Nova Scotia Environment

Compost Maturity Study

Final Report

HMJ Consulting Limited

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1.0 INTRODUCTION

Composting facilities in Nova Scotia receive source separated organics from the residential and business sectors. They also receive fish processing wastes, paper mill residues, septage and biosolids, as well as organic bulking materials. There are currently 18 facilities with an estimated capacity of 100,000 tonnes per year of mainly source separated organics and 100,000 tonnes per year of other organic wastes. These facilities operate as either in-vessel or windrow systems, and vary in age from less than 1 year to 13 years.

With the exception of the newest facility constructed for the Cape Breton Regional Municipality, these facilities were designed and are intended to be operated in compliance with the 1998 version of the *Nova Scotia Compost Facility Guidelines*. The primary difference between the 1998 and 2006 versions of the *Nova Scotia Compost Facility Guidelines* is the elimination of many of the maturity tests and substitution of criteria which have been developed following ongoing experience with compost maturity. The tests were revised by CCME after significant and lengthy consultations with composting industry stakeholders throughout the country.

Sufficient time has now passed since promulgation of the 2006 *Guidelines* for current operators to determine their impact on their respective operations, and to make changes as may be applicable. Nova Scotia Environment has decided that it is timely to now conduct an overall assessment of the state of the industry, with particular reference to the maturity standards contained in the 2006 Guidelines. It is their intention that this assessment would be conducted on a consistent basis.

The objective of this study was to review nine composting facilities in Nova Scotia that each process at least 4,000 tonnes per year of organics and to determine whether they are currently able to meet the compost maturity standards specified in the 2006 *Nova Scotia Compost Facility Guidelines.* Site specific comments have been made only for the purpose of characterization of facilities. Further, the scope of the study has included recommendations concerning management techniques and the potential of new technology which could be used to enable operators to reliably meet the 2006 *Guidelines.*

The scope of the study was addressed through 8 tasks which are listed as follows:

- Task 1 – Review of Existing Information
- Task 2 – Site Visits and Lab Testing
- Task 3 – Review of the Existing Composting Equipment Used in Nova Scotia
- Task 4 – Review of Curing Areas
- Task 5 – Review of New Composting Technologies
- Task 6 – Assessment of the Benefits of Facility Upgrading
- Task 7 – Recommendations to Achieve Required Compost Facility Performance
- Task 8 – Report Preparation

2.0 FACILITIES INVOLVED IN STUDY

The following are the 9 Nova Scotia facilities that each process in excess of 4,000 tonnes per year of organics and are therefore the focus of this study. The order in which they are presented is random and does not infer a hierarchal placement in terms of compost quality or maturity.

Table 1 – Host Facility Information

Facility	Location	Composting Technology	Annual Capacity	Age of Facility (yrs)	Design Life Expectancy*
Cape Breton Regional Municipality	Sydney, NS	Tunnel	12,000T	<1	20
Pictou	Pictou, NS	Wide Bed	5,000T	8	20
Municipality of the County of Colchester	Kemptown, NS	Container	6,000T	12	20
Cumberland	Little Forks, NS	Aerated Windrow	5,000T	8	15
Miller Waste Systems	Dartmouth, NS	Wide Bed	25,000T	10	30
New Era Technologies	Halifax, NS	Container	25,000T	10	20
North Ridge Farms	Aylesford, NS	Bunker	12,000T	5	15
Lunenburg Regional	Lunenburg, NS	Wide Bed	10,000T	14	Unknown
Yarmouth	Yarmouth, NS	Bunker	9,000T	8	20

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3.0 REVIEW OF EXISTING INFORMATION

3.1 Review of Information Prepared for NSE

The reports entitled "Report on Assessing Compost Maturity", October 2001, prepared by Bio-Logic Environmental Systems for the Nova Scotia Department of Environment and Labour and "An Assessment of the State of Provincial Compost Processing Facilities", July 2003 also prepared by Bio-Logic Environmental Systems for the RRFB and Nova Scotia Department of Environment and Labour, were reviewed and all other pertinent information was gathered before the study was commenced.

It is noted that many of the conclusions made in the 2001 report are carried forward to the recommendations of the 2003 report. The recommendations that related to compost maturity are,

- Operators should consider an incremental cost-benefit analysis in comparing the incremental investment required to produce a more mature, stable and valuable product.
- Operators should strive to increase the stability of their product through: (a) accelerating the rate of decomposition through improved operating conditions that are more amenable to microbial activity (greater oxygen exchange), and/or where space exists, and (b) holding material on-site (preferably under cover) for a longer period of time (at least one year). In some cases, this would require the province revising the operating permits to increase the allowable storage on-site.
- The province should consider making the test for maturity more rigorous. Modifying the existing tests for maturity could include reducing the four tests that exist at present to a single respiration test (suggested), or having samples pass at least two of the four existing stability criteria. The process towards making the stability criteria more stringent should be gradual, so that operators have sufficient time to modify operating processes if necessary.
- The Solvita test can be considered as a general means to test for compost stability (more effective for stable material), but formal stability reports should still include one of the four criteria as outlined in the CCME guidelines. A revised opinion on the strength of the correlation could be determined with additional sample results.

Since these reports have been issued the province has, by drafting the *2006 Nova Scotia Compost Facility Guidelines*, begun adopting some of these recommendations because they refer to the 2005 CCME Guidelines for Compost Quality which in terms of maturity are more strict than their predecessor. The new version does not permit the use of the germination test of radish and water cress. It also reduces the permissible temperature rise in a self heating test from 20 degrees to 8 degrees Celsius above ambient measurements.

Some of the facility operators have also changed when their product is marketed. Even though it may pass the guidelines, they like to cure the material for a longer period of time to ensure public acceptance of the product.

3.2 Literature Review with respect to Maturity and the Testing of Maturity

3.2.1 Composting Effectiveness and Maturity

In all types of composting process, the degradation of organic materials is accomplished by a wide variety of microorganisms via complex mechanisms. The effectiveness of the composting process is assessed by degree of bioconversion as well as stability of final products. Compost maturity is one of the most important factors affecting the safe use of these biosolids for agricultural, municipal, industrial and domestic purposes. Maturity of compost is defined as the final stable state of the composted matter which is safe for agricultural applications.

The main purpose of use of composts of various origins in agriculture, municipal and domestic areas is to increase and/or restore the organic matter content in organically poor or depleted soils. Organic matter in soil is well documented as one of the most important factors responsible for soil fertility, crop production, and land protection from contamination, degradation, erosion and desertification[1]. In fact, composting of organic residues, by-products, wastes and effluents, such as municipal sewage sludges and urban solid wastes, food industry and wood processing wastes, agricultural crop residues and animal wastes, has become a very popular and efficient practice for the production of organic soil amendments. [2]. Composts maintain and/or increase crop production and reduce soil exposure to degradation, erosion, desertification and pollution. The agronomically efficient and environmentally safe use of composts require an adequate control of the chemical quality of the humic substance (HS)-like fractions contained, which is an important indicator of the maturity and stability achieved by the compost[3].

Compost maturity was selected as one of the most important parameters for determining the grade of compost in Canada to safeguard this bioconversion process for waste. As a matter of fact, immature compost may stunt, infest, damage, or even kill plants, rather than acting as growth enhancer due to the presence of undecomposed, phytotoxic compounds (e.g., n-hexadecane, pyrene and benzo(α)pyrene) and high microbial activity which can compete for the available nutrients in the soil[4,5].

Existing literature suggests that the most significant effect of immature compost is the biological blockage of soil-available nitrogen which may give rise to critical N-deficiencies in crops with consequent depressive effects[6]. The rapid decomposition of immature compost may cause a decrease of the O_2-concentration and soil pH and as a result, the creation of an anaerobic and strongly-reducing environment surrounding the root system. The low pH of soil could cause an increase of the solubility of heavy metals in the soil and inhibition of plant seed germination by the production of phytotoxic substances[7], ammonia, ethylene oxide and organic acids[8]. Furthermore, the inhibitory environment conditions against plant result in lowering the metabolic rate, reducing root respiration, decreasing nutrient absorption and slowing the gibberellin and cytokinin synthesis and transport.

The majority of evaluation studies have been conducted to assess the effects of composts on total and available amounts of nutrient elements added to soil, phytotoxic hazard to crops, potential modifications of soil microbial populations and activities, and effects of toxic trace metals and organic chemicals on crops and waters[9,10]. However, relatively fewer studies have been performed on the effects that composts may exert on the chemical constitution, environmental conditions and fertility functions of the most abundant and active reserve of humus substances (HS). The analytical and molecular properties of HS-like components in compost amended soil, and the short-term and/or long-term effects of composts additions on the status and quality of indigenous soil HS have been conducted in very few studies.

Maturity is not related to the composition or quality, but to the stage in the composting process to which the raw material has progressed. Sufficiently mature compost should have slow biological activity and be free of easily biodegradable molecules with only complex organic material residual. It is normally difficult to identify the original feedstock materials in properly matured compost, which usually has a fine texture, dark colour, and a rich earthy smell[11].

There are several criteria or methods which have been proposed to establish the degree of maturity. These methods can be broadly divided into five types. Physical tests address temperature, odour, density, particle-size, and colour. Microbial activity is focused on metabolic activity, biomass and the easily-biodegradable constituents, and tests include respirometric indicators such as O_2 uptake rate and CO_2 production rate, as well as rate of heat release, Adenosine triphosphate (ATP and hydrolytic enzyme activity determinations, hydrolysable polysaccharide content, relation between total organic carbon and soluble glucides, and ratio of carbon in reducing sugars to total carbon[8,12].

Determination of the total humus and the degree of polymerization of humic compounds is determined by paper chromatography and photocolorimetric methods. Chemical methods incude C/N ratio in solid phase and in water extracts, pH, cation-exchange capacity and tests for ammonia, hydrogen sulphide, nitrates and nitrites. Biological methods are based on the determination of the germination index of seeds incubated in water extracts of the compost. These parameters can be used to more effectively manage the composting process to achieve desired levels of maturity.

3.2.1.1 Physical Tests

In general, composting can be divided into two phases of aerobic solid-state biological process: a high-rate composting phase and a curing phase. The high-rate composting is the resultant of high microbial activity occurring during this phase and requires an accurate plant design to prevent the formation of anaerobic conditions and odours. The formation of anaerobic pockets in the composted matter mainly depends on the rate of O_2 consumption needed to degrade the substrate, i.e., the biological stability of the substrate.

D'Imporzano et al[13] investigated the relationship between the biological activity, measured by the dynamic respiration index and the potential odour molecules production, measured by an electronic nose during food-waste high-rate composting processes. The authors reported strong anaerobic conditions development even at optimal O_2 concentration (O_2 > 140 ml l^{-1}, v/v) during composting in the biomass free air space. The anaerobic conditions were related to the high levels of sulphur compounds, methane, and hydrogen in the outlet air stream. The high level of O_2 consumption, needed to decompose the high-degradable water-soluble organic matter as well as low water O_2 solubility due to high temperature (up to 60 °C), led to the anaerobic conditions. The researchers established the usefulness of the dynamic respiration index as an innovative parameter to estimate the potential production of odour molecules of the biomass. The in-depth studies revealed that the O_2 uptake rate needed to degrade an organic substrate is directly related to the degradability of the substrate[14]. The degradability of the substrate is measured by using lab tests and data reported on a recognized scale of values (i.e., respiration indexes). This measurement of oxygen uptake represents the biological stability (level of curing) of a biomass[14], and therefore, validates the relationship between the production of odours and the curing process.

Robin et al[15] have focused on the physical characterization of the compost and established that composting can increase the clay-like fraction that is most efficient in the carbon stabilization processes. Therefore, they suggested that the fractionation (particle-size distribution) method can be used to complement a maturity index. Therefore, the fractionation method can be regarded as an appropriate standard for maturity index. Their results clearly showed that the long-term composting increased the C contained in the clay-like fraction. Furthermore, it is well established that the finest C can better migrate through soil porosity during wet events, and facilitate stabilization processes due either to spatial inaccessibility against microorganisms or by various interactions with mineral surfaces[16]. The literature was limited to establish a clear effect of composting on long term C storage. However, both experimental and modelling literature supported the assumption that addition of raw materials should induce a greater C increase during the initial years, and adding composted materials should induce higher long term C storage (i.e. after few decades). Therefore, the models used should consider specifically the fine size fraction (< 2 μm) of organic matter in the matured compost matter[15].

Laor and Avnimelech[17] tested flocculation process as a new and simple approach for compost-dissolved organic matter (compost-DOM) fractionation. The authors reported significant correlations between compost maturity and the percentage of DOM-carbon removal and UV absorbance reduction by flocculation. The results suggested that the flocculation process can be used as an additional tool for evaluating compost quality and maturity. On a dry matter basis, the total amount of flocculated DOM-carbon was similar with all compost samples, whereas the non-flocculated DOM-carbon decreases dramatically upon maturation. It was postulated that the non-flocculated DOM fraction is probably dominated by relatively labile, hydrophilic, and lower molecular weight compounds, which may be responsible for oxygen depletion in the soil as might happen when applying immature compost. On the other hand, the fraction separated by the flocculation process was believed to be dominated by a relatively high molecular weight humic-like substance, and may represent the more resistant organic fraction which will preferably accumulate in the amended soil.

3.2.1.2 Microbial Activity Parameters

Microbial stability can be very useful in assessment of compost's maturity. Several parameters such as, measuring the microbial biomass count, its metabolic activity and the concentration of easily biodegradable constituents can serve as reliable indicators for maturity of compost. Standard laboratory methods for evaluating microbial stability include oxygen consumption or respiration activity, and heat production, both of which are indicators of the amount of degradable residual organic matter and which is inversely related to stabilization[18] Studies related to respirometry, which include the determination of the O_2 consumption or CO_2 production due to mineralization of the compost's organic matter, have been carried out in pure composts as well as in composts mixed with soil in a proportion applicable for agriculture[19]. The studies established that an insufficiently mature compost require substantial quantity of O_2 and produce high amounts of CO_2 due to accelerated growth of microorganisms as a consequence of the abundance of easily biodegradable compounds in the raw material. Therefore, O_2 consumption or CO_2 production are indicative of compost stability and maturity[20].

