COMPOSTING AT TRENT

FEASIBILITY ASSESSMENT

AND

LITERATURE REVIEW

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INTRODUCTION

Compostable yard and food wastes comprise between 30 to 50 percent of the waste stream in North America (Blumberg and Gottlieb 1989, Harper 2003, The Compost Resource Page 2003). The same proportions hold for large institutions such as universities, which are significant contributors to waste generation. At Trent University, food waste accounts for over 25 percent of the total waste stream (PEAC 2002). Trent's current waste management practices focus primarily on the reduction of the overall volume of waste materials requiring disposal, rather than on the diversion of waste from landfill disposal (i.e. through composting). Thus, presently Trent does not have any mechanism in place to prevent yard and food waste from going to the landfill (PEAC 2002). Composting provides a way in which solid waste, water quality, and agricultural concerns can be joined through a more efficient and usually less expensive means of managing organic wastes than landfill disposal (Risse and Faucette 2003, and The Compost Resource Page 2003).

This report will explore the possibilities that a composting system has to offer to Trent. Section one will discuss the potential of a composting system at Trent in light of the University's existing environmental policy. Section two will describe the present situation with regards to waste generation, disposal and monitoring. Section three will present two composting methods selected from an extensive literature review which supplements this report (see Appendix 3). Section four will present the different stake holders involved. Section five will discuss specific and general problems in the implementation of a composting system, and some solutions to such perceived obstacles. Section six will present some successful examples of composting at other colleges and universities. Lastly, section seven will outline some recommendations for future steps in advancing a composting initiative at Trent.

I. POLICY

TRENT UNIVERSITY'S ENVIRONMENTAL POLICY

According to the Environmental Advisory Board (EAB; PEAC 2003a), Trent University has made a strong commitment to high standards of environmental protection and stewardship, as well as a strong environmental research focus. This has not only resulted in a reputation as an environmentally responsible institution but it is also reflected in many of its teaching, research and community service activities. The EAB (2003a) believes that the University has a special responsibility to exercise environmental leadership. Therefore in October 2nd, 2001 the University approved an environmental policy that is consistent with the vision outlined above. The implementation of a composting system is not only congruent with the University's environmental policy but will in fact provide the University with an opportunity to advance in the principles outlined in its policy as shown below:

- The University has a commitment to "minimize waste generation through reduction, reuse and recycling practices (PEAC 2003a)." Composting would allow the diversion of a large amount of food waste from landfill, further enhancing waste minimization strategies.
- The University should "meet and where possible, exceed applicable environmental standards, regulations and guidelines with a view to continual improvements of such standards (PEAC 2003a)." The amount of waste that could potentially be diverted from the landfill with the introduction of a composting system at Trent would be sufficient to achieve Trent's reduction targets.
- The University should "encourage and where appropriate assist members of the University community to adopt environmentally-sound practices (PEAC 2003a)." Composting is perhaps the most environmentally sound waste disposal method. It is

beneficial for water and soil conservation, as well as for ground water quality protection. Furthermore, the application of the end product as fertilizer means a more holistic understanding of waste disposal through which natural cycles are completed.

- The University should "encourage the use of environmentally sensitive products through purchasing practices, consistent with the University's Environmental Procurement Policy (PEAC 2003a)." The end product of composting is much more environmentally friendly than inorganic fertilizers, and it could be used in the fertilization of campus grounds. Unlike most inorganic fertilizers, compost functions as a slow-release store of nutrients, so that the nutrients are available as the plants require them instead of in one intense flush. In addition, compost materials are biologically active full of organic matter which provides habitat to organisms which improve soil structure. Moreover, compost amendments to the soil result in improved water holding capacity and better cation exchange capacity.
- The University should, within available resources, "initiate programs of environmental literacy and the use of environmentally tailored projects on campus for educational demonstration purposes (PEAC 2003a)." A composting system on campus would provide educational opportunities not only for Trent students, but also for college and high-school students from surrounding institutions.

TRENT UNIVERSITY'S SOLID WASTE MANAGEMENT POLICY

In the early 1990s Trent University adopted a loose solid waste management policy (later revised in 1996) in which it committed to reduce the amount of total waste to be disposed of in the landfill by 50 percent by December 1994, and 75 percent by the year 2000 (Myers and Brennan 2000). Currently, recycling is Trent's sole diversion strategy and it accounts for only 33 percent of the waste. Over 50 percent of the waste however, should be diverted from the landfill (Craft 2003).

II. DESCRIPTION OF THE PROBLEM

BACKGROUND

The most recent external waste audit at Trent University was carried out in 1997 by Golder Associates of Mississauga. At that time, the total annual waste production at Trent amounted to 474.73 tons. Of this total amount, 29 percent was recycled, 25 percent was food waste sent to a pig farmer and the remaining 46 percent was sent to the landfill (Bocking 2002). The numbers presented in this audit, however, are of little relevance today. First, shortly after the audit was completed, the food service provider changed along with the food service itself (e.g. possibility of take-out foods). Second, the student population at Trent has increased over 20 percent since then. And third, food waste is no longer sent to a pig farmer. The pig farmer used to pick up the food at each kitchen and took it to his farm for feed. The university paid him $400 per month for the service (Craft 2003).

In 2000 an internal audit was carried out by Myers and Brennan, two environmental science students taking ERSC 308-waste management. This is the first audit carried out at the University since Aramark became the food service provider. The audit, carried out form March 6th to March 16th, focused on the quantification of total waste going to landfill, the percentage of this waste that could be diverted (e.g. recycled or sent to the pig farmer) and total recyclables successfully diverted from the landfill. The study however, did not quantify the amount of food waste collected by the pig farmer. According to this study, 66.34 percent of the waste was going to the landfill, half of which was potentially divertible, and the remaining 33.6 percent was successfully diverted through recycling. Despite the contract with the pig farmer, organic wastes comprised 38.45 percent of the potentially divertible material (Myers and Brennan 2000).

The only data that currently exists on food waste generation after the cancellation of the contract with the pig farmer was provided by Mary Ann Thomas in an internal communication to Wayne Craft. In the e-mail, she stated that Aramark produces about 2,300lt. of wet waste per week (Thomas 2003).

CURRENT WASTE DISPOSAL

When the contract with the pig farmer ended in 2001, Physical Resources (in conjunction with Aramark) looked for private haulers to take the food waste. This alternative, however, proved unfeasible and no other substitute was adopted (Thomas 2003). Thus, all food waste is currently going to the landfill (PEAC 2003b).

Waste is taken to the landfill by M&M disposal, at a rate of $70 per ton that amounts to $75,000 per year (Craft 2003). In addition, Physical Resources has to cover labour costs for the collection of the waste to a central depot where M&M disposal picks it up. Conservatively, garbage collection takes about 60 hours a week from unionized full time employees plus 50 hours a week from student labour (Craft 2003)[1]. This amounts to roughly $51,000 per year. Therefore, with labour and hauling combined, Trent spends about $126,000 per year in waste disposal, a figure which could be reduced by composting.

[1] Unionized labour costs were calculated at twice minimum wage plus 30% benefits. Student labour was calculated at $7.25/hr (Craft 2003)

III. PROPOSED COMPOSTING SYSTEMS

WHAT COMPOSTING INVOLVES

Composting involves the biological decomposition of organic components of the waste stream, resulting in an end product called compost or humus. This end product has numerous applications which facilitate the return of nutrients to the soil. In general, composting requires the separation of the waste stream into organic and inorganic components. The organic material is then placed in either an open field or in a closed mechanical system where bacterial activity can proceed (Neal and Schubel 1987). Numerous composting systems exist with varying levels of technology employed, cost and processing time. Yet, all of them involve basically the same three steps: 1) basic preprocessing, 2) separation and, 3) actual composting.

Both the composting process and different composting systems are described in great detail in a supplementary literature review found in Appendix 3. From that research, two systems appeared to be the most suitable for Trent: a windrow composting or an in-vessel system.

WINDROW COMPOSTING

Windrow is a simple composting technique by which waste is stacked in long piles and turned regularly to aid the decomposition process. Using windrow composting the total waste produced by Trent in one year could be processed in about 500m^2. This area would include both the actual processing area and a recommended buffer area of 15 percent the size of the processing area. For lack of a better source, these calculations were based on the waste amounts provided in the 1997 audit, factoring a 20 percent increase of the student body (see literature review for details). Process time ranges from 6 to 12 months depending on the material being composted and turning frequency, plus a minimum of one month for curing (BioCycle 1989).

Labour is required for collection and transportation of food waste to the composting site, and for mixing of the windrows. Once at the composting site, waste can be piled in windrows 3 to 6m wide and 2 to 3m high. Length is mainly determined by the site layout. These measures are not set, however, as the optimum size will vary both with the type of material and the time of year.

The windrows need to be mixed. This can be accomplished with a front-end loader or a tractor with a bucket. Turning frequency is normally based on temperature: the compost pile is turned whenever temperatures exceed 60 to 65° C, or drop below 21 to 32°. In general it can be expected that turning will be necessary twice a week for the first few months, such regular turning will accelerate the decomposition process. As decomposition proceeds and the compost becomes more stable, frequent turning becomes less important.

Without full data on current food waste production at Trent, it is not possible to calculate the exact cost for constructing and operating a windrow composting facility. Moreover, the general capital costs involved are listed in Table 2. Not all costs are fully applicable for Trent since Trent already owns some of the necessary infrastructure (e.g. tractor with front end loader, facilities for lab testing) and the local conditions may not require certain components (e.g. possibly no need for pad, depending on soil structure, no need for amendments). In addition, the costs vary depending on the materials chosen. For example, the pad can be asphalt or concrete, or simply a weather-proofed firmly packed soil platform. In any case the platform will prevent leakage into the soil and should be built before building the piles, but the cost of the platform will largely depend on the material chosen (Table 1).

Table 1. Typical values for a 12-inch pad (Cornell 2003)

Material	Unit Cost ($/ft^2)
Only remove topsoil and vegetation	0.11
Recycled asphalt	0.70
Recycled concrete	0.60
Sand/gravel/geo-membrane	0.98
Concrete	3.43
Asphalt	3.80

Table 2. General capital costs for constructing and operating a windrow composting system (JSPPOH 2002, and Watgreen 2003).

ELEMENTS
Machinery costs: grinder, compost mixer, trommel screen, windrow turner (all optional) and front-end loader, required
Need to procure amendments (i.e. leaves, manure)
Storage: Cold-rooms Barrels for storage
Site construction: Retention pond (possibly) Pad (possibly)
Personnel
Collection system
Odour control costs
Product utilization
Transportation costs
Quality assurance costs (i.e. lab tests for pathogens and heavy metals)
Composting performance equipment (e.g. temperature probes, oxygen meters)

Once some of the inputs are established at Trent, cost calculation could be facilitated by using *Co-Composter*, a free Excel spreadsheet model for the planning of composting systems for mixtures of dairy manure and other organic wastes prepared at Cornell University. This spreadsheet will be an extremely helpful tool for calculating windrow costs.

It provides mass and volume balances, area estimations, and a cost analysis of alternate composting systems based on inputs entered on the user (see Cornel 2003 for link).

IN-VESSEL

In-vessel systems use anything from perforated barrels, to drums, or specially manufactured containers (Risse and Faucette 2003). The ones describe here belong to the latter category. These systems are more sophisticated, and consist of a horizontal rectangular tank equipped with a specially designed conveyor belt mounted on wheels that move on racks placed on the bottom of the tank. As the belt moves it picks up and deposits composting material, thus serving as a mixing device. The tank can have a perforated bottom to allow air to circulate (BioCycle 1991). Overall, these systems are often preferred over windrow systems because they offer better odour control, have less space requirements, offer greater control over the process and handling, have minimal labour requirements and energy inputs, and are not as weather sensitive (Risse and Faucette 2003). These characteristics elicit greater public acceptance and make it possible to use them in urban and public areas. The initial investment, however, can be high and handling volumes are typically low such that Trent would require more than one unit, further increasing the costs (BioCycle 1991, and Risse and Faucette 2003). In addition, windrows are still required for curing the compost once the initial in-vessel decomposition is completed (Gould 1993).

The following tables compare two in-vessel systems from Wright Environmental a Canadian company based out of Richmond Hill, Ontario.[2] The first model is the WEMI 600ppd, a small model that can take up to 600 lbs of organic waste per day (or 0.27 tons).

[2] WRIGHT ENVIRONMENTAL –Head office- 9050 Younge St. Suite 3000. Richmond Hill Ont. Canda. L4C-9S6. Telephone number: (905)- 881-3950. Fax: (905)-881-2334.

