COMPARTMENTED AND AUTOMATED ROTARY DRUM COMPOSTER

Design Proposal

Presented to

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Executive Summary

Concerns are rising worldwide about waste disposal especially in urban areas because of the economical and environmental cost associated. To address this issue, the Quebec government has set goals to reduce by 60% the amount of waste, including compostible organic material going to landfill sites by 2008. Some of the obstacles in meeting these objectives are the high cost associated with the collect and the treatment of organic material and the lack of public education about the benefit of composting and compost. It is in this context that this team seeked proposes to design a low-cost medium scale semi-continuous composting unit to be implemented on a community scale.

The design proposes to address problems associated with the composting facility operated by the Eco-quartier Jeanne-Mance in Montreal. The project seeks to make the composting system more automated and effective in terms of organic degradation, while reducing the odour impact on the surrounding community and the energy requirements for the composting process. The design will be based on thorough understanding of the biological concepts of composting and on sound engineering principles. It will integrate information obtained from various sources such as professors, industry contacts, textbooks, and journals.

In all, the design of this compost vessel is estimated to take 350 hours over the 12-month span of the project. The expected outputs of the design projects are: technical drawings of the composter with component specification, cost analysis of construction and operation, user manuals and final report. The team has estimated cost for the realisation of this design project at just below 8000 dollars.

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1.Problem statement

1.1 General Context

In the past and still today, most of the waste generated in urban settings was and is sent to landfills sites. This was at some point in time the cheapest and easiest way of disposing of these discarded items. The picture is different today. Presently there is an increasing cost associated with waste disposal as landfills fill up and space to open new ones is becoming scarce. There is also a growing concern about the environmental problems generated by landfills sites such as pollution of groundwater from leachate and the release of greenhouse gases into the atmosphere. It is now widely acknowledged that a large proportion of the waste going into the landfills could have a second life by being recycled or transformed back into a valuable commodity. This is the case for waste of organic nature. In Quebec, organics represent 44 % of the municipal waste from residences (RECYQ-Quebec, 2006-2007). Of these organics, over half is comprised of residues from the yards such grass clippings, leafs and branches, and the rest is residential food waste. This type of waste has valuable nutrients that can be recycled back to the natural environment through composting. Compost can be added to the soil as a source of organic matter to improve soil structure and moisture holding capacity while improving crop growth and vigour (Haug 1993).

In response to the above mentioned problems with landfills, cities have developed and adopted systems and technologies to separate, collect and compost organic waste. The city of Toronto for example collects food waste from over 500 000 single family home under the Green bin program. Its objective is to divert 100% of organic waste produced by the city to its composting facilities by 2010 (www.toronto.ca/compost/defined.htm).

In Quebec, composting of municipal waste is part of the strategy that is put forward in the revised version of the *Politique québécoise de gestion des matières résiduelles 1998-2008.* This document proposes new objectives and management tools to decrease the amount of waste going to the landfill and to find added value for this waste. This is done for the municipal, industrial, commercial and institutional sectors. The objective for municipalities is to decrease by 60% the recyclable waste (including compostables) going to the landfill (Recyq-québec, 2006). However a study by Recyq-québec states that development in composting has been relatively slow especially for food waste (Recyq-québec, 2006, Etude de caractérisation). In 2002, 7 % of organics collected from municipalities were composted and of this percentage 2/3 were yard waste and 1/3 food waste (Recyq-Québec, 2004, Filières des matières compostables). A major drawback according to this same study is that added cost for municipalities for the collect, the construction and the maintenance of a composting facility or site. This cost is simply too high for certain municipalities especially if disposal in landfills is cheap and space is not a constraint.

Other factors also affect the rate of adoption of composting strategies. Susan Antler, the Executive Director of The Composting Council of Canada, stated in one article about the composting situation in Canada that: "Overall, two of the biggest inadequacies have been the limited societal vision for organics recovery and severely restricted budgets directed to public education and communication about the merits of composting/anaerobic digestion (as well education on the value and use of compost for soil health and vitality)" (Biocycle, 2008, vol.49, no.2). A survey realised in 2002 for Recyq-Québec, found that 13% of Quebecers were unaware of the food waste collection mechanism in place but 69 % of them were favourable to such as collection (Recyq-Québec, 2004, Filières des matières compostables). Thus education is important for public adoption of social habits that include waste separation and composting.

1.2 Specific Problematic

Eco-Quartier Jeanne-Mance

Composting systems operate at various scales, from the backyard composting box to the wide scale collecting and composting of city food waste. A key component to start the design process was to decide on the scale that our team wanted to deal with. Based on an educated, integrated look at the compost situation in Québec and Canada this team believes that a key focus to increase composting throughout the country is to increase public knowledge and acceptance of composting while providing low cost composting systems. This team was looking at addressing a problem in our local setting and since Montreal does not have a vast composting scheme in place, it seemed natural to look at the work that was being done at the grass-root in the city to increase education and provide low cost systems.

Our team contacted Mrs. Valérie Koporek from Eco-Quartier Jeanne-Mance in Montreal in order to understand the needs of medium composting facilities operating at the community level. The Eco-quartier are neighbourhood organisations financed by the city of Montreal to promote environmental citizenship. Their work include the promotion of the 3-R's (reduce, recycle, re-use), and other activities that aim at reducing waste sent to the landfills and embellishing the living areas in the city. The Eco-quartier Jeanne-Mance has a composting facility called ''centre environmental Tournesol'' which accommodates the food waste of about 100 residential units. The food waste is brought on site by the members of the composting facility and treated in low cost composters. The compost is redistributed between members who learn about the composting process and the benefits of compost.