Respirometric techniques can provide accurate information on the activity of a compost sample[21]. In fact, there are different commercially available equipment (Costech, OxiTop, Micro-Oxymax, Sapromat, Comput-OX, N-Con systems, Colombus instruments, Arthur respirometers, etc.), however, these respirometers lack economical feasibility and user-friendliness. Numerous methods also exist for the measurement of CO_2 evolution (Fibre-Optic Fluoro-Sensors, Amperometric, Conductometric, Potentiometric sensors, NaOH and KOH absorption) but most of these techniques need more specialized instrumentation and highly skilled labor. In addition the equipment require frequent maintenance and calibration routine. Most of the recent literature on respirometric methods on compost stability was confined to the traditional composting techniques such as windrows and static piles types of composting for various kinds of wastes[14]. Literature on stability of compost in vessel techniques, especially rotary drum for the mixed organic wastes is rather limited. Rotary drum machines enhance agitation, aeration and mixing of the compost, to produce a consistent and uniform final product. The composting duration is sharply reduced to 2–3 weeks. Kalamdhad et al[21] established that the conductivity method was reliable and authentic for assessment of evolution of CO_2 during the composting process within a rotary drum.

Passive aeration is also an important factor in aerobic composting systems, as forced aeration is usually only used during the high rate phase, which typically lasts only one week to one month. After the completion of the active phase, the compost is normally left to cure for longer duration, when only passive aeration takes place. The literature information is limited for the curing phase even though it is an important part of the complete process[22].

3.2.1.3 Analysis of Humic Compounds

Stabilization or maturation also involve the formation of humic-like substances. Thus, the degree of organic matter humification is generally accepted as a criterion of maturity. The different parameters include, humification ratio, humification index, percent of humic acid, humic acid to fulvic acid ratio and the chemical, physico-chemical and spectroscopic characterization of humic-like substances. Fukushima et al[23] observed that the acidic supernatant from an alkaline compost-extract contained fulvic acid and non-humic substances. These compounds were easily separated using a DAX-8 column, in which fulvic acid was specifically adsorbed to the resin. Humification index, the ratio of humic substances- to non-humic substances- total organic carbon, increased with an increase in curing duration. Thus, the humification index was useful for the evaluation of compost maturity based on humic substances content. It was established that during the composting process, the breakdown of organic matter, and its subsequent humification, involves a decrease of polysaccharide content and the production of structures incorporating more aromatic compounds.

Furthermore, the increase of carboxylic groups and the decrease of molecular size of humic acids in wastes during the composting process determine the extent of humification and compost maturity. The analyses of humic acid fractions during the composting process are important to assess quality and maturity of any compost. However, the humification parameters e.g., humic acid carbon, fulvic acid carbon and humification index (humic acid carbon/organic carbon x 100) of composts have very different values depending on the origin of the waste. For example, fast and complete humification of a composting feedstock substantially depends upon its C/N ratio (between 25 and 35) [24]. Therefore, no standard value applicable to all kinds of compost could be established to describe maturity.

3.2.1.4 Chemical Methods

The most extensively studied parameter for composting is the C:N ratio of the initial composting material[20,25,26]; high initial C:N ratio will cause a slower start up of the process and the resulted into longer than usual composting time[27] while low initial C:N ratio results in high emission of NH_3[28]. Chanyasak and Kubota[26] established a water soluble organic-C/organic-N ratio of 5-6 as an essential indicator of compost maturity. However, this ratio was difficult to evaluate due the usually very low concentration of organic-N in the water extract of mature samples.

Hue and Liu[20] suggested using the water soluble organic-C/total organic-N ratio as compost maturity index, proposing a value of < 0.70 as a new standard of compost stability. Bernal et al[25] correlated the ratio of water soluble carbon and organic nitrogen with many chemical characteristics of the feedstock during composting, which indicated either degradability or stability, including C-mineralization. Thereby, suggesting it as the one of the most suitable parameters for describing the maturity and stability of different composts.

The cation exchange capacity (CEC) was also correlated with degradability, stability and mineralization parameters[29]. However, the threshold values of CEC established to indicate the level of maturity for a specific compost cannot be generalized to all composts[30]. Although the monitoring of CEC during composting could be useful for discerning the stage of stability reached.

In general, nitrification is described as the oxidation of NH_4^+-N to NO_2^-, which is further oxidized, to NO_3^-. The rate of NH_4^+ oxidation is normally equal to the rate of NO_2^- and NO_3^- accumulation. Biey et al[31] have mentioned that the examination of the nitrifying activity can be calculated by the measurement of the rate of nitrite, where NO_2^- oxidation is completely and specifically blocked. Finstein and Miller[32] suggested nitrification as compost maturity parameter. They observed that the NH_4^+ concentration decreases and NO_3^- appearance in the composting material could be considered as indicators of maturity. Bernal et al[25] also reported the increase in NO_3^- concentration of the compost during maturation phase. Zucconi and de Bertoldi[18] established that a high level of NH_4^+ points to unstabilized compost, leading to establish a limit of 0.04% for mature city refuse compost. Bueno et al[33] observed a positive N-losses at intermediate time (mesophilic phase) with respect to initial and final composting time. The N-losses were dependent on composting time (55 days) and low values of particle size (1 cm) and moisture content (40%). An increase in total-N could be obtained at high values of moisture and medium values of aeration. The operation time had a negative influence on the N-losses variation, thereby, ensuring a low N-losses (> -40%). Lower N-losses could be obtained at lower values of the composting variables (particle size and moisture) and medium composting time. The higher degradation of the organic matter with respect to the nitrogen losses resulted into the rise of the final nitrogen concentration with respect to initial composts[28]. Furthermore, Busby et al[34] investigated that ammonium concentrations in the compost treatments remained very low and relatively constant, but decreased slightly over time. Ammonium concentrations during the composting treatments peaked at day 60 and decreased to their initial amounts by day 90, indicating a net ammonification during the incubation. The net nitrification could only be observed by the end of the 90 d.

3.2.1.5 Biological Methods

The degree of maturity can also be described by the biological methods involving seed germination and root length[35]. The immature composts may contain phytotoxic substances such as phenolic acids and volatile fatty acids[36]. On the other hand, incubation experiments are reliable for measuring soil N availability, and have been used widely to compare the N supplying capacity of composts added to soils and to monitor their short-term behavior[37]. The first-order mathematical model for simulating the inorganic N accumulation patterns is a useful tool for estimating the amount and the rate of mineralizable organic N. Stanford and Smith[38] defined the quantity of the organic N that is susceptible to mineralization according to the first-order kinetics, as N mineralization potential (N_0). Both the N_0 and rate constants of first-order models indicate the quality of composts/organic waste and could be indicative of level of compost maturity[37].

Kato et al[39] analyzed poultry manure composts to determine the proportion of branched fatty acid methyl esters (branched FAMES) using biomarker for gram-positive bacteria including actinomycetes. The authors had positive and negative correlation to some indicators of compost maturity such as the value of germination index (GI) and the amount of ammonium-ion, respectively. Kato et al[40] also correlated the proportion of branched FAMES only to the value of GI. As GI is related to compost phytotoxicity and is considered to be a very sensitive parameter for determining compost maturity[35]. Kato et al[40] established that the proportion of branched FAMES can be effectively used as the maturity index for cattle manure composts as well as the case of poultry manure composts[39]. In particular, the samples with more than 50 mol% of branched FAMES showed high values of GI, and the day on which the proportion of branched FAMES exceeded 50 mol% (day 39) coincided with the onset of maturity stage as determined by the change in GI for all the composts and/or in NO_3^- content. This process was also reported in poultry manure composts[39]. Therefore, Kato et al[40] regarded cattle and poultry manure composts in which the content of branched FAMES were over 50 mol% to be in the maturity stage.

Murillo et al[41] concluded that the routine chemical analyses of composts cannot be reliable enough and must be confirmed by performing a rapid germination/early growth bioassay. As specific toxicity of composts to most agricultural systems and time required for complete stabilization in soil are not established, the degree of instant toxicity should be tested. The results of Murillo et al[41] showed that the simple and rapid bioassay involving germination and root elongation were reliable to obtain complementary information about the suitability of a particular compost.
Zmora-Nahum et al[42] examined two types of mycoparasitic behavior are described for the antagonists. The *Trichoderma* fungus isolate acted as a primary mycoparasite, colonizing sclerotia of *Sclerotium rolfsii* resistant to the external conditions. On the other hand, the *Penicillium* and *Petriella* isolates acted as weak, opportunistic antagonists, better capable of colonizing the sclerotia under optimal external conditions for the germination of sclerotia. Therefore, compost extracts which inhibited germination of sclerotia (from days 11 and 45 of curing) also increased their susceptibility to attack by these mycoparasites. In the literature, increased susceptibility of sclerotia of *S. rolfsii* to colonization by *Trichoderma* spp. has been reported as a consequence of treatment with metham sodium in sublethal concentrations[43. Zmora-Nahum et al[42] showed that the chemical conditions of the

compost increase the susceptibility to attack by antagonists which naturally inhabit the compost and attack sclerotia when the compost is suppressive. The increase in susceptibility of the sclerotia might be resulted from the delay in germination caused by the compost extracts which allowed the antagonists to germinate and grow on the sclerotia surface before germination initiated.

3.2.2 Maturity and Stability

In the literature, the terms stability and maturity are often used interchangeably for composts. However, they are not really equivalent. Compost maturity is associated with plant-growth potential or phytotoxicity[19], whereas stability is related with the compost's microbial activity. The term maturity refers to slowed biological activity due to the remaining molecules being difficult to break down any further. On the other hand, stability relates to slow biological activity, but it may be due to several factors; the material probably became mature, or it may lack adequate nitrogen, oxygen, moisture or environmental conditions (temperature, pH) for the process to continue. In this case, if the missing factors are added or compensated, biological activity will resume at active levels.

3.2.3 Measurement of Compost Maturity

Currently, there are a number of standard tests available to determine compost stability which are specific to location of the composting facility. CCME require compost facilities in Canada to follow Bureau de Normalisation du Québec (BNQ) standards, which is based on a scientific and non-scientific rationale. The measurement protocols adopted by BNQ include methods from American Society for Testing and Materials (ASTM), International Organisation for Standardization (ISO) and Standards Council of Canada (SCC). In the US, many of these tests have been submitted for publication in the first edition of Test Methods for the Examination of Composting and Compost (TMECC) by the U.S. Composting Council (USCC). Examples of approaches, equipment and costs of compost stability tests are presented in Appendix II. Moreover, commercial laboratories have also developed various other standards, which are currently in practice[44]. These include:

3.2.3.1 Oxygen Uptake Rate (OUR)

This test measures the changes in oxygen concentration with time in the head space of a closed vessel containing a moist compost sample of known volume and weight, at a given temperature and pressure. Samples with large pieces of inerts are rejected. The moisture content of suitable samples is adjusted to 40-50 %, then samples are pre-incubated in bags placed in a constant temperature environment at 37 °C and 100 percent humidity for a minimum of 24 hours. The sample is then added to a container that is sealed with appropriate monitoring equipment to allow measurement of oxygen consumption every minute for at least 90 minutes.

3.2.3.2 Specific Oxygen Uptake Rate (SOUR)

The specific oxygen uptake rate method is identical to the OUR Test, except, the results are calculated as oxygen uptake rate per unit of biodegradable volatile solids. Typical values of specific oxygen uptake rate vary from 4.0-17.5 $mgO_2h^{-1}g^{-1}$ compost solids[45].

3.2.3.3 Carbon Dioxide Evolution Rate

The amount of CO_2 released over time in the head space of a closed vessel containing a moist compost sample of known volume and weight is measured, at a given temperature and pressure. Samples with large pieces of inerts are rejected. The moisture content of suitable samples is adjusted to 50 % moisture, then samples are pre-incubated in bags placed in a chamber at 37 °C and 100% humidity for 3 days. The sample is then added to a container that is sealed with appropriate monitoring equipment to allow daily measurement of carbon dioxide evolved for a 4-day period. The results are calculated as carbon dioxide evolved per unit of total sample solids and total biodegradable volatile solids. The CO_2 evolution rate typically varies from 0-0.3 mmol $CO_2\ h^{-1}\ g^{-1}$ compost solids[45].

3.2.3.4 Respiration Rate

The respiration test is similar to the CO_2 evolution rate tests, albeit with a few modifications. Following removal of large particles (>4 mm) and inerts, the material is mixed with saturated sand (about 4:1 ratio) to adjust moisture and ensure uniform release of carbon dioxide. Before a three-day incubation at 37 °C, the sample receives additions of a Hoagland's nutrient solution and mesophillic microbial inoculant to remove any biological limitation. After three days, several sub-samples are aerated then are incubated for one hour at 37 °C and the resulting carbon dioxide concentration in the air space of the container is determined.
The results are calculated as carbon dioxide evolution per unit of volatile solids. The compost is considered relatively stable when the respiration rate decreases below 5.0 mg $CO_2\ g^{-1}$ compost solids[45].

3.2.3.5 Dewar Self Heating Test

The Self-Heating test comprise of a standardized steel container that holds approximately 2 litres of compost with moisture content adjusted prior to incubation. A maximum-minimum thermometer is then inserted to about 5 cm of the bottom of the container. The container is then placed in an area that can maintain temperatures between 18 and 22 °C for a period of 5 to 10 days. The temperature of the compost sample is monitored daily.

The results are calculated as maximum temperature rise during the test period. The typical temperature range for mature compost is < 30°C[45].

3.2.3.6 Solvita® Test

The Solvita® Test is a colour-coded test procedure that determines a maturity index based on a two-tiered test system using respirometry and ammonia gas emission. The moisture content of a composite sample is determined qualitatively by visual and "feel" criteria. Moisture adjustments or drying are used prior to running the test. A known volume (adjusted by tapping or tamping) of the sub-sample is then added to a test jar. Once the sample has been adjusted (adding water or drying) then it is allowed to incubate or equilibrate for 16 to 24 hours prior to the test. Following the equilibration period a specially treated paddle is placed in the test jar and after 4 hours the color developed on the gel surface of the paddle is visually compared to a coded color chart. Two gel results indicate CO_2 and ammonia (NH_3) concentrations.

Woods End Research Laboratory[46] guidelines for the Solvita® maturity index test indicated that the pig manure-wood compost (value of 7 after 91 d of composting) as stable. However, the dairy manure, wheat straw and dairy manure-sawdust composts only reached Solvita® values of 6 after 70 and 98 d of composting, respectively, in spite of the release of more N as the compost matures. Thus, the Solvita® maturity index had limitations to determine N immobilization potential regarding specific compost types. Nevertheless, this test method estimates respiration and NH_3. The most significant fact about this test is relatively low cost and quick analysis (Table A2), thus, it could also be used as preliminary test prior to run recommended standard tests.

