ROTS Composting

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1.0 ROTS COMPOSTING

1.1 HISTORY

Recycle Organics Together Society (ROTS) started as a grass roots composting organization in Whitehorse, Yukon in 1990 relying upon volunteer work and dedication.

The mandate of this society is to divert organic waste from the Whitehorse Landfill Site. Organic waste can be recycled into a valuable soil enhancer and its diversion from landfill burial serves to prolong the life of the site. ROTS' composting operations are growing and allowing more organics to be diverted from the landfill each year. The expansion of the composting operation has been generously funded by both government and private sources.

The society is presently run by a volunteer Board of Directors who oversee the staff, consisting of an office manager, site manager, restaurant program driver and summer students.

ROTS' operations commenced at a site located at the airport. This site will be converted into a community garden in the future. Presently, ROTS' composting site is located at the Whitehorse Landfill. The new site at the landfill enables ROTS to accept and compost more materials because the facility is larger and more centrally located for waste diversion.

In 1992, ROTS implemented a year round restaurant pick up program. This was deemed a worthy program since restaurants produce large amounts of organic waste. In the past, those who participated in community composting dropped off their wastes at the airport. Currently, over 30 restaurants and other institutions (including barber shops) participate in the ROTS pick up program. Daily pick up is offered to restaurants Tuesday through Saturday. To help pay for a portion of this program, a cost of forty cents per pick up is being charged.

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1.2 MATERIALS

ROTS accepts grass, yard waste, leaves, sawdust, wood chips, horse manure, straw, fruits, vegetables, egg shells and coffee grounds from family residences. Most of the grass, leaves, and shrubs are dropped off by local landscapers and the City of Whitehorse at the landfill site. The restaurant program provides ROTS with a daily supply of fruits, vegetables and hair clippings throughout the year. During the winter, ROTS chips and utilizes Christmas Trees collected by the City of Whitehorse.

1.3 OPERATIONS

The diverted organics are composted into a soil amendment using the method of windrow composting. Windrow composting is an aerobic process in which organics are layered to build composting rows. The windrow dimensions are usually 2 metres wide, 2 metres high and 7-10 metres long. A properly constructed and maintained windrow should lead to the rapid decomposition of organics over a summer composting season.

The windrows are constructed manually and a front end loader is used to periodically turn the windrows to maintain aeration. The windrows are watered weekly using a garden hose.

ROTS conducts its composting operations year round. During the winter season, windrows are constructed using wood chips and the organics collected from the restaurant program. In January, discarded Christmas Trees are collected by the City of Whitehorse, chipped at the ROTS site and also utilized. The goal of winter windrow construction is to stockpile the organics such that composting commences when temperatures rise in the spring, since after October, low temperatures inhibit organic degradation. Maximum degradation occurs during the warm summer months, from approximately mid April until mid September. In the summer, additional materials such as grass, manure, yard waste and leaves are included in the windrows.

1.4 COMPOST

Whitehorse has a brief composting season compared to more southern areas. It appears that two full summer composting seasons are required before the compost can be considered mature enough for gardening or agricultural use.

To date, no controlled plant growth experiments using ROTS compost have been conducted. However, several individuals have used the compost and successfully grown gardens.

This summer, ROTS was involved with the McIntyre Dump Reclamation Project. ROTS donated 10 cubic metres of compost for a test plot at this old dump site. Project Organizers have re vegetated the site with indigenous grasses and shrubs. By the end of the summer, it was apparent the ROTS' compost outperformed test plots enhanced by fertilizer. However, there are concerns about ROTS compost containing too many weed seeds. ROTS aims to sell compost during the summer of 1994. Already several interested individuals and landscapers have approached ROTS in regards to purchasing compost. There is an excellent opportunity for marketing compost in Whitehorse due to the shortage of top soil.

2.0 COMPOSTING BASICS

2.1 WHAT IS COMPOSTING ?

Composting is the controlled degradation of organic wastes into a nutrient rich form called humus.

2.2 WHY USE COMPOST ?

1) Compost improves the water retention property of soils.

2) Nutrients from compost are slowly released to the soil over a long period while chemical fertilizers provide only a quick burst of nutrients.

3) Using compost reduces the need for chemical fertilizers which can be harmful to the environment.

4) Composting diverts wastes from landfill burial which increases the lifetime of a landfill cell.

2.3 ANAEROBIC COMPOSTING

The process in which microorganisms degrade organic waste in the absence of oxygen is known as anaerobic respiration and is often referred to as fermentation.

In the presence of water, anaerobic bacteria degrade organics to produce methane and carbon dioxide. This generation of methane is responsible for the strong odours associated with anaerobic composting.

Most of the energy created through anaerobic decomposition is stored in the production of methane and therefore very little heat is generated during this process.

Municipally, anaerobic composting occurs in closed vessels which provide an oxygen free environment and collection of the odiferous methane. Often, the collected methane is sold as a fuel source.

2.4 AEROBIC COMPOSTING

In the presence of oxygen, aerobic microbes degrade organic material, generating carbon dioxide, water and heat. The heat generated during aerobic decomposition can cause the internal temperature of a composting pile to reach temperatures as high as 70 to 80 °C. Temperatures between 55 and 60 °C are often sufficient to destroy pathogens, weed seeds and human parasites.

When properly maintained, aerobic composting is odourless. One benefit of this process is that organics degrade at a much faster rate compared to anaerobic decomposition.

ROTS is involved in aerobic composting. Rows of layered organic material called windrows are constructed outdoors. They are turned weekly during the summer composting season to ensure that an adequate supply of oxygen is available.

2.5 COMPOSTING CRITTERS

There are three main types of microorganisms responsible for the breakdown of organic materials. They are bacteria, actinomycetes and fungi.

Bacteria are responsible for the initial breakdown of the organic material, and generate the high temperatures associated with aerobic composting.

Actinomycetes are microorganisms which are intermediates between bacteria and fungi. During composting, actinomycetes form symbiotic relationships with fungi, appearing at the same time and in the same location. Actinomycetes become visible as a white powdery film, and produce the earthy smell associated with aerobic composting.

Fungi are responsible for the breakdown of more woody materials containing cellulose and lignin.

2.6 THE COMPOST CYCLE

Bacteria initially decompose the materials in a windrow to form organic acids. The production of these acids lowers the pH of the compost windrow to around 5.0, thereby slowing the process of degradation until bacteria which favour acidic conditions proliferate. As the organic acids are broken down into more inert chemicals, the pH of the windrow slowly rises to 8.0 or 9.0. During this time, fungi and actinomycetes become responsible for the action of degradation. The pH eventually levels to neutral as the compost reaches maturity.

The addition of lime during composting is sometimes employed to try and control the fluctuation of pH during decomposition. By controlling the acidity of the windrow, individuals hope to avoid the lag period in composting which is created by the production of acids. Caution is advised when using lime because its use often encourages the generation of odour causing ammonia.

2.7 WINDROW COMPOSTING

Microbes require a food source, water and oxygen for successful composting. Carbon, nitrogen, potassium and phosphorus are necessary food sources.

Windrows operate most efficiently when the moisture content is maintained between 60 - 70 percent. For this reason, they are periodically watered to replenish moisture lost by decomposition and evaporation.

Spaces between the materials in a windrow trap air. It is these spaces that supply the microorganisms with a source of oxygen. To replace the depleted oxygen supply, the windrows are occasionally turned to create new air spaces.