The Eco-quartier is presently looking at expanding their activities at another site. This team has offered to design a composting unit that would accommodate the needs of the new composting site while improving on the already existing one.

Composting Facility Problems

When considering the choice of a system to be designed the team looked into different problems that the compost facility at Eco-quartier Jeanne-Mance was facing as well as more general problems related to medium scale composters in an urban context. The following is a summary of the different issues that came from discussing with Mrs. Valérie Kopenek, Professor Suzelle Barrington, Professor Grant Clark and from a report of a study conducted by a student on the compost activities at the "centre environmental Tournesol".

These problems include: a surplus of moisture characterized by sludgy conditions, a lack of aeration, inadequate temperatures in the vessel and a lack of mechanisation which increased the man power required to operate the facility. To address these problems the team will have to develop efficient compost recipe (bulking agent, aeration) adapted to the type of compost unit that will be designed. It will also look into increasing the mechanisation of the different steps of the process (i.e. mixing the bulking agent, shredding the food waste ...). The material for the drum vessel is another important factor that needed to be considered because of the highly oxidizing environment created by composting. Presently the compost units are made from corrugated PVC which has a tendency to deform in the summer time under the effect of heat.

Another issue that the team seeks to address is the fact that in densely populated areas the space available for a community compost facility is usually scarce or expensive. Keeping in mind the goals set by the government of Quebec for 2008 of increasing the amount of food waste composted, it is important to decrease the ratio of the volume of the composter to the volume of food waste treated.

The last factor to be mentioned although it is probably the one that will be most constraining is the cost involved in the construction and maintenance of the composting unit. This is especially important for community organisations that operate with limited budget.

2. Preliminary design

2.1 Selection of a composting system

Composting can be defined as: "*the biological decomposition and stabilization of organic substrates, under conditions that allow the development of thermophilic temperature as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land*" (Haug,1993). The main objective behind any composting system is to provide adequate environmental conditions to allow bacteria to thrive and decompose the organic matter. It also has to allow a high enough temperature to be achieved to kill off any plant and human pathogens for a safe compost to be produced. Biological degradation can be done under aerobic or anaerobic conditions, but composting of food waste is mostly done aerobically because it is faster and less odorous.

Some of conditions that need to be considered for adequate composting are: aeration, temperature, Ph, carbon to nitrogen ratio and humidity. Different bulking agents, such as wood chip or straw, are often added to the food waste to provide structure and maintain air space for aerobic conditions.

The composting systems are broadly classified under reactor and non-reactor categories. Reactor processes are those for which composting materiel is placed within a reactor (or bin or vessel or digester) and non-reactor processes are those for which the material is not placed in a reactor.

Different kinds of reactors can be designed depending on the type and volume of waste to be treated and the desired quality of the end product. For a medium scale, urban context, the types of reactor that can be used can be classified generally depending on the type of flow (horizontal or vertical) or non flow, the type of bins or vessel (drums or other shape bins) and the method of agitation (agitated beds or rotary) or no agitation (static)(Haug 1993). The flow or non-flow processes are commonly referred to as batch

or continuous. Batch type consist typically of a bin that is filled once and allowed to compost while continuous refers to the continual addition of material to the bin.

For medium scale operation typical systems on the market are rotating drums that operate on a batch or semi-continuous basis. These systems allow the food waste to be added on a continuous basis at one end of the drum or vessel while the compost exits at the other end. To offset the fact that adding new food waste can short-circuit the composting process, the drum can by separated in a number of cell operated in series. The material from one cell is sequentially fed into the next cell as the process takes place thus separating the material according to its degree of degradation. The food waste is added to the first cell on an intermittent basis as it is emptied to the next cell. Compartmented drums are believed to be the most efficient because of the reasons mentioned above (Haug, 1993).

2.2 Design Objectives

Based on an analysis of the different composting systems available and taking in consideration the problems existing at the Eco-quartier Jeanne-Mance, the team decided to design a user-friendly compartmented drum composter that operates under a semi-continuous process. The composter will be designed so as to accommodate the composting of food waste for medium size composting facility such as Eco-Quartier Jeanne-Mance in Montreal.

The objectives of this project are to design a composter that will:

-Integrate the benefits of batch and continuous composting

-Effectively provide adequate composting conditions for the food waste (temperature, humidity, bulking agent, Ph,)
-Operate according to an adequate recipe for composting (mix of bulking agent and food waste.

-Have a small ratio of volume of composter to volume of food waste treated.

-Automatically calculate the amount of bulking agent required with a given volume of food waste added to the system

-Minimise the external energy requirements for the composting process
-Be user friendly: increase mechanisation and automation

-Reduce odour (increase public acceptance)

-Provide quality compost from the composter i.e. provide optimum temperatures for sterilisation and killing of plant seed.

-Be durable, have a long life expectancy i.e. choose adequate material

The steps taken by the design team to fullfil these objectives are outlined in the remainder of the paper and specifically in the section on expected outputs.

3.0 Method

3.1 Sources of Information

For a design project to be successful a team must draw on a varied array of expertise in the field of interest. No one individual source will be able to provide all the solutions to the problems encountered in designing a prototype composter. For this reason the team has used a combination of human, electronic, and physical resources to provide us with a good basic understanding of the composting process and to help along with our design. Many of these sources were also valuable because they opened doors to other sources and information. The following section will go through these various sources, where they were obtained, and what information or type of information was obtained from them.

