Composting Food Waste as an Alternative to Landfill Disposal:

Proposed Guide for the City of Menomonie, Wisconsin

by

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ABSTRACT

The disposal of food waste in landfills has severe environmental consequences that range from water pollution to the emission of green house gases. Furthermore, the disposal of food waste into landfills occupies valuable space that, over time, may fill up causing communities to spend money on the acquisition or construction of a new landfill facility. Composting food waste and other organic waste produces an effective soil amendment that improves soil quality and is environmentally sustainable. Composting food waste allows communities to craft a marketable product that generates income from organic wastes that, if disposed in landfills, will merely decompose and pollute the environment. Research was performed to put together a guide that will aid with the creation and implementation of a food waste composting network in the city of Menomonie, Wisconsin. This study aimed to create a guide that will help the city improve its landfill diversion rate, minimize its environmental footprint and strengthen the community.

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Chapter I: Introduction

The constantly increasing population of the world and the constant push for more profitability that has come from the industrialization of our food system has pushed farmers to produce more food per acre of arable land and to increase productivity. To be able to produce more food and therefore be more productive, farmers are every day more dependent on synthetic fertilizers. In the United States (U.S.) the expansion of synthetic fertilizer use can be traced back to the days after World War II when the government was left with a huge amount of ammonium nitrate, an important ingredient in the making of explosives. The government decided to transform the production of its explosives and ammunition plants to producing chemical fertilizer in order to put to use the vast amount of ammonium nitrate that it had in its hands (Pollan, 2006).

The shift to mass-produced synthetic fertilizers came at a high environmental cost because the production of synthetic fertilizer uses non-renewable resources and causes air and water pollution. Furthermore, in order to combine hydrogen and nitrogen gases to make fertilizer, chemists use a process that submits both elements under enormous pressure and heat in presence of a catalyst (Pollan, 2006). To supply the process with the needed energy a great amount of electricity is needed, about 0.2 kW hr/kgN (Von Blottnitz, Rabl, Boiadjiev, Taylor & Arnold, 2006), and electricity in the U.S. is mostly produced by burning fossil fuels (Energy Information Administration, 2008), which is the leading cause of global warming and other environmental problems. Furthermore, the hydrogen used in the process is provided by oil, coal or natural gas making the process even more dependent on non-renewable resources as well as environmentally polluting. Moreover, the constant use of synthetic fertilizer does not improve the quality of the soil and it is a considerable expense for farmers in developed countries and most of the time a non- viable option for farmers in developing countries.

In addition, excess fertilizer from agricultural lands and residential areas is a non point pollution contaminant that can cause severe damage to ground waters, rivers, lakes and coastal zones (Environmental Protection Agency [EPA], 2008). Based only on the environmental footprint of synthetic fertilizer, compost represents a much more sustainable and viable soil amendment. The composting process does not burn fossil fuels and the use of compost as soil amendment does not pollute our waters.

Food waste is an important component of all municipal waste generated and its disposal in landfills has critical environmental effects (EPA, 2009). Every day local and national governments are pushed more and more by their citizens to manage their waste handling needs, but increasingly more scrutiny has been put on the way the waste is handled with citizens now asking for this to be done in an environmentally sustainable way. Furthermore, a constantly increasing population makes the land available to use as landfills more difficult to find (especially in metropolitan areas) and local governments are faced with the need to extend the life of their landfills and avoid the cost of purchasing and building a new landfill. European countries have already started to create legislation to address this issue. Waste Strategy 2007 for England identifies food waste as a key priority for improving the landfill diversion performance of local authorities (Department of Environment Food and Rural Affairs, 2007).

Eureka Recycling (n.d.) explained that there are two kinds of composting processes, anaerobic and aerobic. Anaerobic composting happens when organic materials are broken down by bacteria without the presence of oxygen, which is what happens to food disposed in landfills. This process produces methane, a gas more powerful than carbon dioxide (CO2) when it comes to global warming. On the other hand, the aerobic process happens when organic materials are broken down by bacteria in the presence of oxygen. This process emits CO2 in negligible quantities and does not emit methane. The diversion of food waste and all other organic waste from landfills for composting represents a clear option for local governments and communities when trying to lower green house gas emissions.