2.8 CARBON TO NITROGEN RATIO

Bacteria require a food source that contains a carbon to nitrogen ratio (C:N) of 25:1. A ratio of 25:1 translates to a requirement of 25 parts carbon to 1 part nitrogen. The carbon is required as a source of energy while nitrogen is incorporated in synthesizing protoplasm.

All organic materials have a carbon to nitrogen ratio. In order to supply bacteria with a proper food source, the goal of windrow construction is combining the ingredients to obtain an overall C:N ratio of 25:1. It is important to remember that not all of the carbon present in a material is available to the bacteria because some may be tied up in molecules like lignin which are resistant to degradation. Wood and paper often contain a high percentage of lignin.[1] The following is a list of possible composting ingredients and their lignin content.

Table 2.1 Lignin Content of Potential Composting Ingredients

ComponentLignin Content	
Food Wastes	0.4
Newsprint	21.9
Office Paper	0.4
Mixed Paper	5.8
Yard Wastes	4.1

Since most carbon to nitrogen ratios are based upon the total organic carbon and not the biodegradable organic carbon, the ratios quoted tend to be somewhat higher than the carbon component actually available. For example, wood contains a lot of lignin and therefore has a relatively low biodegradable organic carbon content. A carbon to nitrogen ratio of 500:1 is almost double the biodegradable value. It is important to consider these facts when designing windrows.

There is a definite operating region for windrow C:N ratios. If the ratio exceeds 25:1, the whole process of decomposition is inhibited by the excess carbon. If the carbon to nitrogen ratio is below 15:1, odours can develop due to the excess nitrogen being released as ammonia.

Even though literature suggests that bacteria require a carbon to nitrogen ratio of 25:1, several composting sites operate with a lower ratio around 20:1. The Rodale Research Institute conducted a study on winter composting.[2] They found that for winter composting in Pennsylvania, a lower carbon to nitrogen ratio was more efficient and the compost matured at a faster rate. This suggests that the C:N ratio recommended for composting is not cast in stone and can be altered to enhance composting in different environments. Whitehorse has a cooler summer composting season with temperatures that can reach extremes at the beginning and end of the season. For this reason, a lower C:N ratio which increases the decomposition rate is essential.

2.9 SUMMER WINDROW CONSTRUCTION

The base of a windrow should be constructed from materials that form a porous layer which will trap oxygen, thereby maintaining good aeration within, even when weighted. Hedge clippings, wood chips and straw are ingredients which form a good windrow base.

Alternating layers of nitrogen and carbon rich material form the bulk of the windrow. Usually, a material rich in nitrogen such as grass or vegetables is placed upon the base of the windrow. On top of this layer, another layer rich in carbon consisting of leaves or wood chips is placed. Soil or manure can be sprinkled over the carbon layer. However, soil is very dense and too much causes compaction in the windrow which eliminates air spaces.

The base of the windrow should be constructed to be 2 metres wide and 10 metres long. These dimensions have been designed to allow for manual construction of the windrow. Alternating layers of materials rich in carbon and nitrogen are piled until the windrow is approximately 2 metres high.

3.0 WINTER COMPOSTING

When constructing windrows in the winter one has to consider the availability of materials and weather conditions. ROTS collects fruit and vegetables from local restaurants year round. The vegetables could be stockpiled over the winter, however, two potential problems may arise. The first being the attraction of animals to an easily available food source. Secondly, fruit and vegetables will compact easily promoting anaerobic respiration and odours when thawed in the spring. For these reasons, composting materials should be properly constructed into windrows during the winter. Leaves and yard waste are scarce during the winter months. An alternate carbon source is wood chips and saw dust. Wood Chips are available from chipping Christmas Trees while bucking wood provides a source of saw dust.

In a cold environment like the Yukon, it is important to keep windrow maintenance to a minimum. To make windrow construction simple a 12 cm base of wood chips should start the windrow. Alternating layers of wood chips and fruits and vegetables can be used to build the windrow to a height of 2 metres. Snow should be left on the pile to act as an insulator and provide a source of moisture when the windrow thaws in the spring. Most wood chips and saw dust in the Yukon come from coniferous trees which tend to be acidic. This acidity can stall the composting action of a windrow if present in large amounts. Therefore it is recommended that coniferous wood chips and needles be limited to 10 per cent of the volume of the pile. Thus, the ratio of wood chips to fruit and vegetables should be 1:10.

In the spring, the windrow needs to be broken up and turned with a front end loader to promote thawing and aerate the pile.

3.1 COMPOST PROBLEM SOLVING GUIDE

Symptom	Problem	Solution
Odours	Too much nitrogen.	Add a carbon source to the pile. (leaves, wood chips)
	Too much moisture.	Mix in dry materials. Improve drainage.
	The pile has become anaerobic.	Turn the pile to increase the oxygen supply.
Windrow not generating heat	Pile has finished composting.	Compost is ready for use.
	Pile is too small.	Increase the volume of the pile.
	Not enough oxygen in pile.	Turn the pile to increase the. oxygen supply.
	Pile contains materials too high in carbon.	Add grass, fruits and vegetables to add more nitrogen to pile.
	Pile lacks moisture.	Add water to the pile.
Decomposition occurs too slowly.	Not enough moisture.	Water the pile.
	Pile is anaerobic.	Turn the pile to add oxygen.
	Composting materials too bulky	Shred Ingredients.
	Too much carbon in pile.	Add grass, fruits or vegetables to pile.

3.0 PROJECT BACKGROUND

During the fall of 1992, the Industrial Research Assistance Program (IRAP) granted ROTS $14,800 to research and develop northern composting methods. This research was to focus on:

1. Reducing the salinity of the compost produced by ROTS.

2. Development of a method to determine compost maturity.

3. Creation of a model to aid in the design of windrows according to carbon to nitrogen ratio requirements.

4. Developing a program for summer research.

5. Adopting composting production and quality guidelines.

3.1 BRIEF OVERVIEW

1) SALINITY REDUCTION

The compost produced by ROTS during the summers of 1990 and 1991 was tested for salinity, acidity, nutrients, and organic matter. An analysis conducted by Norwest Labs revealed that the compost had a salinity that was intolerable to several plant species if used as the sole growing medium. Normally, compost is not used on its own and is mixed with soil in a 1:5 ratio. This dilutes the salinity of the compost. Whitehorse area soils tend to have higher salinities because of the semi-arid environment. This environment inhibits the leaching of salts from the soil which generally occurs in warmer and wetter climates. Since the soils of this area already have a tendency to be saline, care must be taken to ensure that the addition of compost does not further increase the salinity such that plant growth is inhibited.

During the summer of 1991, ROTS conducted research to determine the origin of salinity in the compost. The experiment was conducted by building windrows which eliminated different materials to assess whether these ingredients affected salinity. The results from this study were inconclusive due to the fact that there were too many uncontrolled variables. In order to establish those components responsible for salinity, it was proposed that research be conducted to determine the salinity of each ingredient in the composting process. The information gained from this research will be implemented in the reduction of ingredients potentially responsible for high compost salinity.

2) COMPOST MATURITY

The initial breakdown products of organics can be toxic to plants. For this reason, it is important to apply compost to soils only after the organic material has fully broken down into an inert form. When compost is ready to be applied to the soil, it is said to be mature. There are several testing methods used to determine compost maturity. Compost maturity is an issue in the North because composting is limited to such a short season. ROTS has to be certain that the compost is ready and safe to use before it can be marketed. Determination of a quick and easy method to establish compost maturity will be focused upon in Section 5.0.