Professors

Students in the bioresource engineering department are very lucky to have professors who are so willing to engage in discussions about design projects. This expertise was used during many stages of the creation of the design proposal. Two professors in our department, Dr. Suzelle Barrington and Dr. Grant Clark, are either actively involved or have a lot of experience with research involving composting systems. Prof. Raghavan was also an asset in learning about the actual design process in general.

During the brainstorming process all three of these professors where used to bounce ideas off of and discuss possible projects. Although the team was decided on designing a medium scale composter, it did not know what novel idea could be brought forward and what challenges would be faced. Speaking to such experts in the field really helped define the project.

Industry Contacts

The industry contacts that were formed during the design process can be divided into two groups. On one side the team was interested in making contacts with individuals or companies that constructed and designed actual composting equipment, and on the other hand it was interested in the actual needs of the client. It is interesting to note that it is sometimes the case that the goals of these two groups do not meet perfectly. This is why part of our goal in this design process was to improve on conventional industry designs to meet the needs of our client.

Agri-Ventes Brome is a company that is on the production side of the composting equipment equation. This is a company that specializes in agricultural equipment, handling and storage equipment, and environmental equipment. Their environmental equipment division just recently unveiled its new design of a modular composting bioreactor for use on the farm, in abattoirs, for septic treatment, and for municipal and industrial use. As this is a local company based in Cowansville, Quebec, the team is in

the process of planning an excursion to see the factory to further understand the design and construction of composting equipment.

On the other side of the equation are organizations and companies that use composters. We have been in contact with informed parties at universities in Montreal namely Gorilla composting at McGill and Sustainable Concordia at Concordia university. Both these university groups have been operating composting operations for the same scale we are interested. They have been indispensable for their advice on what improvements they would like to see for composting systems.

Éco-quartier Jeanne Mance has been another great source of information because of their past experience with operating a low-cost, low-technology compost facility. The team plans to visit their composting site as soon as it starts operating for the summer.

Contacts:

Agri-Ventes Brome :
Alain Senay
450-266-5323

Gorilla Composting (McGill):
David Gray-Donald
Coordinator of Operations at Gorilla Composting
david.gary-donald@mail.mcgill.ca

Sustainability Concordia:
Louise Hénault-Ethier
R4/Environmental coordinator and designer of the vermicompost system in the greenhouse atop the Hall building on Sir George William Campus.
(514) 848-2424 #7351
recycle@alcor.concordia.ca

Éco-quartier Jeanne Mance et Mile-End:

Valérie Koporek
(514) 288-1402
monquartier@ecojm.org

Textbooks

The team was directed by Prof. Grant Clark to the textbook, "The Practical Handbook of Compost Engineering" by Roger T. Haug, as it is the most comprehensive reference on composting processes. This resource has been invaluable for information on the bacterial kinetics, process kinetics, and design parameters of our project. Other reference texts of note include those on heat transfer an environmental biotechnology.

Governments and Organizations

An important part of the design is to know what standards to adhere to for the final output as well as other output levels. Bacterial levels and seed viability in the output compost and the emission of noxious gases during the start-up phase are two specific examples where established standards are going to be constraints to our design. In Canada such regulations are the responsibility of the provinces and no Canada wide standards have been set. The Composting Council of Canada has been a useful source of information as it has agglomerated the standards from across the country in hopes of creating some uniformity. They are a "national non-profit member driving organisation with a charter to advocate and advance composting and compost usage".

Composting Council of Canada
http://www.compost.org/englishoverview.html

Journals

Peer reviewed scientific journals and other types have been an important part of the research. They provide scientific background information on composting as well as ground breaking advances in technologies. The two main journals of interest are:

BioCycle and *Compost Science and Utilisation.* Biocycle is magazine that has been promoting composting, organic recycling and renewable energy in North America since 1960. It provides useful information on the latest development in the composting realm of activity, from small to large scale. Compost Science and utilisation is a peer reviewed journal that focuses on management techniques to improve compost process control and product quality, with special emphasis on utilization of composted materials.

Figure 1: Biocycle Journal

Internet

It is possible to get lost in the vast amounts of information on composting that is available online. The team has restricted itself to educational sites (ex. University sites) and sites of composting organizations and manufacturers to ensure that the data received is as accurate as possible. The following is a selection of the sites that the team has found most useful:

Cornell composting

http://www.css.cornell.edu/compost/Composting_Homepage.html

University of British Columbia

http://www.recycle.ubc.ca/compost.htm

University of Guelph

http://www.pr.uoguelph.ca/sustain/compostoncampus.html

Sustainable Development Montreal

http://ville.montreal.qc.ca/portal/page?_pageid=736,4731559&_dad=portal&_schema=PORTAL

3.2 Input Data Requirements

A vast amount of concepts and principles are required to design a composter. The information required for the design project has been organized conceptually and the data required for each concept are presented in the following section.

Heat and Mass Transfer

The concepts advanced in the fields of heat transfer and mass transfer, are essential to address several of our objectives, such as developing an energy efficient system, assuring that an adequate temperature and humidity level within the composter can be obtained. Heat transfer is essential in the design of heat exchangers and the choice of material for the shell drum for temperature regulation. Mass transfer is an important part of understanding the loss of moisture content through diffusion and aeration.

Heat transfer from the compost drum occurs by different pathways. Convective and radiative heat transfer dominates on the outer surfaces of a drum, and conduction occurs within the shell material of the drum. The following equation will be used for the purpose of calculating heat losses.