The second model, WEMI 3tpd, can process up to 3 tones per day. In both models the material consists of up to 70 percent food waste. The main associated costs with these systems are set-up, maintenance and labour (Table 3). Additional costs include windrow maintenance, labour, site preparation, transportation of unit and training of staff (Table 4). Both systems operate typically on a 14-day retention cycle and are fully self-contained, thus requiring no additional enclosure structures (Wright Environmental 2003).

Table 3. Cost comparison for two models of in-vessel composters (WEMI 3tpd and WEMI 600ppd)

Model	Set up costs	Maintenance costs	Labour costs	Additional costs
WEMI 3tpd	$377,420	$3,984.59	1 worker/3hrs/day	$47,881.86
WEMI 600ppd	$66,000	$730.00	1 worker/2hrs/day	$41,329.86

Table 4. Detailed cost comparison of the additional costs for two in-vessel composters

Model	In-vessel labour	Windrow maintenance and labour	Site preparation, transport and training
WEMI 3tpd	$19,656.00	$25,725.86	$2,500
WEMI 600ppd	$13,104.00	$25,725.86	$2,500

This cost calculation only includes the initial phase of in-vessel composting. After this phase is completed, a windrow curing operation is necessary (WatGreen 2003), the cost of which is not included in this calculation. Given these high initial costs, the windrow option seems more financially viable for Trent.

IV. THE STAKE HOLDERS

ARAMARK

Aramark is the main food service provider and food waste generator at the University. The company is not required by the University to keep track of how much food waste it generates, or to pay for its disposal. However, Trent receives a fund from Aramark, and although there is no specific allocation it is possible that some of it is allotted towards waste management (Thomas 2003).

In the past, composting initiated by students in the dinning halls have seen limited success due to infrequent collection. This has resulted in flies and odour problems. Therefore, in the case of the implementation of a composting system, the director Mary Ann Thomas (2003) sees Aramark's primary role as separating the waste both behind the counter, as well as post-consumer waste. In addition, Aramark staff would collect the waste from both of those sources into big barrels that would then be picked up by physical resources. Aramark's involvement is independent of the composting system selected.

PHYSICAL RESOURCES

Physical Resources is the entity that ultimately defines waste management practices. This department is divided into two sub-departments, one that gathers the waste from indoor locations (e.g. kitchens, dormitories and office areas) throughout the campus into central depots in each college and the other (Physical Resources-grounds) collects waste from outdoor locations including central depots at each college. From there, Physical Resources takes it to an outdoor main location where M&M disposal picks it up.

Physical Resources would collect the waste from Aramark's kitchens into main depots from where Physical Resources-grounds would collect it and transport it to the composting site. Once at the composting site, Physical Resources-grounds will likely be responsible for mixing or turning the piles (in the case of implementing windrow composting) along with any other maintenance requirements.

THE STUDENTS

Trent students are important actors in the implementation of a composting system at the University. They are the main food consumers and as such their willingness to cooperate with food waste reduction and separation is crucial. In addition they could benefit from the research opportunities that a composting system has to offer and could potentially be a source of labour.

Therefore, to find out about their views on the issue of waste disposal and the possible implementation of a composting system on campus a survey was conducted (See Appendix 1 for a template of the survey). Of the 120 students interviewed, 86 percent were either very concerned or concerned with the amount of waste generated at Trent (Figure 1).

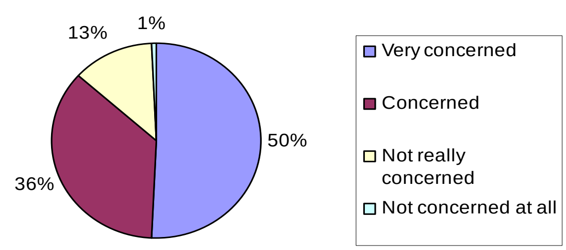

Fig. 1. Answer to the question: are you concerned about the amount of waste generated by food services at Trent?

Furthermore, 71 percent of the students surveyed agreed that implementing a composting system at Trent is a very good idea, and another 24 percent answered that it was a good idea (Figure 2).

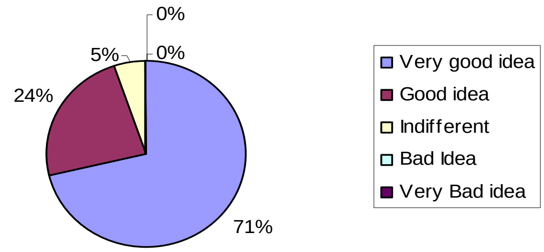

Fig.2. Answer to the question: What do you think of the idea of a composting plan at Trent?

The amount of food waste produced is a result of the relation between the students as waste producers and Aramark as the food supplier. Therefore in the survey, two questions regarding the size of the meals were asked in order to determine if the students identify this as affecting the amount of post-consumer food waste, and what their preferred option to address this issue would be. The answers ranged widely, and were split almost equally in thirds. Of the respondents, 45 percent agreed that reducing the meals size could influence the amount of post consumer waste produced. Thirty three percent did not know, and in those cases many comments were added to the surveys. Comments mainly focused on the quality of the food as a factor influencing the amount of post-consumer waste (Figure 3).

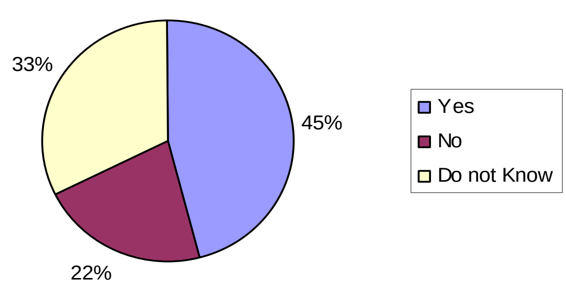

Fig. 3. Answer to the question: Do you think that post consumer waste (i.e. leftovers) could be reduced by modifying the serving sizes?

To the issue of reconsidering (decreasing) the serving sizes as a way to address post-consumer waste, many students answered ‘maybe’ or ‘not interested’. Many of these students, however, added that they would only be willing to do so if prices were adjusted accordingly. This is difficult to do as all of the meal plans (except for the flex dollars at Otonabee College) are offered on the basis of all you can eat buffets. The students that did not respond to that question commented that they did not use the food services on regular basis (Figure 4).

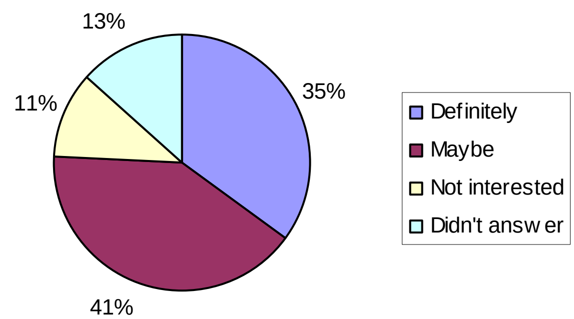

Figure 4. Answer to the question: Would you be willing to reconsider the size of your meals to reduce post consumer waste?

Of the students surveyed, 85 percent did not know of any other composting systems at other Universities. Those that mentioned other universities, often mentioned institutions that do not currently have a food composting system (Figure 5), such as University of Waterloo (only composts yard waste) or Guelph University (their waste management involves dry and wet separation in compliance with the city’s waste management).

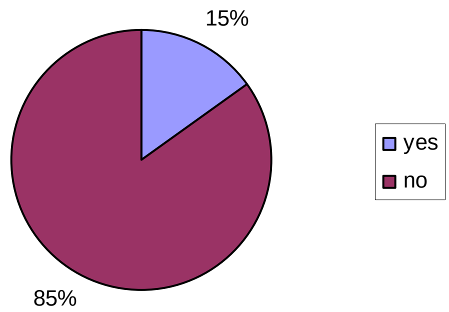

Figure 5. Answer to the question: do you know of any composting programs at any other universities/colleges?

Overall the students showed interest in the implementation of a composting system at Trent and in being active participants in this process. Many students, however, expressed concerns with regards to the relationship between the food services and the amount of food waste produced. For this issue, it may be necessary to establish a direct dialogue between the users and the service providers to negotiate things such as changing meal sizes along with its price, which seemed to be one of the major reservations of the students.

V. PROBLEMS IN IMPLEMENTATION AND POSSIBLE SOLUTIONS

LABOUR REQUIREMENTS

The department of Physical Resources is experiencing a labour shortage in relation to the waste disposal requirements of the University (Craft 2003). Therefore, the implementation of a composting system appears problematic if it would require extra pressures on the labour force presently available in this department. According to Craft (2003), however, this is an ideal time to be working towards the implementation of a composting system at Trent since a full time employee has been recently hired to exclusively manage garbage and recycling. Craft (2003) thinks that this person could play a crucial role in facilitating the implementation of a composting system as the labour requirement for a composting system could be incorporated into his/her duties.

In addition, the contract with M&M disposal will expire soon. Therefore there will be a bidding match between haulers and the contracts will be open to negotiation. This, according to Craft, creates an ideal scenario to propose any waste management alternatives. Moreover, potential economic benefits that will derive from implementing a composting system at Trent (e.g. savings in fertilizers and revenue generated from the sale of the finished compost) will allow the hiring of additional labour to alleviate pressures on the Physical Resources department without representing any further expenditure on their part.

COSTS

With regards to costs, there are two main considerations. First and most obvious, budgeting concerns. Second, the misconception that composting is often more expensive than waste disposal to the landfill. Since Trent is already spending money on waste disposal ($70/ton plus labour requirements) the money that would not be spent paying M&M for their disposal service could be diverted to cover composting costs. Thus, aside from start up costs, there will likely be no need to find any new sources of money to fund the composting venture. As for the second concern, composting is generally cheaper than landfill disposal (Risse and Faucette 2003). Middlebury College has been composting since 1993, when the college was awarded a state grant to expand its recycling program. Through composting the College diverts 75% (300 tons/year) of food waste from the landfill. Because the average composting cost per ton of food waste is estimated at $62, compared to $195/ton for trash taken to the landfill, this program marks considerable savings for the College. Since 1993, they have spent about $48,000u.s. on food waste disposal, compared to the estimated $220,000 they would have spent if the food waste had been sent to the landfill. Overall Middlebury College has saved approximately $148,000 between April 1993 and 1998 (Hazen 1998).

OWNERSHIP

When presented with the idea of a composting system at Trent Craft (2003) expressed interest. He is very concerned with the waste disposal situation at Trent, and sees much positive potential in composting. Craft (2003), however, sees lack of ownership as an obstacle in implementing a composting system. He believes that for the successful implementation of a composting system at Trent *everybody* (i.e. both staff and students) needs to take *ownership*. By ownership, Craft explained, he means "to be willing to dispose properly of the waste made." This comment arises from the current difficulties in properly recycling all potentially recyclable material due to improper disposal of the waste by students and staff. However, the responses from other stakeholders (Aramark and the students) indicate that this concern might be unfounded.

Mary Ann Thomas (Director of Aramark; 2003) not only expressed interest in the implementation of a composting system at Trent but stated that the implementation of a composting program would not be difficult for Aramark, as the staff has been trained on how to separate the food waste and most of the infrastructure (e.g. cold storage room, bins, etc.) is already in place. Aramark has separated wet and dry waste since the beginning of their arrival to Trent until the termination of the contract with the pig farmer.

Recently the Seasoned Spoon was opened, a student-run cafe that serves only soup twice a week. As their food generation is negligible compared to Aramark they were not discussed as a major stakeholder. Their current practices (i.e. their own composter), however, indicate that they would be interested and willing to partake in larger scale composting initiatives.

In addition, an overwhelming 65 percent of the students surveyed stated that they would be willing to take ownership in the case of the implementation of a composting system at Trent. Of the respondents that chose 'no', many commented that they would not be at Trent next year (Figure 6). This commitment is further reflected by the student's practices at their homes, where 56 percent of the students interviewed compost their own waste (Figure 7). This also reflects that many students are familiar with what composting involves.

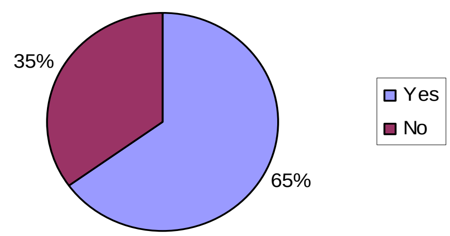

Fig. 6. Answer to the question: Would you be interested in getting involved with a composting initiative at Trent?