Compost continues to attract more and more people not only due to being an environmentally sustainable product but also for its great qualities as soil amendment. Compost use not only helps to improve soil quality and reduces soil loss, but also increases soil water retention and reduces the need for extra inputs (United States Composting Council [USCC], 2008).

In addition, composting food waste represents a sustainable alternative for businesses, public institutions and schools to save money on tipping fees and profit from the advertisement of green practices. Currently in Menomonie, WI businesses such as supermarkets, restaurants and municipal governments dispose of such waste with no return benefit. Therefore, establishing a network of organic waste providers (supermarkets, restaurants, etc.) and connecting them with clients in need of compost (farmers, citizens, businesses) would reduce the amount of waste sent to landfills, minimize the environmental impact of incineration, improve current food waste handling processes and offer a stable and local alternative to the community. Furthermore, the creation of a composting network will not only have environmental benefits, it will also create new jobs, generate more tax income for local governments and strengthen the local community.

Statement of the Problem

How can the city of Menomonie, Wisconsin improve its landfill diversion rate, as well as reduce its environmental footprint to become a more environmentally sustainable city?

Purpose of the Study

The purpose of this study is to produce a guide to help lead the creation of a food waste composting network based on the participation of large stakeholders (restaurants, educational institutions, hospital, and supermarkets) for the city of Menomonie in Wisconsin. The product of this study will help improve the food waste diversion rate of the city and minimize landfill use and pollution. In addition, the product of this study will help reduce the city's green house gas emissions, improve soil quality and lower water pollution.

Assumptions of the Study

This research assumes that food waste providers such as the hospital, restaurants, the University of Wisconsin – Stout, supermarkets and schools will participate in the network and that they have interest in sustainable solutions to food waste management.

Data are available and can be applied to this study.

The community will be interested in supporting and benefiting from the creation of food waste composting network and its organic fertilizer.

Definition of Terms

Compost. Earth-like material produced by the decomposition of organic waste.

Dead zones. Areas of the world's oceans where waters are deprived of oxygen or have very low levels of oxygen as to not be able to support most animal life.

Food waste. Biodegradable material from kitchens and supermarkets, that are discarded as waste i.e.: fruit scraps, egg shells, vegetable peelings, coffee grounds/filters, teabags, and dairy and bread products. Alternatively food waste can have cooked food, frozen food, meat, fish, bones, etc.

Humus. Degraded organic material that is rich in nutrients.

Leachate. Liquid that drains from the mix of fresh organic matter in mixed municipal solid wastes.

Organic waste. Biodegradable materials from kitchens and gardens that are disposed as garbage.

Soil amendment. Material used to cure soil deficiencies and therefore improve plant growth and health.

Limitations of the Study

The study is limited to the city of Menomonie, Wisconsin and is intended to be used as a reference or guidance for the community to create a food waste composting network. The information used, discussed and exposed through this research only applies to cities with the same size, population and weather characteristics. The study is also limited to the information obtained through the literature review; there was no direct survey given to the potential stake holders in this study.

Methodology

The researcher will collect information from books, scholarly texts, institutional publications, magazines, journals and professional publications, in print and electronic version, to gather the necessary data to create a food waste composting guide for the city of Menomonie, WI. The researcher will also compare the information gathered with the city of Menomonie, WI to provide recommendation and select the practices that will better suit the city.

Chapter II: Literature Review

The literature review will focus on two areas: (a) environmental benefits of composting, and (b) the economics of composting.

Environmental Benefits of Composting

Although the environmental benefits of composting are many this section of the literature review will focus on four of the most important benefits of composting. Landfill diversion and pollution, reduction of synthetic fertilizer use, soil enrichment and soil erosion reduction.