Fourier's Law of one-dimensional conductive heat transfer is as follows:

$dQ/dt = -k * dA * dT/dx$

where: dQ = Amount of heat

dA = Area of plane the heat passes through

k = Thermal conductivity

dT/dx = Temperature gradient

Convective heat transfer can be calculated with:

$q = U * A * (T1-T2)$

where: U = overall heat transfer coefficient (function of wind speed, humidity, and other factors)

A= area from which convection heat transfer operates

$T1-T2$= temperature difference between the 2 environment between which heat transfer process occurs

Radiative Heat loss from the composter is modeled with the Stefan Boltzman Law

$q = \sigma * A * (T_a^4-T_b^4) * F_a * F_e$

σ = Stephan Boltzman constant

A=area*

$(T_a^4-T_b^4)$=Temperature difference

F_a & F_e= Shape factors

The parameters required in these calculations will be obtained from the determination of the geometry and the materials characteristics of all the components (drum, heat exchanger,...).

Microbial Kinetics

The composting process is essentially based on the microbial degradation of the food waste. The release of enzymes aids in the degradation of complex molecules and the energy released by the microbial metabolism aids in increasing the temperature to ensure that pathogenic bacteria are sterilized. The most common microbial growth equation, the Monod equation, is in fact not perfectly applicable to composting systems since it is derived for a homogeneous system where the bacterial access to the substrate is not limiting. Compost systems however, are classified as heterogeneous systems with solid substrate and limited moisture. Such systems have their own types of microbial kinetics equations, which are modeled after enzyme systems as followed.

$dS/dt = -k * A_v$ (when $X >> K_x$)

$dS/dt = -(k/K_x) * A_v * X$ (when $X << K_x$)

Where: dS/dt = rate of hydrolysis of substrate

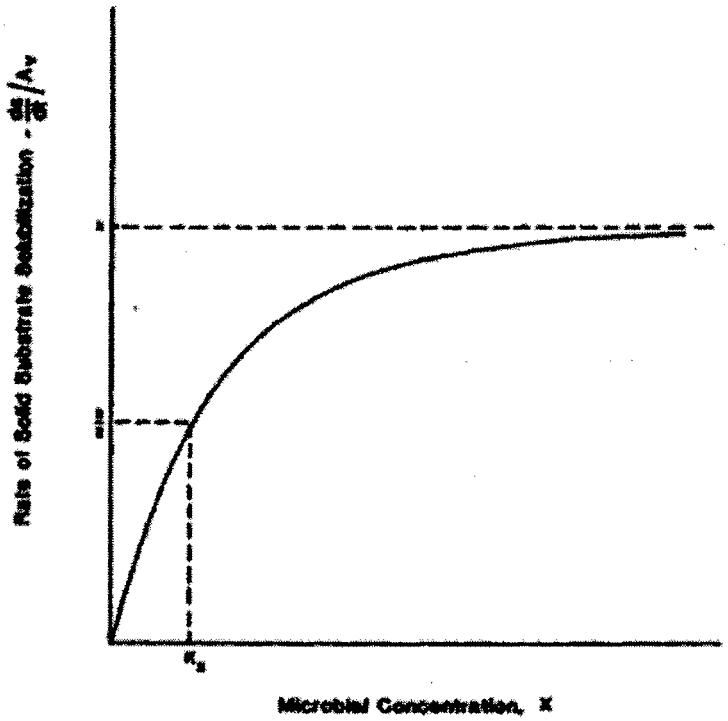
k = maximum rate of substrate hydrolysis

A_v = available surface area per unit volume

X = mass concentration of microbes

K_x = Half velocity coefficient ([microbe] at $dS/dt=k/2$)

Figure 2: Graph of Solid Solubilization Rate for Different Microbial Concentrations, Demonstrating Kx



To ensure that the maximum rate of growth and therefore the maximum composting rate are achieved, care must be taken that certain factors do not hamper the microbial growth. Such factors are listed below:

-Lack of degradable organics

-Very low or high process temperatures

-Low Moisture Conditions

-Lack of free air space

-Low Oxygen conditions

-Imbalanced pH conditions

-Lack of inorganic nutrients

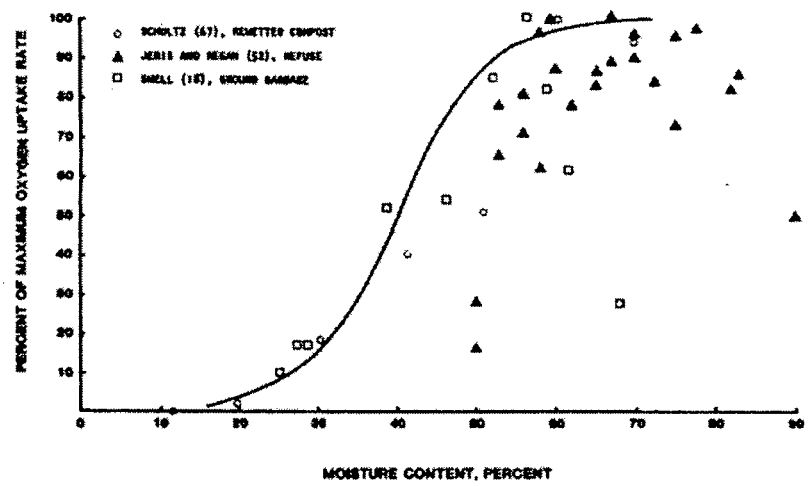
-Lack of microbes

-Presence of toxins

*(Haug,1993)

The effect of one of the factors, moisture is demonstrated the following graph. The other factors that we have to deal with in our design and information we need is to be able to provide the microbes with conditions that avoid the above situations.