3) CARBON TO NITROGEN WINDROW MODELING

ROTS constructs their windrows by layering materials rich in carbon and nitrogen. Decomposition occurs at a maximum rate when the carbon to nitrogen ratio of a windrow is approximately 25:1. Presently at ROTS, there is only one method for determining whether a compost pile is too high in nitrogen or carbon. This method is trial and error. If the pile contains too much nitrogen, odours will be produced, and if there is too much carbon, the decomposition of the pile stalls. Modeling can be employed to design windrows with the correct C:N ratio prior to construction. In order to model windrow design, the C:N ratio and the moisture content of each ingredient are required. The C:N ratio of most composting materials can be determined through available literature while the moisture content can be established in the laboratory. This portion of the report covered in Section 6.0 will propose a model to aid in compost design.

4) SUMMER RESEARCH PROGRAM

The aim of the summer research program is to produce compost of the highest quality in the shortest amount of time. In order to reduce the time to maturity, optimum operating conditions for composting in a northern environment need to be established. This research aims to determine the optimum moisture level and the optimum carbon to nitrogen ratio for windrow composting.

To improve the quality of the compost, those materials high in salinity will be reduced or eliminated during windrow construction.

ROTS hopes to expand the range of organic materials that can be accepted. Therefore, several windrows incorporating new materials will be constructed and monitored on a trial basis.

5) COMPOSTING GUIDELINES

Composting regulations are being developed by the Ontario and British Columbia governments. These guidelines suggest standards for the process and quality control of compost production. The ***Interim Guidelines for the Production and use of Aerobic Compost in Ontario***[3]and the ***Regulation For The Production And Use Of Compost From Municipal Solid Waste For British Columbia***[4] is focused upon in Section 8.0. These guidelines present standards to which the quality of ROTS compost can be compared.

4.0 SALINITY REDUCTION

4.1 BACKGROUND INFORMATION

Salinity is determined using the method of Electrical Conductivity (EC). Electrical Conductivity measures the current created by ions in a solution. Ions are any atoms or molecules that have a negative or positive charge. The measurement for Electrical Conductivity is dS/m (decisiemen per meter). A siemen is the unit for conductance which is the reciprocal of resistance, measured in ohms.

In November of 1991, ROTS had 16 samples of compost analyzed for salinity. For plant growth, it is recommended that the salinity be a maximum of 4 dS/m[3]. The proposed B.C. regulations recommend that compost have a salinity of 3 dS/m [4] while the Ontario Composting Guidelines suggest a salinity less than 3.5 dS/m.[5] The salinity of the analyzed compost produced by ROTS was estimated as ranging from 5-12 dS/m.

When there are excess salts in a soil, the germination and growth of plants is reduced. This occurs because an osmotic gradient develops which inhibits plants from drawing up moisture from the soil. There are four salts that are usually considered when discussing soil salinity. These are sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg). High levels of sodium can cause the dispersion of soil particles, reducing soil structure and infiltration. Since high levels of sodium can cause detrimental effects to plant growth, a Sodium Adsorption Ratio (SAR) is usually calculated. This ratio compares sodium with the other exchangeable salts present in the soil. Sensitive plants can tolerate a SAR of around 4.0.[5]

$$SAR = Na^{+} /\{ \tfrac{1}{2} [Ca^{2+} + Mg^{2+}]^{1/2} \}$$

Electrical Conductivity is not specific to the four salts mentioned. Instead, it measures the current produced by any charged particle. Therefore, electrical conductivity is only an estimate of the soil salinity. Other salts such as sulphates, chlorides, ammonium, and nitrates as well as other organic ions are also determined by measured conductivity. Table 4.1 is a chart which relates crop responses to EC[5].

TABLE 4.1 CROP SENSITIVITY TO SALINITY

Table Salinity EC (dS/m)	Crop Responses
0-2	Salinity effects almost negligible
2-4	Yields of very sensitive crops may be restricted
4-8	Yields of many crops may be restricted
8-16	Only tolerant crops yield satisfactorily
>16	Only a few tolerant crops can yield

As was mentioned earlier, the compost produced by ROTS in 1991 was estimated as having an EC anywhere between 5-12 dS/m. This analysis suggests that many crops would have growth restriction if germinated in this compost. The soils around Whitehorse are naturally more saline than other regions because of the semi-arid climate. The EC values for Whitehorse soils are normally between 1-5 dS/m. (These values were obtained from Scott Smith from Environment Canada). Discussions with several composting organizations have revealed that the salinity of their compost tends to be greater than the salinity of the soils of their region. The common practice is to recommend a rate at which the compost should be applied to the soil. Usually it is applied in such small quantities that the effect of compost salinity is diluted by the soil. In Whitehorse, the soil already inhibits the growth of certain plant species. The addition of saline compost to an already highly saline soil could raise the salinity of the soil sufficiently to inhibit the growth of some common garden plants. Table 4.2[5] shows the EC at which a 50 percent growth restriction occurs for some of these plants. For this reason, it is imperative that ROTS attempt to decrease the compost salinity.

This winter, research was conducted to determine which materials used in composting are high in salinity. The Electrical Conductivity of all composting materials was determined. The results from this study are presented in Section 4.3. The information gained will be used to modify the construction of the windrows to reduce or eliminate the use of those ingredients which are high in salinity.

TABLE 4.2 SENSITIVITY OF SOME GARDEN PLANTS TO SALINITY (EC)

Garden Plant	Salinity at which plant growth is restricted by 50 percent (dS/m)
Beans	4
Potatoes	6
Lettuce	5.5
Onions	5

4.2 PROCEDURE

Three methods were employed to determine the Salinity (EC) of the compost, top soil and peat soil. The first method used is that suggested by Agriculture Canada. Samples of compost and soil were analyzed for salinity by Norwest Labs as a comparison of research results. A third method was developed in the laboratory to aid in compost maturity research. Lastly, a separate procedure was used to determine the salinity of organic materials and fertilizer.

AGRICULTURE CANADA METHOD

1. Weigh 20 g of soil into a beaker.

2. Add 40 mL of distilled water.

3. Stir the mixture for 30 minutes using a magnetic stirrer.

4. Allow the bulk of the solution to settle.

5. Measure the conductivity of the suspension using a conductivity meter.

6. Record the temperature of the filtrate to the nearest 0.1 °C.

7. Correct the reading for 25 °C.

NORWEST LAB METHOD

1. Weigh out 250 g of air dried soil.

2. Add distilled water from a burette and stir the mixture with a spatula until the soil is saturated.

3. Cover the container and allow the samples to stand for an hour. If the paste has stiffened or lost its glisten, add water and mix again.

4. The saturation percentage may be determined by taking a subsample of the saturated paste, oven drying it at 105 °C and reweighing.

5. Allow the saturated paste to stand for 4 hours and transfer to a Buchner funnel fitted with a low ash, highly retentive filter paper. Apply a vacuum and collect the filtrate.

6. Measure the conductivity of the saturation extract. Report this conductivity at 25 °C.

3:1 LAB METHOD

1. Dry 200 g of sample in the oven for six hours at 105 °C

2. Weigh out 30 g of oven dried material.

3. Add 90 mL of distilled water to the soil.

4. Transfer the mixture to the pressurized cylinder.

5. Bolt on the cap of the cylinder and tighten to ensure that the top fits flush with the cylinder. The bolts should be tightened like the lug nuts on a car tire. That is, always tighten pairs of opposite bolts together. Never tighten the bolts in a clockwise fashion because this will create an uneven distribution of pressure between the cylinder and the top.