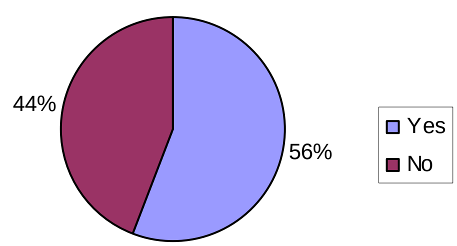

Fig. 7. Answer to the question: Do you compost your own waste at home?

VI. SUCCESS STORIES

There seems to be a growing trend in universities and colleges throughout North America towards waste disposal methods that generate economic revenues and are environmentally sound. Many case studies provide evidence that the implementation of a composting system at Trent is not an impossible or risky option since these systems have been widely tested and proven to be successful in other universities. These case studies are presented in a supplementary literature review in Appendix 3. A synopsis of some of the case studies is presented in a comparative table in Appendix 2.

One of the most outstanding programs presented in the literature review operates at Cornell University. This University began composting food scraps from the campus' dining facilities in 1997 through the conjunct effort of the Farm Services Department, the Waste Management Institute and the University's Dining Services. The waste collected, comprises about 17% of the University's waste stream that had been going to the landfill. The program's only financial support is the equivalent of what had been paid for food waste disposal to the landfill. The ability of the program to operate with no other financial support is strong evidence of its economic viability. Additional economic benefits are achieved from the use of the finished compost as a soil amendment in the campus grounds. The finished compost is spread on agricultural fields which are used for the production of animal feed and runoff stored in retention ponds is used to irrigate dry piles and adjacent hay fields (Cornell b 2003).

VII. FUTURE STEPS

One of the major challenges faced in the completion of this research process was accessing information, either due to a difficulty in contacting people, or in accessing information. The latter was either the result of privacy policies or the lack of a centralized library where all of the projects related to this topic carried out so far at Trent could be found. Therefore, the first recommendation for the future is to compile all of this information and make it accessible to future students that will be carrying on with the idea of working towards a composting system at Trent. This would greatly facilitate their research and action.

The second challenge was to determine Trent's requirements with regards to a composting facility, given that there have been not been any waste audits or comprehensive analysis of Trent's waste disposal requirement carried out in the past 5 years. At this point a waste audit is in order to successfully determine future strategies for waste management at Trent. Once these tow things are in place, it will be much easier for staff and students to work together towards deciding what is the most suitable option for Trent.

Finally, given that there are no set standards for composting it appears that the best way to design appropriate guidelines for a composting system at Trent would be to start with a windrow pilot project. This would also guarantee that the University does not embark in any major capital investment without having proven the appropriateness of the choice in situ. It appears that the best option for a pilot project would be Otonabee dinning hall, as it produces moderate amounts of waste compared with other kitchens (e.g. Lady Eaton's Kitchen; Myers and Brennan 2000). In addition th Otonabee kitchen is located on the west bank, same bank where Wayne Craft suggested a site for a composting system, thus reducing transportation requirements.

CONLCUSIONS

The implementation of a composting system at Trent will provide a way in which solid waste disposal, water quality and environmental concerns can be addressed conjunctly in a more efficient and less expensive way. In general, composting is a beneficial practice for water and soil conservation, as well as for ground water quality protection. Further, the application of compost provides a long term stable organic matter source that has the potential of mending contaminated, compacted and marginal soils (Risse and Faucette 2003, TNRCC 2003 and BioCycle 1989). The implementation of a composting system will also provide an opportunity for advancing the principles outlined in the University's environmental policy as well as research and teaching opportunities.

These environmental benefits will be coupled with economic benefits. Composting can significantly reduce waste disposal costs and generate revenue through the sale of the end product. Because landfill space is decreasing and landfill fees are increasing, composting can be a highly lucrative endeavor (BioCycle 1989, BioCycle 1991, and TNRCC, 2003). Both the environmental and economic benefits of composting are widely exemplified in successful stories throughout colleges and universities in North America.

It appears that the stake holders are aware of the challenges faced by the University with regards to waste disposal, and are willing to take ownership by participating cooperatively in the implementation of a composting system. Therefore, this is an ideal time for implementing such as a strategy at Trent. Of the two systems presented windrow composting is the most versatile and presents the lowest initial setup costs. Its main drawback is the land requirement, which does not appear to be a great barrier for Trent.

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APPENDIX 1 : QUESTIONNAIRE RE : COMPOSTING AT TRENT

The information collected with this anonymous survey is part of a composting research project conducted for the Ontario Public Interest Research Group (OPIRG). The questionnaire is geared towards establishing what the students at Trent University think about food waste production and the idea of composting at Trent. Thank you very much for your help!

1. Are you concerned about the amount of waste generated by food services at Trent (i.e. Aramark)?

☐ Very concerned ☐ Concerned ☐ Not really concerned ☐ Not concerned at all

2. What do you think of the idea of a composting plan at Trent?

☐ Very good idea ☐ Good idea ☐ Indifferent ☐ Bad idea ☐ Very bad idea

3. Do you think that post consumer waste (i.e. leftovers) could be reduced by modifying the serving sizes?

☐ Yes ☐ No ☐ Don't know

4. If yes, would you be willing to reconsider the size of your meals to reduce post consumer waste?

☐ Definitely ☐ Maybe ☐ Not interested

5. Do you compost your own waste at home? ☐ Yes ☐ No

6. Do you know of any composting programs at other colleges/universities?

☐ Yes ☐ No

7. If yes, which college/University? (please give details if you'd like) ____________________

____

____

8. Would you be interested in getting involved with a composting initiative at Trent?

☐ Yes ☐ No

If you require any further information, please contact OPIRG: 748-1767 or opirg@trentu.ca
THANK YOU FOR YOUR FEEDBACK!

APPENDIX 2: COMPARATIVE TABLE OF COMPOSTING CASE STUDIES

University	Type of Composting	Details	Amount Composted	Maintenance Costs	Money Saved	Operational Since
Dartmouth College	Off-campus: formerly windrows, now hi-tech facility, jointly with city of Hanover	Handles all food and compostable waste as well as sewage sludge from Hanover	windrows=20,000 lb. for first 8 months	windrows= Minimal, covered by Buildings and Grounds and Food Services	windrows= net savings of $10,000 for first 8 months	Windrows1992, Composting facility-1998
Ithaca College (NY)	Off-campus: Pre-consumer waste only; aerated static piles	Computerized temperature controlled off-campus facility	5 tons/week or about 160 tons/year	Initial cost of machinery and setup = $67,000	Not available, but diverts about 13-15% of total waste stream	1993
Johnson College (VT)	Passive pre-consumer waste, vermicomposting. Also, research on post-consumer composting by windrows and aerated windrows	Small holding piles on concrete slabs aerated by pipe; 12 vermi-composting demonstration projects in community	N/A	N/A	N/A	1991
University of Waterloo	Windrows, Wooden Bins, Vermicomposting	N/A	Windrows compost about 10-15 tons/year	N/A	N/A	Windrows since early 1970's wooden bins since 1996
Texas A&M University	off-campus Animal Science facility (with close neighbours), in-vessel composting	7 EarthTubs, 7 Comp-tainers, using animal waste and bedding	N/A	Equipment start-up Cost: ~$350,000	N/A	1998
Tulane University	3+ Large Recycled, Wooden Bins	Proposal Stage	N/A	N/A	N/A	N/A
Cornell University	Off-campus windrows facility	Agricultural waste, and pre- and post-consumer food	4151 tons/year (including 700 tons of food)	Provided from the tipping costs of food removal paid by food service	Product applied to college farm, will reduce tipping fees from food service	1992 for agricultural waste, 1998 for food waste
Middlebury College	Off-campus windrow facility	Wood chips and horse manure mixed with food waste	260 tonnes a year of food waste	Paid for through savings in tipping fees	Humus used by MC and money saved through tipping fees	1996

From Rice University at <www.ruf.rice.edu/~envintrn/other_colleges.html>. The table at the website contains links to several of the Universities included.

INTRODUCTION

In Ontario, millions of tones of waste materials, both hazardous and non-hazardous, are generated and disposed of every year (RCO 2003). Yard and food waste are major components of the waste stream which are generally disposed of in the landfill along with the main waste stream. These practices are not environmentally or economically sound. When sent to the landfill, yard and food wastes break down very slowly due to lack of oxygen, producing methane and acidic leachates which pose environmental threats. Food waste placed in airtight landfills stops the earth's natural cycle of decomposition which plays a crucial role in the health of our environment. In terms of economic costs, many landfills are reaching their limits and even closing down, resulting in increased user fees for businesses and institutions generating waste (Risse and Faucette 2003, The Compost Resource Page 2003). Incineration does not offer a better alternative since the procedure is inefficient and results in poor combustion. Specifically, the high moisture contents of yard and food waste disrupt the energy generation of the facility thus increasing the pollutants released by the operation (The compost resource page 2003).

Large institutions such as universities contribute significantly to waste generation. At Trent University, the day to day activities of students and staff in 1997 resulted in 474.73 tones of waste. Since then the student population has increased by 20 per cent, undoubtedly increasing waste output. Food waste accounts for approximately 1/4 of the total (Bocking 2002 and PEAC 2002). Although Trent's Environmental Advisory Board (EAB) promotes 'reduce, re-use and recycle' practices in the University, Physical Resources is the entity that ultimately defines waste management practices. Moreover, Trent's waste management practices focus primarily on the reduction of the overall volume of waste materials requiring disposal, rather than reducing diverting the waste from landfill disposal (i.e. through composting) (RCO 2003). For example, Trent does not have any mechanism in place to prevent yard and food waste from going to the landfill (PEAC 2002). In the past, Trent food services used to collect food waste and donate it to local farms, but this practice has been recently halted because of changes in regulations that deem food waste unsuitable for pig feed due to health concerns (Bocking 2002). Thus, currently there is no food diversion program taking place at Trent and all this waste goes to the landfill.

Composting provides a way in which solid waste, water quality, and agricultural concerns can be joined through a more efficient and usually less expensive means of managing organic wastes (Risse and Faucette 2003, and The Compost Resource Page 2003). Therefore, the aim of this paper is to present current knowledge on composting methods and diversion practices, in hopes that this information will provide a solid background for the implementation of a composting system at Trent. Implementing a composting system at Trent would provide the University with an opportunity to reduce its ecological footprint and profit economically.

1. Why should we compost

Globally, urbanization, modernization and industrialization have resulted in patterns of increased consumption and waste production. The disposal of a rising amount of solid waste is one of the major environmental problems of our time (Ullah 2002). Composting yard and food wastes could potentially decrease the waste stream in North America by 30 to 50 percent thus, greatly reduce the amount of municipal solid waste requiring disposal (Blumberg and Gottlieb 1989, Harper 2003, The Compost Resource Page 2003). As part of this global context, Trent is contributing to the problem as long as it does not implement alternative waste disposal strategies. Therefore, before an in-depth explanation the composting process and available methods, it is important to assess environmental and economic benefits.

1.1 Cost reduction

Composting can significantly reduce waste disposal costs and generate revenue through the sale of the end product. Because landfill space is decreasing and landfill fees are increasing, composting can be a highly lucrative endeavor (BioCycle 1989, BioCycle 1991, and TNRCC, 2003). Composting (and subsequent diversion of organic material from landfills) has been proven to offer substantial savings in disposal costs (TNRCC 2003, and Blumberg and Gottlieb 1989). The markets and uses and application of the end product will be discussed in section 5. Although costs vary for each context, composting systems generally have lower capital costs than landfill and incineration methods

(BioCycle 1991 and JSPPOH 2002). Appendix 1 contains a cost comparison between windrow composting and landfill disposal. Where possible, the specific costs to various composting methods will be provided in the pertinent sections.

1.2 Environmental benefits

By diverting organics from landfills, the environmental threats of methane production and leachate formation in the landfills are avoided. Returning organic materials to the land (i.e. in the form of compost) also reduces non-point source pollution. Non-point source pollution consists of pollutant discharges generally carried by runoff or leachates to surface or ground water. The pollutants include sediments, nutrients, pesticides, metals and pathogens. Composting results in buffering of soil pH levels and binding of heavy metals, preventing migration to water sources, absorption by plants or exposure to humans (BioCycle 1991).

In general, composting is a beneficial practice for water and soil conservation, as well as for ground water quality protection. Moreover, the application of compost provides a long term stable organic matter source that has the potential of mending contaminated, compacted and marginal soils. This facilitates reforestation, wetlands restoration, and wildlife habitat revitalization efforts and results in the revitalization of soils and land (Risse and Faucette 2003, TNRCC 2003 and BioCycle 1989). These important environmental benefits result from the application of compost rather than the composting process itself. Without the return of organic materials to the land, the process of composting would be meaningless; the benefit of composting is that it not only focuses on the diversion of food waste from the main waste stream but also entails a more holistic understanding of waste disposal through which natural cycles are completed.