Landfill diversion and pollution. Food waste diversion from landfills is necessary as food waste is a large and important component of all municipal waste generated (EPA, 2009). In fact, in 2007 food scraps represented almost 12.7% of the total municipal solid waste generated in American households and less than three percent was recovered (EPA, 2008). Data shows that Americans throw away more than 25% of the food we prepare, that amounts to about 96 billion pounds of food waste each year (United States Department of Agriculture [USDA], 1997). Moreover, food waste handling and delivery into landfills and incinerators is costly and the accumulation of it in landfills can lead to environmental problems and create health hazards (Means, Starbuck, Kremer, & Jett, 2005).

The decomposition of food waste in landfills mostly occurs under anaerobic conditions which produces and releases methane (Walsh, 2008). Decomposing garbage in landfills release about 10 million metric tons of methane each year in the United States (P, 2004), a gas that according to Wolfson (2007) "is 23 times stronger than CO2 in its warming effects" (p.3) and now landfills are the single largest human source of methane emissions in the United States and in the world (Eureka recycling, n.d.).

Once food waste is dumped in landfills, it gets compacted and liquefies and it mixes with many toxics (i.e. paints, oils, detergents) and continues to seep down through the ground polluting underground waters (Crawford, 2003) and from there rivers, lakes and coastal areas. Composting food waste and organic materials reduces the production of methane from landfills and leachate and their corresponding impacts on global warming and water pollution (University of Colorado Recycling Services, 2002)

Reduction of synthetic fertilizer use. Another important benefit of composting is that its use eliminates the greenhouse gas emissions related to synthetic fertilizer manufacturing (Eureka Recycling, n.d.) and the terrible environmental damages that its use can cause. Synthetic fertilizers are mostly used in agricultural lands and account for most of the reactive nitrogen (N) produced by humans (Howarth, 2007), and for a significant percentage of the total greenhouse gases emissions. When synthetic fertilizer is applied on fields soil bacteria decompose nitrates and emit nitrous oxide (N2O) a very powerful greenhouse gas. N2O is about 310 times more powerful than C02, in other words 1 kilogram of N20 causes as much global warming as 310 kilograms of CO2, the application of synthetic fertilizers account for 5% of the total global warming (Von Blottnitz, Rabl, Boiadjiev, Taylor, & Arnold, 2006).

When used at a small to moderate scale synthetic fertilizers have nutrients that benefit lands and increase yields, but their excessive use carries devastating consequences for the environment. For example, synthetic fertilizer overuse (from residential and agricultural sources) is the largest cause of the nitrogen flux down the Mississippi and Atchafalaya rivers to the dead zone in the Gulf of Mexico (Gruby & Crowder, 2009). Furthermore, to make synthetic fertilizers vast amounts of fossil fuels are burnt to generate the electric power needed in the manufacturing process and for its raw materials (ammonia and nitric acid), allowing the deposition of nitrogen from the atmosphere, which in turn can also contribute to the pollution of waters and acid rain (Howarth, 2007).

Plants can only take so much of the nutrients provided by synthetic fertilizers and the rest (excess) of the nutrients go to pollute rivers, lakes and coastal zones (Dybas, 2005). The public does not realize the damage that the excessive use of synthetic fertilizer has on our waters, to provide an idea of the impact (Howarth, 2007) listed the consequences that excess nutrients from synthetic fertilizers have on coastal waters and coastal communities as follows:

- Creation of dead zones.
- Loss of biodiversity.
- Change in ecosystems and detriment of habitat quality.
- Increased cloudiness of water and greater odors from water.
- Loss of sea-grasses and other ecologically valuable submerged aquatic vegetation.
- Decline of coral reefs.
- Decreased production of commercially important fish and shellfish.
- Increased frequency, duration, and extent of harmful algal blooms, with risk to human health and great damage to marine mammals.
- Increased transmittance of some human diseases such as cholera.

Synthetic fertilizer use has severe environmental consequences ranging from global warming to water pollution and soil acidification, but another consequence of synthetic fertilizer use that is not always taken in to consideration is the economic cost that its environmental footprint has. The economic costs of synthetic fertilizer use include the effects of green house gas emissions, water pollution, fisheries' decline, aquatic life's loss of habitat, and soil acidification, thus the importance of reducing its application.