6. Screw the bicycle pump onto the valve of the pressure cylinder and pressurize the cylinder to 8 bar.

7. Close the cylinder valve and unscrew the bike pump.

8. The cylinder should be pressurized for twenty minutes. Every five minutes shake the cylinder for two minutes.

9. After twenty minutes, open the valve on the cap and insert the pin on the pump valve. There may be a small spray of water so it is wise to hold a paper towel over the valve.

10. Once the cylinder has been depressurized, the bolts on the cap can be loosened and the lid removed.

11. Filter the samples using a Buchner funnel and vacuum filtration. Pour the extract into a 100 mL beaker.

12. Measure the conductivity of the filtrate and report at 25 °C.

ANALYSIS OF ORGANIC AND UREA SAMPLES

The organic samples were blended with distilled water (in a 5:1 or 10:1 water to organics ratio) on high speed for five minutes. The mixture was filtered with a window screen to remove the pulp and then the process was continued using suction filtration.

Urea was mixed with distilled water using a 100:1 water to urea ratio and the salinity measurement was determined after 15 minutes to ensure that most of the fertilizer had dissolved in the water.

4.3 RESULTS AND CONCLUSIONS

The Electrical Conductivities of the samples were not all determined at a set water to soil ratio. Organic samples required a higher water ratio for practical use of the blender. The results, therefore, can not be compared directly. However, they do give a broad picture of how the different materials contribute to compost salinity.

Table 4.3 ELECTRICAL CONDUCTIVITY RESULTS

Ingredient	Water to Soil Ratio	Electrical Conductivity (dS/m) at 25 °C
Fruit and Vegetables	5:1	6.0-8.4
Grass	10:1	6.1
Urea	100:1	5.4
Leaves	10:1	4.8
Immature Compost	3:1	7.2-7.3
Peat soil	3:1	2.4
Whitehorse top soil	3:1	1.2
Manure	3:1	1.2
Wood chips	5:1	1.0

It can be seen from Table 4.3 that the top three contributors to compost salinity are urea, fruit and vegetables, and grass. Of these three ingredients, the only one that can and should be eliminated is the use of urea, which is a fertilizer. Urea has an Electrical Conductivity of 5.4 dS/m at 25 °C when diluted with water 100 times. This value is extremely high when compared to Whitehorse top soil which has a salinity of 1.2 dS/m with a dilution factor of only three.

Urea is used in composting to supply a readily available source of nitrogen to the bacteria in the compost pile. Fruit, vegetables and grass are also sources of nitrogen which can quickly be utilized by the bacteria. If the compost heap is correctly constructed, there is no need to add nitrogen in the form of urea or fertilizer.

Top soil, peat soil and compost were all analyzed for salinity using the three procedures previously mentioned. The results vary according to the method used. The variation is partially due to the different water ratios used in each method. The saturation method used by Norwest Labs is based on a 1:1 water to soil ratio. Norwest Labs full results can be found in Appendix I. The method recommended by Agriculture Canada is based upon a 2:1 water to soil ratio while the method developed in the laboratory is based upon a 3:1 water to soil ratio.

Sample Codes

TS	Whitehorse Top soil
PS	Whitehorse Peat soil
C1	Compost Pile 1 produced summer 1991 at airport
C2	Compost Pile 2 produced summer 1991 at airport
C3	Compost Pile 3 produced summer 1992 at airport
C4	Compost Pile 4 produced summer 1992 at airport
AP92	Active Windrow produced summer 1992 at airport
AP93	Active Windrow produced winter 1993 at airport
LF92	Active Windrow produced summer 1992 at landfill

Table 4.4 **Salinity (dS/m) at 25°C**

Compost sampleAgriculture Canada Method	3:1 Ratio Method	Norwest Labs	
C1	4.3	4.2	5.4
C2	6.4	7.0	8.9
C3	4.8	7.0	8.9
C4	5.8	6.8	8.8
AP93	----	7.0	----
AP92	----	7.3	----
LF92	----	4.8	8.7
TS	1.3	1.3	1.3
PS	1.8	2.4	1.7

Compared to the other two methods, Norwest Labs obtained results for each sample which were equal or much higher in salinity. Electrical Conductivity is reduced by dilution. Norwest Labs analyzes soil samples with a 1:1 water to soil ratio. Therefore, one would expect the salinity readings to be higher when using this method. The conductivities obtained from the 3:1 method were higher than the results obtained from the Agriculture Canada method which has a 2:1 ratio. Considering that dilution reduces salinity, these results seem at first odd. It is probable that pressure extracts salts from the compost and it appears from the 3:1 method that more soluble salts are extracted from the soil by using pressure in addition to mixing.

All of the tested compost samples have salinities that exceed the recommended B.C. and Ontario composting regulations, independent of the testing procedure. The compost analyzed came from windrows to which urea was added as an ingredient. Urea should be eliminated from windrow construction this summer.

The compost produced by ROTS will always be slightly saline because several materials (grass and yard waste) which are used in windrow construction are grown in the saline soils of Whitehorse's semi-arid environment. However, with proper windrow construction, the salt levels should be reduced to a minimum.

Four compost samples were analyzed by P&R Hancock Consulting to attempt to isolate those salts responsible for the salinity of the compost produced by ROTS. The results found in Table 4.5 were determined by P&R Hancock and are given fully in Appendix II.

Table 4. 5 **SALINITY ANALYSIS**

Sample	K (%)	Ca (ppm)	Na (%)	Mg (%)
C1	2.0	2.9	1.78	<.5
C2	2.0	3.7	1.95	<.4
C3	1.9	3.2	1.60	<.6
LF92	1.7	2.9	2.28	<.4

Sodium and potassium appear to be the major components contributing to compost salinity. The presence of a high percentage of sodium in the compost is a concern because it is known to inhibit plant growth and affect soil properties.

Norwest Labs analyzed five compost samples for soil nutrients. Table 4.6 states whether the nutrients (which are also the salts responsible for compost salinity) are available at an optimal level for plants or in excess.

Table 4.6NUTRIENT ANALYSIS

Sample	K	Ca	Na	Mg
C1	excess	optimum	excess	optimum
C2	excess	optimum	excess	optimum
C3	excess	optimum	excess	optimum
C4	excess	optimum	excess	optimum
LF92	excess	optimum	excess	optimum

Potassium and sodium salts are present in excess of plant nutrient requirements while calcium and magnesium salts are present at optimal levels in the compost samples. It appears that sodium and potassium are not only the major components which cause compost salinity but are also present in amounts exceeding plant requirements.

It is recommended that compost not be used as a sole growing medium but instead be mixed with soil. To create more realistic growing conditions salinities were determined for several mixtures of compost (sample C2) and Whitehorse top soil. Table 4.7 indicates the mixture ratios and the resulting salinities.

Table 4.7 Salinity of Compost and Top Soil Mixtures

Sample	Top soil:Compost Ratio	E.C. at 25 °C
1	1:0	1.4
2	2:1	2.9
3	1:1	4.3
4	1:2	4.6
5	0:1	8.1

When top soil was mixed with compost in a 2:1 ratio, the salinity of the sample was 2.9 dS/m at 25 °C which falls below the salinity specifications suggested in the B.C. and Ontario Guidelines. The conductivity of compost was reduced from 8.1 dS/m to 2.9 dS/m by mixing with soil. Therefore mixing ROTS compost with Whitehorse top soil dilutes compost salinity and adds valuable plant nutrients to the soil. To introduce a factor of safety, ROTS should recommend that the compost be utilized in a soil to compost ratio of 5:1.