1.3 Agricultural benefits

Since compost materials are biologically active, when added to the soil, organic matter results in better cation exchange capacity which improves the ability of the soil to retain nutrients and water. Better water holding capacity means that both rain and irrigation water are held in the root zone for plant use therefore requiring less irrigation. Similarly, nutrients are kept from leaching into the ground water meaning that fewer fertilizers are required and the risk of ground water pollution decreases. Organic matter also provides a habitat to organisms which improve soil structure. Enhanced soil structure results in 1) improved drainage, allowing better infiltration of both air and water into the root zone which improves plant health and prevents sealing of the soil surface caused by water pooling that leads to runoff; and 2) extensive root growth and greater aggregate stability so that the soil is less subject to erosion by either water or wind. Once added to the soil, compost continues to break down, providing nitrogen, phosphorus, and potassium in forms that are readily available to plants, as well as a wide range of important micronutrients not found in commercial fertilizers. Furthermore, unlike most inorganic fertilizers, compost functions as a slow-release store of nutrients, so that the nutrients are available as the plants require them instead of in one intense flush. Finally, compost amendments result in increased yield and size in some crops and it appears to suppress some types of plant disease (CCC 2003, NSC 2003, and Risse and Faucette 2003).

2. What is Composting

The process of composting involves the biological decomposition of organic components of the waste stream. In this procedure, the conditions to facilitate the breakdown of organic matter through anaerobic and aerobic processes are created. The final result is a humus rich soil amendment called compost. There are numerous applications for this end product which facilitate the return of nutrients to the soil. Therefore, composting can be understood as a natural form of recycling (Acheson et al. 1995, Risse and Faucette 2003, The compost resource page 2003, Blumberg and Gottlieb 1989 and Neal and Schubel 1987).

The transformation of the organic components of the waste stream into compost is carried out by invertebrates (insects and earthworms), and microorganisms (bacteria and fungi) that break down organic matter and produce carbon dioxide, water, heat, and compost (The compost resource page 2003, and Trautmann and Olynciw 2003). These organisms are arranged into a complex food web representing a pyramid with primary, secondary, and tertiary level consumers. The base of the pyramid, or energy source, is made up of organic matter including plant and animal residues (Cornell a 2003, and Richard and Trautmann a 2003). Bacteria are the most numerous organisms present in the compost; accounting for 80 to 90 per cent of the billions of microorganisms typically found in a gram of compost. They are responsible for most of the decomposition and heat generation in compost and are the most nutritionally diverse group of compost organisms, using a broad range of enzymes to chemically break down a variety of organic materials (Cornell a 2003, and Trautmann and Olynciw 2003).

Under optimal conditions, composting undergoes three phases: 1) the mesophilic, or moderate-temperature phase, which lasts one to three days, 2) the thermophilic, or high-temperature phase, which can last from a few days to several months, and finally, 3) a cooling and maturation phase lasting several-months (Trautmann and Olynciw 2003). During these three phases, different temperature ranges result in optimum ranges for different communities of microorganisms to predominate (BioCycle 1991). In addition to specific temperature requirements, the right food (C/N ratio and other nutrients), air, and water, are necessary to create a good composting environment (Richard 2003).

2.1 Carbon to Nitrogen (C/N) ratio

Of the many elements required for microbial decomposition, carbon and nitrogen are the most important and most commonly limiting[1] (occasionally phosphorous can also be limiting). Carbon makes up 50 percent of the mass of microbial cell and it is digested or ‘oxidized’ as an energy source by the bacteria and fungi in compost. Nitrogen is ingested for protein synthesis and rapid

[1] A limiting resource is the required resource whose supply most strongly influences microbial activity.

growth. Insufficient nitrogen will cause the composting process to slow down, as the microbial population will not grow to its optimum size. In contrast, excess nitrogen allows rapid microbial growth, accelerating decomposition but can result in anaerobic conditions, creating serious odour problems or in too much heat, killing the compost microorganisms. Excess nitrogen will also be given off as ammonia allowing the valuable nitrogen to escape (this is what generates the fetid odor) and potentially polluting runoff water. (Richard and Trautmann a 2003, Richard 2003, and The Compost Resource Page 2003).

The bulk of the organic matter should consist of carbon with just enough nitrogen to aid the decomposition process. The usual recommended range for C/N ratios at the start of the composting process is roughly 30 parts carbon to one part nitrogen (30:1) by weight. In practical terms, adding 3-4 pounds of nitrogen material for every 100 pounds of carbon should provide the required ratio for efficient and rapid composting. Wood chips, leaves, bark and saw dust, are good sources of carbon; fresh grass, manures and blood meal are good sources of nitrogen. For most materials, this ratio will keep these elements in approximate balance, but this ideal may vary depending on the bioavailability of the carbon and nitrogen and several other factors. For instance, as carbon is converted to CO2 (and assuming minimal nitrogen losses) the C/N ratio decreases during the composting process, with the ratio of finished compost typically close to ten parts carbon to one part nitrogen. It is also important to note that varous materials have different nitrogen contents, thus requiring different management choices and different blending proportions in the compost pile. For instance, food waste is typically 15:1, fruit waste 35:1, leaves 60:1, bark 100:1, and sawdust 500:1. A recipe using one part leaves and one part food waste by volume would achieve close to a 30:1 ratio, but the proportions might have to be adjusted if the food waste is largely comprised of fruit waste (Richard and Trautmann a and b 2003, Richard 2003, Risse and Faucette 2003, The Compost Resource Page 2003, and Ullah 2003).

2.2 Oxygen availability

Although compost organisms can survive with as little as five percent oxygen, when oxygen levels falls below ten percent in the large pores, parts of the compost pile become anaerobic (i.e. without oxygen). Anaerobic organisms can still decompose wastes, but they produce methane gas, which is an odorless gas, and hydrogen sulfide, which smells like rotten eggs. Because odor complaints are the most common problem at yard waste composting sites, maintaining an adequate oxygen supply is critical. Therefore, aerobic composting is preferable and sufficient oxygen supply is essential for microorganism populations to efficiently decompose the composting material. Because decomposition uses all the available oxygen, the replacement of oxygen to the center of the compost pile is necessary for the continuation of aerobic decomposition. If pile size remains moderate, aeration can occur naturally by wind or by fresh air from the outside of the pile. Diffusion and natural convection cause the air warmed by the compost process to rise out through the top of the pile and fresh air from the surroundings to be drawn in at the bottom.

Aeration can also be accomplished mechanically by turning or mixing the pile using a pitch fork, a shovel, a front-end loader or a specialized compost turner. Although the oxygen added by turning only lasts a few hours, turning also loosens the piles so that air can flow more easily by natural convection. In addition, turning the compost pile brings newly added material into contact with microbes. In some compost operations, additional oxygen is supplied using blowers, fans, aeration tubes, and aeration holes. These forced aeration systems are more expensive, but they may be worthwhile if the operation has consistent odour problems. Finally, aeration can be achieved by building or rebuilding the pile correctly, or by raising the compost off the ground so that surface air can diffuse (Richard 2003, Risse and Faucette 2003, The Compost Resource Page 2003, and Ullah 2003).

2.3 Moisture content

Moisture is essential to all living organisms. This is particularly significant since most composting microorganisms lack mechanisms for moisture retention, and thus are particularly sensitive in this regard. Further, microorganisms can only use organic molecules if they are dissolved in water. Moisture is also important for heat storage in the compost bulk. Optimal moisture for composting ranges between 40 and 60 percent. If the moisture content falls below 40 percent the decomposition rates are greatly reduced, and below 30 percent, they practically stop since microorganisms become dormant. If the moisture content exceeds 60 percent, aeration is hindered because the pore spaces are filled with water, nutrients are leached out, decomposition slows, and anaerobic decomposition starts to occur, emitting foul odours. The upper limit of moisture varies with different materials, and is a function of their particle sizes and structural characteristics, both of which affect their porosity. The moisture content of fresh food waste is 80 to 90 percent, sawdust is 25 percent, and yard waste is 70 percent (Richard 2003, Richard and Trautmann a 2003, Risse and Faucette 2003, Schaub and Leonard 1996, The Compost Resource Page 2003 and Ullah 2003).

Starting moisture contents usually fall in the upper range because composting occurs as a drying process (through evaporation due to microbially generated heat). Compost with a proper moisture content will form a clump and will slightly wet your hand when squeezed. If the clump drips water, it is too wet and may require additional aeration or more bulking agent. If the compost falls through your fingers, it is too dry and may need water additions or more food waste. The "squeeze test" is a good way to determine the moisture content of the composting materials. Squeezing a handful of material should have the moisture content of a well wrung sponge. In the event of the moisture content being too high, the pile can be turned or can be corrected by adding dry materials. If the pile is too dry, water can be added by turning the compost pile on a rainy day, using an overhead sprinkler, or simply hosing the pile. If the water is applied slowly, it is more likely to infiltrate the pile, rather than running off the surface. Another method involves the use of a drilled pipe as an injection probe, delivering pressurized water from a water truck to the center of the pile where it can be readily absorbed (Richard 2003, Richard and Trautmann a 2003, Risse and Faucette 2003, Schaub and Leonard 1996, The Compost Resource Page 2003 and Ullah 2003).

2.4 Temperature range

As mentioned above, microbial activity will increase the temperature of the pile, and as a result different microbial populations (with particular optimal temperature ranges) will flourish and die off, decomposing particular types of materials throughout the process. Mesophilic bacteria have an optimal range of 20-50°C, and termophilic bacteria can take over at temperatures between 40-70°C, with the optimal range being between 50-65°C. The high temperatures reached at the termophilic stage destroy weed seeds and pathogens in the compost. Although the broadness and variability in temperature ranges for different organisms has created some disagreement as to what the optimum temperature should be, most authors seem to agree on a desired minimum temperature between 21 to 32°C, and a maximum temperature between 60 to 65°C. A compost pile within this temperature range is composting efficiently (BioCycle 1991, BioCylce 1989, Richard 2003, Risse and Faucette 2003, Schaub and Leonard 1996, The Compost Resource Page 2003 and Ullah 2003).

Warmer conditions speed up the process while low outside temperatures slow down the process. Accordingly, the composting process will inevitably slow during the winter months, yet it will not stop completely since some microorganisms have a high tolerance for cool temperatures and will continue the decomposition process at a slower pace. If the temperature rises above 60°C, however, the activity of many of the most important and active organisms is inhibited, and if it rises above 71°C, the compost can sterilize itself, killing off the beneficial organisms. Higher temperatures can also result in spontaneous combustion. Under normal conditions, if the temperature drops below 21°C, it is an indication that the composting process is nearly complete. It is possible however, that the temperature will drop before the composting process is completed due to imbalances in oxygen availability and moisture content. Therefore, it is important to turn and adjust the pile size to improve the oxygenation levels and to expose new surfaces to decomposition, causing temperatures to rise. Turning is also beneficial in the event of temperatures above the optimum range (BioCycle 1991, BioCylce 1989, Richard 2003, Risse and Faucette 2003, Schaub and Leonard 1996, The Compost Resource Page 2003 and Ullah 2003).

3. Types of composting systems

In general, composting requires the separation of the waste stream into organic and inorganic components. The organic material is then placed in either an open field or in a closed mechanical system where bacterial activity can proceed (Neal and Schubel 1987). All composting systems, which vary in the level of technology employed, cost and processing time, involve basically the same three steps: 1) basic preprocessing (i.e. grinding, and shredding, to reduce the particle size, and mixing if different materials are used); 2) separation to remove metals, plastics and other materials that can not be composted and; 3) composting of the remaining material (Blumberg and Gottlieb 1989).

There are three bases for classification of composting systems: 1) degree of aeration (aerobic vs. anaerobic); 2) temperature (termophilic vs. mesophilic); and 3) technology (mechanized vs. non-mechanized or closed vs. open) (BioCycle 1991). These classes are not exclusive categories of composting systems. For instance, an aerobic windrow system generally undergoes both mesophilic and termophilic decomposition and can have different degrees of mechanization. These classes do however, provide a useful means for understanding the general characteristics of different composting systems and will thus be discussed briefly before providing a more in depth explanation of the different composting methods.

AEROBIC vs. ANAEROBIC

Aerobic composting process requires the presence of oxygen, whereas anaerobic composting does not. In aerobic digestion, the wastes take a slurry form whereas in anaerobic composting, the waste remains in solid state. Aerobic composing is the most commonly chosen because 1) it is not characterized by fetid odours (as anaerobic composting is); 2) it reaches high enough temperatures to kill most plant and animal pathogens, parasites and weed seeds; thus presenting less health and crop safety concerns and; 3) it is faster that anaerobic fermentation. Nevertheless, aerobic decomposition is not without drawbacks. It involves more handling and greater spatial requirements. The cost of the structures required to keep an odour free anaerobic operation however, far exceeds those for handling of an aerobic process (BioCycle 1991).

