become reactive if it is not weathered properly.

Electrical Conductivity (EC) is higher than the recommended ideal EC, which means that the ratio of dissolved salts is elevated. As high levels of salt can impact soil and plant health, a high EC can inhibit plant growth. However, because of the dilution of bottom ash in compost, the EC of the final product should be significantly lower than the EC of the feedstock material.

Some metals are necessary for healthy plant growth in small doses. Too much metal can become toxic for plants, which is why control limits exist for the quantities of metals found in ash. Metals in the bottom ash samples are below control limits except for one sample which had excessively high levels of boron (B). The amount of boron in the bottom ash samples is lower than in the fly ash.

As with the fly ash, manganese levels were highly variable in the bottom ash. Chloride is present at much lower values in the bottom ash than the fly ash. Additionally, bottom ash has much smaller quantities of zinc than fly ash. Because zinc is a useful micronutrient, its small presence in bottom ash reduces the efficiency of bottom ash as a fertilizing material.

Sodium adsorption ratio (SAR) levels were non-available and were therefore not considered for the purposes of this study.

5.1 Differences between fly ash and bottom ash

Fly ash contains significantly higher levels of available nutrients. Major nutrients such as calcium, phosphorus, nitrate and potassium as well as minor nutrients like copper, sulphate, zinc, cadmium, chloride and iron are much more present in fly ash than bottom ash. Boron levels are doubled in fly ash compared to bottom ash. The amount of carbon is also higher in fly ash. Manganese seems to vary greatly within all the samples of fly and bottom ash.

Additionally, although the fly ash samples have higher pH values, the average acid neutralizing value (ANV) of fly ash is slightly lower than that of the bottom ash (91.8% for fly ash compared to 96.05% for bottom ash). Although the Electrical conductivity (EC) of fly ash is higher than that of the bottom ash, both types of ash are higher than the Alberta guidelines control limit for EC. As discussed above, the dilution effect of mixing with a receiving material will diminish the effect of this parameter in the final soil product.

Overall, the fly ash provides higher levels of required nutrients and has a smaller effect on the pH of the receiving material. Both types of boiler ash can be used separately or mixed together to create a soil amendment as they are generally below control limits for fertilizing materials. Best results would likely be found by prioritizing the use of fly ash as a fertilizing material over bottom ash.

Table 6: Stove Ash Content

Parameters Measured in mg\kg unless otherwise indicated	Nitrate (N)	Calcium (Ca)	Phosphorus (P)	Potassium (K)	Zinc (Zn)	Boron (B)	Moisture (%)	CCE (%)	pH	Electrical Conductivity (dS\m)
Household 1	20	17900	1000	46900	33.5	64.7	0.7	94.5	12.6	10.6
Household 2	180	113000	1400	74700	37.4	96.7	0.4	103	12.7	11.8
Household 3	190	118000	2100	77700	37.2	86.0	≤0.1	97.6	11.8	2.1

Stove ash is believed to have the highest amount of uncombusted material in it because of the relatively low combustion temperatures (uncombusted material is measured as total carbon content). However, although there is more carbon in the stove ash than in bottom ash, this study found that the amount of carbon in the stove ash samples was lower than the fly ash average.

The wood pellet stove ash samples did not contain PAHs higher than recommended health guidelines.

Stove ash samples have moisture levels that are below the recommended limits for moisture in wood ash. This means that calcium in the ash can react with oxygen to create the highly reactive CaO. This element can produce alkaline-related problems in the soil.

Stove ash has similar pH to the fly ash and bottom ash samples: all stove ash samples are highly alkaline. The Electrical conductivity (EC) is somewhat variable but is consistently above the Alberta guidelines control limit.

The Calcium carbonate equivalent (CCE) of stove ash is variable but is fairly similar to the CCE of fly and bottom ash samples. This means that stove ash has an elevated Acid neutralizing value (ANV) and can therefore greatly increase the soil pH if added at a large dose.

Like the fly ash and bottom ash samples, all metals contained in stove ash are at levels beneath the control limits except boron. However, stove ash has higher content of nutrients and micronutrients than most of the bottom ash samples. Stove ash has high calcium levels that more closely resemble the calcium found in fly ash than in bottom ash. The amount of phosphorus and potassium are similar to that of the bottom ash but slightly lower than the amounts of these nutrients found in fly ash. Stove ash has more sulphate, copper, zinc, ammonium, boron, cadmium and carbon than the bottom ash, but less than fly ash samples. It can therefore be concluded that stove ash is more nutrient-rich than bottom ash, but does not quite attain the nutrient levels of fly ash.