3.2.4 Limitations and Troubleshooting

3.2.4.1 Limitations

Compost samples with moisture content below 30-35 percent may be biologically inactive, thereby, resulting in artificially low respiration rates in the absence of additional water. Therefore, a standard adjusted moisture content must be applied for all samples. Previously dried or cold stored samples may exhibit abnormally high biological activity (respiration) following moisture adjustment or increased temperature. Therefore, a pre-incubation or equilibration of each sample must be employed to assure accurate measurements of respiration activity. The duration of pre-conditioning or pre-incubation step may not be uniform for different laboratories and may range from 24 hours to 3 days. This could result in different and possibly erroneous interpretations for an identical sample analysis. Improperly prepared samples, such as overly moist or tightly packed in a sealed container and shipped at temperatures above about 40 °F may arrive to a laboratory in anaerobic condition and not be representative of the source material. Samples of actively composting material, particularly from thermophillic zones will largely contain microorganisms which are not active at lower, mesophillic (~37 °C) temperature conditions used in respiration based methods and will misinterpret the microbial activity. Similarly, compost from heat or moisture affected windrows may falsely test as stable due to the lack of viable microbial populations. The respirometry-based and Dewar Self-Heating procedures can provide erroneous determinations when compost with the above characteristics are tested. Moreover, costs associated with the tests can also be a limitation for compost facility (Table A2).

3.2.4.2 Troubleshooting

The limitations of microbial respiration tests can be overcame by re-equilibration of the compost samples collected from active piles at room temperature for having reliable results. The Soil Control Laboratory method for measuring potential respiration, which attempts to remove nutrient and microbial limitations, may successfully overcome the limitations due to anaerobic condition, samples from thermophilic zones, or heat damage. The Solvita test measures compost respiration rate and ammonia liberated from a standardized volume of sample, as opposed to weight. A number of factors may interfere with reliable reaction of the CO_2 gel. High levels of volatile organic acids (VOA) will interfere positively with the Solvita gel, thereby increasing the apparent respiration by as much as one unit of color change. High levels of ammonia (NH_3) in compost may lower the CO_2-evolution rate due to toxic effect on microbial activity, but errors can be corrected by reference to the ammonia gel reading. In certain cases where the compost sample is anaerobic, other gaseous by-products can be produced resulting in an offcoloring of the Solvita® gel. If the test is run at temperatures outside of the range (20-25 °C), the results should be read at more or less than four hours.

3.3 Standards, Guidelines and Regulations for Compost Maturity

3.3.1 Canada

The maturation of compost is a complex process; therefore, the prior version of CCME guidelines[11 2] offered four ways of establishing compost maturity. These methods were aimed at confirming the actual execution of the composting process. These laboratory tests had been aimed at being easy, rapid and reliable for evaluation of composts produced from all types of wastes with many different process methods. The use of more than one test was recommended, since there was no standard single test that could reliably verify maturity.

The compost maturity guideline established by CCME in 1998 is presented in Table 2.

The recent version of CCME guidelines for compost quality (2005) has been modified[11 2]. In order to be considered mature and stable, a compost must be cured for a minimum of 21 days and meet one of the following requirements:

a) the respiration rate should be ≤ 400 mg O_2 kg^{-1} volatile solids (or organic matter) h^{-1}
b) the CO_2 evolution rate ≤ 4 mg C (as CO_2) g^{-1} organic matter d^{-1}

c) the temperature rise of the compost above ambient temperature ≤ 8 °C

Table 2. CCME Guidelines (1998) for Compost Maturity[2]

Required Tests of Compost Maturity (must conform to one of the following four)	**Significance**
1. Two of three of the following tests:	
a) C:N ratio less than or equal to 25.	a) As carbon is broken down through composting, the C:N ratio drops. (C:N ratio starts ideally at 30, but can be higher).
b) Oxygen uptake less than 150 mg O_2/kg organic matter/hour.	b) Microbes require oxygen, so a drop in the O_2 required signals a slowing of microbial activity.
c) Germination of cress or radish seeds in compost equal to more than 90% of that of control sample and plant growth rate in soil/compost mix not less than 50% that of control sample.	c) Cress (*Lepidium sativum*) and radish (*Raphanus sativus*) are small seeds, quick to germinate and sensitive to phytotoxic (plantdamaging) substances like the organic acids temporarily present in immature composts.
2. Compost must be cured* for a minimum of 21 days, and must not reheat upon standing to greater than 20 °C above ambient temperature.	Microbial activity produces heat. When pile is no longer heating up, the level of microbial activity has dropped.
3. Compost must be cured* a minimum of 21 days and organic matter must be reduced by at least 60% by weight.	As composting progresses, water vapour and carbon dioxide are given off, resulting in a lighter, denser product.
4. Compost must be cured* for a six-month period.	In the absence of other tests, six months under proper conditions to promote effective composting was considered sufficient to achieve maturity.

* The conditions of the curing pile “must be conducive to aerobic biological activity”, i.e., there must be sufficient oxygen and moisture to allow microbial activity to continue.

The mandatory curing requirement for a minimum of 21 days may affect the processing capacity where a shorter compost maturity period is possible, depending upon the composting feedstock. This may lead to additional curing area requirements in the existing facilities. The lowering of allowable temperature rise of compost from 20 to 8 °C, may also require the compost facilities to employ more intense aeration and increased frequency of turning/mixing during composting process, thereby, affecting the overall treatment cost. The modified guidelines do not include analytical and molecular properties of HS-like components in compost to determine maturity due lack of research in this area.

3.3.2 United States of America

Reasoning that compost maturity ought to be determined by a test considering multiple properties, the California Compost Quality Council (CCQC) has defined the maturity index, based on qualifying by two or more standard tests which have demonstrable relevance to stability and maturity. A Maturity Index characterization requires reporting of the C:N ratio of the finished product and at least one parameter from each of the following Group A and B.

Group A

- Carbon Dioxide Evolution or Respiration (2-8 g CO_2/g volatile solids/day)
- Oxygen Demand (0.4-1.3 g O_2/g total solids/hr)
- Dewar Self Heating Test (10-20 °C)

Group B

- Ammonium:Nitrate Ratio (0.5-3)
- Ammonia concentration (100-500 ppm, dry basis)
- Volatile Organic Acids concentration (200-1000 ppm, dry basis)
- Seed Germination (80-90% of control)

3.3.3 Europe and Australia

North American guidelines and standards, while specific, do not appear more definitive than those from other western countries. A range of views and regulatory guidelines are seen regarding necessary hygiene in compost operations and products which depend upon compost maturity standards. Differences are found with regard to test organisms and duration of time and test temperatures[63]. Like many other guidelines and standards, these jurisdictions’ standards are unclear regarding performance traits: e.g. phytotoxicity, nutrients or other potentially important agronomic traits. Use of such standards by biosolids composters to imply a product meets a high standard can be misleading.

Table 3 summarizes temperature and time requirements and testing guidelines for compost products in other countries:

Table 3. Selected Compost Hygiene Standards (dependent on maturity)

Country	Compost Method	Temperature / Pathogens
Australia	All methods	> 55°C for at least 3 days; allowance for variation and lower temperatures
Germany	Open Windrow Closed/ In-Vessel PLUS All New Facilities: no presence in 25 g of: No-survival of added:	> 55°C 2 weeks or > 65°C for 1 week > 60°C for 1 week Human/Veterinary Hygiene: *S. senftenberg* W775 Phyto-hygiene: Tobacco-mosaic Virus (TMV) & *Plasmodiophora brassicae*
Austria	all composts	> 60°C 6 days or > 65°C 3 days, or > 65°C 2 x 3 days
Switzerland	all composts	> 55°C for 3 weeks, or > 60°C for 1 week, or proven time temperature relationship
Denmark	all composts	> 55°C for 2 weeks

4 SITE VISITS AND LABORATORY TESTING

4.1 Site Visits

Visits were made to the specified nine composting facilities, each of which receive over 4,000 tonnes per annum of source separated organic material from both the residential and institutional, commercial and industrial (ICI) sectors. A questionnaire was developed prior to the visits to ensure that the same questions were asked of each. A brief tour followed the interview explaining the process. At the end of the tour a composite sample of market-ready (i.e.: mature) compost material was assembled and then split into 2 equal portions. One of the samples was sent to A&L Laboratories in London Ontario, and the other sample was given to the operator so that they could also have the sample analyzed as either a verification of in house analytical methods or a comparison with a lab that they currently use. A&L Laboratories was chosen to perform the testing as they are one of the few labs in that are accredited as a Compost Quality Alliance (CQA) laboratory. The Compost Council of Canada's website defines the CQA as

> **"a voluntary program established by the Composting Council of Canada and the compost producers utilizing standardized testing methodologies and uniform operating protocols to improve customer confidence in compost selection and utilization."**

Appendix A contains a summary of the completed questionnaires. The following table summarizes the findings of the interviews.

1. All but one of the facilities believed that they could not produce compost that would meet the requirements of the 2006 Nova Scotia Compost Guidelines

2. Many of the facility operators believed they were short of the required space.

3. Many cited that they cannot control the material that enters their facilities in terms of quality and consistency

4. Most of the facilities' operators have changed or desire to change the way in which air is handled through the product and their systems.

5. Most of the operators believed that they could increase the price of their finished compost if the product were more mature.

4.1.1 Operating Parameters

The various facilities often process the organics differently to prepare the organics to begin composting, depending on the technology employed and the type of waste being received. This includes adjusting the moisture content, decreasing particle size, and adjusting the Carbon:Nitrogen ratio of the incoming feedstocks. During composting, the facilities also utilize different methods of ensuring that the oxygen demands are met. The following table provides facility information specific to these parameters.

Table 4 Operating Parameters

Facility Number	Moisture Control	Particle Size	C:N Ratio	Aeration
1	60%	1.9cm	NR	NR
2	50-60%	1cm x 3cm	Varies	1 cfm / ft^2 of compost area
3	30-64%	5 cm	Unknown	Unknown
4	NR	NR	NR	NR
5	NR	NR	NR	NR
6	Unknown until samples sent to lab	10cm	Unknown – no corrections are made due to tipping area restrictions	80-110 m^3/hr during intensive phase
7	55% in high rate phase; 50% in curing; and 45% when product leaves	6.4cm	15:1-25:1 depending on seasonal fluctuation of feedstock constituents. Bulk feedstock with screened overs when required	7 ft^3/min/tonne of material
8	Variable moisture content. Getting wetter as more IC&I feedstock is becoming available	5cm	Varies and is seasonally dependant. Lower in summer and corrections are made.	16m^3/hr during composting and is reduced to half for curing.
9	34-60%	7.5cm	Unknown – leaf and yard waste added depending on the moisture of incoming material	Unknown – has never worked

NR – Not Reported

Table 5 - Conditions that Suppress the Rate at which Maturity is Attained

	Condition	Cause(s)	Remedy(s)	Implications
1	Inadequate aeration during composting	- insufficient mixing of shredded of received material	-increase frequency of turning	- increases the amount of time necessary to mature the product
			- decrease particle size resulting from shredding	- inclusion of wet clumps that may go anaerobic
		- too wet	-mix with large woody overs	
		- insufficient porosity	-mix with large woody overs	
2	Inadequate aeration during curing	- insufficient mixing	-increase frequency of turning	
		- too wet	-mix with large woody overs	
		- insufficient porosity	-mix with large woody overs	
3	Excessive Moisture from Precipitation during Outdoor Curing	-improperly shaped windrows/piles	-stack with high angle of repose to increase ability to shed water. Use a tarp or membrane to provide physical barrier	
		-precipitation cannot drain away from windrow	-curing area constructed so that the windrow is placed on top of a crown to facilitate the movement of precipitation away from the windrow/pile	
4	Insufficient Space for Outdoor Curing	-not enough room to manage product	-increase the size of the curing yard	- requires additional land abutting the plant property, plus cost of expansion of pad
			-develop satellite curing yard if space is too constrained at the parent yard	- requires land acquisition and permitting (requires an additional operating permit for the satellite yard and a revision of the composting facilities operating approval to reflect the facilities need to ship product before it is deemed mature). - transportation cost from parent yard to satellite yard, or possibly for additional distances to market, will be added to input costs.

4.2 Laboratory Analysis and Results

As discussed, the Canadian Council of the Ministers of the Environment (CCME) 2005 Guidelines for Compost Quality *(PN1340)* state that mature compost must meet one of the following three criteria to be considered a mature and stable compost product:

1. the respiration rate is less than, or equal to, 400 milligrams of oxygen per kilogram of volatile solids (or organic matter) per hour; or,

2. the carbon dioxide evolution rate is less than, or equal to, 4 milligrams of carbon in the form of carbon dioxide per gram of organic matter per day; or

3. the temperature rise of the compost above ambient temperature is less than 8^{o}C.

The compost samples collected during the site visits were analyzed for self-heating using the Dewar flask method (Reference methods), and for CO_2 respiration (Reference method). The results of these analyses for each of the facilities are represented in the Tables 1 and 2. Each facility was given a number so as to preserve the confidentiality of the facility. The laboratory certificates are included in Appendix B.