On the other hand, compost releases its nutrients slowly, thereby minimizing nutrient losses (Sullivan, 2004). This in turn allows plants and crops to intake the nutrient as they grow. Additionally, compost keeps the nutrients in the soil not permitting rain runoff or leakage into ground waters.

In conclusion, using compost as soil amendment eliminates the following negative aspects of synthetic fertilizer and in consequence provides a much more sustainable option:

- Global warming due to the production of fertilizer.
- Air pollution emitted during the production of fertilizer.
- Global warming and air pollution due to the application of fertilizer.
- Water pollution due to leaching of applied fertilizer and runoff, creation of dead zones.
- Economic damage due to environmental harm.

Soil enrichment. The (University of Minnesota [UOM], 2000) through its Extension program website defines compost as an organic soil amendment that improves the physical, chemical, and biological properties of soils. The UOM also affirms that Compost has the ability to increase soils capacity to hold and release essential nutrients and also promotes the activity of earthworms and microorganisms beneficial to plant growth. Compost radically improves the moisture holding capacity of sandy soils, which in turn reduces drought damage to plants. In addition, when compost is added to heavy clay soils, it improves drainage and aeration, thereby diminishing the damage that excessive moisture causes to plants. The EPA explains in its website for the benefits of compost how its use helps regenerate poor soils. They explain that composting process of organic waste encourages the production of beneficial micro-organisms (mainly bacteria and fungi) which in turn break down organic matter to create humus. The humus obtained through composting increases the nutrient content in soils and helps soils retain moisture. Furthermore, compost is not only good reducing the need of chemical fertilizers but also it's been shown to suppress plant diseases and pests, which consequentially promotes higher yields of agricultural crops (2009). (Larkin, Tavantzis, Bernard, Alyokhin, Erich, & Gross, 2008) stated that the appropriate use of compost and biological amendments produces important and positive effects on soil quality, disease reduction, and yield (increased tuber yields by 13-23%), and should play an important role in sustainable soil and disease management programs.

Compost can also be used as soil amendment to remediate metal-contaminated sites because it binds metals and reduces metal uptake by plants (Shuman, Dudka, & Das, 2001). The U.S. National Park Service (NPS) affirms that the composting process has shown the ability to absorb odors and treat semi-volatile and volatile organic compounds, including heating fuels, polyaromatic hydrocarbons, and explosives. Moreover, the NPS explains that the compost process degrades and, in some cases, completely eliminates wood preservatives, pesticides, and both chlorinated and non-chlorinated hydrocarbons in contaminated soils (2009).

However, when using compost as an organic soil amendment the user needs to be careful of several problems that employing compost can bring. (Powers & McSorley, 2000) expressed that valuable nitrogen may be lost by volatilization as ammonia ($NH3$) or nitrogen ($N2$), or by leaching into the ground during the composting process. Additionally, (Powers & McSorley, 2000) stated that composts derived from urban wastes may be contaminated by traces of metals and other non-biodegradable materials that can gradually build up over time if composts from these sources are continually applied to the same site. In addition, compost made from materials low in a particular nutrient will remain low in that nutrient, creating the need to add nutrients to the compost. Thus the importance of testing the quality of the compost, and to provide adequate measures in order to avoid environmental damages cause by the use of low quality or contaminated compost.

Soil erosion reduction. (Means, et al., 2005) exposed another very important and positive effect of composting, soil erosion reduction. By stimulating soil biological activity compost helps release nutrients for plant use and improves soil structure, thereby reducing soil erosion.

As explained by the Natural Resources Conservation Service (NRCS) soil erosion is the breakdown, detachment, transport, and redistribution of soil particles by natural forces like water, wind, or gravity. The impact of soil erosion on cropland is of particular interest due to its on-site repercussions on soil quality and therefore on crop productivity, and its off-site impacts on water quantity and quality, air quality, and biological activity (NRCS, 2003).