4.4 RECOMMENDATIONS

1. Urea should be eliminated from windrow construction during the summer of 1993 and in the future. At the end of the season, the compost should be analyzed for salinity to determine whether the absence of this ingredient decreased the salinity of the compost.

2. The source and affect of sodium in the compost produced by ROTS should be established.

3. ROTS compost should be mixed with Whitehorse top soil in a 1:5 ratio to produce a soil amendment which is rich in nutrients and low in salinity.

5.0 COMPOST MATURITY

5.1 BACKGROUND INFORMATION

The application of immature compost to soils can inhibit plant growth. The two main causes of plant growth inhibition associated with immature compost are the immobilization of nitrogen in the soil and phytotoxicity.

High C:N ratios are characteristic of immature compost. When applied to the soil, immature compost increases microorganism activity. These microorganisms proliferate to decompose the excess carbon compounds found in the soil. Thus, plants are forced to compete for nitrogen with the microorganisms and this often creates a nitrogen deficiency.

The rapid decomposition of immature compost creates a soil environment which is anaerobic and strongly reducing. Plants react to these conditions by lowering their metabolic rate which in turn stunts plant growth. Heavy metal solubility increases in this reducing environment which in turn plants absorb; sometimes to the point of toxicity. These soil conditions do not occur when well matured compost is applied to the soil.

Phytotoxicity of compost appears to be associated with the initial decomposition of easily metabolized organic materials. This period is a transitory one in which further decomposition transforms the toxic compounds into an inert form. Organic materials are initially decomposed into organic acids. It was discovered by Chanyasak et al. (1983a)[6] that propionic, n-butyric and acetic acids all cause phytotoxic effects.

The presence of ammonia in soils is known to stunt root growth and the normal development of plants, while ethylene oxide is known to inhibit seed germination. Both of these compounds are linked to the decomposition of immature compost in soil.

There are several physical tests which can be employed to determine compost maturity. These are temperature, pH and colour.

The temperature in a windrow quickly increases after the first couple of days to between 50 and 60 °C. After this period, the temperature decreases until it reaches approximately 20 degrees above the ambient temperature. If the temperature does not rise after turning or consolidation into a larger pile, the compost is considered mature enough for agricultural application.

As mentioned earlier in Section 2.6, the initial decomposition in a windrow forms organic acids which lower the pH of a compost heap to approximately 5.0. These acids are further decomposed into alcohols, ketones and aldehydes which cause the pH of the windrow to become slightly basic. When the compost reaches maturity, the pH stabilizes between 7.0 and 8.0. Acidic compost indicates a lack of maturity.

During the decomposition of organic wastes, the compost gradually darkens over time. Mature compost should be dark brown to black in colour and organic materials should no longer be recognizable in form.

These physical tests are not very accurate and many circumstances can inhibit heat generation and decomposition of organics. Therefore, several chemical and biological tests have been proposed to determine compost maturity.

The maximum time period for the Whitehorse composting season does not exceed four months. This season is very brief. Most composting operations in the south have the luxury of letting the compost mature over a period of six months. If the compost produced by ROTS is not mature by the end of a season, if must be left over the winter to resume composting during the following summer season. This means that if the compost has not matured in the first four months, it will likely take another twelve months to ensure proper curing. The following statistics from Environment Canada list the average temperatures for Whitehorse for the past three summers.

Table 5.1AVERAGE TEMPERATURES (°C)

Month	1990	1991	1992
May	8.3	------	5.8
June	11.8	12.7	12.3
July	15.0	11.7	12.3
August	14.0	11.7	12.3
September	8.9	8.3	2.7

A particular concern with Northern composting lies in attempting to minimize the time required to produce mature compost. Preferably, that time frame would be four months for Whitehorse. Maturity testing of compost produced under optimum operating conditions will aid in determining if this is a realistic goal.

5.2 PROCEDURE

The procedure employed to determine compost maturity is a modified version of a pressure extraction method designed by F. Zucconi, M. Forte, A. Monaco and M. de Bertoldi. Two articles, ***Biological Evaluation of Compost Maturity***[7] and ***Evaluating Toxicity of Immature Compost***[8] were used as references.

1. For each sample and control, set up six petri dishes with filter paper at the bottom of each dish.

2. Evenly distribute 10 cress seeds on the filter paper.

3. Preheat the oven to 27 °C. The oven at Yukon College takes approximately 30 minutes to preheat. Place the shelf on the upper rung of the oven to ensure that the samples do not dry out.

4. Extract the nutrients from the samples using the 3:1 lab procedure outlined in Section 4.2.

5. Pipette 5 mL of each extract solution into the corresponding petri dishes. Place the lid on the petri dishes and place in the oven.

6. Cover the window of the oven with a piece of paper to ensure that the seeds are germinated in the dark.
7. After 48 hours establish the germination index of the sample.

To do this, count the number of germinated seeds in each control dish. Average the percent germination within the controls. This number is the control germination index. Determine the average length of the cress seeds for the controls.

Compare the average germination length of the control to the length of each germinated seed in each sample dish. If the seedling length is smaller than the control average, do not count this seedling as having germinated. If the seedling is larger or equal in length, it is considered to have germinated. For each sample, total the number of germinated seeds for all six dishes. This total is divided by six to determine the germination index for each sample.

8. Calculate a germination ratio for each sample by taking a ratio of the sample germination index to the control index. The ratio is reported as a percentage by multiplying by 100.

The germination ratio of the control should always be 100 and the germination ratio of the sample should always be between 0 and 100.
If the compost has a germination ratio greater than 40 percent, the compost is considered mature enough to apply to soils in a 5:1 soil to compost ratio.

5.3 RESULTS AND CONCLUSIONS

Six different samples of compost, peat soil and top soil were analyzed for compost maturity using the procedure outlined above. Table 5.2 shows the results. The sample codes are identical to those listed in section 4.3.

Table 5.2 MATURITY ANALYSIS

Sample	Germination Ratio	Salinity (dS/m) at 25 °C
TS control	100	1.3
PS	106	2.4
C1	77	4.2
C2	40	7.0
C3	44	7.0
C4	30	6.8
AP92	0	7.3
AP93	0	7.0
LF92	15	4.8

From Table 8, it can easily be seen that there are significant differences between the germination ratio of Whitehorse top soil (the control) and the samples of compost. Only compost sample C1 had a germination ratio above 65 percent and can be considered mature enough to apply to soils. Peat soil had a germination ratio greater than the control. This can be contributed to the richness of nutrients that peat soil possesses and Whitehorse top soil lacks (subsequently promoting or slowing plant growth).

In Section 4.1, it was discussed how Electrical Conductivity readings above 4 dS/m inhibit seed germination. In Section 5.1, inhibition of seed germination due to the application of immature compost to soils was addressed. From these two discussions, it appears that seed germination can be inhibited by both immature compost and salinity. Since the compost analyzed was high in salinity, it is difficult to isolate whether the reduction in the compost germination ratio was due to the immaturity of the compost, the salinity or perhaps a combination of these two factors.