MESOPHILIC vs. TERMOPHILIC

As mentioned above, mesophilic and termophilic refer to the optimum temperature range within which different organisms partake in the decomposition process. In an aerobic mass of material the temperature will inevitably rise from the mesophilic to the termophilic level. Both levels are equally important, and might be concluded that the ideal temperature for the process is a compromise between the optimum temperatures of the various microbes present in the process (as discussed earlier in the paper).

MECHANIZED vs. NON-MECHANIZED

Mechanized composting entails the use of automated, enclosed units equipped to provide control of the major environmental factors. Non-mechanized on the other hand, involves manual stacking of the raw material in elongated piles (windrows) (BioCycle 1991). This classification, however, does not provide a space for intermediate levels of mechanization. For instance, in the case of windrow piles there are various degrees of mechanization from completely passive, to aerated static piles, to non-static windrows. Furthermore, the idea of mechanized vs. non-mechanized seems to imply that in some instances it is possible to run a composting system entirely manually. Although this might be possible at the back yard level, at the institutional level there is always reliance on machinery. Therefore, a more useful classification is that of high- and low-technology as it is more flexible and it implies that no matter how simple the operation, there is always some degree of mechanization.

3.1 Bins

Bins are built using wire mesh or wooden frames which allow good air circulation. Bins are inexpensive, and require little labor. Three chamber bins allow for faster compost production as varying stages of decomposition can happen simultaneously (Risse and Faucette, 2003). Bin composting is typically used for smaller amounts of food waste. In the particular case of Trent, they might offer a useful alternative for decentralized composting (i.e. at the departments or colleges, without including the dining halls).

3.2 Passive composting or piling

Passive piling is the cheapest and most simple method of composting. It only requires stacking the materials and letting them decompose naturally relying on natural convective airflows for aeration (As shown in figure 1). This method has some drawbacks: it is very slow, may result in objectionable odors and it requires large areas of land (Risse and Faucette 2003, and Schaud and Leonard 1996).

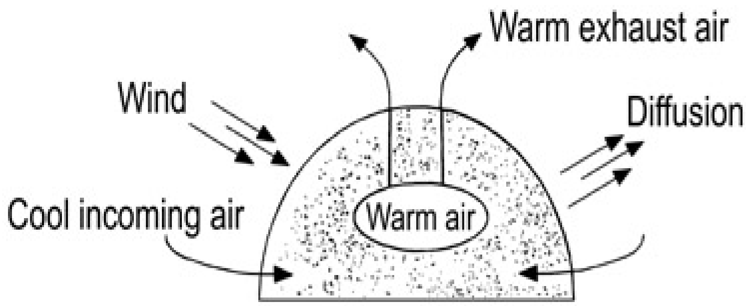

Figure 1. Natural convective air flow in a passive compost pile (from Risse and Faucette, 2003).

An improved version of this method is the passively aerated windrow system (shown in figure 2). In this system, air is brought through the pile by passive means, eliminating the need to actively turn the piles, yet improving airflow significantly. Other advantages of this method include: low start-up costs and operating costs; low requirement of staff time or special skills; and fewer odors and pests (than with the passive piles). The compost recipe is made up of a layer of manure and wood chips to sponge up moisture (placed on a concrete pad); perforated PVC pipes laid perpendicularly to the windrow (with the ends sticking out to passively aerate the compost pile); food waste and paper products and finally a six-inch top layer of dry manure to seal in odors (Hazen 1998). This is the method that has been in use at the Middlebury College (NY) since 1996 with incredible economic benefits (described below).

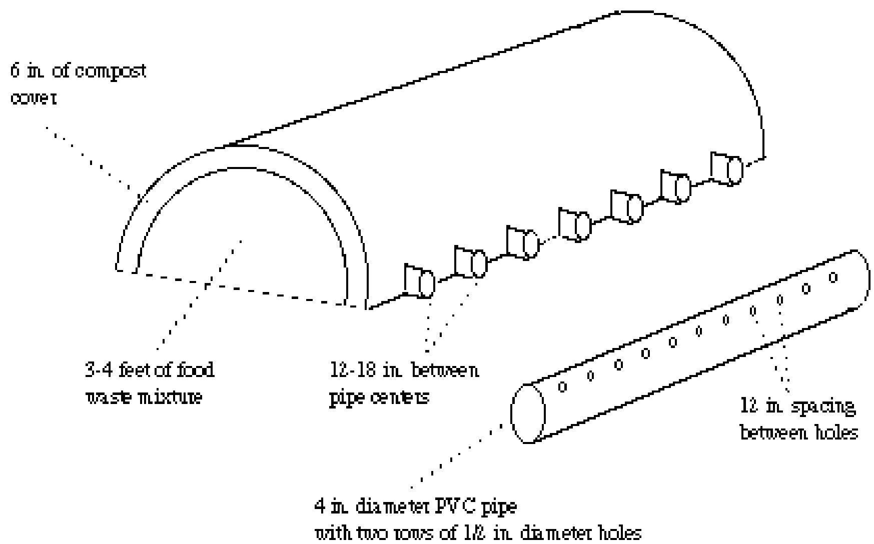

Figure 2. Passively Aerated Windrow System (PAWS). (From Hazen 1998)

The materials required for this system are (Hazen 1998):

- Pre-consumer food prep scraps, post-consumer food residuals, waxed cardboard, paper towels, napkins, and food prep wastepaper,
- Truck to transport compost that is specially designed to lift toters from food service areas,
- One large preliminary food waste storage container,
- At least one acre of land,
- Concrete pad,
- Manure and wood chips (this might be difficult for Trent)
- and Perforated PVC pipes.

3.3 Aerated static piles

In this method, aeration is further improved by forcing air flow through the pile by placing perforated pipes with a fan or blower system inside the pile. Similar to passive piles, this method requires no labour to turn the piles yet more control is retained over the aeration rate (Blumberg and Gottlieb 1989 BioCycle 1991, and BioCycle 1989). The windrow material is aerated either by pushing or pulling air through the pile. By pulling air through the pile, the air can be treated before releasing it into the atmosphere, this is also possible when pushing air through the pile, but it requires a special structure with a very sophisticated ventilation system. The aeration system is limited and still requires occasional turning. Moreover, this method is weather sensitive and can have unreliable pathogen reduction due to imperfect mixing (BioCycle 1991, and Risse and Faucette 2003).

3.4 Vermicomposting

Vermicomposting is a form of composting that can be done indoors (i.e. in greenhouses) or outdoors using an insulated outdoor bin. Vermicomposting uses worms to consume the food waste and utilizes its castings (end product) as high quality compost. Many schools use this type of composting as an environmental education tool. Typically 1 pound (0.45 kg) of worms can eat 4 pounds (1.81 kg) of waste per week (Risse and Faucette 203). In the case of a middle scale composting system, however, the initial amount of worms required is often a drawback as stocking still would be high, and so would be the investment. In the case of Trent, where about 3.5 tons of waste are produced weekly (based on the 1997 estimate of 118 tons per year, and adding an estimated 20 percent increase), almost one ton of worms would be initially required. Nevertheless, vermicomposting systems can be customized to handle quantities of 50 pounds up to 30 tons of organic matter per day, and are suitable for food distribution facilities, retailing facilities, food processing plants, kitchens or any sector that generates organic matter. Original Vermitech Systems Limited is the only manufacturer and supplier of mid-scale to large-scale vermicomposting units in Ontario (RCO 2003). Other drawbacks include: 1) if too much waste is added anaerobic conditions may occur; 2) worms cannot process meat products and 3) vermicomposting by itself does not elevate internal temperatures of the compost sufficiently to reach temperatures at which plant and animal pathogens and parasites would be killed (BioCycle 1991, and Risse and Faucette 2003).

A related method of vermicomposting is called the worm gin. This system is a medium to large-scale composter that combines aerobic composting with worms, working as a stacked series of conveyor belts for worm beds. The cost of the system is specific to the volume of waste being processed, and thus cannot be calculated until a waste audit is completed. Although the description seems highly efficient, this is a very new system (patent pending) and therefore resources on the topic are very limited (i.e. only one web based source found). A complete description of the system however, is available on the World Wide Web (see references for worm gin web site) and it might be worthwhile to get in contact with Harry Windle (Worm World, Inc. 352-485-1903, windle@gnv.fdt.net) the designer of the system for a in depth description of the system.

3.5 Windrows

When carried out in large scale, windrow composting requires large decomposition area. In the Trent context, however, these space requirements are still considerably lower than landfills. Windrows generally require about one acre of land for every 4,000 to 6,000 cubic yards of leaves (Blumberg and Gottlieb 1989, BioCycle 1991, and BioCycle 1989).[2] Based on the 1997 estimate of 118 tons, and factoring a 20 percent increase of the student body, Trent produces about 141.6 tons of food waste annually. Thus the total amount of waste produced by Trent in one year could be processed in about 0.113 acres (457.3 m^2). If we then add 15 percent of the size of the windrow composting area to account for recommended buffer area, the total area required to compost the food waste at Trent is 0.129 acres (522.04 m^2) (see appendix 4 for calculations). The composting process time using windrow and turn ranges from 6 to 12 months plus a minimum of one month for curing (BioCycle 1989). Thus the area calculated (based on the annual waste production) will not have to increase every year as area will be freed with harvesting of the end product.[3]

In the event of implementing a composting system at Trent, several types of waste could be composted together (e.g. leaves, and grass clippings, food

[2] One cubic yard of leaves, is equivalent to approximately 500 lbs, or 1/4 ton (BioCycle 1989).

[3] These calculations are based on composting solely leaves. I am aware that composting at Trent might be mainly food waste, and as such the calculations are not entirely accurate. They are useful, however, in the sense that they give a sense of how much (or how little) area is required for a composting operation.

scraps and paper). In this case, the first step would involve thoroughly blending all materials. Mixing is required to balance the carbon and nitrogen ratio and distribute moisture throughout the pile. Blending is also carried out to ensure an even texture, and hence an even distribution of large pores so that oxygen can move freely. This blending process is particularly critical if grass clippings or other high nitrogen materials are being composted. Mixing can be accomplished with a front-end loader, although other equipment such as tub grinders or specialized windrow turning machines are commonly used when mixing grass clippings, which tend to mat together (Richard 2003).

Asphalt or concrete pads, or a weather-proofed, firmly packed soil platform should also be built before building the piles. This enables ease of operation and maintenance and provides an environmental and hygienic barrier. These specifications can be relaxed for curing stages (BioCycle 1991). The pads should run up and down rather than across slopes to allow leachates and runoff to move between piles, rather than through them, and there should be enough space between them to allow for turning (BioCycle 1989).

The size and shape of the windrow are very important to allow oxygen to flow throughout the pile while maintaining temperatures in the proper range and to maintain appropriate moisture contents. The pile has to be small enough for oxygen to penetrate to the center and large enough for the pile to heat up properly. The optimum size varies both with the type of material and with the time of year, therefore most of the sizes provided in the literature are approximate and may need to be adjusted somewhat anyways. Windrows can be as long as is convenient for the site, up to several hundred meters in length. Fig. 2 is only a general example of the shape and dimensions of a leaf compost pile.

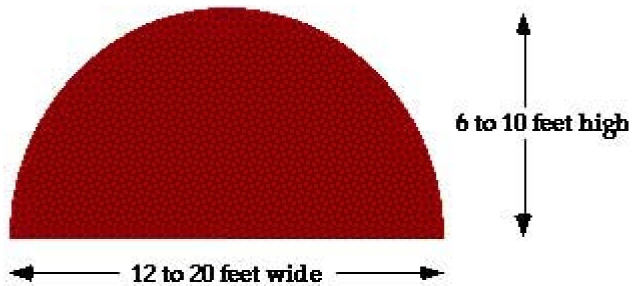

Figure 3. Cross section of a leaf compost windrow (From Richard 2003)

In terms of moisture content, scooping out the top of the pile to create a concave shape will maximize water absorption, so that rainfall can help replenish the moisture that is lost from the piles as steam. If the pile is saturated with moisture, anaerobic odors and leachates will be produced. Therefore, the pile should be shaped to form a peak that will minimize absorption by shedding water (Richard, 2003).