Figure 3: Effect of Moisture Content on Maximum Oxygen Uptake Rate



Compost Completion: Pathogenic Inactivation and Stability

As composting substrates can often contain plant, animal, or human pathogens, it is important that the process be able to effectively eliminate these threats. To be able to do this one of the first thing we need to know is acceptable levels of pathogen concentration at the output as defined by regulatory bodies. This is of particular interest for the team since the compost material produced by the composter will be used by members of the Eco-quartier in the community gardens or for house plant. It should be risk free for handling and for growing vegetables.

Another important aspect of composting is that it oxidizes reducible organic compounds until only the resistant humics remain. The question that one must answer is, when is this composting procedure is over? This is often determined by when the compost mixture is no longer toxic to the plant on which it is to be applied. This is important since most composters such as the one that this team is considering do not allow sufficient retention time for the compost to be completely "cured". The end

material must then be put in piles for a significant amount of time before the compost can be used.

Other important facts that need to be known for judging compost completion and quality:

-Canadian standards for compost to measure against

-Effect of continuous process on cross-contamination

-Possible pathogens present

-Necessary temperatures to kill seeds and pathogens

-C:N ratio of the mixture

Input Feedstock and Necessary Conditioning

It is very important in composting systems to have a good balance between pore space and moisture content to allow good access to the microbes for both the substrate and the oxygen. There are many things that need to be known to ensure this. The biodegradability and the make up of our feedstock is the most paramount of these conditions. Fortunately, with the help of Eco-quartier Jeanne Mance and McGill Gorilla composting, we have been able to find some preliminary data for these conditions.

Table 1: Chemical Characteristics of Feed Substrate

	Moisture Contents [%]	TKN, % of dry matter	C, % of dry matter	Particle density [kg/m^3]
FW (food waste)	84.0	3.89	0.47	1029
SP (straw pellets)	6.0	0.64	0.50	1474
WC (wood chips)	38.1	4.25	0.52	973

With the preceding information available, one is able to calculate the needed amount of bulking agent, and nutrient amendment to provide the ideal conditions to the bacteria. Our design intends to automate the bulking agent addition calculation and therefore adds a further level of complexity. The following information are required:

-Ideal pH

-Ideal moisture content

-Bulking agent ratio,

-What type of scales, probes and programming are available for automation?

-What mechanization tools are available to input, shred and mix the food waste and bulking agent?

Process Kinetics and Dynamics

Determining the volume of composter that is needed is an important step. To determine this, one of the most important facts needed is the volume of food waste to be processed depending on the population size we are serving. Another important aspect to determine is the level of volume reduction for each phase of the composting process so the team can properly design the size and number of compartment. For this the following information will need to be determined:

-Rate of volume decrease for each compost phase

-Best ratio of total volume of composter to total volume of compost

-Retention time of different compost phases

Odor Management

Odor control is one of the most difficult aspects to a composter design and a very important one for a bioreactor that will be located in a high-density urban area.

Anaerobic processes in the compost heap results in the release of common noxious gases such as H_2S, volatile organic acids, and methyl sulfides. Although anaerobic conditions in the composter should be avoided, compound released by the aerobic parts of the reaction can be odorous as well, though perhaps less obnoxious to humans. Some examples of possible processes to deal with odors include thermal oxidization, biofiltration, absorption, and adsorption.

To properly control the odours released by the compost process, a proper odour control system will be included in the composter design. Many factors should be taken in consideration when choosing such as system. The type of food waste that is treated by the composter affects the compounds and the odours that are released from it. It is thus important to have detailed information about the inputs. The threshold levels of detection as well as any regulations surrounding these levels are also important since they will dictate the efficiency that should be obtained by the odour reduction component of the composter. Another important factor to consider when looking at the possible odour reduction solutions is the costs and related efficiencies associated with each.

Aeration Requirements

Since the process under consideration for the design of this composter is aerobic, it is important to ensure that the aerobic bacteria received adequate amounts of oxygen to perform their metabolic reactions. The aeration requirements of a composter are determined though stoichiometric means by analyzing the waste for chemical make up. A number of researchers have done this for various composting inputs to determine the amount of oxygen needed for different quantities of carbohydrates, proteins, fatty acids etc. This value undoubtedly changes depending on the time of year and type of population the composter is serving. For this reason it is important to team up with Eco-quartier to get an idea of the waste make up.

They type of process (batch or continuous) that is going to be used also has an effect on the aeration rate. As the aeration demands of the microbes can change throughout the process, at times the aeration may not be enough and at other times it may

be too great. Information must be obtained on what type of aeration control should be used in order to best design the process. Some of the most popular aeration control techniques are: uncontrolled, manual, on/off by timer, feedback control based on O2 or CO2 measurements, feedback based on temperature, and air flow rate control.

Cost and Pricing

Cost of various components of our design will undoubtedly be an important input to the design since one of the objectives of the design is to keep costs as low as possible. Such information should be fairly easy to find from supplier product or price lists.

Mechanics and Materials

One of the main complaints of the current system in use at the Eco-quartier is a lack of automation. To be able to automate our composting process motors and different means of moving compost around will be needed. The characteristics of the building material to be used are also very important to determine the reliability, lifespan and the necessary maintenance on the system. The following informations are needed:

-Material qualities and resistance to oxidizing environment

-Type of temperature, humidity probes and sensor

-Auger and conveyors characteristics, as well as other methods of frictional material displacement

General Information on Composting

Information on what types of composters are already available is another important piece of information that is needed. We want to try to avoid being redundant in designing something that has already been done. To avoid this, access to patent records and industry contacts will be very important.

3.3 Method of Solving the Problem

The design of a new product or process can be very lengthy and involves many different steps. Every decision made during the process will take into account cost, user friendliness, efficiency, effectiveness, robustness, and life span. To maximise all of these elements requires great familiarity with all possible solutions. The following section will explain the steps the design team took and will take in the future to design a semi-continuous composter.