The compost samples were analyzed by P&R Hancock Consulting to determine which salts were the cause of salinity in the compost. As was discussed in Section 4.3, potassium and sodium were responsible for the bulk of the salinity in the compost. To try and establish whether potassium or sodium salts are responsible for the inhibition of cress seed germination in the maturity test, distilled water was mixed with potassium chloride to produce three solutions with electrical conductivities of 3.6, 7.2 and 14.4 respectively. These solutions were used to germinate the cress seeds. A second experiment using sodium chloride was conducted to determine whether sodium has a toxic effect on cress seed germination.

Table 5.3 Potassium and Sodium Content of Compost

Electrical Conductivity of salt solutions (dS/m) at 25 °C	Germination Ratio
KCl 3.6	100
KCl 6.2	95
KCl 14.4	50
NaCl 3.6	89
NaCl 6.2	54
NaCl 14.4	0

These results indicate that the potassium salts present in the compost are not responsible for the reduction of the germination ratios for the compost samples. It took a solution with an electrical conductivity of 14.4 to reduce the germination ratio by 50 percent. Salt solutions created with sodium chloride appear to have a stronger effect on inhibiting cress seed germination. A sodium chloride solution having an electrical conductivity of 6.2 was able to reduce the germination ratio of the cress seeds to 54 percent.

In Section 4.3, the salinities of mixtures of compost (C2) and Whitehorse top soil were evaluated. A maturity test was conducted for each of these mixtures. Table 5.4 lists the results.

Table 5.4 Germination Ratio of Compost and Top Soil Mixtures

Sample	Soil:Compost Ratio	Germination Ratio
1	1:0	100
2	2:1	95
3	1:1	55
4	1:2	45
5	0:1	40

When top soil was mixed with compost (C2) in a 2:1 ratio, the germination ratio for the mixture was 95. The germination ratio for pure compost (C2) was 40. Therefore it appears that mixing compost with soil improves the germination ratio. To add a factor of safety and ensure that the compost does not inhibit plant growth, ROTS should recommend that the compost be applied to the soil in a 1:5 ratio.

5.4 RECOMMENDATIONS

1. Compost should be mixed with soil in a 1:5 ratio when used as a growing medium.

2. Pure Compost should have a germination ratio of 65 before being used as a sole potting medium.

3. For mixtures of compost and soil, a germination ratio of 40 for the pure compost is desired before it is used in a mixture.

4. To ensure compost maturity, germination ratios should be determined for the pure compost and 5:1 mixtures every month during the summer.

6.0 CARBON TO NITROGEN WINDROW MODELING

To assist in design, a model which estimates the carbon to nitrogen ratio and moisture content for a proposed windrow is outlined in this section. A file entitled **ratio.xls** has been created (in EXCEL on the ROTS computer) to perform all the model calculations. All the spreadsheet requires is for the user to enter the wet mass of materials used in windrow construction.

6.1 PROCEDURE

1. For each material used in windrow construction, determine:

a) The C:N ratio and percent nitrogen.
b) The wet weight.
c) The moisture content.
d) The dry weight.
e) The dry weight of nitrogen.
f) The dry weight of carbon.

a)C:N RATIOS AND PERCENT NITROGEN

Table 6.1

Ingredients	C:N	%N	Reference
Wood (Pine)	723:1	-------	1
Wood	700:1	-------	13
Mixed Sawdust	511:1	0.2	9
Raw Sawdust	208:1	0.25	2
Sawdust	200-500:1	0.1	3
Sawdust	173:1	-------	13
Paper	173:1	-------	9
Paper	170:1	0.1	10
Newspaper	173:1	-------	13
Fresh Leaves	40-80:1	0.5-1.0	9
Fresh Leaves	30:1	1.5	11
Raw Leaves	40-80:1	0.5-1.0	10
Leaves	40-80:1	--------	13
Dry Leaves	45:1	1.0	9
Fruit Residue	35:1	1.52	9
Fruit Wastes	35:1	--------	13
Vegetable Wastes	15:1	.93	10
Vegetable Wastes	11-12:1	2.5-4.0	4
Food Wastes (table scraps)	15:1	-------	13
Potato Tops	11-12:1	1.5	9
Potato Wastes	15:1	0.2-0.45	10
Coffee Grounds	25:1	--------	9

If the material of interest has several referenced C:N ratios take the average and use this value for calculations.

Continued

Ingredients	C:N	%N	Reference
G ass Clippings	20:1	2.2	9
Fresh Grass	12:1	4.0	11
Sun Dried Grass	19:1	2.4	11
Grass Clippings	12-15:1	3.0-6.0	12
Grass Clippings	19:1	--------	5
Yard Waste	19:1	2.0	9
Mixed Yard Waste	20:1	2.0	11

b)DETERMINATION OF WET WEIGHT

To determine the wet weight of a material, first calculate the volume of the ingredient in the windrow using the following mathematical model. The volume for each layer is calculated separately and then totalled to find the overall volume for each material.

Volume= $1.778\ L\ [\ h_f^{3/2} - h_i^{3/2}]$

where **L** is the length of the windrow

Both h_f and h_i are the theoretical heights prior to compaction.

h_f is the height from the top of the windrow to the bottom of the layer of the ingredient having its volume calculated.

h_i is the height from the top of the windrow to the top of the layer of the ingredient of interest.

The total weight of each ingredient found in a windrow can be determined by taking the total volume of the ingredient and multiplying it by its density. Table 6.2 is a list of ingredients commonly composted at ROTS and their densities.

Table 6.2Densities of Some Composting Ingredients

Table Ingredient	Densities (kg/m^3)
Dry Grass	130
Green Grass	220
Leaves	170
Wood chips	180
Top soil	1000
Sawdust	130
Fruit and Vegetables	350

Wet Weight = Volume * Density

c) MOISTURE CONTENTS

Moisture contents were established for each ingredient used in ROTS composting operation during the summer of 1992. The moisture content was determined by placing a weighed amount of material in a beaker and drying it in the oven for six hours at 105 °C. The dried sample was weighed and the moisture content of the sample was calculated using the following formula and listed in Table 6.3.

$$\text{Moisture Content} = \frac{\text{Sample Wet Weight - Sample Dry Weight}}{\text{Sample Wet Weight}} * 100\ \%$$

Sometimes the moisture content of compost is determined as a dry weight. That is the weight of water determined in the material is deviled by the dry weight instead of the wet weight. However for these calculations the moisture content is determined using the wet weight.

Table 6.3MOISTURE ANALYSIS

Ingredient	Moisture Content (%)
Grass	60
Leaves	54
Fruits and Vegetables	70
Wood chips	46
Manure	10
Top soil	25
Peat soil	42
Compost	30 to 50

d) DRY WEIGHT

Dry Weight = Wet Weight [1 - Moisture Content]

e) NITROGEN DRY WEIGHT

Weight Nitrogen = Dry Weight * Percent Nitrogen

f) CARBON DRY WEIGHT

Weight Carbon = Weight Nitrogen * $\frac{C}{N}$ ratio

2. TOTAL WEIGHTS

Calculate the total wet weight, total dry weight, total weight of nitrogen and total weight of carbon of the compost windrow. These values can be calculated be simply adding up the values for each material in the windrow.

3. WINDROW C:N RATIO AND MOISTURE CONTENT

The following formulas can be used to calculate the overall C:N ratio for the windrow and the moisture content.

$$C{:}N = \frac{\text{total weight carbon}}{\text{total weight nitrogen}}$$

$$\text{Moisture Content} = \frac{\text{Total Wet Weight - Total Dry Weight}}{\text{Total Wet Weight}}$$

7.0SUMMER RESEARCH PROGRAM

7.1 INTRODUCTION

Recycle Organics Together Society is a unique composting organization in that operations are located in a semi-arid northern environment. Most research conducted on composting occurs in much milder climates. ROTS has been producing compost for three summers indicating that indeed compost can be produced in a northern climate. Research will be conducted to optimize the compost production, answer questions regarding northern composting and determine the most efficient operating conditions for the climate of Whitehorse.