Turning is an important step in windrow composting, since it is the mechanism by which moisture, oxygen, and temperature (and thus decomposition rate and odour) are controlled. The best results from turning are achieved when: first, the material from the outside of the pile is moved to the middle, where it can decompose more quickly; and second, the material is loosened and fluffed, so it will be more porous and air can move freely (Richard 2003). Turning can be accomplished using all-purpose machinery (e.g. bulldozer, or front-end loader) or specialized machines (e.g. mechanical turners). All-purpose machines are adequate when dealing with small daily inputs of waste (such as Trent's). Specialized automatic machines are more efficient and have greater throughput capacities, but involve higher purchase, maintenance and operation costs (Blumberg and Gottlieb 1989, BioCycle 1991, and BioCycle 1989). The figure below, illustrates how the job can be done with a front-end loader. First flip the top of the windrow over just beyond the existing windrow. Second, take the compost from the bottom of the old windrow and place it on top of the new windrow. Let the compost cascade out of the loader, to keep it as loose as possible (Richard 2003).

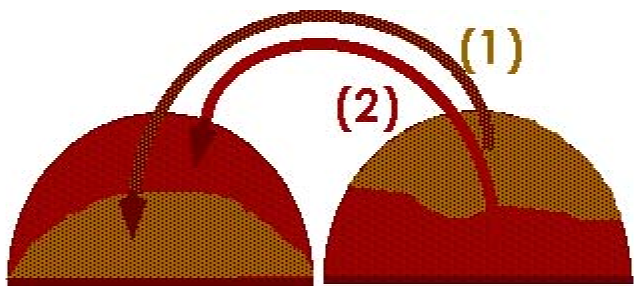

Figure 4. How to turn a compost pile using a front end loader (From Richard 2003)

Frequency of turning is a function of many factors: the oxygen demand of the active microbial population, the nature and conditions of the substrate, the type and capacity of the turning equipment, space requirements and economic factors (BioCycle 1991). Practically, however, turning frequency is normally based on temperature: the compost pile is turned whenever temperatures exceed 60 to 65° C, or drop below 21 to 32°. If the compost remains in this range independently, regular turning can accelerate decomposition by mixing the material and exposing new surface. As decomposition proceeds and the compost becomes more stable, frequent turning becomes less important. By following this general guidelines a uniform product can be expected (Richard 2003). The main draw back of this method is the turning requirement, since turning all-purpose equipment can be labor intensive, yet using specialized equipment is very expensive (Risse and Faucette 2003).

As mentioned above, the cost of constructing and operating a windrow composting facility will vary from one location to another (JSPPOH 2002). In general terms, the capital costs could include (JSPPOH 2002, and Watgreen 2003):

1. Machinery costs: Compost pads, grinder, compost mixer, trommel screen, front-end loader, and windrow turner.
2. Need to procure amendments
3. Cost of site construction
4. Personnel
5. Collection system
6. Odour control costs
7. Product utilization/transportation costs
8. Quality assurance costs (i.e. lab tests for pathogens and heavy metals)
9. Composting performance equipment (e.g. temperature probes, oxygen meters)

The above elements of windrow composting do not have exact prices since the prices largely depend on geographic and climatic factors. Therefore, before associated costs can be determined, a proposed system, including site location, must be established (WatGreen 2003). Given that no comprehensive analysis of what Trent would require is available, it is difficult to assess the costs. Cornell University (b 2003) however, has a large scale windrow composting system that has been operating since 1997 that can provide a lot of insight for the particular situation of Trent (in fact a lot of the information presented in this section was drawn from their experiences). Furthermore, Cornell (c 2003) has developed *Co-Composter*, an Excel spreadsheet model for the planning of composting systems for mixtures of dairy manure and other organic wastes (see Cornel d 2003 for link). Co-Composter provides mass and volume balances, area estimations, and a cost analysis of alternate composting systems based on inputs entered on the user. Thus, once some of the inputs are established at Trent, this spreadsheet will be an extremely helpful tool for calculating windrow costs.

3.6 In vessel systems

In-vessel systems use anything from perforated barrels, to drums, or specially manufactured containers (Risse and Faucette 2003). More sophisticated ones consist of a horizontal rectangular tank equipped with a specially designed conveyor belt mounted on wheels that move on racks placed on the bottom of the tank. As the belt moves it picks up and deposits composting material, thus serving as a mixing device. The tank can have a perforated bottom to allow air to circulate (BioCycle 1991). Less sophisticated ones are rotating barrels, as shown in appendix 5. Overall, these systems are often preferred over other composting methods because of better odour control, less space requirements, greater process and materials handling control, better public acceptance, minimal labour requirements and energy inputs, are not weather sensitive, and can be used in urban and public areas (Risse and Faucette, 2003. The initial investment can be high and handling volumes are typically low (BioCycle 1991, and Risse and Faucette 2003).

In general the initial decomposition of the material in an in-vessel composter occurs inside the composter at optimal conditions for decomposition. The composter rotates the food waste internally and in this process allows necessary oxygen in to aerate the compost. Some in-vessels require additional materials (i.e. leaves, sawdust, etc.) to absorb the excess moisture created during the decomposition process. Once the initial decomposition is complete, the compost needs to be cured (for 2 to 4 months) in order to create a useful end product (Gould 1993).

Following is the examination of two in-vessel composters (products of Wright Environmental) drawn from a report found in the WatGreen Student Library (WatGreen 2003). The first model is the WEMI 600ppd, a smaller model that can take up to 600 lbs per day (or 0.27 tons). The second model, the WEMI 3tpd model can take up to 3 tones per day of material. In both models the material can be up to 70% food waste. Outlined in table 1, are the costs for both models at the three main levels of associated costs (set up, maintenance and labour) plus additional costs. Additional costs are broken down in table 2, and they include: windrow maintenance, labour, site preparation, transportation of unit and training of staff.

Table 1. Cost comparison for two models of in-vessel composters (WEMI 3tpd and WEMI 600ppd)

Model	Set up costs	Maintenance costs	Labour costs	Additional costs
WEMI 3tpd	377,420	3,984.59	1 worker/3hrs/day	47,881.86
WEMI 600ppd	66,000	730.00	1 worker/2hrs/day	41,329.86

Table 2. Detailed cost comparison of the additional costs for two in-vessel composters

Model	In-vessel labour	Windrow maintenance and labour	Site preparation, transport and training
WEMI 3tpd	19,656.00	25,725.86	2,500
WEMI 600ppd	13,104.00	25,725.86	2,500

This cost calculation only includes the initial phase of in-vessel composting. After this phase is completed, a windrow curing operation is necessary. That cost is not included in this calculation (WatGreen 2003).

3.7 Collecting systems

Although strictly speaking, choosing a collecting system is not the same as implementing a composting system, it is important to consider this option as it offers an alternative when there is the willingness to separate compostables from the waste stream but a composting facility on site is not a viable option.

When selecting a waste collection system, first it is important to define the short and long term objectives when choosing such an option. Second it is important to consider what equipment is already available in the institution, such as, compaction vehicles, dump trucks, front-end loaders, skid loaders and vacuum equipment. Other factors to be considered include specifying the waste streams to be incorporated (e.g. yard waste, food waste, and or waste paper) and finally the seasonality and frequency of the pickup service (BioCycle, 1989).

It is also important to mention that there are numerous collecting methods that involve the use of various types of machinery. Different methods will be suitable for different applications and have different costs. A detailed explanation of these, however, is beyond the scope of this paper, as the information will likely be dependant (and provided by) the collecting company chosen.

The City of Peterborough is currently running a composting pilot project, with curb side composting for residential areas. The project, might potentially expand to the institutional sector, providing an opportunity for Trent to establish a contract with The City (Sauvé 2002). It is important to bear in mind, however, that a composting facility on campus would offer a more solid and sustainable alternative, as agreements with haulers can fall through (i.e. contract with the pig farmer). If despite this knowledge Trent still chose this option, they should have an environmentally sound back up plan, in which case it is still worthwhile to explore composting systems with certain depth.

4. Benefits and drawbacks

After having described different composting methods, it is important to summarize their benefits and drawbacks. This comparison will facilitate the work of future students in assessing the feasibility of each method as a function of how they stand in relation to the particular context of Trent University.

Table 3. Comparison of the benefits and drawback of various composting methods.

METHOD	BENEFITS	DRAWBACKS
Bins	- Some diversion of waste is achieved - Marketable end product	- Only for small scale - Seasonal (summer only) - High maintenance (otherwise attracts fruit flies and rodents) - Only certain foods can be added
Passive Compost	- Some diversion of waste is achieved - Marketable end product	- Great potential for odour problems - Slow - Difficult to obtain an homogenous end product
Aerated Static Piles	- Some diversion of waste is achieved - Marketable end product	- Recurrent mechanical problems with the piping system (i.e. Clogging) - Mild potential for odour problems
Vermi-composting	- Waste diversion - Marketable end product - Fun and novelty - Warms reproduce (therefore, only start up cost) - Fast, odourless - Can be performed indoors (therefore, can be performed all year round)	- In a medium scale, it would require large amounts of worms - Low efficiency in terms of time, effort and cost - High maintenance (otherwise worms can die) -Only certain foods can be added
Windrow	- Waste diversion - Marketable end product - All foods can be added	- Need for government licensing and adhering to ministry of the Environment standards - Labour intensive or expensive equipment - In the winter, requires snow removal (increasing labour requirements) or the composting process will slow down too much - Has high start up costs
In-vessel	- Waste diversion - Marketable end product - All foods can be added - Gives Trent environmental leadership as no other Canadian universities have this system in place - Odour control - Efficient space use - Good control of process and material handling - Aesthetic enclosure. Therefore, better public acceptance - More consistent product quality	- Requires highly trained staff - High maintenance - Still requires land to cure compost - Very high start up costs
Haulers	- Waste diversion - Can be relatively inexpensive (depending on the arrangement) - Very low start up costs (because a	Not as much waste might be accepted (i.e. if arrangement is with a pig farmer, napkins and cardboard will not be accepted)

	similar system has already been in place in the past) - Does not require any major changes or investment from The University	- Un-sustainable - If pick-up frequency is low, might generate odour, fruit fly problems - Lack of true engagement from the university - Does not result in direct revenue generation (only economic benefit through avoided costs)

5. Institutional composting case studies

There seems to be a growing trend in universities and colleges throughout North America towards waste disposal methods that generate economic revenues and are environmentally sound. Following are some case studies of universities and colleges that have implemented composting programs on site and found them to be widely beneficial (see appendix 3 for a comparative table of some of the case studies presented below and other ones). These case studies provide evidence that the implementation of a composting system at Trent is not an impossible or risky option since these systems have been widely tested and proven to be successful in other universities. Throughout the case studies, various composting methods are presented, as every method has benefits and disadvantages that make it suitable (or not) for the particular circumstances of each college or university.

5.1 Cornell University

Cornell University is considerably larger than Trent, with a student population of nearly 19,000 students, and consequently produces a larger amount of waste compared to Trent (approximately 700 tons of compostable food scraps annually). In addition, they offer a variety of programs that make their composting methods unique such as, agriculture and veterinary medicine. However, they are one of the leading universities in composting programs and have a wealth of information on the subject. As such their experience might be of insight for the context of Trent (Cornell b 2003).

Cornell began composting food scraps from the campus' dining facilities in 1997 through the conjunct effort of the Farm Services Department, the Waste Management Institute and the University's Dining Services. The waste collected, comprises about 17% of the University's waste stream that had been going to the landfill. Although the Division of Dining and Retail Services pays Farm Services the same rate per ton to collect and compost their food scraps as they would have paid to have the food scraps land filled, the tipping fee may be adjusted after the program has been in place long enough to gage its cost. Furthermore, the arrangement allows Dining Services to participate in a environmentally sound program at no additional cost. This arrangement also provides funding for the program, which does not receive any other financial support. The ability of the program to operate with no financial support (other than the tipping fee) is strong proof of its economic viability. Although state regulations prohibit the sale of the compost, economic benefits arise from the use of the finished compost as a soil amendment. The finished compost is spread on agricultural fields which are used for the production of animal feed and runoff stored in retention ponds is used to irrigate dry piles and adjacent hay fields (Cornell b 2003).

Both pre- and post-consumer food wastes are collected. Scraps are collected in 32-35 gallon plastic barrels on casters. Most of the scraps are ground and dewatered by dining staff in a pulping machine which was in operation prior to the implementation of composting. Food scraps are collected daily from the dining facilities in a small pickup truck with a sealed dump body and taken to a staging area at the Farm Services Complex; animal bedding is collected in the bottom of the truck to absorb excess liquid from the food scrap. At the Farm Services Complex, scraps are transferred with a front-end loader from the truck body into an agricultural feed batch mixer and sawdust/manure bedding is added to achieve the desired consistency and moisture content. The mix is then blended for 5 to 10 minutes. The feed batch mixer has knife attachments on two of its augers to chop up any large pieces of cardboard or food. The mixture can be stored in the mixer overnight and then transported to the compost site using a tractor (Cornell b 2003).