Soil erosion is a very serious problem. Soil is a finite resource, a commodity that affects the life of all human beings and should be protected and restore. Eswaran, Lal and Reich stated in (2001) that erosion and desertification have made the productivity of some lands fall by 50 % and yield reduction in Africa due to past soil erosion may range from 2 to 40 %, with a mean loss of 8.2% for the continent. The effects of erosion are not only felt on agricultural lands but in urban spaces as well. The (EPA, 1997) explains that construction of new buildings and roads usually require the removal of top soil and all vegetation leaving the sub-soil at the mercy of erosion forces. Moreover, the EPA affirms that on steep embankments along roads and highways, compost can be more effective than traditionally used materials such as hydromulch because compost forms a thicker, more permanent growth due to its ability to improve the infrastructure of the soil. The Minnesota Department of Transportation has used compost for many years as a standard specification item and has completely eliminated bringing in topsoil and peat moss to job sites, also compost is used as a soil amendment and conditioner at construction sites (Mitchell, 1997).

The Economics of Composting

For a composting network to be able to become a reality it has to make economic sense especially in the current economic situation. Sadly, the environmental benefits alone will not make the public support a food waste composting network, but the reasons for composting food waste are more than environmental. Economic incentives, local jobs creation and the use of local knowledge are an important part as well. Plus, the creation of a composting network adds a step towards the development of an environmentally sustainable economy.

Economic benefits for communities and businesses. A food waste composting network will make the local economy stronger because it uses local resources and provides compost to local users. As (Rahmani & Kiker, 2004) found in their study, besides specific types of compost for nurseries and golf courses 64% of the compost used was hauled less than 30 miles. Moreover, the accessibility of compost within an economically feasible distance is important for the development of a market for compost. The market for a composting network in Menomonie, Wisconsin should be principally constituted by large users such as local farmers of agricultural and ornamental crops, golf courses and landscaping business (Rahmani & Kiker, 2004) and lastly smaller users made of citizens and businesses with a small need for compost.

Stimulated by the economic benefits many cities are now implementing composting networks in order to make money through the sale of composted food and other organic wastes and by saving money through reducing operational costs and enlarging the life of landfills. An excellent example of what cities can achieve is shown by (Miller & Angiel, 2009) using the town of Amherst, New York where their composting facility has produced cumulative net public benefits equivalent to $22, 8 million, which is more than double the financial resources the community invested. Another form of income for local governments is the taxes that can be collected from the development of businesses and the local economy.

The state of California through its Integrated Waste Management Board (2003) listed on its web site the economic benefits of using compost to reduce reliance on synthetic/chemical fertilizers and herbicides. They state that money can be saved by:

- Conserving water
- Reducing the use of herbicides
- Reducing the use of chemical fertilizers
- Creating markets for local compost producers
- Avoiding landfill disposal costs for organic material.

Most businesses are diverting (or studying the feasibility of diverting) their food waste, not only for the environmental benefits of composting, but because they can create profitable relationships with haulers and composters (Connolly, 2006). Grocery stores, institutions and restaurants are increasingly looking at composting as a way to save money. Tipping fees at composting sites are usually lower that of landfills, not including collection costs, turning cost saving into a determining factor in making businesses divert their organic waste for composting. Furthermore, most of the compostable garbage is wet and heavy especially from kitchens, and usually waste handling companies charge by the ton. An example of what businesses can save is represented by Gurney's Spa and Inn in East Hampton, New York which diverts 13 to 15 tons of organic waste each month to composting, saving nearly $1,000/month (Kunzler & Farrell, 1996).

The (Massachusetts Department of Environmental Protection [MDEP], 2009) states that supermarkets with effective programs for recycling organics have saved between $20,000 and

$40,000 per store per year, on average, in avoided disposal costs. In addition, the MDEP certifies super markets that are dedicated to reducing waste and being protective of the environment and have recycling and reuse programs. The certification allows the stores to benefit from the positive recognition and to collect the benefits of the resulting positive public image.

The U.S. federal government and states' governments also aid the creation of food waste composting networks through grants, tax exemption and financial aid. The state of Wisconsin provides in its website an electronic list of grants given to waste reduction programs and composting and promotes the demonstration of innovative waste reduction and recycling through its Waste Reduction and Recycling Demonstration Grants. Moreover, Wisconsin also offers property tax exemption for machinery and equipment and their parts, when used exclusively and directly in waste reduction or recycling (EPA, 2009). Furthermore, the Wisconsin Department of Natural Resources administers the Recycling Market Development Board, which is attached to the Department of commerce, and is responsible for encouraging the development of markets for recovered materials and the marketing of these materials (Wisconsin Department of Natural Resources, 2000).