7.2 OBJECTIVES

1. To reduce the salinity of the compost.

2. To determine the most appropriate carbon to nitrogen ratio for windrow composting in Whitehorse.

3. To determine optimum operating conditions for northern composting such as moisture content and aeration requirements.

4. To establish appropriate ingredients for northern composting.

7.2.1 Salinity Reduction

The research conducted for this report tested all the materials ROTS includes in windrow construction and discovered that urea, fruits and vegetables, and grass were the main culprits of compost salinity. Since diversion of organics is an aim of ROTS, it would not make sense to limit or eliminate materials such as fruits and vegetables or grass. Urea is not required in composting if windrows are designed properly. Urea and other fertilizers have always been included in windrow construction by ROTS in the past. This summer, the use of urea will be eliminated.

The compost will be tested for salinity weekly over the summer to establish whether a salinity cycle during the composting process exists. Salinity testing will also aid in determining if eliminating urea from windrow construction reduces compost salinity.

The 3:1 Lab Method outlined in Section 4.2 will be used to determine compost salinity on a weekly basis.

7.2.2 C:N RATIOS

To determine whether lowering the C:N ratio of a windrow reduces the time it takes for ROTS compost to mature, ROTS will produce several windrows with varying carbon to nitrogen ratios. During the summer, the compost will be tested for maturity to determine how varying the carbon to nitrogen ratio affects composting in the north.

Windrows will be constructed with three different carbon to nitrogen ratios to determine which ratio is the most applicable to northern composting in Whitehorse. The three ratios will be 16, 20 and 25.

Below is Table 7.1, listing the ingredients and ratios of ingredients for construction of each test windrows.

Table 7.1 Construction Ratios For Composting Ingredients

C:N ratio	Ingredients	Ratio
16	Grass:F&V	1:3
20	Grass:Leaves:F&V	4:1:3
25	Grass:Leaves:F&V	4:2:1

Three windrows will be constructed for each carbon to nitrogen ratio. The dimensions of the windrows will be 4 m long, 2 m wide and 2 m high. The moisture contents for each of the three windrows for each C:N ratio will be maintained at 50, 60 and 70 percent. To ensure aeration, the windrows will be turned weekly.

Maturity testing will be employed weekly to evaluate which C:N ratio is most effective at increasing the organic decomposition rate. Section 5.2 outlines the procedure for maturity testing.

7.2.3 OPERATING CONDITIONS

MOISTURE LEVEL

Bacteria require water like all other creatures. The optimum moisture content for bacteria is 100 percent. This number is unrealistic for composting because 100 percent moisture content would eliminate the available oxygen in the windrow . When the windrows are being constructed, there are naturally occurring spaces that form between the materials. It is these spaces that provide oxygen for the bacteria. When the moisture content becomes too high, the air spaces are filled with water and the windrow becomes anaerobic.

The minimum moisture content for a windrow is approximately 50 percent. The maximum water content depends upon the materials being composted. For example, a windrow constructed of shredded newspaper with a moisture content of 75 percent will compact almost 80 percent. Compaction of this nature would result in an anaerobic composting pile. A windrow constructed with wood chips with the same moisture content compacts approximately 40 percent. Wood chips have a much sturdier structure and do not compact under the weight of water.

During the summers in Whitehorse, there is a daily average of 20 hours of sunlight. The longer days and the dry climate lead to a loss of moisture through to evaporation from the windrows. To determine the optimum moisture content for northern composting, windrows will be maintained at three different moisture contents; 50, 60 and 70 percent.

The productivity of the windrows in relation to moisture content will be monitored by temperature. The temperature of a windrow is established by taking the average of five random readings from the center along the pile. If the moisture content is either too low or too high, the activity of the bacteria will decline and reflecting this change, the temperature of the windrow will correspondingly decrease.

In order to determine the moisture content of the windrow, samples from each windrow will be taken for analysis. 200 g of these samples will be weighed out and heated in an oven at 105 °C for six hours. After drying, the sample is reweighed. The calculation for moisture content is described in Section 6.1. Moisture content analysis should be conducted once a week to aid in establishing and maintaining the desired moisture level.

OXYGEN LEVEL

The oxygen level of a windrow is maintained by periodically turning the windrow. Both the Ontario and British Columbia Composting Guidelines require that the windrows be turned five times during the high temperature period. This exposes all parts of the windrow to temperatures above 55 °C which will ensure pathogen reduction. In order to follow these quidelines, the length of the high temperature period needs to be determined for composting in Whitehorse. To establish this time period, the temperature of the windrows will be monitored every day throughout the summer. Once this period has been determined, ROTS can adjust the turning of the windrows to be weekly or biweekly. For this summer, the windrows should be turned weekly.

7.2.4 NORTHERN COMPOSTING INGREDIENTS

Currently, ROTS is composting fruit, vegetables, grass, yard waste, leaves and wood chips. ROTS would like to try and divert more organics from landfill burial to compost production. Presently, Whitehorse has no method for diverting or recycling newspaper. Collecting fruits and vegetables from restaurants in Whitehorse only diverts a fraction of the waste produced in a restaurant. Therefore, there is an interest in Whitehorse to include newspaper as well as cooked foods in municipal composting.

The inks used to print newspapers contain heavy metals. The only way to determine the effect that newspaper will have upon metal concentrations in the compost is to construct a test windrow. Once the compost has reached maturity, heavy metal analysis on the compost should be performed. These results will help ROTS assess the feasibility of composting newspaper. The windrow should be constructed with a grass:leaf:newspaper ratio of 2:2:1. The newspaper must be shredded before utilization in windrow construction.

If ROTS were to accept cooked foods from the restaurant pick up program, this would lead to a greater diversion of all restaurant food in Whitehorse. The problem with accepting cooked food is animal scavenging and the increased time it takes for cooked foods to degrade. This is compounded when one considers that the composting season in Whitehorse is limited to four months.

To establish the practicality of incorporating cooked foods into windrow construction, a pilot restaurant should be chosen from which all restaurant food waste is accepted. The organics from this restaurant will be used to construct a test windrow. At the end of four months the compost will be tested for pH, salinity, heavy metal concentrations and maturity. This windrow should be fenced in and monitored to ensure that it does not attract any vectors like coyotes, rodents, ravens or insects. The windrow should be constructed with a C:N ratio of 25:1 as in outlined in Section 7.2.2.

8.0COMPOSTING GUIDELINES

8.1 COMPOSTING OPERATING CONDITIONS

The following composting operating requirements are those outlined by both the ***Interim Guidelines for the Production and Use of Aerobic Compost in Ontario*** and the **Regulation For The Production And Use Of Compost From Municipal Solid Waste For British Columbia.** ROTS should adapt these regulations because they establish basic guidelines for composting temperatures, pathogen control and windrow turning.

1. The optimum operating temperature for thermophilic composting is between 55 and 60 °C.

2. In order to reduce pathogens the temperature of a windrow should be maintained at, a minimum of 55 °C for 15 cumulative days.

   The temperature of the windrow should be monitored daily during the period of pathogen inactivation (high temperature period) and weekly until the compost has been determined to be matured.