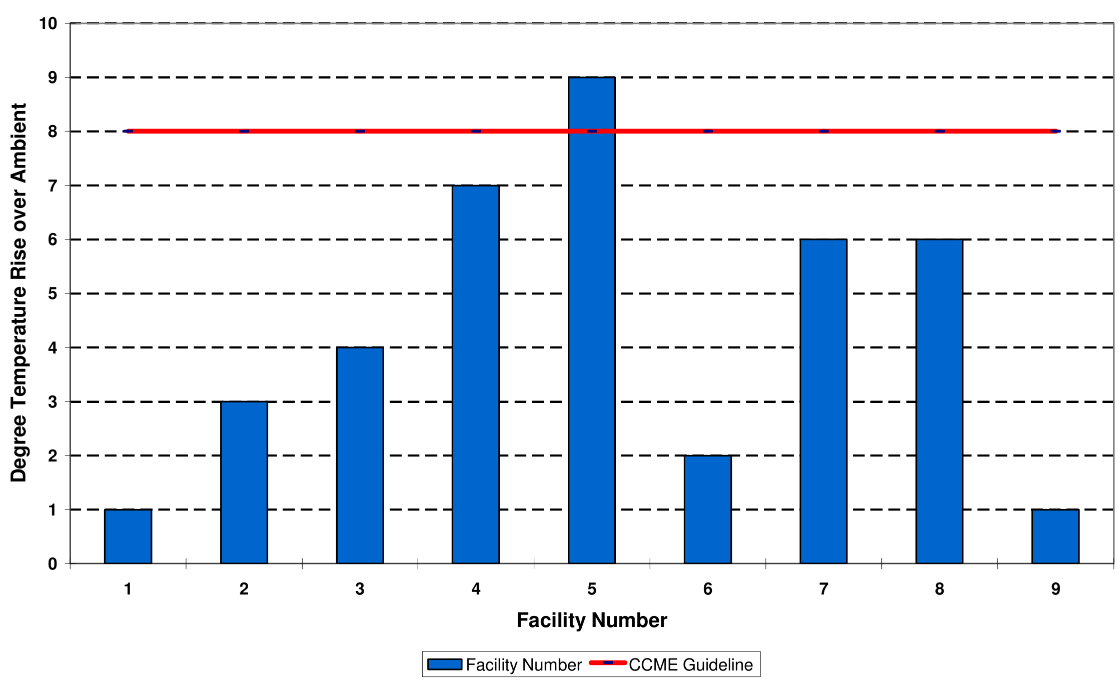

Figure 1 – Dewar Self-Heating Results

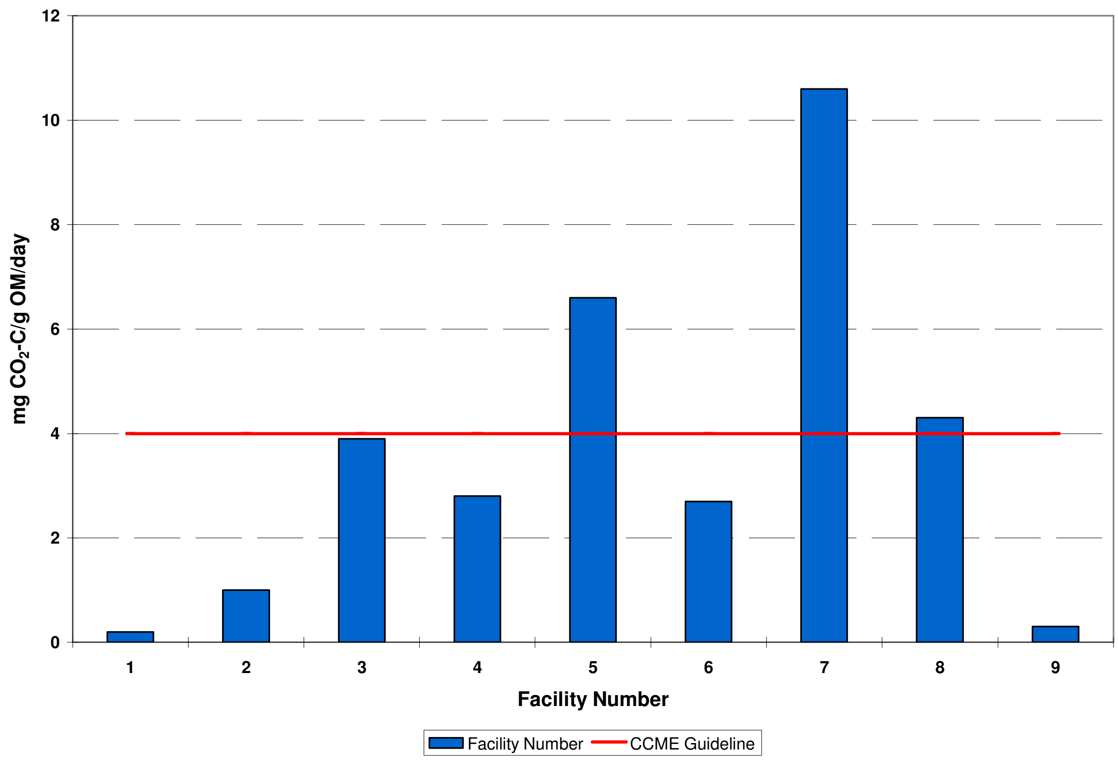

Figure 2 – CO_2 Respiration Results

The results indicate that only one of the facilities did not meet the target *CCME Guidelines* for the Dewar Self Heating test, as shown in Table 1 above.

Three of the facilities failed the CO_2 Respiration test.

Facility Number 5 failed both the Dewar Self Heating test and the CO_2 Respiration test.

Product sampled from the remainder of the facilities passed both tests.

It should be noted and understood that the above results were derived from only a single sample from each facility and represent a single snap shot in time. The results should not be taken to reflect the ongoing status of any of the operations but be used to provide an early indication of what the results could be. Clearly, to draw any definitive conclusions many more sampling events must take place to build a good dataset of information.

Facilities 7 and 8 tested their portion of the composite sample taken during the visit for comparison. Facility 7 also sent their sample to A&L Laboratories to be tested for CO2 respiration. Their result was 9.4 mg CO2 which contrasts with the value of 10.6 for the other half of the sample. Facility 8 tested their sample in a Dewar self heating flask and reports that the sample failed, which contrasts with the results from A&L Laboratories in which the sample passed with a rise in temperature of $6^{o}C$ above ambient conditions.

The variability in sample results can be explained by again stating the fact that compost is not a homogeneous medium and that there is variability of conditions and characteristics within any given sample. There is also considerable variability in the operating conditions and management of the compost facilities as evidenced in Table 4 and Appendix A. This reinforces the need to collect further samples over time to present a more statistically accurate assessment of compost quality to gain a better understanding of each individual operation and how they compare collectively. Until this is completed, it is too speculative to formulate a recommendation with respect to equipment upgrading and classifying the facilities on their ability to meet the maturity standard.

5.0 REVIEW OF EXISTING COMPOSTING EQUIPMENT USED IN NOVA SCOTIA

There are numerous technologies used to produce compost in Nova Scotia. As described in a previous section, this study only considers 9 of the 18 permitted facilities in the province. This section will briefly describe the various categories of technologies that are hosted by the 18 facilities in Nova Scotia. They are bunker, wide bed, container, tunnel, and aerated floor and open windrow. The following gives a brief synopsis of each technology.

Container

This type of system utilizes numerous stainless steel lined containers to process organic waste. The sorted organic waste is shred to increase surface area and placed into the container which is then sealed. The container is taken and plugged into an air header through an inlet and exhaust port. Air is then pushed through the organics within the container to furnish the naturally occurring microorganisms with an aerobic environment within which to thrive to consume and degrade the material. The material typically resides within the container for about 10 days to ensure that pathogen kill has occurred. Following this the contents of the container are dumped and then managed in either indoor or outdoor curing areas for the remainder of the process.

Wide Bed

The wide bed system resembles a long channel with an open top. A large paddle wheel attached to an overhead crane is suspended over top of the bed. Processed organics are loaded into one end of the bed daily. The paddle wheel turns and aggressively mixes the entire bed and by doing so, the material is advanced in the bed by a set amount daily. The underside of the bed is furnished with aeration piping which draws air either up or down through the organic material to provide the naturally occurring microorganisms with an environment within which to thrive to consume and degrade the material.

After approximately 20 days, the material has advanced the entire length of the bed and is moved by industrial loader to either an indoor or outdoor curing area where it spends a couple of months. The material is then screened and then either sold or held outdoors for further curing.

Bunker

The bunker system utilizes open topped concrete bunkers of three different sizes. Shredded organics are placed within the longest set of bunkers. Air is either pulled down into a floor channel or blown upwards and exhausted. After a week, the material is moved into the second set of bunkers which are shorter due to the volume reduction that occurs during that first time period. After another week the material is moved again to yet a shorter set of bunkers. Following this the organic material is transported to another building where the product begins curing and is passively aerated and turned about once every 3 weeks. After a period of up to 1 year the material is taken outside, screened and then stockpiled for outdoor curing.

Tunnel

The tunnel system is similar to the bunker technology with the difference being that the bunkers have a roof and door and thus are viewed as tunnels. When full the door is sealed, and a computerized air handling system regulates the air flow through the organics by pre-programmed parameters. Processed and shredded organic materials are placed within the available tunnel (Phase 1). The door is sealed and the blowers begin pushing air up through the organics. After 11 days, the material is moved from the Phase 1 tunnel to the Phase 2 tunnel. The tunnels are seemingly identical in dimension however the computer program differs slightly from that used in the Phase 1 tunnel. The Phase 1 tunnels are to provide high rate composting that is necessary to achieve pathogen kill temperatures. The Phase 2 tunnels are used as an intense curing phase and receive a different aeration program. The Phase 2 process is also for 11 days in length. Following this the organics are removed and placed within a roofed building for curing for an additional 32 days. After this time the product is ready for sale and can be stockpiled on an outdoor pad.

Aerated Floor Windrow

The aerated floor windrow system is just as the name implies. Within a large clear span building there are numerous channels that traverse the width of the building. Processed and shredded organics are formed into windrows on top of the aerated floor. The air is pulled down through the organics and exhausted to a biofilter. The windrows are turned from time to time for a period of about 2 months. Following this, the material is transported outside to an outdoor curing area.

Outdoor Windrow

Sorted and shred organics are windrowed outside on a pad and compost while exposed to the weather of the season. Windrows can be actively aerated via perforated pipes placed through the mass of composting material, with air being mechanically blown into them, or passively aerated solely by natural convection of air through the pipes into and out of the windrows. Mechanized windrow turners or a loader are used to agitate and aerate the material until such time that it is stable.

Windrow composting typically takes longer as it management is extremely weather dependant, especially during cold and wet seasons.

6.0 DESIGN AND OPERATION OF COMPOST CURING YARDS

The design and operation of a pad, whether under a shelter or not, on which compost is to be cured must satisfy two fundamental engineering objectives:

• It must provide for leachate capture such that leachate is captured, ie: it must shed waters from it to perimeter ditching or through it to other features which will convey the liquid to a point selected for treatment or transportation off site, and,

• It must provide a structurally stable and trafficable surface which will bear and withstand the vehicle traffic upon it.

These engineering objectives can be achieved in a variety of ways, using natural or manufactured materials. Natural materials are generally comprised of impermeable soils such as clay, related to impermeability objectives, and road-building aggregates such as rock and gravels for the base and surface.

The cost of construction using natural materials is highly variable according to availability, unit price, and haul distance from their source to pad, so it is difficult to generalize on costs. Where natural materials are relatively expensive, manufactured materials such as synthetic membranes, geosynthetic clay lining (GCL) materials, structural geosynthetics, filter fabrics, and underdrain piping can be used to good financial advantage.

The design approaches to achieving each objective include the following considerations:

• Geotechnical conditions, ie: the nature of the soils and groundwater found on site, must be competently investigated to determine the means by which stabilization of the base can be achieved most economically. On sites where underlying soils are inherently capable of bearing vehicle weights (on the finished surfaces), little more than a leveling and drainage course of coarse aggregate is required, topped by the selected surface course.

• Further to the above, on soils which are weak, such as clays, silts, loose sands, and the like, especially where groundwater tables are near the surface, more elaborate construction is involved. Piped or clear-stone under-drains may be needed to keep the base course dewatered, and strengthening of the base by deep layers of coarse rock will usually be indicated. Where the prices of locally available suitable aggregates are high, use of geosynthetics as noted above, or cementitious materials such soil-cement, as may be cost effective. In any event, the pad must be constructed with a structurally stable base.

• The surface of the pad must be capable of withstanding the frequent abrasion and loading of heavy vehicles, including trucks delivering and removing compost, compost turners, snow removal equipment, loaders, conveyors etc. operating on it. In many cases, especially where the operation of the pad involves frequent turning of the windrows, the pad is constructed of asphalt or concrete so as to provide all-weather capability. Less durable materials such as in-situ soils or surface courses of gravel, which are attractive as they represent lower capital costs, can provide adequate trafficability but with certain consequences. Soils and gravels will more readily abrade and become mixed with the curing compost, which may then require removal via screening at a later stage as the material moves to market. Failure to maintain the surfaces with additions of aggregate and/or regrading will soon lead to differential settlement causing ponding of leachate, or in the extreme case, to failure of the pad structure at depth, with breakthrough to underlying features.

• The degree to which trafficability requires construction of surface courses will vary greatly according to the traffic frequency and loads imposed by vehicles. At one extreme, vehicles used in a static pile operation in which windrows are placed and very infrequently turned, may be able to operate on a natural clay surface (in situ or imported), using flotation tires and by minimizing turning movements. Such as scenario may be quite satisfactory, in conjunction with careful attention to regrading to maintain crowning of the pad surface. An accordion style surface topography would be appropriate, in which each windrow is individually crowned and drainage is achieved by longitudinal swales between windrows. In contrast, a simply crowned, flat asphalt or concrete-surfaced pad could sustain frequent movement of turners, loaders and trucks under all weather conditions and higher tire pressures and much turning. This point is simply that the design of the surface should be in response to the specific nature of the operation to be carried out upon it.

• Leachate capture is often achieved by constructing the pad with a layer of relatively impermeable soils somewhere in its construction, and directing the flow across its surface to interceptors. A well crowned pad in which the impermeable layer is comprisesd of locally available (or in-situ) glacial till or marine clay soil, will adequately shed surface waters including rainfall, snowmelt, and leachate. A pad constructed in that way, with a cross-slope of about 2 to 6%, will shed water to collecting ditches or drains without penetration of the pad itself. The minimum thickness of the impermeable layer required to prevent breakthrough is a function of the nature of the soil, which should be determined through conventional civil engineering analysis such as one would use in any containment scenario. At the risk of generalizing on a topic which is very specific to the soils available in the area, one would expect to place about 500 mm of glacial till with a hydraulic conductivity in the 10^{-6} cm/sec. area. Even though a calculation may show that such a thickness is excessive considering a simple advective breakthrough model, some substantial thickness is needed to deal with the risk of potholing and wheel rutting. Again, geosynthetics such as membranes or GCL's may be cost effective where available soils are not economically competitive, bearing in mind that a protective layer of suitable aggregates must be overlaid to protect them from wheel loading and mechanical damage from equipment. An interesting, acceptable concept is to place the curing pad on the top of a landfill which is fitted with a liner system and leachate treatment system. In that concept, the pad need only be sufficiently stable to bear the vehicle traffic and surfaced so as to permit handling the curing compost without mixing it badly with the pad materials. Leachate which would pass through the pad, or off its edges, into the underlying waste in the landfill cell, would ultimately be captured in the leachate collection system and be conveyed to treatment. This could be done on the final cap of the landfill or on intermediate cover materials, in any case ensuring that leachate resulting from contact of precipitation with the curing compost material is directed through the waste or by other means to the landfill leachate collection system. Conceptually, the liner in the landfill base is the "impermeable barrier" that captures and directs the leachate to a suitable destination.