Problem Identification

The first step in the design involved a period of brainstorming where the team explored the different problems that required an engineered solution. The brainstorming began at a very coarse level and looked in general at the problem of lack of composting in our waste disposal system. As the team narrowed down the topic of interest, ideas for topics became more and more precise and specific until the team was focused on improving communal composting in the urban environment.

Preliminary Ideas

Once the general problem the group wished to address was identified, the process of choosing an appropriate solution began. In this step the group members examined the many different types of composting systems that could be implemented. Through conversations with experts in composting, the team was able to narrow down the list of possible solutions in order to select a design of system. An automated semi-continuous composter was selected as the best solution for the problem the design team wished to address.

Problem refinement

This design step involved looking at the chosen solution and exploring how it could be implemented, improved, and altered to best address the problem at hand. In this step the team explored the potential of using the composter design for hotels, universities, and community organisation. Opening communication lines to determining what these groups expect to gain from a composter is a crucial part of refining how the team intends to design the composter. This step in the design project also involved a client selection in order to determine our exact design requirements. A literature review is another important part of this step in the design process to obtain a greater grasp of the problems with the chosen design and to find possible solutions. A good deal of this literature review will be done over the coming summer.

Theoretical Design, Analysis, and Decision Step

In this step of the design the team will use all the gathered information to design the many processes involved in the proposed composting unit. This part of the design process will be very iterative as inputs to the design such as size and materials are changed in order to maximise the cost effectiveness and the efficiency of the process. It will also be comparative as many different designs will be created and compared and contrasted in hopes of creating the best possible composter for this situation. The order that the different processes are to be examined in is as follows.

First, the recipe of compost mixture will be determined based on optimum composting conditions and the quality of compost that we want to produce.

Second, the design parameters for the drum: size, materials (for insulation and shell), number and size of compartments will be evaluated and chosen.

Third, automation of the composting vessel will be undertaken and other auxiliary elements such as odor control units and temperature probes will be designed.

The best solutions in all these processes will be collected together and implemented in the final product.

Technical Drawing, Presentation, and Implementation

As our objectives do not include the actual construction of the composter prototype but only the design, it is important to have proper technical drawings that can be followed by whichever client wishes to use it. Such drawings will be done using a proper design graphic program such as Solid Works or Autocad. The final step in our design process is to create the accompanying documentation as well as the final project report.

3.4 Output of Expected Results

It is primordial to clearly define the output that should be produced out of the design project. First, the expected results have to be in accordance with the objectives of design. Second, in order to be realistic the expected results should also be defined taking into consideration the competences of the design team (in this case three students in their last year of bioresources engineering), the time available for the design process and the resources available. The expected outputs were defined following all those criteria.

Components of the design

At this point in time we have a general idea of what the design will be. The components of our design are the following:

-Compartmented vessel

-Composting parameters verification devices (probes and sensors)

-Bulking agent scale

-Odor control device

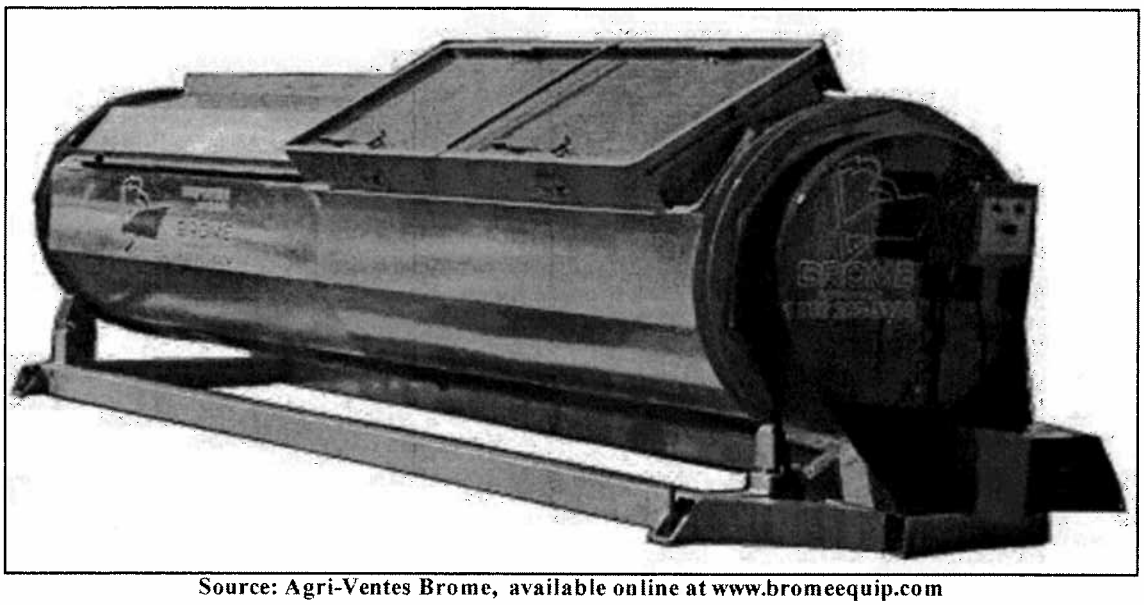
-Heat exchangers

Even though some modifications may occurs during the design process a description of the components will help to show in this proposal the potential of our design.