3. To ensure that all the compost is subjected to the required temperature of 55 °C for pathogen reduction, the windrow should be turned over at east five times during this high temperature period.

   Oxygen levels should be maintained at 12 to 18 percent of the volume of the windrow.

8.2 COMPOST QUALITY

Under the ***Interim Guidelines for the Production and Use of Aerobic Compost in Ontario,*** the following specifications must be met to establish unrestricted compost use. If the compost does not meet these specifications, it is considered waste and disposal in a landfill site is required. Therefore, ROTS should aim to meet all of these specifications to ensure that the compost produced in Whitehorse is of the highest quality. The British Columbia Composting Regulations have also been included in this report for the sake of comparison. British Columbia has a rating system in which they assess the quality of the compost. The end use of the compost is either restricted to certain applications or unrestricted, depending upon the rating it receives. The unrestricted compost specifications are stated in this report. ROTS should strive for unrestricted use of their compost because this operation has clean feed materials and does not involve sludge composting. It should be no problem for ROTS composting to meet these regulations.

8.2.1 GUIDELINE REGULATIONS

1. The Ontario and B.C. Guidelines have established heavy metal concentration limits for compost. Two compost samples, C2 and LF92 were analyzed in 1993 for heavy metal concentrations by Norwest Labs.

The results indicated that ROTS compost concentrations fell well below the guideline limits for all the heavy metals tested. Table 8.1 lists the Ontario and B.C. Guidelines and compares the analyzed compost results.

TABLE 8.1 HEAVY METAL CONCENTRATIONS (MG/KG DRY WEIGHT)

Metal	Ontario Guidelines	B.C. Guidelines	C2	LF92
Arsenic	10	<13	4.98	5.23
Cadmium	3	<2.6	0.4	0.5
Chromium	50	<210	40.8	32.3
Cobalt	25	<26	6	5
Copper	60	<50	28.0	30.4
Lead	150	<150	17	11
Mercury	0.15	<0.8	0.10	0.12
Molybdenum	2	<5	<2	2
Nickel	60	<50	18	16
Selenium	2	<2	.52	.42
Zinc	500	<315	73.6	80.7

2. The concentration of PCB's found in the compost on a dry weight basis should not exceed 0.5 mg/kg dry weight.

ROTS compost has not been tested recently for organic pesticides or PCB's.

3. The mature compost should be screened to remove non-biodegradable material and any material greater than an 8 mesh screen.

ROTS needs to develop a method for screening compost to remove foreign objects, partially decomposed wood and rocks. The site at the landfill is very rocky and when the compost is turned a lot of stones are incorporated into the windrows.

4.Compost must be established as stable by a maturity test before marketing.

The British Columbia Composting Guidelines considers compost mature when windrows do not reheat to 20 °C above the ambient temperature. This level of maturity is indicated by a 60 percent weight reduction in organic matter. The compost should have the texture of soil and be dark brown to black in colour.

Section 5.2 outlines the Maturity Testing Method developed and utilized to determine the maturity status of ROTS compost during research this winter.

8.2.2 GUIDELINE RECOMMENDATIONS

The Ontario Composting Guidelines suggest characteristics for good compost. It should be noted that these are only specifications.

1. The compost particle size should be less than 25 mm.

2. The minimum mineral concentrations for essential nutrients should be as follows.

Parameter	Concentration (% dry weight)
Total Nitrogen	0.6
Total Phosphorus	0.25
Tot al Potassium	0.20
Calcium	3.0
Magnesium	0.3

Compost samples C1, C2, C3, C4, LF92 and Whitehorse top soil were analyzed for their essential nutrients. The top soil was deficient in phosphorus and potassium, while the essential nutrients in the compost samples were all at optimal levels or in excess. If ROTS compost is mixed with top soil in a 1:5 ratio, the growing medium produced by this mixture should enhance crop and garden growth.

3. The total organic matter content of the compost should be greater than 30 percent on a dry weight basis.

The organic contents of compost samples C1, C2, C3, C4 and LF92 were analyzed by Norwest Labs and determined to be below 20 percent. On a dry weight basis, the compost produced in 1991 contained on average 30 to 50 percent Whitehorse top and peat soil. To improve the organic content of the compost, the amount of soil used in windrow construction should be reduced.

4. The typical carbon to nitrogen ratio should be 22.

No analysis of the C:N ratio for mature compost has been conducted to date. Section 6 describes a methid for modelling C:N ratios for windrows.

5. The salinity of the compost should be less than 3.5 dS/m and the Sodium Adsorption Ratio should not exceed 5. The British Columbia composting regulations require the compost to have an Electrical Conductivity of less than 3 dS/m.

The Salinity of the compost produced by ROTS and recommendations are discussed in detail in section 4.0.

6. According to the Ontario Guidelines, the pH of the mature compost should be in the range of 5.5 to 8.5. The British Columbia Guidelines requires that the pH of mature compost fall between 5.0 and 8.0.

The pH of the compost was analyzed at Yukon College during the winter research and was determined to lie in the range of 6.9 to 7.1. Even though ROTS is incorporating acidic coniferous wood chips in windrow construction, the pH of the compost is neutral.

7. The moisture content of the mature compost should be in the range of 30 to 50 percent.

The moisture content of the ROTS compost is between 30 and 50 percent.

8. The water holding capacity of the compost should be three times its dry weight.

The compost produced by ROTS only has a water holding capacity of one and a half times its dry weight. This corresponds with the low organic content that the compost possesses. Once again, reducing the amount of soil used to construct windrows should improve the organic content.

8.2.3 MONITORING

The objective of monitoring the compost is to establish its quality and consistency. The following guidelines are those suggested by the Ontario Composting Guidelines.

SAMPLING

In order to maintain consistency in analytical testing, it is important to follow an established procedure for sampling. For each windrow constructed, 5 samples should be taken from a depth of one metre consisting of 100 g each. These samples should be combined to form a composite sample on which the analytical testing will be performed.

The Ontario Guidelines suggest that analysis be performed on feed stocks until the quality appears to be relatively consistent. ROTS is not involved in sludge composting and the feed stocks generally consist of fruit, vegetables, grass clippings, yard waste and wood chips. Since these feed stocks pose no real concern for heavy metal contamination or organic residues, this type of testing is not imperative for ROTS. However, in the future, if ROTS incorporates impure feed stocks into their operations, analytical testing of this material will be required.

Compost should be tested bimonthly until product quality becomes consistent. At this point, testing can be reduced to once every four months.

REPORTING

The Ontario Composting Guidelines require that the following records be kept to monitor the activities of composting facilities.

1. The source, type and quantities of wastes received should be recorded.

2. Temperature, the frequency of windrow turning, the moisture content and other relevant operating conditions should to be recorded for each windrow.

3. The weight and volume of the compost produced needs to be recorded.

4. A list of the compost markets or the end use of the compost is required.

5. All analyses and copies of laboratory reports should be maintained.

9.0 CONCLUSIONS

Comparing the quality of ROTS compost to the Ontario and B.C. Guidelines, reveals that ROTS produces a good product. The compost is high in nutrients and low in heavy metal concentrations. To improve compost quality even further ROTS should eliminate the use of urea in windrow construction to reduce compost salinity to limits below the guidelines. The reduction of top soil and peat soil in windrow construction will improve the water holding capacity of the compost and the organic content. ROTS should develop a method for screening the compost to remove foreign materials before it is marketed. For optimum performance of ROTS compost, it should be applied to soils in a 1:5 ratio when determined to be mature.

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