In summary, it is necessary to treat the design and operation of the curing pad as an engineering subject, in which the specific activity to take place upon it is considered in detail, and the engineering objectives of leachate capture and trafficability are properly addressed. Cost effective solutions will vary widely, and it is best to require proponents to detail the circumstances and engineering responses specific to their site and needs.

Unit costs will vary widely, from approximately $25.00 per square metre for a simple gravel base course (400 mm) topped with 75 mm asphalt, to as little as is required to bulldoze organics and vegetation from a natural, in-situ glacial till clay surface, in either case with ditches at the perimeter. A concrete pad will be considerably more than that, in the range of double the price per square metre, all else being equal.

Table 6 – Curing Pad Costing

Type of Curing Pad	Possible Range of Cost ($\$/m^2$)
In-Situ Soils	Not applicable—soil already on site; only clearing and forming needed, at about $1 – 5/ m2
Imported Clay	5-15
Asphalt	25-30
Concrete	50-60
Membrane	3-5

Related to the design and operation of the pad itself is the ditching and/or piping features needed to convey the liquids shed from the pad to the intended points of treatment or transport. The materials in which ditches are constructed need to meet the same objectives of impermeability, which may in some cases involve lining the ditches with suitable natural or geosynthetic materials. Conventional engineered features to mitigate erosion and bank instability will be needed. Piped systems would be designed as wastewater systems, with particular attention to trapping the significant sediment loads that will be carried in the leachate streams.

The leachate produced at curing pads will in most cases be relatively innocuous compared to sewage and landfill leachate, but the degree of treatment of it before discharge to the environment must be considered. Each case will vary according to the specific throughput volumes, method of management of the curing material, measures taken to minimize contact of the curing material with precipitation, and the discharge standards applicable to the receiving waters.

Groundwater and surface water monitoring features should be included, to provide reliable data on baseline and impact phenomena. Given the nature of the material being cured on the pads, simple indicator parameters related to the leachate expected from organic materials should be selected for routine monitoring and reporting.

7.0 REVIEW OF NEW COMPOSTING TECHNOLOGIES

The following are examples are of organic waste treatment technologies. They are not all composting technologies nor all they all new, however they do represent variations of management techniques that are not currently employed or are used to a lesser extent for the processing of municipal and IC&I organics in Nova Scotia. Discussion regarding what is believed to be the most suitable of specific technologies for the existing Nova Scotian facilities and their pricing will be detailed in the next sections of this report.

The technologies presented have been categorized by type of technology.

7.1 Outdoor Composting Technologies

7.1.1 Static Windrow

A windrow is defined as a pile, triangular in cross-section whose length is more than width and height. The width to height ratio is maintained around 3:1 to 2:1. The ideal cross-section of a windrow pile allows for generation of sufficient heat and maintenance of temperature, still suitable enough to allow oxygen to diffuse to the interior of the pile. For most materials windrows are constructed between 4 and 7 feet in height with a width from 10 to 16 feet. The pile is aerated either manually or using automated machinery such as a bucket loader or by specialized compost turners equipped with augers, paddles, or tines. Turning allows re-introduction of air into the pile and increases porosity so that efficient passive aeration from atmospheric air continues at all times, and as well as the inner portions of the piles (low in oxygen) are exposed to the atmosphere.

There are many facilities throughout the world that employ this type of composting. It is not necessary to procure a highly mechanized technology as what is more necessary is proper site selection and having an operator that understands the process science. However, there are companies that do market their expertise and provide design assistance to develop a compost facility. Biomax Inc. is such a company that have more than 15 facilities in Quebec and New Brunswick.

7.1.1.1 Maxipile

The MaxiPile technology is developed by Biomax Inc. which incorporates simple turn-over mechanism for static pile composting of organic waste. This system requires relatively more space and time, but offers easy operation (Figure 3). The waste to be composted is placed into relatively large piles (windrows) and oxygenation is ensured through mechanical turn-overs. The turnover frequency and the type of machinery used is determined based on the productivity required.

These types of facilities do work well if they are sited on large tracts of land, remote from other uses, and with low permeability soils and slope to prevent odour impingement and groundwater contamination respectively. Surface water is generally directed to a lagoon to reduce suspended solids and then to a wetland to provide further treatment of the water prior to it being released back to the environment.

Due to the nature of residential and IC&I organic waste being moist and of relatively small particle size, this system normally requires bulking with larger sized blocky materials such as bark to promote air exchange throughout the pile.

The management of the composting windrows requires the operator to be wary of current and forecasted weather conditions as turning can only be performed when the land is sufficiently dry enough for machinery transport but also to prevent waterlogging of the compost.

Figure 3. Biomax Inc. Maxipile facility at Québec

7.1.2 Aerated Static Windrow

Aerated static pile composting requires the composting mixture to be placed in piles that are aerated using forced or naturally convected air. The windrows are equipped with a network of pipes, which supplies the oxygen for composting. Quicker and more controlled composting rates are achieved by mechanically blowing the air supply, either under positive or negative pressure in the piping. The forced, controlled air supply enables construction of large piles, which increases the composting capacity per unit of land area, making it somewhat more efficient than naturally aerated outdoor windrow systems.

The odours from the exhaust air may be removed using filters and scrubbers. Aerated static pile composting systems have been used successfully for municipal solid waste, yard trimmings, biosolids, and industrial composting. It can be carried out under a roof or in the open. The cover provides protection from the elements. Examples of aerated static pile composting technologies are produced by Engineered Compost Systems Inc. and W.L Gore.

7.1.2.1 AC Composter™

This is a covered aerated static pile system developed by Engineered Compost Systems Inc. It provides a cost effective approach for controlling odour, volatile organic compounds and NH_3 emissions. The cover material is designed for negative-only aeration and includes single direction air inlets. Suction from the negative-only aeration makes the cover material cling to the piles (Figure 4 & 5). This technology is appropriate for composting most feedstocks (yard waste, food waste, source separated organics, biosolids and industrial wastes) and provides an effective barrier to vectors (birds, rats, flies).

The aeration can be provided by in floor or above grade pipe. The above grade pipe system called CompDog is a collapsible tube which has 3 inflatable bladders within it. (Reference: http://www.compostsystems.com/ac_composter_video.html). The composting organics are placed over the Compdogs and then the cover placed on top. After 6-12 hours the Compdog is deflated and pulled out of the windrow leaving a tunnel within the windrow. The aeration system is then started and pulls air from the tunnel and the remainder of the windrow. The process is repeated every 15-20 days to ensure thorough aeration throughout the windrow.

Figure 4. AC ComposterTM based facility at Silver Springs Organics, LLC. Tenino, WA

Figure 5- CompDog System for AC Composter

7.1.2.2 Gore Cover Systems

The Gore Cover System manufactured by W.L. Gore and Associates Inc. in appearance is very similar to that of the AC Composter but in operation is a completely different system. The Gore system uses an underlying aeration system that forces air upwards through the windrow. The proprietary Gore fabric that covers the windrow allows gases and water vapour to escape but does not permit precipitation to enter the windrow or odour to escape. Because of this, there is no need for a biofilter.

Gore has over 150 facilities in 20 different countries processing over 2 million tons of organics using plants with capacities ranging from 3,000 to 260,000 tons per year. Figure 6 illustrates the Gore system using either the in-floor and on-floor aeration techniques.

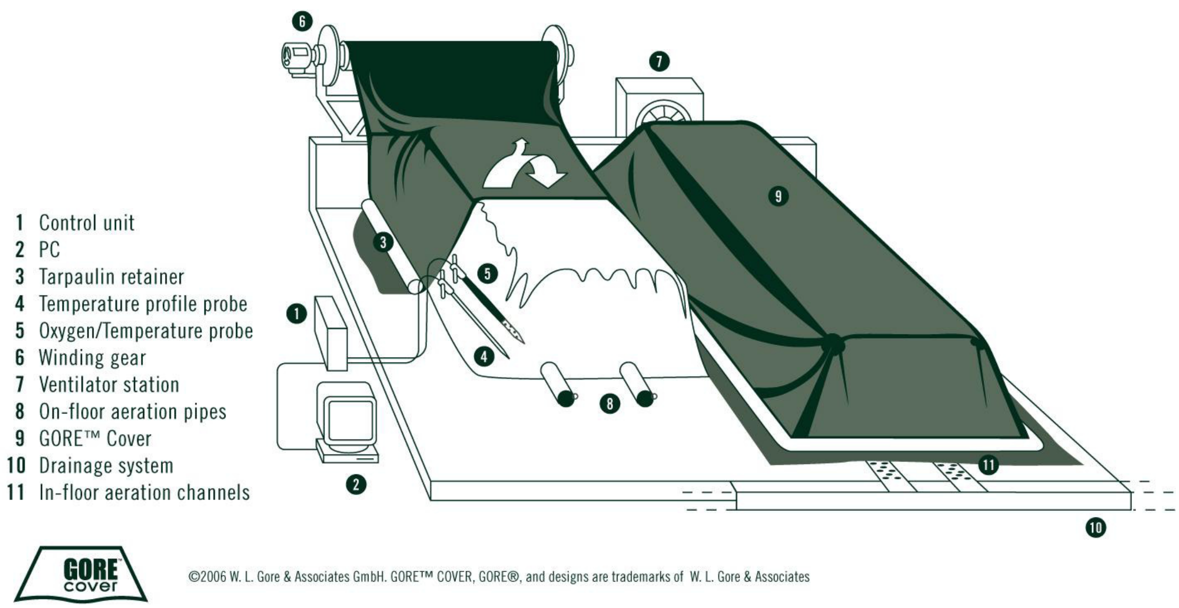

Figure 6 – Gore Cover System Layout

7.2 In-vessel Technologies

In-vessel composting systems are systems which process organic waste in a completely isolated and controlled environment (inside vessels or buildings) and can be operated regardless of the outside weather conditions. The organics are kept within the vessels or buildings until such time that they are no longer putrescible thereby decreasing the potential for odour events and attraction of vermin.

In-vessel systems are available in continuous-feed as well as in batch modes. Many of the technologies are also modular meaning that additional capacity can be added during operations without impacting production of the existing plant. Most of the product managed in in-vessel systems requires further curing after being discharged from the vessel.

There are various in-vessel systems that have been developed and are in use in many parts of the world but not at this time in Nova Scotia, namely, Engineered Compost Systems Inc., HotRot Exports Ltd., Nature's Soil, Inc., NaturTech Composting Systems, Wright Environmental Management Inc., Green Mountain Technologies, Biomax Inc. and BioSystem Solutions Inc.

7.2.1 SV Composter

The SV Composter (Stationary Vessel) is a variant of the tunnel technology developed by Engineered Compost Systems. Tunnels are preloaded with organics, making it a batch system, at which time the doors are sealed. The controlled aeration system then blows the amount of oxygen required into the tunnel. These insulated tunnels can be built within a building or outside. Loading of the tunnels can be done with a loader or by conveyor. The capacities of these facilities range from 1-500 tons per day. Figures 7 and 8 show how this technology can be placed either within a building or outside as a stand alone unit.


Figure 7. SV Composter located within plant


Figure 8 - SV Composter located outside

7.2.2 HotRot Composting Units

The HotRot composting technology (Figure 9) developed by HotRot Exports Ltd. Is a continuous fed reactor that receives regular mixing of the organic feedstock. The slow mixing reduces the creation of zones of poor porosity, air channelling and uneven treatment. The organics are fed into one end of the vessel, and the machine achieves mixing by means of slow rotation of the mixing shaft. The rate of throughput is set in accordance with the desired processing time, which depends upon the desired quality of the final. A partially composted product can be achieved in 10 days, but the product at this point still requires extended curing to produce a mature compost. Company literature indicates that a stable product can be achieved in 18-25 days without the requirement for further curing, and that no leachate is produced.

The different models of this technology have a capacity range of as little as 0.2 tons/day to 11 tons/day, which can be easily increased due to modular design.

Figure 9. HotRot composting unit at New Era Technologies, Halifax, Canada

7.2.3 Wright Environmental Management In-Vessel Composter

The In-Vessel Composter (Figure 10) developed by Wright Environmental Management Inc. is a daily fed plug flow type of composter. Everything in the unit is contained within a box resembling a shipping container. The floor of the container is made up of trays which support the mass of organics above. At the beginning of the operational day a hydraulic ram pushes the trays horizontally to advance the plug within the container. This causes one of the trays in the system to be forced out of the other end.

Air is continuously circulated around and through the composting material to allow accelerated microbial activity. As the decomposing waste passes through the vessel on the trays, it traverses through three composting zones and two mixing zones. The temperature, oxygen and humidity levels are constantly monitored within each zone and airflow rates are controlled to optimize composting conditions. The temperature is maintained around 72 °C for pathogen removal and accelerated microbial activity. Normally, the oxygen level in the vessel is maintained around 17%, and the process requires minimal amounts of water.

In the mixing zones, proprietary spinners advance the waste forward to ensure proper mixing and aeration. The negative air pressure maintained by the system prevents air from escaping from the vessel and ensures that all exhausted air is passed through an integrated biofilter to remove contaminants and odours. The waste retention time can be as high as 28 days in the vessel before curing. This technology is well established and has close to 55 installations in United States, Canada, and the United Kingdom.