Once at the composting site, the food scrap mixture is spread. The windrows are turned as needed based on temperature monitoring. When the internal temperature reaches 55-60°C (131-141°F), the windrow is turned and mixed with a windrow turner. Water or dry bedding is added as needed to maintain moisture content of approximately 40 per cent. Wind conditions are taken into account when turning the pile to avoid odor problems and unwanted drying of the piles. The windrows are approximately 250 feet long, and 6-8 feet tall and 14 to 18 feet wide. The organic material is kept on the compost pad about six months before spreading (Cornell b 2003).

5.2 Dartmouth University

Dartmouth launched its composting program in the summer of 1998. This is an interesting case study as it not only deals with pre- and post-consumer food waste but it also deals with both the centralized and non-centralized sources of food waste. Centralized food waste production is dealt with in the initial component of the program, by waste separation in the dining halls, a complicated process still in operation but currently being streamlined. The second component of the program is to separate food waste from the dorms; this would address non-centralized sources of food waste (Dartmouth 2003).

The food waste separated from the main waste stream (which is about 2300 tons per year), goes to a privately-owned facility three miles away on an old landfill site. At the facility, food waste is mixed with dry matter (e.g. sawdust or shredded waste paper) and put into one of three chambers in the facility. It stays in the chamber for 14-21 days, during which it is periodically mixed with an automatic stirring device. After this stage, the compost cools in a special room and is then moved outside. The last step is sifting, when any remaining largesized waste is removed and returned to the start of the process to cycle again (Dartmouth 2003).

During an eight month period, composting food waste brought Dartmouth $1,712 in savings in landfill costs and $9,702 in savings in fertilizers. To date, such savings are still the norm. Moreover, these figures do not include the associated savings from less water and electricity use in garbage disposals (Allen 1999).

5.3 Ithaca College

Ithaca College began periodically composting food scraps from its dining halls in 1993. It was not until 1995 however, that composting became a year-round practice. In 1998, the success of the program led to the planning of a new compost facility large enough to handle all food scraps generated on campus. In the plans for this facility an area for student research was allotted. The construction started in 1999, and was completed and in operation by 2000, with a goal of diverting 100% of food scraps from dining halls (REMP a 2003).

Currently, the College collects both pre-consumer food scraps from the dining hall kitchens and some post-consumer plate scrapings. The collected food waste is gathered in the trash collection areas at dining hall loading docks in a dumpster that is used for weekday collection. On Saturdays, the scraps are included with other materials to be taken to the landfill, and on Sundays food scraps are kept until collection on Monday. The food scraps collected during the week are composted in aerated static piles, and the final product is used as a soil amendment on campus grounds. The College is composting about 5 tons of food refuse per week, which account for approximately 13-15 percent of the total waste stream (REMP b 2003). Although specific figures on savings are not provided anywhere in the college's website, it is possible to presume that the use of the end product as a soil amendment brings economic benefits to the college, and that the overall benefits mentioned above are also applicable in this case.

5.4 Mohawk Valley Community College

The Mohawk Valley Community College has a student population of 6000 which is closer to that of Trent's. In the fall of 1996, this College began a food scrap composting pilot program using passive composting. The scraps and chips were formed into a static pile approximately 10 feet high by 12 feet wide by 20 feet long, constructed on a 20 foot by 20 foot gravel pad on a two-acre site. The pile did not require turning since it was built in layers, and covered with a layer of chips to act as a biofilter. By proper stacking, there is enough air circulation in the pile that allows the pile to compost passively. Unfortunately a mishap with an outside contractor accidentally bulldozed the pile, thus interrupting the composting process. Because the program had been otherwise successful, the College plans to start the program again by constructing a three-bin unit near the kitchen dumpster (Cornell d 2003).

At the Mohawk Valley Community College, the food scrap composting program adds to the students' education by demonstrating alternatives to traditional food scrap disposal methods and promoting sound environmental practices. Accordingly, the trained chefs emerging from the College's culinary program will work in many different locations where they could potentially start composting programs. In addition, the program has reduced disposal costs and has reduced other costs since the finished compost will be used in landscaping projects on campus (Cornell d 2003).

5.5 Middlebury College

Middlebury College has been composting since 1993, when the college was awarded a state grant to expand its recycling program. Through composting the College diverts 75% (300 tons/year) of food waste from the landfill. Because the average composting cost per ton of food waste is estimated at $43, whereas the average cost per ton for trash taken to the landfill is $135, this program marks considerable savings for the College. Since 1993, they have spent about $48,000 on food waste disposal, compared to the estimated $150,000 they would have spent if the food waste had been sent to the landfill. Overall Middlebury College has saved approximately $102,000 between April 1993 and 1998 (Hazen 1998).

The composting system employed at Middlebury College is similar to that initially used at the Mohawk Valley Community College. Generally this process involves four basic steps: dumping and mixing, passively aerated windrow, curing and finally screening and spreading (Hazen 1998).

5.6 University of Colorado

Many colleges and universities do not have the possibility to implement a composting system on site, either because of staff shortages, economic constraints or lack of suitable land space. This is the case of both Dartmouth and Colorado University. As mentioned above, Dartmouth University saved costs because the composting tipping fee was lower than the landfill tipping fee. In the case of Colorado, the cost of composting is not lower than that of land filling yard wastes. However, the University still saves money because it receives a 50 per cent discount on finished compost which it buys back from the private composting facility and uses for campus landscaping. These savings amount to $1,300 annually (Allen 1999).

5. 7 University of Waterloo

The University of Waterloo has had windrow composting for leaves, yard waste and flowers from the beds on campus since the early 1970's. This comprises approximately 10-15 tonnes of material composted each year. The windrows are long rows of organic material stacked into elongated piles with a triangular cross-section (approximately five meters across and two meters high). The windrow is turned with front-end loaders on a regular basis, as time permits or as needed (approximately every 2-3 months). The end product is used for greenhouse potting soil, fill for tree holes, and topsoil (Waterloo 2000).

Although the University of Waterloo does not have a food waste composting system, it was the only Canadian university with any kind of composting project found during this research. Several attempts have been made to implement composting systems that include food waste. The WATgreen student library[4] includes numerous proposals for the implementation of food composting systems on campus as well as papers discussing the reasons for the failure of such proposals (largely lack of interest and follow-up).

6. Uses and applications

Finally it is important to discuss the various uses and application of the end product of composting since the economic benefit derived from them might act as a strong incentive for the possible implementation of a composting system at Trent. The more innovative uses of composting include:

- Bioremediation and Pollution Prevention
- Disease Control for Plants and Animals
- Erosion Control and Landscaping
- Composting of Contaminated Soils

[4] http://www.adm.uwaterloo.ca/infowast/watgreen/projects/library/index.html

- Reforestation, Wetlands Restoration,
- and Habitat Revitalization

(From US EPA 2003)

Amongst the more well known applications of the end product of composting are: soil conditioner, mulch, fertilizer, and landfill cover. The latter, extends landfill life by replacing about 17% of the capacity by volume taken up by ordinary landfill cover (Blumberg and Gottlieb 1989). The amount of compost that can be used per unit area, further demonstrates its marketing potential: one inch of compost spread over one acre represents about 65 tons at a 40 percent moisture content (BioCycle 1991).

In the case of using the end product for landscaping and gardening purposes the BioCycle staff (1989) recommends the following three marketing methods:

A. Bag and bushel program: this is a small scale program where gardeners bring their own containers and pay per bushel.
B. Bulk load pick-up: this option involves loading up the costumer's trucks and charging per cu. yd.
C. Home delivery: this method is the most popular, and it consists of providing a home delivery service available spring summer and fall for several days a week. The minimum residential sale is 2cu.yds. and the maximum is 10cu.yds. In addition semi truck loads are delivered to landscapers and commercial growers, sold at a discount to encourage the use of composted material on lawns and in potting medium for nursery stock.

The third method appears to be the less suitable for Trent as it would require increased personnel and possibly purchasing of a delivery vehicle. The other two methods however have good potential, especially considering Trent's strategic location and the fact that the peak season for the sale of compost will be during the summer, when most students are away, and thus wandering potential buyers would not interfere with the regular pace of things. In fact these options might provide a good space for work or volunteer opportunities on campus, and all sorts of other possibilities for expansion in the future.

Finally, Trent's grounds offer a good destination for the end product. Although, there would be no direct revenue generation, Trent could save money by avoiding fertilizer costs, and what is more important, continue to move towards management practices that further reflect its concern for environmental protection as stated by the PEAC (2002).

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US Environmental Protection Agency, ‘Composting’. US EPA. January 5th 2003. <http://www.epa.gov/epaoswer/non-hw/compost/>

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PERSONAL COMMUNICATION

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Sauvé S. Waste Reduction coordinator, City Hall, Peterborough, ONT. Personal communication, November 15th, 2002

JOURNAL ARTICLES
Schaub S.M. and J.J. Leonard. 1996. ‘Composting: An alternative waste management option for food processing industries’ *Trends in Food Science and Technology*, Vol. 7, pp. 263-268.

ADDITIONAL RESOURCES

WEB PAGES

Alexander, R. 'School Food Collection and Composting Program'. The Composting Council of Canada.
<http://www.compost.org/AlexanderRon_SchoolFoodCollectionArticle.PDF>
This article describes the case study of a successful composting program at a school in NC, USA.

'Bio Resource Management' Bio Resource Management.
<http://www.recycle.net/bioresource/page2.html>
This is the link to Bio Resource Management home page. This page contains information on the medium to large scale in-vessel composting systems that the com company sells and leases.

'Biosolids Technology Fact Sheet' EPA.
<http://www.epa.gov/owm/mtb/invessel.pdf>
This is a fact sheet on the use of in-vessel systems for the treatment of biosolids. Published by the EPA, USA.

Government of Ontario. 'Green Workplace Program' Ontario Government.
<http://www.ilsr.org/recycling/wrrs/food/food4.pdf>
This is the governmental brochure describing this program. It is a good example in the preparation of brochures explaining/promoting composting programs

Ministry Of Agriculture Food and Fisheries, BC. 'Composting fact sheet'. MAFF, BC. <http://www.agf.gov.bc.ca/resmgmt/publist/300series/382500-14.pdf>
This fact sheet contains the basic economics of composting for on-farm manure composting

National Standard of Canada, The Canadian Council of Ministers of The Environment (CCME) Guidelines, Agriculture and Agri-food Canada (AAFC) Criteria. 'Support document for compost quality criteria'. The Composting Council of Canada. < http://www.compost.org/compostqualitydoc.pdf>

'RRFB Nova Scotia'. RRFB Nova Scotia. 2001.
<http://www.rrfb.com/pages/Secondary%20pages/sourcesep.html >
This page contains links and contact information about companies that sell source separation and recycling containers.

'The US Composting Council'. The US Composting Council. 2003.
< http://compostingcouncil.org/>
This page contains useful information on projects, publications and links to other pages related to composting.

'Wat Green Student Library'. University of Waterloo. 2003
< http://www.adm.uwaterloo.ca/infowast/watgreen/projects/library/index.html>
This page contains the reports for several ERS courses of the University. Several of the reports have explored the issue of composting, in the particular context of the University of Waterloo.

- www.dep.state.pa.us/dep/deputate/airwaste/wmi/RECYCLE/
  Notes on a workshop on food waste composting in Philadelphia

- www.state.co.us/oemc/comm/press/pr020820.htm
  Planning guide to enable Colorado institutions to choose best method for composting
- www.biocompostable.com
  Web site of the company 'Biocompostable'. This company makes compostable products such as garbage bags and disposable cutlery.

OTHER CORNELL UNIVERSITY RESOURCES
'Composting challenges and solutions in New York State'. Cornell University
<www.cfe.cornell.edu/wmi/PDFS/compchal.pdf>

'Reducing NY's waste stream: The potential role of composting'. Cornell University. <www.cfe.cornell.edu/wmi/composting.html>
This article summarizes the discussion of experts in composting alternatives for NY state

'Yard waste composting'. Cornell University.
<www.cfe.cornell.edu/wmi/composting.html>
This page presents and describes various composting methods for yard waste

'Composting in Schools'. Cornell University.
<www.cfe.cornell.edu/wmi/compost/>
This page contains an interesting array of resources with educational materials, in-the class room activities, and student research activities.