Compartmented Drum

We are planning to base our design on composters already available on the market and to modify them in order to adapt them to our design objectives. So far the most interesting design is the rotary drum such as the modular composter manufactured by Brome (see figure no 4). In order to prevent short-circuiting of the material through the reactor, the cylindrical container will be compartmented into sections, each one corresponding to the different steps of the composting process. The size of each section will be calculated based on the residence time in each section and the percentage of volume reduction of the organic matter in between each step. In order to move the organic matter between each section we are actually studying two options and have not decided yet which one will be employed. The first option is to rotate the container by 90 degrees and to move the material by gravity from a section to the other. The second option is to use augers or conveyor belts in between each section to transport the material.

Figure 4:Modular composter by Brome



Source: Agri-Ventes Brome, available online at www.bromeequip.com

Composting Parameters Verification Devices

In order to assure proper conditions for the composting process, probes will be added at critical points to measure the moisture content. This will allow the user to gage wetter the bulking agent ratio is adequate or not. In order to assure the eradication of all potential pathogens a probe reading the temperature will also be added in the section where sterilization is suppose to occurs and a electronic device will turn a light on after the temperature will have remain over a sufficient temperature for an adequate amount of time to assure the sterilization. Since the temperature is also a good indicator of the composting process, the same probe will be also used to determine when the organic matter should be transferred to another section.

Bulking agent scale

Another part of the automation of the process will concern the addition of a bulking agent scale. After the characterization of the input or organic matter and the choice of bulking agent is made, a weight ratio of bulking agent to organic matter will be determined. A scale will be installed at the entrance of the composter to weight the organic matter input and an electronic device will indicate to the user how much bulking agent should be added to the mix in order to optimize the composting process.

Odor control device

In order to minimize the odor from the composting process and therefore make it more acceptable for the population living close to the site we have to include in our design a solution to reduce the odor. Possible solutions such as thermal oxidizers or biofilters, will be studied and one of them will be selected and added to our design

Heat exchangers

An important factor influencing the efficiency of the composting process is the temperature. In order to maintain the temperature within optimal range heat exchangers may also be added to the composter. Those heat exchangers can be used either to exchange heat between the compartments or with the exterior environment.

Priorities

Since unexpected difficulties may occur during the design process and because of the fixed deadline to submit the project it is important to determine the importance of each component relatively to each other. This will allow later on, if problems occur during the design process, to prioritize certain aspects over others and consequently will permit to produce satisfying results within the time frame even though all the expected output will not be produced.

We will design in priority the main container therefore we will need to establish first the ratio of bulking agent to organic matter and when the number of section and the residence time in each section. Once the container will be design we will then focus on the automation of the process including the moving of the organic matter from one section to the others, the installation of probes and the choice and programming of the electronic devices. We expect to have enough time remaining to allow the design of the accessory components such as biofilter or thermal oxidizer and heat exchangers.

Type of design

Since we dispose neither of the necessary resources to build a prototype and of a site to operate a composting facility it will be impossible to produce a design of the type "design-build-operate". We are planning to produce a "ready to build" design. By that we mean that a potential client will be able, using the documentation we will generate, to build a composting facility. The potential user will also dispose of all the necessary information to operate such a facility.

Documentation provided to a potential client

In order to reach our objective to allow a potential client to build and operate a composting facility following our model, the following documentation will be produced by the design team.

- Technical drawings (made with the appropriate graphic tools and including choice of material)
- List of potential manufacturers and equipment suppliers
- Maintenance and operation manuals
- List of bulking agent suppliers
- Cost analysis (including materials and labor for the construction as well as cost of maintenance and operation)

4. Time Frame

4.1 Work Schedule

Table 1

Work Chart

Task	January	February	March	April	May	June	July	August	September	October	November	Decembrer
Preliminary Brainstorm												
Prliminary Lit review												
Meeting with resource people												
Definition of the project												
General Lit Review												
Writing of the proposal												
Preparation of the presentation												
Specific Lit. Review												
Visits of Manufacturers and Potential Clients												
"Recipe" (absorbent material ratio)												
Volume/time analysis												
Design of the main component (drum)												
Design of auxiliary components (ex: biofilter)												
Research of potential manufacturers												
Cost analysis												
Writing of the manuals												
Writing of the final report												
Preparation of the final presentation												

4.2 Estimated work time for each step

Preliminary Brainstorm

The team met for the first time around mid-January in order to discuss the general topic of the design project. The meeting lasted about two hours (2hours x 3 persons).

Preliminary Literature Review

In order to define more specifically the project, a preliminary literature review was conducted between mid-January to mid-February. Each team member spent about two hours on this review (2 hours x 3 persons).

Meeting with Resource Peoples

To get more information about composting and some suggestions of design we decided to seek advice from professionals involved in the field. Those included researchers, manufacturers and organization that use, design or manufacture composters. In total six individuals, companies or organization were met. Each meeting lasted about one hour (6 meetings x 1 hour x 1 person).

Definition of the Project

The team met for a second time in order to define with more precision the project using the information acquired in the precedent steps. The meeting lasted about two hours (2 hours x 3 persons).

General Literature Review

Before the writing of the proposal, another literature review was conducted to get all the necessary information fro the report. Each team member spent an average of 5 hours on this step (5 hours x 3 persons).

Writing of the Proposal

The outline of the proposal was written with the participation of each team member. Then we separated the proposal in three parts and each team member took the responsibility to write one. Finally we all worked in collaboration to join the three parts in a coherent way and to make the final corrections. Each team member spent an average of 10 hours on the writing and correction of the proposal (10 hours x 3 persons).

Preparation of the Presentation

A Power Point presentation with an overview of the proposal was prepared. The role of each team member in the presentation was defined and the team also practices the presentation. The preparation took about 2 hours (2 hours x 3 persons).