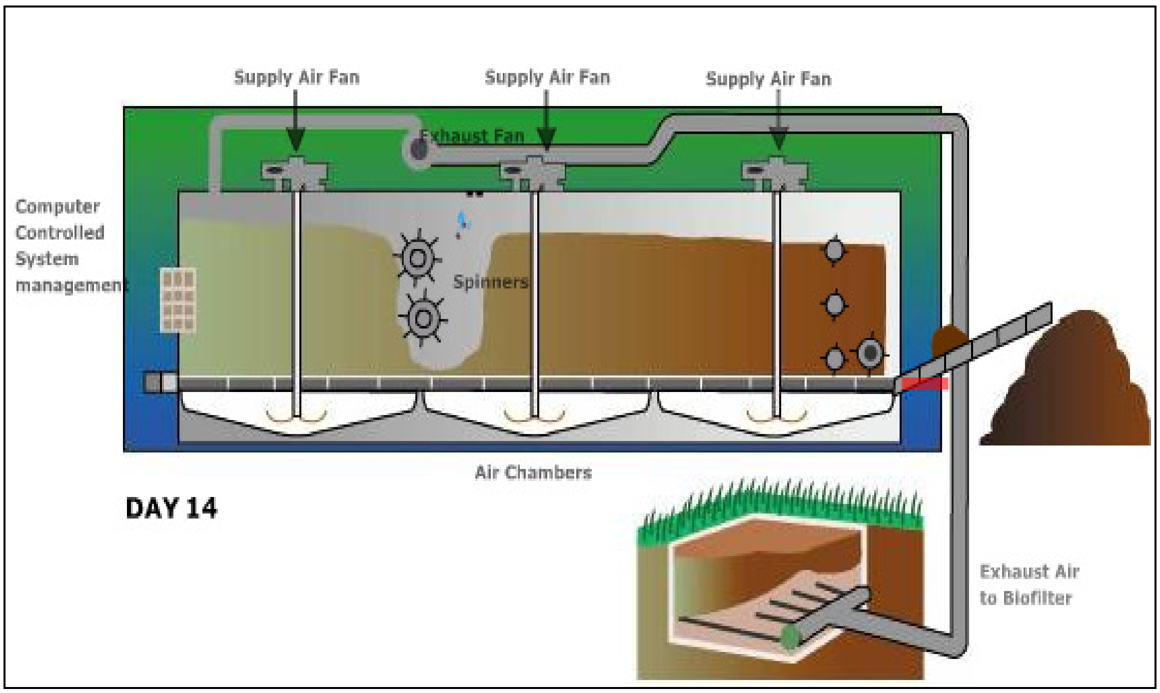

Figure 10. Process description of Wright Environmental Management Inc. In-vessel system

7.2.4 AirLance™ Composting System

This in-vessel composting technology developed by American BioTech Inc. (Figure 11 & 12) is very different from any other in-vessel system presented. The technology is used in a 700 ton per day facility in New York and has been operating for 12 years. The system is made up of several cells (number depends on size of facility and daily throughput). The pre-processed organics are added to the top of the cell. The company likens the daily addition to the cell to a card and that multiple daily additions begin to build a stack of cards. Additionally, each day, an auger removes material from the bottom of the cell. This then causes the contents in the cell to fall. A cell takes about 0.5 hours daily to maintain.

Within the cell there are several probes which can either disperse or draw air controlled by a computer interface. These probes are called the Air Lances. They can be controlled independently so as to self clean the holes in the lance. Air drawn from the lances is then sent to a biofilter.

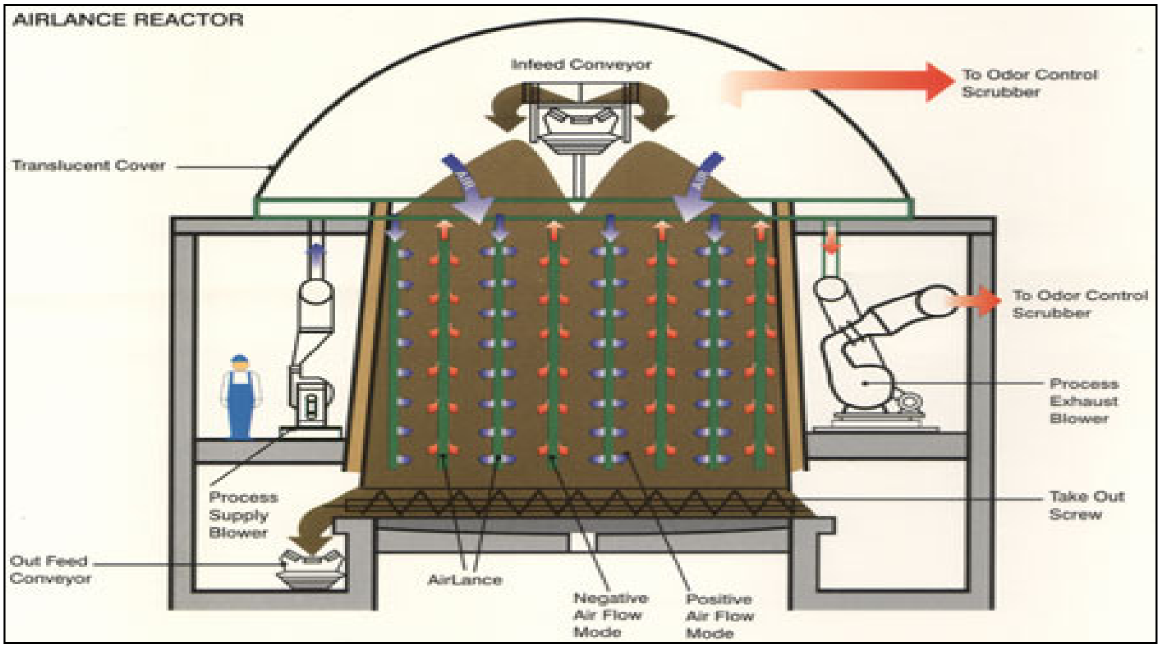

Figure 11 - Schematic cross-section showing aeration movement of the AirLance system


Figure 12 - Top view of AirLance cells

7.2.5 RobotCompost™

RobotCompost™ is a horizontal bunker silo type composting system developed by Biomax Inc. and combines agitation and forced aeration. In general, it is constructed of two or more coupled concrete bunkers measuring 4.2m wide and 40m long with a double floor that serves as a continuous plenum to diffuse the forced air through the composting organic mix above it (Figure 13). A mechanical agitator on a rail (on the top of the bunker wall) is used to homogenize the waste while moving from the entrance to the outlet over a waste retention period of 18 to 21 days. At the outlet, a Biomax Inc. proprietary designed module grabs and automatically evacuates the raw compost toward the maturing zone. This module can also transfer the mixer from one bunker silo to the next.

A freestanding and isolated gas chamber above the silos collects and sends the process gases to a processing and biofiltration unit. This automated composting technology can process more than 100,000 tons of organic wastes per year. The entire operation is controlled by a programmable logic controller which can be managed online. Peripherals, including an air-water system, a heat recovery unit, a bunker-biofilter, wells for maintenance and mixer clean-up, and a weather station are also available depending upon process requirements.

Figure 13. Side-view of RobotCompost system

7.2.6 BioChamber™

The BioChamber™ is a self-contained, automated, in-vessel thermophilic composting system developed by BioSystem Solutions Inc. for processing food waste (including meat, dairy & fish waste), animal manure, sewage sludge (biosolids) and other biodegradable organic materials. This system is scalable and features a modular design which allows for waste processing capacities from 1 to 800 or more tons/day with minimal space requirements.

The BioChamber™ is equipped with automated loading, turning and compost discharge, and process controls for temperature, oxygen and moisture content to maintain ideal conditions for accelerated stabilization of waste without odor (Figure 14). The composting temperatures and residence times can be easily adjusted so as to optimize the process in response to product quality objectives. All exhaust air is treated through an integrated bio-filter which controls odor and captures 100% of leachate (liquid) for agricultural/garden reuse. In general, the process is programmable for 7-21 day organics waste retention time. The BioChamber™ can be used as a stand-alone system as well as an ideal pre-composting stage for other processes to produce valuable end products.

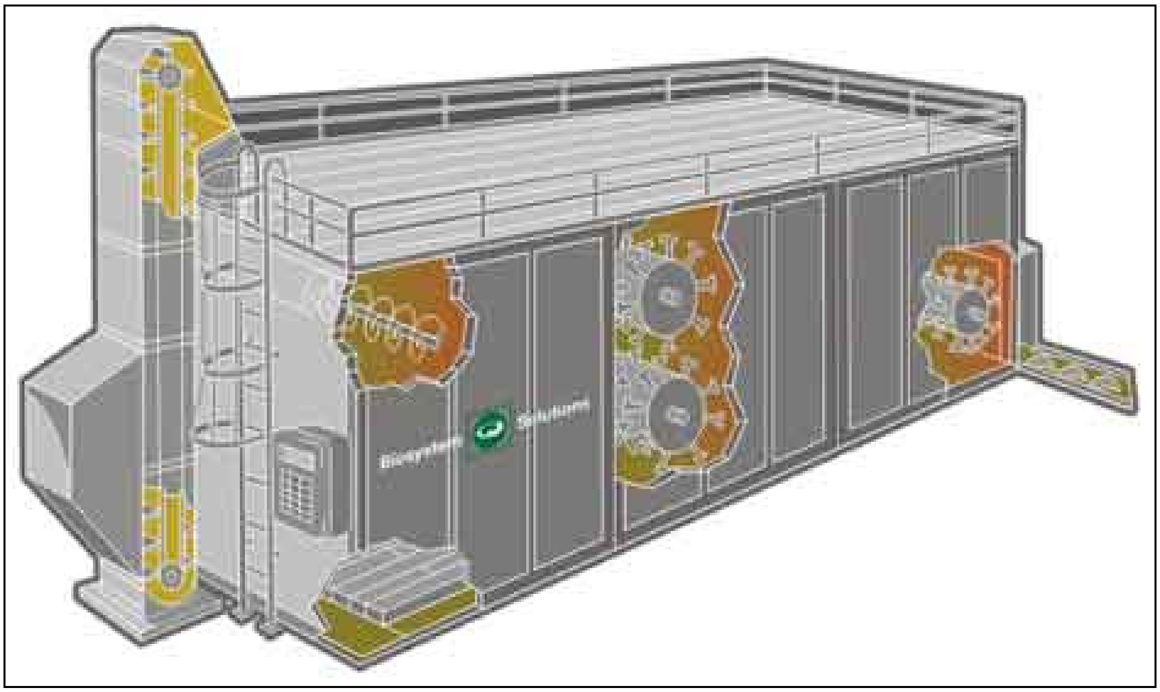

Figure 14. In-vessel BioChamber™ composting system

7.3 Anaerobic Digestion

Anaerobic processes are well established for biologically stabilizing biosolids from municipal sewage treatment plants for many years. However, several commercial systems have been developed and implemented to a limited extent to stabilize municipal solid wastes. Anaerobic processes involve facultative organisms (acetogens) to break down complex organic materials to alcohols, volatile fatty acids, hydrogen and others in the absence of oxygen, following which strictly anaerobic bacteria (methanogens) act to produce methane from the alcohols, volatile fatty acids, and hydrogen.

Under efficient operation, these processes can generate sufficient energy in the form of methane, which constitutes somewhat over half the gas produced, to operate the process as well as surplus as saleable product. On the other hand, conventional composting systems need substantial overall energy inputs to aerate or turn piles. Anaerobic digestion of waste feedstocks exist as single-stage or multiple-stage digesters.

The single-stage process consists of one air-tight container. The waste feedstock is mechanically shredded and placed in the container with suitable amounts of water and nutrients, if required. The digester may also contain an agitation system. The amount of water/nutrient added and the presence or absence of agitation equipment depends on the particular proprietary process employed.

Two-stage digestion involves circulating a liquid supernatant from the first stage digester to a second-stage digester which may also eliminate the need for agitation equipment and also provide more flexibility of control of the biological process. A stabilized residue is generally obtained after the completion of the digestion process and the residue is either removed from the digester with the mechanical equipment such as bar conveyors, or pumped out as slurry.

The residue is chemically similar to compost but is less in quantity and contains much more moisture. Conventional dewatering equipment is used to reduce the moisture content enough to handle the residue as a solid. However, the digested residue requires further curing by windrow or static pile systems in order to be used as finished soil amendment. The material retains fertilizer values as the process does not remove phosphorous, nitrogen or potassium (the PNK values).

The organic fraction of municipal solid waste can be composted aerobically, but there is a growing interest in anaerobic digestion of the organic fraction of municipal solid waste due to good business cases seen in the overall process. However, some of these technologies are only cost effective at large throughput volumes, and their applicability to Nova Scotia's composting plants' issues concerning maturity of product, must be assessed carefully before decisions are made to implement them.

Some current and future anaerobic processing based composting technologies are:

7.3.1 ArrowBio Process

The ArrowBio process is a mechanical biological treatment system patented by Oaktech Environmental Ltd. that uses water as a carrier for the gravitational separation of inorganic and organic fractions of municipal solid waste under anaerobic conditions (Figure 15). This process is an Upflow Anaerobic Sludge Blanket (UASB) Digestion system which is optimized for maximum biogas yield. In addition to being sustainable policy, the gas/electricity produced is approximately five times the operational load of the plant. The surplus energy can generate revenues which can offset the operating cost of the plant.

In addition to the energy, the process also produces digested biomass which is used as low cost organic amendment for agricultural/garden use. A full scale plant in Tel Aviv, Israel has a working capacity of 70,000 tons/year of municipal solid waste, which produce around 18000 m^3/day of CH_4 (70-80% of the overall gas volume, depending upon waste composition) that is equivalent to 2.5-3.0 MW of continuous generation of electricity. The system can process 200 tonnes/day and can be expanded by 100 tonnes /day modular units.

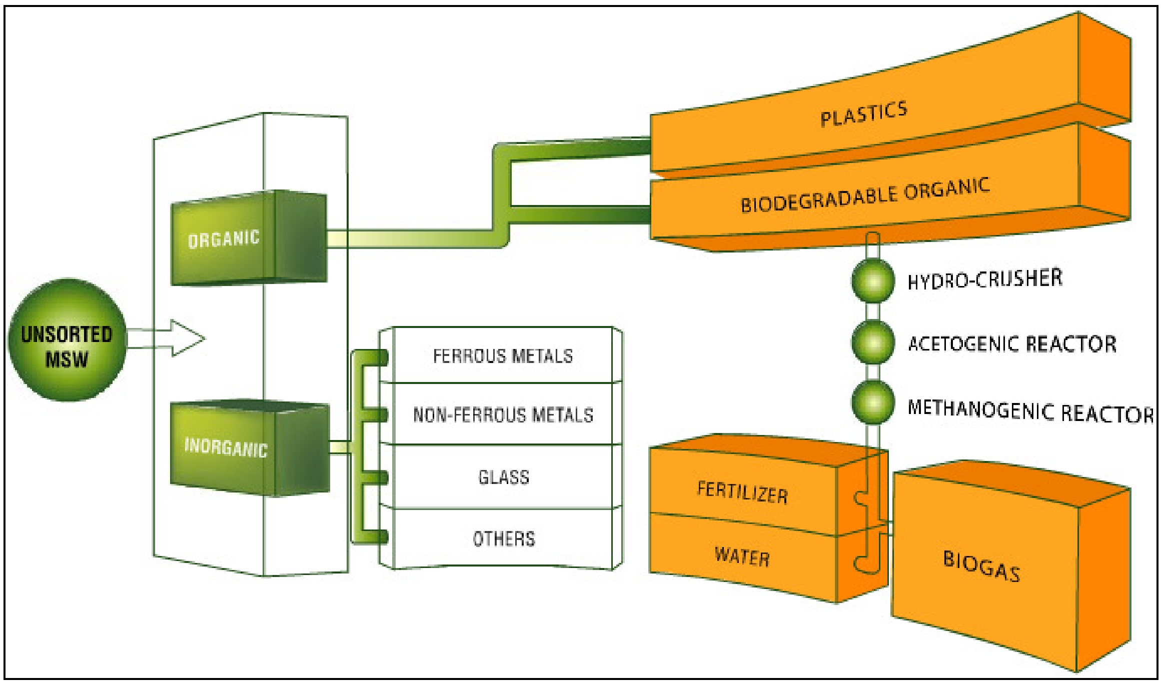

Figure 15. ArrowBio process flow diagram

7.3.2 DRANCO process

The DRANCO process has been developed by Organic Waste Systems, Belgium for the anaerobic conversion of solid organic wastes, specifically the organic fraction of municipal solid waste, to biogas and a humus-like final product, defined as Humotex. The digester operating temperature is 55°C and the total solids concentration is around 32% (w/v). The average biogas production rate of this process is 3.33 m^3 CH_4/m^3 /reactor/day which is equivalent to about 440 KWh electricity/ton waste. The gas production process is complete in 3 weeks.