GOVERNMENT AND OTHER PUBLICATIONS
The composting council of Canada, National survey of solid waste composting operations in Canada, Environment Canada, May 1993.

Centre and South Hastings Recycling Board, The YIMBY program, final report, February, 1994.

Compost Ontario, Guide to Setting up a home composting demonstration site, Recycling Council of Ontario, October, 1990

Recycling Council of Ontario, Multi-residential composting in Ontario, may 1993

Thompson, D., and S. van Bakel, 1995. A practical introduction to environmental management on Canadian campuses, National Round Table on the Environment and the Economy, Ottawa, Canada

BIOCYCLE
This magazine is a wonderful magazine on composting and organic recycling. Unfortunately, Trent does not have a subscription and it is not available on line. OPIRG has two copies, and these are the articles that I found particularly relevant:

- Hoff, J. 'Best strategies for biosolids', *Biocycle,* vol.: 36, No 4, pp. 42-47
- Sinclair, R., and M. Kelleher. 'Anaerobic digestion for household organics', *Biocycle,* vol.: 36, no 4, pp. 50-53
- Kunzler, C., and R. Roe, 'Food service composting projects on the rise', *Biocycle*, Vol.: 36, no 4, pp. 64-71
- Day, G. 'McDonald's behind the counter composting pilot', Vol.: 36, No 4, pp. 72-76
- Freinbaum, R., and W. Gehr, 'Testing the logistics of source separation', *Biocycle*, Vol.: 36, no 4. pp. 94-99

APPENDIX 1

Table 1. Annual Operating Cost Comparison of Diversion (Windrow Composting) and Disposal (Landfill)

	Diversion	Disposal
Operational Costs:		
Labor and maintenance:	$165,000	$0
Landfill costs:	$0	$84,000
Transport/waste pickup costs	$0	$150,000
Total Operational Costs:	$165,000	$234,000
Total Recovered Income (Topsoil Savings):	$37,500	$0
Net Annual Cost/Benefit:	-$127,500	-$234,000

- These costs are given in US dollars

Economic Analysis Summary:
Annual Savings for Diversion Method over Disposal: $106,500
Capital Cost for Diversion Equipment/Process: $600,000
Payback Period for Investment in Equipment/Process: 5.6 years

From: Air Force Center for Environmental Excellence / Environmental Quality (AFCEE/EQ), Joint Service Pollution Prevention Opportunity Handbook (JSPPOH). 'Windrow Composting'. Joint Services P2 Technical Library. 2002. <http://p2library.nfesc.navy.mil/P2_Opportunity_Handbook/7_II_A_2.html>

APPENDIX 2

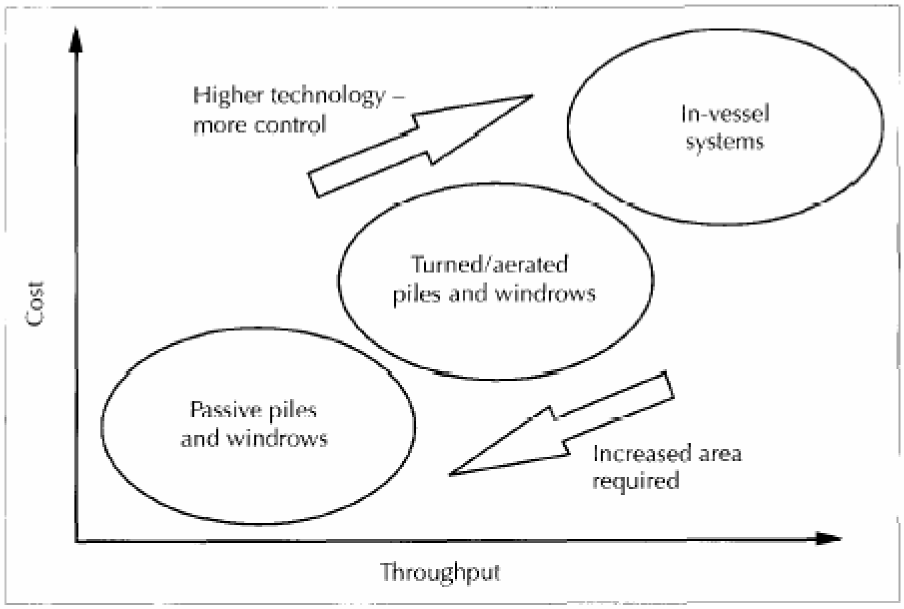


Fig. 2
Schematic comparison of composting methods.

From: Shcaub and Leonard, 1996.

APPENDIX 3

Table 2. Comparison of College and University Composting Programs

University	Type of Composting	Details	Amount Composted	Maintenance Costs	Money Saved	Operational Since
Dartmouth College	Off-campus: formerly windrows, now hi-tech facility, jointly with city of Hanover	Handles all food and compostable waste as well as sewage sludge from Hanover	windrows=20,000 lb. for first 8 months	windrows= Minimal, covered by Buildings and Grounds and Food Services	windrows= net savings of $10,000 for first 8 months	Windrows1992, Composting facility- 1998
Ithaca College (NY)	Off-campus: Pre-consumer waste only; aerated static piles	Computerized temperature controlled off-campus facility	5 tons/week or about 160 tons/year	Initial cost of machinery and setup = $67,000	Not available, but diverts about 13-15% of total waste stream	1993
Johnson College (VT)	Passive pre-consumer waste, vermicomposting. Also, research on post-consumer composting by windrows and aerated windrows	Small holding piles on concrete slabs aerated by pipe; 12 vermi-composting demonstration projects in community	N/A	N/A	N/A	1991
University of Waterloo	Windrows, Wooden Bins, Vermicomposting	N/A	Windrows compost about 10-15 tons/year	N/A	N/A	Windrows since early 1970's wooden bins since 1996
Texas A&M University	off-campus Animal Science facility (with close neighbours), in-vessel composting	7 EarthTubs, 7 Comp-tainers, using animal waste and bedding	N/A	Equipment start-up Cost: ~$350,000	N/A	1998
Tulane University	3+ Large Recycled, Wooden Bins	Proposal Stage	N/A	N/A	N/A	N/A
Cornell University	Off-campus windrows facility	Agricultural waste, and pre- and post-consumer food	4151 tons/year (including 700 tons of food)	Provided from the tipping costs of food removal paid by food service	Product applied to college farm, will reduce tipping fees from food service	1992 for agricultural waste, 1998 for food waste

Middlebury College	Off-campus windrow facility	Wood chips and horse manure mixed with food waste	260 tonnes a year of food waste	Paid for through savings in tipping fees	Humus used by MC and money saved through tipping fees	1996

From Rice University at <http://www.ruf.rice.edu/~envintrn/other_colleges.html>. The table at the website contains links to several of the Universities included.

APPENDIX 4

Calculations for the area requirements in a windrow composting system

- 1 acre required for 5000 cubic yards of leaves or 1,250 tons because:

  1 cubic yard = ¼ ton Therefore, 5,000 cubic yards = 1,250 tons

- If 1 acre = 1,250 tons

  X = 141.6 tons (Trent's annual food waste production)

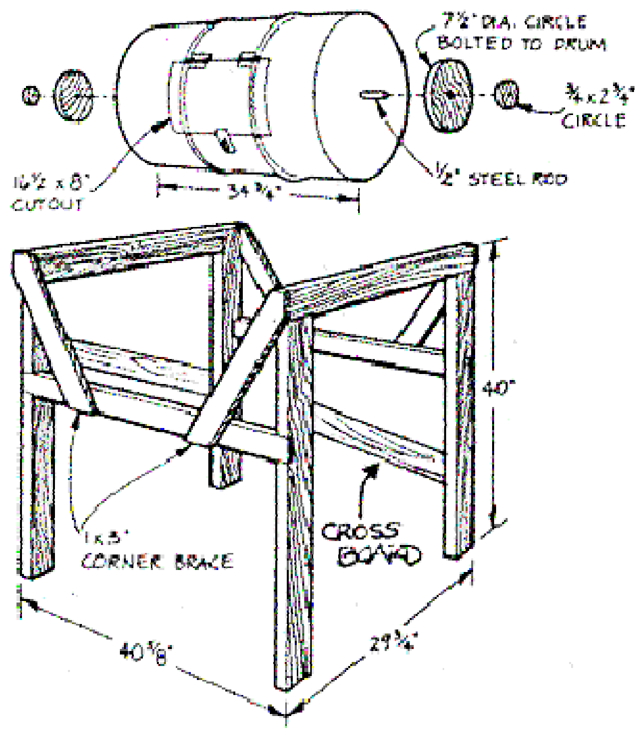
  X = 0.0113 acres (or 457.3 m^2)

- Then, to account for the buffer zone 15% (0.016 acres) of the total windrow area (0.0113 acres) is added to the windrow area, for a total area of 0.129 acres (522.04 m^2)

APPENDIX 5

ROTATING BARREL COMPOSTER

This is a composter suited for small operations, where there is no time for turning. The barrel is rotated several times whenever new materials are added. It is constructed with a minimum of hand-powered tools, and is not difficult or time-consuming to build. It will cost about $60 to build providing you use second-hand materials.



MATERIALS
1 - 45-gallon drum, use 'food grade' drum only (composter)
4 - 40 x 2 x 4" (frame uprights)
2 - 29 3/4 x 2 x 4" (frame horizontals)
2 - 40 5/8 x 1 x 3" (cross braces) white pine
4 - 23 3/4 x 1 x 3" (corner braces) white pine
2 - 27 x 2 x 4" (cross boards) white pine
2 - 7 1/2" dia. x 3/4" (bearings) white pine or plywood
2 - 2 3/4" dia. x 3/4" (bearings) white pine or plywood
2 - 1 1/2 x 2" hinges
1 - small hasp
1 - 1/2 x 40 1/2" steel rod
8 - 1/4 x 1 1/4" stove bolts
12 - 1/4 x 1" stove bolts
28 - 1 1/2" #10 wood screws

wood glue
approximately 1 pint of flat black paint

CONSTRUCTION

1. Obtain a good 45-gallon drum that has not had any toxic chemicals in it. Ask for a 'food grade' barrel. It must be unpainted on the inside and de-rusted. Add a protective coating inside. A plastic drum can also be used.
2. Drill a 1/2" hole in the exact centre of both ends of the barrel to accommodate the 1/2" steel rod. (See illustration for how to make a simple tool to locate centres.) Hold the rounded end of the gauge anywhere along the circumference and scribe a line on the approximate centre. Move the gauge 90 degrees and scribe another line. The intersection of these lines will be the exact centre.
3. Next scribe the lines for the opening in the barrel making sure to round the corners slightly. Drill a 1/4" hole somewhere along one of the lines to start the saber saw. If your barrel has ribs, as most do, you will have to cut a 1" vee notch on each rib to facilitate opening the door. Attach the hinges and the hasp to the barrel and lid using 1 x 1/4" stove bolts.
4. From 3/4" white pine, cut two circles 7 1/2" in diameter and two circles 2 3/4" in diameter. Drill a 1/2" hole in the centre of each and apply glue to the 2 3/4" circles. Glue the 2 3/4" circles to the 7 1/2" circles. This can be done easily if the circles are temporarily slipped over the 1/2" steel rod and clamped. After the glue has dried, remove the disks, insert the rod through the barrel and assemble as shown in the illustration, using four 1 1/4 x 1/4" stove bolts in each.
5. To build the support frame, cut the 2-by-4's to length and, using a corner lap joint, assemble with two 1 1/2" #10 wood screws in each joint. The uprights will also have to be dadoed 23 inches from the bottom to accept a 1 x 3" board. To make a corner lap joint, simply remove one-half the thickness of the stock to a length comparable to the width of the stock, on both ends of all pieces.
6. Half-inch holes to accommodate the rod will have to be drilled in the exact centre of the top horizontal pieces before assembling the top portion of the support frame. Slip the 1/2" steel rod with barrel attached, through these holes and insert the cross members into the dadoed uprights. Fasten with 1 1/2" #10 wood screws. Next cut the 1 x 3 x 23 1/4" piece at 45-degree angles at both ends, and attach with 1 1/2" #10 wood screws across corners as shown in the illustration.
7. For extra support, use 2 x 4 x 27" cross boards on each side. Cut them to an angle as the upper end is at 14 1/2" and lower end at 29" from the top of the 2 x 4 frame horizontals.
8. Drill several rows of 1/4" holes along the bottom of the barrel exactly underneath the door opening to eliminate excess moisture. Paint the outside of the unit a flat black colour.

(This design information was taken from the book The Rodale Guide to Composting, by Jerry Minnich, Marjorie Hunt, and the Editors of Organic Gardening Magazine, Rodale Press, Emmaus, PA)