Specific Literature Review

All the input data requirements listed previously will be found during the summer from a more in depth literature review. The pertinent information will be shared between team members via email. We may find later on in the process that we need more information on a topic it is why this step remains open up to December (in yellow in the chart). We are planning to spend an average of 25 hours each on this step (25 hours x 3 persons).

Visits of Manufacturers and Potential Clients

In May and June we are planning to go visit the manufacturer Agri-Vente Brome as well as the Eco-quartier Jeanne-Mance. Those visits should take a total of 10 hours. The time is not included in the cost analysis since we already account 300,00$ in travel expenses.

"Recipe" (absorbent material ratio)

Based on the information from the literature review a "recipe" including the choice and ratio of bulking agent will be determined. The elaboration of the "recipe" will take about 2 hours (2 hours x 1 person)

Volume/Time Analysis

An analysis of the average volume of organic matter (including the absorbent material) and the residence time for each compartment will be conducted by mid-September. We are planning that this analysis would take about 4 hours (4 hours x 1 person).

Design of the Main Component (drum)

By mid-September up to the end of October the main component of the composter, the compartmented drum, will be designed. This step also included the technical drawings of this component. Each team member will work on this part of the design process for an average of 25 hours (25 hours x 3 person).

Design of Auxiliary Components

By mid-October to the mid-November we will design the auxiliary components such as the probes, the scale, the odor reduction solution and the heat exchangers of the composting facility. This step also included the technical drawings of those components Each team member will work on this part of the design process for an average of 15 hours (20 hours x 3 persons)

Research of Potential Manufacturers

Once the design will be complete (by mid-November) we will research potential manufacturer. The Research should take about 5 hours (5 hours x 1 person).

Cost Analysis

A cost analysis of construction, maintenance and operation will be conducted. This cost analysis will include price searching for material, labor and energy cost. We are planning to spend about 5 hours on the analysis (5 hours x 1 person).

Writing of the Manuals

The maintenance and operation manuals will be written in November. The writing should take five hours (5 hours x 2 manuals).

Writing of the Final Report

The final report including a description of each step of the design process and the results will be produced from mid-November to mid-December. Each team member will spend an average of 20 hours on the writing of the report (10 hours x 3 persons).

Preparation of the Final Presentation

A Power Point presentation with an overview of the design project will be prepared. The preparation should take about 3 hours (3 hours x 3 persons).

The design of the composting facility should take in total 350 hours over a period of twelve months. We considered it reasonable for a design project of this size. We expect to be able to follow the work schedule we established in this proposal but we are aware that some steps of the design may involve more or less work than planned. Therefore the work schedule is an approximation and we will remain flexible in our time planning.

5. Cost Evaluation

Since we are planning to produce a "ready-to built" design project our cost of design do not involves any material cost. We base the cost evaluation on the time we will spend on the design process as well as the cost for consulting and travel expense.

Design Work

As mentioned in the precedent section, we are planning to work 350 hours on the design of the composter. We apply a hourly rate of 19,97$/hour, based on the hourly rate remuneration of a junior engineer , with less than 6 months experience, working for the Quebec public function (source: Secretariat du conseil du trésor, http://www.tresor.gouv.qc.ca/fr/ress_humaine/emplois/liste_emplois/186R-8503651.asp). The cost is therefore of 6989.50 $

Consulting

We are planning to use the services of external consultant for this project. We already consulted Dr. Barrington and Dr. Clark for a total of 2 hours. We may also need to consult electrical and mechanical engineers to help us with the automation of the process, we expect that we will not need more than 10 hours of consultation with those professionals for a total of 12 hours.. We base the hourly rate cost for consulting on the rate recommended by the Canadian Legal Information Institute for the service of a senior principal engineer (source : Canadian Legal Information Institute, http://www.iijcan.com/qc/legis/regl/a-6.01r.9/20070307/tout.html). The rate is 49.35$ / hour for a total of 592.20$.

Travel Expense

We are planning to visit the composting site managed by Eco-quartier Jeanne-Mance. We are also planning to visit the composter commercial builder Agri-Ventes Brome located in Cowansville. We are planning an average cost of 150.00$ per visit for a total of 300.00$.

The total cost of our design is 7881.70$, details of cost can be seen on table XX. It may appear at first as a bite high for a design that will be only on paper, but considering that the concept developed in our design project can be built multiple times without involving any other cost for research and development; we think that it is reasonable price.

Table 2: Cost Analysis

	Time	Rate	cost
Design work	346	19,97 $	6 989,50 $
Consulting	12	49,35 $	592,20 $
Travel expense	N/A	N/A	300,00 $
Total			7 881,70 $

6. Conclusion

With the idea of promoting availability of low-cost composting options in Quebec, this team projects to design a user-friendly composter for the Eco-Quartier Jeanne-Mance in Montreal. From looking at the benefits of different composting systems, a choice was made for the system that seemed the most promising for this scale. This is a compartmented drum operating on a semi-continuous basis. The team has identified some of the challenges that the composting facility operated by the community organisation were facing and with this is mind has determined different objectives to be met by the design. The objectives stated are numerous, for this reason priority is given to some design component such as deciding on an optimum recipe and designing the compartmented drum. For design purposes, biological and engineering principles and concepts will be used. The information required for these will be gathered from the literature and from topic related textbook. The design team estimated around 350 hours of work to be done over the 12 months duration of the design project. The team projects to be able to deliver ready-to-build documents to the Eco-Quartier Jeanne-Mance as well as a final report to professor Rhaghavan by the end of this period. The team feels that their objective are realist but they approach the design process in a way that allows new information to be brought in and changes to be made to the preliminary design choice of composting system and objectives.

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