The DRANCO process utilizes a proprietary dry anaerobic fermentation technique in order to produce both biogas as well as a stable humus-like final product, called Humotex. The raw material is introduced at a total solids content of 25-40 % (w/v). The overall efficiency of a reactor is very high in comparison with a conventional low solids reactor (about 5 to 8 times more biogas is produced per unit of reactor volume).

The second important characteristic of the DRANCO process is the operating temperature range of the reactor. As dry or solid fermentation can take place at both mesophilic (30 - 40 °C) and thermophilic (50 - 60 °C) temperatures, the DRANCO process utilizes a thermophilic operation as this improves the rate of bioconversion and overall energy efficiency. The DRANCO process itself consumes 30 to 50% of the produced electricity.

The digested residue is subsequently dewatered to 60% total solids by means of a screw press/filter press. The filtered liquid is further treated in an evaporation plant and the cakes from the filter press/screw press and the dried sludge of the evaporator are mixed. The Humotex thus produced is stabilized and free of pathogens.

The high temperature of the process ensures pathogen free Humotex. However, concentrations of heavy metals can only be controlled through source separation to have a waste stream of only vegetable, fruit, garden and non recyclable paper waste. A full scale DRANCO-plant under operation in Brecht, Belgium has a treatment capacity of approximately 55,000 ton per year of vegetable, fruit, garden and non-recyclable paper waste (Figure 16).

Figure 16 - Dranco installation Brecht, Belgium

7.4 Vermi-composting

Vermi-composting is composting with worms. The use of worms accelerates the process of decomposition of waste to produce a richer end product. The worms work in symbiosis with microbes to execute breakdown processes.

The worms need to be kept warm during the process. The most frequently used worms for vermi-composting are red wigglers (*Eisenia foetida*) on the other hand, earthworms found on the prairies are not suitable for vermi-composting. The success of vermi-composting depends upon maintaining optimal worm to waste ratio, waste type, composting temperature (16-27 °C), moisture content, aeration, and protection from sun light.

The maintenance of worm requires "bedding" to provide a balanced diet as well as a damp, light and fluffy matrix to allow air exchange. Vermi-composting is very suitable for the production of high quality plant fertilizer compost. However, the process is relatively susceptible to handling and environmental factors (mixing, aeration, temperature and waste composition) and the complete process may take as long as 3-6 months. An example of a larger vermi-composting based technologyies is produced by BioSystem Solutions Inc..

7.4.1 BioLane™

This is an automated, scalable and stackable large volume, in-vessel vermi-composting system invented by BioSystem Solutions Inc. (Figure 17). It is designed to optimize and accelerate the waste conversion process utilizing high densities of worms to convert biodegradable waste into a premium soil product - worm castings. Biolane™ is equipped with a climate controlled environment for maximum waste conversion efficiencies in all climates, year round. Proprietary automated waste loading, worm separation, soil harvesting and collection system increases overall process efficiency. The existing capacity of the waste processing varies between 1 to over 200 tons/day.

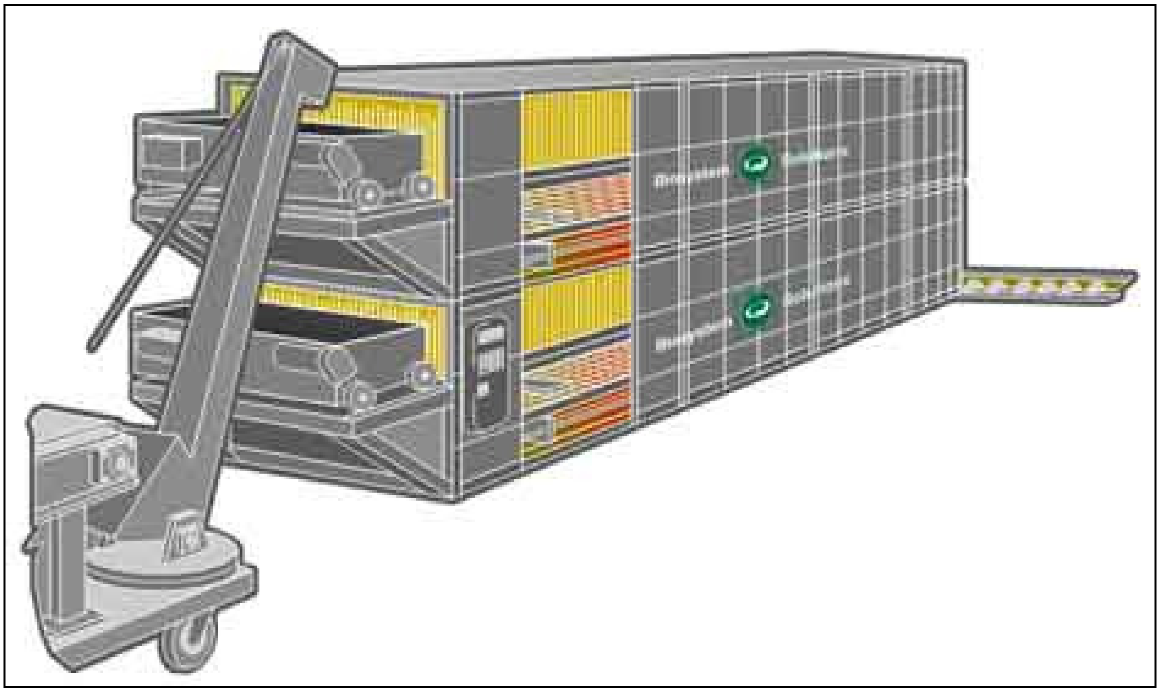

Figure 17. Fully Automated Vermi-Composting System for large scale use

8.0 ASSESSMENT OF THE BENEFITS OF COMPOST FACILITY UPGRADING

Consultations were made with industry stakeholders, such as landscapers, garden nurseries, custom soil manufacturers, and garden centre retailers to see if increasing the level of compost maturity to a point satisfying the 2006 guidelines would yield greater revenue for the sale of product.

Currently the compost facilities sell their products for between $2.50/tonne to over $50.00/tonne. The table below shows the price that is currently obtained by the stakeholders for their compost product. Many of the operators suggested that a higher price could be attained if a greater level of maturity could be reached. Some of the operators suggested that a greater price could be achieved if the aesthetics (inclusion of foreign objects such as scraps of plastic and glass shards) of the product were improved.

Table 7 – Facility Compost Product Costing

Facility	Price per Unit *
1	$20/yd^3
2	$20-30/tonne
3	$5-18/ yd^3
4	$20/ yd^3
5	$20/tonne
6	$17-50-30/tonne
7	$25-30/yd compost blended soil
8	$2.50/tonne
9	$44/tonne

* assume 2 yd^3 to each tonne

The views of the industry stakeholders contacted were widely varied. The following list is a summary of the responses received when asked if a more mature product would command a greater price in the market place. Appendix B tables these responses.

1. Compost sold for residential use,

• Maturity is not the issue. Moreover, it is the aesthetics of the product which prevents a higher sale price.
• Difficult to compete with the bagged market as sold by the larger grocery chains;
• Difficult to dry material sufficiently for bagged market

2. Compost sold for Landscaping and Commercial Use

• For sod applications, maturity is less of an issue because it is mixed with soil;
• The same sentiments expressed concerning residential use was echoed by some top soil manufacturers

• Overall, most thought that they could not retail their products for a higher price if they were to produce compost that was matured more than the industry is currently providing, specifically to the 2006 guidelines.

A couple of compost producers in the region stated that the bagged market is too difficult to enter because of the inability to dry the material sufficiently for bagging and difficulties in achieving thorough cleaning. The wet product in a bag produces an odour and produces and grows a green algal type substance on the interior of the bag which detracts customers. Mixing the product with peat to help dry the product and absorb odour was discussed but it wasn't felt that they could remain competitive with the products produced for the likes of the major grocery store chains.

In spite of the above comments one of the compost producers still sells a considerable volume of bagged product. This product has been screened very fine (3/8"). They claim that their company captures 65% of their total revenue from 30% of their overall product.

It seems that, at this time, the largest positive influence on price would be to improve the aesthetics of the product and to provide a means of preventing stored product from getting saturated with water. Specifically, this means that more education and enforcement are necessary to ensure that the compost facilities receive a feedstock that has less plastic and glass.

Other factors that would require consideration when evaluating the need for facility upgrading include leachate treatment costs, transportation costs, and odour potential. Reducing or minimizing any of these should be taken into consideration when preparing a detailed analysis of the costs of upgrading. This analysis would be part of a facility specific evaluation and has not been completed under the scope of this study.

9.0 RECOMMENDATIONS TO ACHIEVE REQUIRED COMPOST FACILITY PERFORMANCE

It appears that academics, governmental officials, and practitioners are gaining a better understanding of the science of composting and in particular the operational practices leading to the making of a quality product.

It was evident during the facility interviews that the majority of the operators have overcome significant operational hurdles and learning curves to bring the state of the composting industry in Nova Scotia up to where it is today. As a result of the early stresses the operators have learned what does and does not work well in their facilities and have adapted as well as they can to get the most out of their technologies, usually within very limited budgets for technology improvements.

The general recommendations made in this report are focused on meeting target objectives for product maturity. It is believed, and operators have said this clearly, that there is a need for a greater level of education and enforcement to decrease the contamination levels in the waste receipts, as the quality of the feedstock affects the aesthetics of the product, through the presence of foreign objects that persist in the processing of the material. However, that issue, legitimate and important though it may be, does not relate to the issue of maturity of the compost material.

The major remedial actions should be to improve the maturity of compost product to the desired standard, where it is not already achieved, in a cost effective and quick fashion. Technology and management practices in some cases require change. In addition, preventing moisture saturation during curing and storage will maintain product quality. To accomplish this however, more product testing and facility specific study are necessary.

Recommendation 1 – Compost Sampling and Facility Specific Study

It was learned that much more information is required from each of the facilities to provide greater insight as to how the facilities would perform when the new standards come into effect. It is recommended that the compost facilities submit compost samples for maturity analysis (using accepted tests based on the 2005 CCME maturity standard) after 3 months following receipt and then again in 6 month intervals. This approach standardizes the way data is obtained so that facility comparisons can be made as well as gain a better understanding as to how each of the facilities performs.

It must be noted that because the nine facilities are so different in terms of technology and feedstock quality, there is no set of recommendations applicable to all that would provide a common solution to address the objectives. The following 2 recommendations are variously applicable to the nine plants:

Recommendation 2 - Utilize a "bolt-on" technology to further the degree of maturation of the compost product at the existing compost facility locations.

This means that a suitable technology would be integrated into the existing operation to optimize the maturation process.

Section 7 briefly described various types of technologies that are not currently in use in Nova Scotia. The following table uses a matrix to explain the suitability of the technologies as suggested candidates that will further the state of maturity being produced.

Table 6 -Available Technologies Not Already in Operation in Nova Scotia

Technology	Technology Type	Modular*	Front End / Back End Process	Integratability with Current Systems**	Comments
Maxipile	Static Windrow	**Y**	**Front/Back**	**Y**	Most facilities are either situated on or have access to large tracts of land
AC Composter	Aerated Windrow	**Y**	**Front/Back**	**Y**	Uses existing commonly used mobile equipment
Gore Cover Systems	Aerated Windrow	**Y**	**Front/Back**	**Y**	Requires no other mobile equipment that isn't currently used
SV Composter	Tunnel	**Y**	**Front**	**N**	Requires building
Hot Rot Exports	Continuous Flow Vessel	**Y**	**Front/Back**	**Y**	Small Footprint, thorough aeration, no leachate, local presence for support, pilot plant operating in Halifax
Wright Env. Mgmt. Composter	Continuous Flow Container	**Y**	**Front**	**N**	Designed as Front End system, mixes only in one part of the container
Air Lance Composting System	Plug Flow Vessel	**Y**	**Front**	**N**	Requires building
Robot Compost	Bunker	**Y**	**Front**	**N**	Requires building
BioChamber	Continuous Flow Container	**Y**	**Front**	**N**	Designed as Front End System,
ArrowBio Process	Anaerobic Digestion	**Y**	**Front**	**N**	Designed only as Front End system, Requires fresh organics for optimized methane production
DRANCO Process	Anaerobic Digestion	**Y**	**Front**	**N**	Designed only as Front End system, Requires fresh organics for optimized methane production
BioLane	Vermicomposting	**Y**	**Front**	**N**	Worm populations are sensitive to temperature and feedstock quality

* - assumes that current front end pre-processing can still be used

** - assumes that much of existing equipment can be used

Front End - means a technology that is designed to process fresh organics

Back End - means a technology that can process both fresh and pre-composted organics

The technologies were assessed based on their ease of integration into existing operations and also the way they would aid in furthering the maturity of the compost currently being produced. These technologies can also act as stand alone systems, meaning that they can be expanded to assume greater roles as the existing plants continue to age and some equipment becomes obsolete or undersized. The 3 suggested bolt-on technologies are,

- *AC Composter developed by Engineered Compost Systems;*
- *Gore Cover Systems by W.L.Gore & Associates, and;*
- *HotRot developed by HotRot Exports Limited.*

Budget pricing obtained from these technology providers is shown below for 4,000, 10,000, 20,000, and 40,000 Tonne/yr facilities, with the exception of the outdoor windrow facility since it was felt that the operators already have sufficient experience. The pricing is given for comparative purposes only and would require refining when site specific conditions are taken into account that could influence cost of materials, land, amongst others.