Because the SAR is unavailable, this parameter was not taken into account for stove ash samples.

RECOMMENDATIONS

It is difficult to produce overall recommendations for direct application of ash to NWT gardens because crops and soils vary in their need for nutrients or pH amendments. However, the analysis results provide information as to the amount of nutrients and minerals in the ash, which can then be used to determine the proper application rates for soils or compost. Wood pellet ash should only be used as a direct fertilizer if the needs of the soil and the characteristics of the ash are known through testing.

As shown in the analysis, fly ash has higher quantities of nutrients than bottom or stove ash. It is therefore the type of ash that would provide the largest amount of fertilizing properties to compost or soil. This does not mean that it is the only type of ash that should be used in gardens, but it is the most efficient. Stove ash is also fairly high in nutrients, which means that backyard gardeners that want to use the ash from their wood pellet stoves will benefit from doing so almost as much as if they had used fly ash. Bottom ash should not be prioritized for use in the garden as it is relatively poor in essential nutrients.

Gardeners in much of Northwest Territories do not depend on the local soil properties as much as farmers and gardeners in other jurisdictions. However, some regions do have arable soil, which can be amended to create good growing material. Garden soils in the North must generally be mixed with bagged soil or highly amended with fertilizers or compost (Milne, 2014). For this reason, the recommendations from this study will be based on wood pellet ash as a compost amendment. Because compost is supposed to provide an overall balanced soil supplement, it is easier to produce generalized recommendations for it.

Backyard gardeners who want to experiment with adding wood pellet ash to their compost should follow the recommendations from this study. However, they should be particularly wary of monitoring the amount of ash added to the compost in order to avoid alkalinity problems. One simple way of integrating ash into backyard compost would be to add only the minimum amount (5% total compost weight) the first year, and progressively modify the amount of ash according to results from the previous year.

Presently, Yellowknife is the only community in the NWT to have a fully-functioning centralized composting facility. In the case of ash integration in this system, compost that is to be sold must meet Class A quality standards. If ash is to be implemented into the centralized compost system it must therefore be monitored so as to remain below the CCME compost quality guidelines, especially concerning trace metals (CCME, 2005). Because analyses of wood ash show that most trace metals do not exceed guidelines, they present a minimal risk to the final compost except possibly for boron, which should be closely monitored.

Proper management of wood pellet ash is important for human and environmental health, as well as long-term sustainability for gardens. To avoid leaching and to facilitate dust management, ash should be stored in a closed container (Steenari et al., 1999), preferably outside, before mixing with compost. The container should also have a closed bottom so as to avoid raising the soil levels underneath it to prohibitively alkaline levels. The alkalinity and corrosive nature of ash mean that it must be handled carefully. If ash is to be mixed with compost over time, the storage capacity must take the amount of ash produced into account.

The recommended amounts of ash to be added to compost are based on research conclusions from other jurisdictions. On average, the safe and beneficial amount of ash that can be applied to compost is between 5 and 15% of the total weight of compost feedstock (food and yard waste). Results from the literature review find that it is best to add ash to compost at the beginning of its decomposition cycle, which for NWT backyard composting likely means before or during the spring.

Moisture levels analyzed in this study are lower than the recommended minimum of 1% moisture from the Alberta guidelines. However, if it undergoes the carbonisation process following wetting and aging its reactivity will be reduced prior to its mixing into compost (Kuba et al., 2007). Mixing the ash into humid compost should have similar results by increasing the moisture levels in ash. Moisture levels of wood pellet ash are therefore not limiting factors for its safe use in compost as long as they are weathered before use or mixed into well-hydrated compost.

Although the electrical conductivity of the ash is higher than the Alberta limit for wood ash application on agricultural soil, diluting the ash in a mixture such as compost will reduce the amount of decisiemens of dissolved salts per metre.