Engineered Compost Systems AC Composter – 35 day retention time

Design Data					
Total Mix Weight - Annual Amount	Tpy	4,000	10,000	20,000	40,000
Assumed Settled Mix Density	kg/m3	533	533	533	533
Total Retention Under Aeration & Control	days	35	35	35	35
Estimated Average Continuous Fan Power	Hp	4.5	5.6	6.4	11.5
Total Facility Footprint (1)	m2	1,000	2,100	3,900	5,900
Length of Pushwall (Typically 1.8 m high)	m	37	66	99	143
Capital Cost Estimate					
ECS AC Composter™ Package Includes: Process design; startup & training, AC cover system and mobile roller; automated controls; aeration equipment; CompDog pipeless aeration floor system with inflation, FOB NS	USD	$340,000	$550,000	$680,000	$980,000
Other Construction Costs Not Included Grading & paving, surface water control, push walls, utilities, shed for control system, ACC installation, biofilter, permits, site engineering.					

Engineered Compost Systems AC Composter – 65 day retention time

Design Data					
Total Mix Weight - Annual Amount	Tpy	4,000	10,000	20,000	40,000
Assumed Settled Mix Density	kg/m3	533	533	533	533
Total Retention Under Aeration & Control	days	65	65	65	65
Estimated Average Continuous Fan Power	Hp	7.2	8.7	11.5	23.0
Total Facility Footprint (1)	m2	1,500	2,900	5,200	10,300
Total Length of Pushwall(s) (Typically 1.8 m high)	m	46	77	126	231
Capital Cost Estimate					
ECS AC Composter™ Package Includes: Process design; startup & training, AC cover system and mobile roller; automated controls; aeration equipment; CompDog pipeless aeration floor system with inflation, FOB NS	USD	$390,000	$600,000	$870,000	$1,380,000
Other Construction Costs Not Included Grading & paving, surface water control, push walls, utilities, shed for control system, ACC installation, biofilter, permits, site engineering.					

Note: Includes aeration floor, mechanical space, biofilter, and approach apron.

W.L.Gore & Associates – Gore Cover Systems

GORE™ Cover System	Configuration	System Pricing
In Floor Solution		
5,000 ton (25m x 8m x 3m)	4 heaps (4 covers) NO Mobile Winder	€ 300,000. 00 EURO
10,000 ton (25m x 8m x 3m)	8 heaps (6 covers) with Mobile Winder	€ 700,000. 00 EURO
20,000 ton (50m x 8m x 3m)	8 heaps (6 covers) with Mobile Winder	€ 900,000. 00 EURO
40,000 ton (50m x 8m x 3m)	16 heaps (12 covers) with Mobile Winder	€ 1,600,000. 00 EURO

System Pricing includes GORE™ Cover, in-floor aeration, aeration blowers, oxygen and temperature sensors, controllers, computers, software, cover handling systems, training, engineering guidance, installation support and the experience gained through over 150 facility installations worldwide utilizing an 8 week model to produce stable compost.

Note: concrete and site works is not included. Package price excludes shipping, duty and tax from Germany.

We have estimated what the concrete pad would cost given relatively flat site conditions with soils having good bearing capacity. Prices for concrete work varies considerably from site to site, so the estimates presented must be taken with a caution that local pricing must always be secured in the course of decision making.

Facility Size	Concrete Area (m^2)	Concrete Volume (m^3)	Cost Installed (including site works)
5,000	1000	150	$50,000
10,000	2000	300	$100,000
20,000	4000	600	$200,000
40,000	8000	1200	$400,000

Hot Rot Exports – HotRot System

Facility Size	Price*
4,000 TPY	$1,500,000.00
10,000 TPY	$4,000,000.00
20,000 TPY	$7,000,000.00
40,000 TPY	$13,600,000.00

* - Budget pricing includes the HotRot unit, hoppers, feed and discharge conveyors, electrical panels, and programmable logic controllers. It does not include the cost of civil work, buildings, field wiring, Bio filters, and loaders.

Recommendation 3 – Provide for additional curing space or an additional curing yard offsite when space is a limitation.

This is conceptually simple—curing requires room on a pad, the size of which is determined through considering the volumes to be processed per year or other relevant time period, the unit footprint required for curing the material, and the time required in the curing phase. The footprint required for windrows, vehicle movement, drainage features, and buffer distances from other features ideally would be located on the same site as the composting plant, to minimize the cost and other implications of transporting immature compost during the process.

Where there is insufficient room on site for whatever reason, the alternatives are clear. One can either acquire adjacent land to add to the curing pad, or, if that is not possible or comparatively attractive, to acquire rights to land elsewhere upon which to establish a satellite curing pad. Operating a satellite curing pad involves the issue of transporting immature compost to it, and potentially additional haul distance from the satellite pad to market when the curing process is completed. Also, equipment and personnel will need to be dedicated to some extent to the operation of the transport function and the curing process.

As the regulations require that all aspects of the composting plant design and operation be regulated by Departmental Approval, to the point in the process where the cured compost is market-ready, it follows that a satellite curing pad design and its operating protocols should be considered within the terms of the Approval of the activity. This means that there would be regulation of design and the operations manual will include requirements for monitoring, hours of operation, security, management of leachate and drainage, etc. as if it were located at the parent site. In addition, the transportation function should be subject to specific terms, that the material meet the 1998 standard for maturity as a minimum objective.

Finally, the concept of a satellite operation does not mean that it must be on an area of land remote from other activities. For example, a satellite curing pad could be operated on the site of a landscaping firm, with operating responsibilities divided contractually between the composting entity and the landscaper. Nevertheless, the Approval for such a curing operation would no doubt place the overall responsibility for performance on the composting entity, up to the point where the material is mature, at which point it would then pass out of the ownership and off the curing pad of the composting entity to the landscaper. This notion begs the question of whether a composting enterprise or agency should be allowed to sell partly cured material, with the balance of the curing taking place by another party who would have their own independent Approval for their part of the operation. Again, conceptually, this ought to be possible, but whether it represents a desirable provision would require public policy considerations outside the scope of this report.

Generic pricing for this option is provided in Section 6, however caution must be emphasized as these costs can vary significantly depending on site specific details. For example the requirement to build a road, construct a treatment plant/containment pond, blast rock are all items that can significantly impact pricing and can not be priced until those details are known.

Recommendation 4 – Maintenance of Performance of Parameters

The results of the interviews indicate that performance parameters, that affect the speed at which organics are degraded, varied greatly between the facilities. The US Compost Council in their 1994 Compost Facility Operating Guide suggest that the following parameters be maintained,

- *Reduce particle size of feedstock to 25-50mm*
- *C:N ratio of 30:1 at onset of process decreasing to 20:1 or less when completed.*
- *Moisture level kept between 50-60%*
- *pH kept between 6 and 8. Biological activity reduced when pH falls outside of this range.*
- *Temperature maintained between 40 and 50^{o}C during composting following pathogen reduction.*
- *Oxygen maintained at more than 16%*
- *Aerate/turn at least 2-3 times per week where permissible.*

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Appendix A

Summary of Facility Visit Notes - Response to Questionnaire

	Facility / Questions	1	2	3	4	5	6	7	8	9
1	**What problems do you have with contamination of feedstock? What type of contamination is present and what percentage of throughput does it represent?**	Plastics, Metals (3-5% mostly residential, 0.5% IC&I)	Plastic, Steel and Glass approximately 10% by weight	Plastic: oversize after curing is 50%; ICI and Residential has 7-8% contamination	Plastics - Not serious (dealt with at curb) <1% contamination equal between ICI and Residential	Plastic is not bad.	Plastic and compostable bags	Fairly consistent, ICI represents 40% of feedstock and has 0% contamination, Residential has 6% contamination which consists mainly of plastic and to a lesser extent glass (real problem)	ICI represents 35% of feedstock with 0% contamination. Residential comprises 65% of feedstock with <10% feedstock.	Plastic Bags
2	**What operational difficulties do you encounter?**	Garbage/plastics. Plastics impede aeration and microbial colony growth.	Too high tech. bells and whistles and computer system. Building receiving too small. Contamination is a problem	Corrosion: is a problem, Aeration Pipes: crushed rock packed with fines, blowing works better than sucking air through the bed although leads to greater corrosion. Biofilter should be changed every 2-3 years	Operates anaerobically in bunkers. Turned every 3 weeks in bunkers. Need more machinery and labour to turn material more. Temperature still at 45 degrees after 1 year.	Floor ducting hard to clean. Air channelling in bed.	Temperature. Cannot maintain temp. in winter	Boxboard in waste stream (residential) has high lignin content which slows rate of maturation. Corrosion - this is now under control. 60% moisture in ICI - routing changes between Miller and New Era have solved this	Plant runs well - better than in early days. Have to haul leachate, "Water is the enemy"	Not enough space
3	**How well are you able to remove contaminants from the feedstock?**	Able to remove 60% of contaminants in front end	Moderately - 1 person presorting. Screener works quite well at removing contaminants	Good, except for plastic, 2 people presorting	Not a problem. Bobcat operater picks most of contaminant out. 1 sorter on pre sort.	No problem. No presort. Contaminants removed during screening.	Not very well with only 1 sorter	~85% at front end.	Very well, sorter staff receive bonuses for amount of material removed.	OK, All are separated at back end through screening
4	**Are there processing technology difficulties that cause you problems achieving the required product quality?**	No	Connot make computer changes, high level of maintenance, limit switches don't work well, air system is not good, piping freezes each winter.	Need longer retention time in the bed. Have trouble with the aeration system.	Nothing except high temperature	No	Insulation in vessels breaking down, Leachate drains plug. They want to replace system.	Presort works very well. Forced air curing changed to windrow curing - works better. Removal of boxboard would reduce quality problems.	None of the facilities are working properly. pH is too low, boxboard, high moisture in ICI	No
5	**Were you able to meet the compost quality standards before the 2006 guidelines came into effect?**	Yes, Germination and Time	Yes, met temperature and time requirements	Yes- using time parameter of 6 months	Yes, Time Parameter - currently up to 3 years before product is sold	n/a	Yes, based on temperature rise and time	Yes	Yes, germination test passes	Yes (stored up to 2 years)
6	**Can you meet the 2006 compost maturity standards?**	Yes	Yes, curing pad has been made larger. Have sufficient space to ensure that material can cure as long as it needs to meet regulations.	Next to impossible even with expanded coverall building adding 3 months of covered curing.	By means of time, Currently can store material on landfill site. They do not have enough of there own space on the compost facility site to reach maturity.	Yes - temperature	Probably not	Probably not	No	Probably not without extending the curing pad
7	**If not, what do you believe are the reasons why you cannot meet the standards?**	n/a	n/a		Compost Maturity, space restrictions	n/a	Would need a turner to cure product properly	Probably boxboard	Low pH, high moisture	Space limit with current pad
8	**What improvements would you like to see that would improve the overall operation, in particular the finished product quality?**	-screen a finer product (3/16" minus) , more extensive use of EM inoculants', develop made to order compost teas for fruit and vegetable production	Curing product under cover, air classifier to remove plastic	Need more space or emerging technology to reduce space	More space, more machinery to turn product.	None	Want to change the entire system to either outdoor windrow or AD	Aeration changes, Sprinkler changes, biological	Polish back end product using the Hot Rot technology. Need capacity for 10KT/yr. Takes 10 days in this system to make product meet CCME	have a turner instead of a loader, own their own screener instead of renting
9	**How long is material cured after removal from the active compost bed before the material is marketed?**	12-14 months	15-18 days in vessel, cured for 11-12 months	2-3 months	21 days in bunkers before curing. Curing in Quonsets and greenhouses for up to 1 year.	Composting for approx. 28 days, curing for approx. 30 days	Active Composting - 10 days, Curing - 9-12 months, need more pad space	28 days in the vessel, 60+ days in indoor curing, the screened, then marketed	In-vessel 8-20 days, Curing in buildings 2.5+ months (3.5-4 months in winter). All material then sold to landscaping company	Material stays in the building for 6 months after which it is cured outside for up to 1.5 years
10	**Do you store material off site? If so at what point in time after on-site curing does this occur?**	No	No	No	At landfill for up to 3 years	No	No	90% of the product is sold following screening. The other 10% is cured offsite and then brought back to be sold to the public.	No	No
11	**How is the off-site material managed?**	n/a	n/a	n/a	Turned only when time permits usually every 2-3 months	n/a	n/a	Partnership with company to manage 10% of the material.	Not applicable	n/a
12	**How is your product sold, direct in small quantities to the public, in bags to retailers or in bulk to contractors? What is the percentage of sales of each?**	All sold as bulk	70% bulk, 30% bagged	Direct to public	All material sold in bulk to contractors and public	Bulk	Public giveaway and bulk	10% - some is bagged, 90% sold in bulk to 3rd party	All bulk	Bags and Bulk
13	**What is the current selling price for each product?**	$20/yd	$2/bag (80-100 lbs), $30/T for small truck, $20/T for dump truck	$18/yd for drier material, $5/yd for wet clumpy product	$20/yd. Operator think that $30/yd is attainable	$20/T (could probably sell for more)	$30/T	$30/yd compost, $25/yd soil blend	$2.50/T	$2.50 / bag (40 lbs.), $40/ton (Imp.)
14	**Do you think that you could sell for a higher price if a greater level of maturity could be reached?**	Material screened finer to improve aesthetics could yield $30/yd	Yes if more plastic could be removed and the material was kept under cover (drier)	Maybe a little more	Yes	n/a	Yes	Yes if sold at approx. 12-18 months of age at top quality	Yes	Yes with better screening.
15	**At what age is your material sold?**	12-18 months	12 months	3-4 months	3 years	60 days	12 months	12-18 months	2.5-4 months	2 years

Appendix B

Summary of Interview Responses of Industry Stakeholders

	Landscaping Firms	Compost Facility*	Top Soil Manufacturers	Sod Growers	Nurseries
Do you sell pure compost product?	• No	• Yes	• No	• No	• Not anymore • Some used to but aesthetics are a distraction
Do you think that SSO compost would have more value if were more mature when entering the marketplace?	• No	• Yes	• No	• No, it is applied to the soil	• No, sell only manure composts.
What is the largest factor in preventing SSO compost from being sold for more money?	• Aesthetics	• Moisture – difficult to keep product dry for bagging and bulk sales. • Aesthetics	• Aesthetics	• Aesthetics	• Some did not know • Some said aesthetics

* - facility other than what was included in the study