Because most heavy metals contents of the ash are situated below the CCME and other limits in Table 2: Laboratory Analysis of Parameters and Values, ash will not increase the amount of heavy metals in the overall compost past control limits. The high levels of boron (B) found in the fly ash and stove ash samples will be diluted in the compost if it is applied at recommended ratios, and the overall mix should be far below control limits for that metal. As long as the recipient of the ash (in this case the compost) has low metals content, it will dilute the overall presence of heavy metals from ash (Majeau et al., 2013). All the same, ash admixture to compost must be evaluated on a case-by-case basis following analysis.

Ash must also be managed to avoid the toxic build-up of any parameter. An overly high dose of any nutrient or metal over a prolonged amount of time can be toxic for plants as well as soil or human health. Because most micronutrients are more readily available in acidic soils, toxicity is generally not a problem for soils that receive wood ash because it increases the overall pH (Weil and Duval, 2009). However, alkaline soils can cause deficiencies in nutrients, which reduce the productivity of gardens. Because the pH of wood pellet ash is highly alkaline, it should be weathered (exposed to water and air) before application into compost in order to reduce alkaline shock. Additionally, the pH of the final compost should be tested to ensure that it is not negatively impacting the end material.

When mixed with compost it can produce significant differences in local produce growing capacities and recycle valuable nutrients back into the soil.

Given growing interest throughout Northwest Territories in gardening, increasing concern about food security, and greater emphasis on waste diversion finding an appropriate use for wood ash can be part of a more general, sustainable solution. Using wood pellet ash as a soil amendment presents an opportunity to divert ash from the waste stream and instead transform it into a valuable product. In addition, because wood ash is produced in communities, it can replace imported soil amendments thereby reducing costs for food producers and the energy required to transport amendments.

FURTHER STEPS

This study produces a general overview of conclusions from previous studies and analysis of wood pellet ash produced in different biomass systems from the NWT, but no trial tests were done to verify study conclusions. Trials with ash-amended compost would greatly increase knowledge about the use of NWT wood pellet ash as a fertilizing agent and provide more substantial recommendations as to the ideal application rates for this jurisdiction. Trials should focus on:

- The required amount of time and weathering to induce a reduction of wood ash alkalinity. As this process should greatly reduce the high pH of ash, it would be interesting to look at the nutrients found in the final product to determine the efficacy of leached ash as a fertilizer.

- The ideal mix ratio for ash-amended compost to favourably increase nutrient availability without inducing phytotoxic levels of metals or over-elevating pH.
- The response of common garden crops to wood pellet ash-amended compost.

Following trial test conclusions, relevant NWT limits could be developed for the use of wood pellet ash in soils.

If conclusions from trial tests are positive, wood pellet ash could be integrated into centralized compost production. This would require the development of ash collection systems in communities with centralized compost. Because the amount of ash added to compost would need to be closely monitored, it would be advisable to collect ash separately from the organic waste during the testing period so as to properly understand the effects of wood pellet ash on compost.

The demand for wood pellet ash in NWT agriculture and gardening is far inferior to the amount of ash generated each year. Research should be done into alternative methods of recycling the surplus of ash. In this way, larger quantities of ash could be diverted from landfills. This study notes the integration of wood pellet ash in cement, as a roadside herbicide and as an animal hide softener as potential topics of interest.

REFERENCES

Agriculture and Agri-Food Canada (2010). Soil Orders of Canada [Map]. 1: 5,000,000, Soils landscapes of Canada, Ottawa, Government of Canada.

Alberta. Alberta Environment (2002). Standards and Guidelines for the Use of Wood Ash as a Liming Material for Agricultural Soils. Alberta Environment, 19 p.

A&L Laboratories (2005). Compost Management. A&L Canada Laboratories, 18 p.

Arctic Energy Alliance (2009). NWT Community Wood Pellet Study. GNWT Environment and Natural Resources, 26 p.

Brady, N. and Weil, R. (2002). The Nature and Properties of Soils. Thirteenth Edition, Upper Saddle River, Prentice Hall, 960 p. (Prentice Hall)

Breton, B. and Hébert, M. (2008). Recyclage agricole des cendres de bois au Québec- État de la situation, impacts et bonnes pratiques agro-environnementales. Agrosolutions, vol. 19, n 2, p. 18-33.

British Columbia. Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice (2008). British Columbia Ministry of the Environment. 300 p.

Canada. Natural Resources Canada (2001). Canadian Forest Service. In Natural Resources Canada. Frontline Express. Plant hardiness in Canada. Http://www.glfc.forestry.ca/VLF/landscape/bulletin_13_eng.pdf (Consulted March 28th 2014).

Canada. Soil Classification Working Group (1998). The Canadian system of soil classification. Ottawa, National Research Council, 202 p.

Canadian Council of Ministers of the Environment (CCME), (2005). Guidelines for Compost Quality. Revised edition, Winnipeg, Canadian Council of Ministers of the Environment, 22 p.

Code of Practice for Soil Amendments, BC Reg 210/2007.

Demeyer, A., Voundi Nkana, J., and Verloo, M. (2001). Characteristics of wood ash and influence on soil properties and nutrient uptake: an overview. Bioresource Technology, vol. 77, pages 287-295.

Dinwoodie, G (March 5th, 2014). Questions re using wood pellet ash as a soil amendment. E-mail sent to Shannon Ripley, e-mail address: Gordon.Dinwoodie@gov.ab.ca

Estevez, B. (2006). L'importance des éléments mineurs : des carences à la toxicité. Une préoccupation en agriculture biologique? (Study). Longueuil, Syndicat de Producteurs de Grains Biologiques du Québec, 25 p.

Havlin, J., [et al.](2005). Soil Fertility and Fertilizers. 7th edition, Upper Saddle River, Pearson Prentice Hall, 515 p. (Pearson Education).

Hébert, M (March 5th 2014). Recyclage de cendres. E-mail sent to Alex Cool-Fergus, e-mail address: marc.hebert@mddep.gouv.qc.ca

Manuilova, A. and Johnston, M. (2011). Greenhouse Gas Emissions Assessment, The Substitution of Fossil Fuels with Woody Biomass in the Northwest Territories. GNWT Environment and Natural Resources, 90 p.

Majeau, J. [et al.](2013). Les cendres des poêles à bois. *Vecteur Environnement*, May 2013, p 43-49

Milne, J., (2014). Garden soils in the NWT. Personal communication. February 27th, 2014, Yellowknife.

Nader, G. and Thompson, M. (2013). Use of Wood Ash as a Soil Amendment on Annual Rangelands. Sustainable Agriculture Research and Education (SARE). Project Reports. Http://mysare.sare.org/mySARE/ProjectReport.aspx?do=viewRept&pn=FW11-037&y=2013&t=1 (consulted on March 5th 2014).

Northwest Territories. Environment and Natural Resources (2012). NWT Biomass Strategy 2012-2015. Yellowknife, Government of the Northwest Territories, 16 p.

Northwest Territories. Public Works and Services (2013). Public Works and Services Energy Conservation Projects. Annual Report 2012-2013. Yellowknife, Government of the Northwest Territories, 40 p.

Obernberger, I. and Supancic, K. (2009). Possibilities of ash utilisation from biomass combustion plants. Proceedings of the 17th European Biomass Conference and Exhibition. Hamburg, June\July 2009. Hamburg, ETA-Renewable Energies (Ed.).

Pinnacle Renewable Energy Group (2011). Residential Pellet Fuel. Pinnacle Renewable Energy Group. Products. Http://www.pinnaclepellet.com/packaged-pellets.php (consulted on March 5th, 2014).

Pelkey, B (2014). Biomass in the NWT. Personal communication, January to March 2014, Yellowknife.

Ripley, S (2014). Soil analysis. Personal communication. February and March 2014, Yellowknife.

Steenari, B., Karlsson, L., Lindqvist, O. (1999). Evaluation of the leaching characteristics of wood ash and the influence of ash agglomeration. Biomass and Bioenergy, vol. 16, pages 119-136.

Sweden. Swedish Forest Agency (2006). *International Handbook- From Extraction of Forest Fuels to Ash Recycling*. 400 ex edition. Swedish Forest Agency, 40 p.

Van Eijk, R.J., Orbernberger, I and Supancic, K. (2012). *Options for increased utilization of ash from biomass combustion and co-firing*. KEMA, 40 p.

Weil, A., Duval, J. (2009). Les fertilisants autres que les fumiers et les composts. In Équiterre, Guide de gestion globale de la ferme maraîchère biologique et diversifiée (chapter 13). Montreal, Équiterre. (Équiterre).

Wood Ash Industries Inc (2014). Wood Ash Industries. In Wood Ash Industries. Research with High Carbon Wood Ash. http://woodash.net/WAI/wood-ash/r-d/ (consulted February 2014).