In the state of Minnesota recycling and composting activities are exempt from solid waste management taxes that are applied to garbage, therefore making composting financially attractive (BioCycle, 2006). A great example of how state aid can benefit composting businesses is Black Oak Organics in Missouri who recently received a $22,595 grant from Missouri Solid Waste Management District to purchase its own collection truck, and the company had $400,000 in gross revenues in 2007, and over $500,000 in 2008 (Tucker, 2009). Another case of governmental assistance is the state of Massachusetts where the Department of Environmental

Protection aids composters with financial assistance through its Recycling Industries Reimbursement Credit grant and Recycling Loan Fund program; they also assist with hands on education and logistics to tie haulers, food waste producers and composters. In addition, the department of environmental protection works with the Massachusetts Highway Department and Operational Services Division to create state agency demand for finished compost (MDEP, 2005).

Economic benefits for educational institutions. Composting food waste also has benefits for educational institutions where tipping fees and waste handling can be a major expense for dining services due to the heavy weight of food waste. Composting at Washington State University in Pullman saves $200,000 a year in avoided disposal cost and at Dartmouth College in Hanover, New Hampshire, composting of produce residuals last year saved over $10,000 (Kunzler & Farrell, 1996). Composting at Harvard University have save more than $35,000 a year in hauling cost and another extra $10,000 in reduce soil amendment purchase (Raver, 2009). Universities and schools also benefit from the great publicity provided by having a green campus because a constantly increasing number of students see sustainable practices like composting as an incentive to pick those schools (Jan, 2008).

Chapter III: Methodology

Food waste comprises about 12.7% of the total municipal solid waste generated in the United States (EPA, 2009) which is about 96 billion pounds of food waste each year (USDA, 1997). The disposal of this organic waste in landfills has environmental consequences ranging from global warming, as a result of gas emissions (Eureka Recycling, n.d.), to water pollution (Crawford, 2003), not to mention the energy waste that decomposing food waste without benefit represents. Composting food waste is a sustainable alternative to landfill disposal. The USCC states that the composting process, when properly executed, has very small green house gas emissions, in addition to extending the life of existing landfills and producing a very sustainable and efficient soil amendment (2009); thus justifying the need to create a food waste composting network to improve landfill food waste diversion rates, lessen synthetic fertilizer use, strengthen the community and make the city of Menomonie, Wisconsin a more environmentally sustainable city.

Data Collection Procedures

The data collected for this study was gathered from books, magazines, journals, scholarly texts, institutional publications and professional publications, in print and electronic version.

Data Analysis

This research comprises data about the benefits of composting food waste, the environmental impact of disposing food waste in landfills, the benefits of compost as soil amendment and the environmental footprint of synthetic fertilizer. Furthermore, data about existing composting networks, their benefits and best practices was also researched in order to benchmark their best practices and use that knowledge to make a guide for the creation of a food waste composting network for the city of Menomonie, Wisconsin.

After all data was collected the information was prioritized to follow a logical flow as to start the guide with activities that needed to be completed before the next phase could be started.

Limitations

The results and data collected for this study are limited by the data collection methods previously described. No survey was performed to obtain direct information from possible stakeholders as to determine readiness and will to participate in a composting network and the amount of food waste produced, leaving this area to future research. Limited information was obtained about costs and investments needed to make the composting network a reality creating the need for further research in this subject.

Chapter IV: Results

The purpose of this study is the creation of a guide to aid with the design and implementation of a food waste composting network in the city of Menomonie, Wisconsin. Data was gathered from books, magazines, journals, scholarly texts, institutional publications and professional publications. This chapter will present the results of the research.

The guide will be divided into two major phases: planning and implementation. These phases will be described in detail during this chapter and will be comprised of different elements and steps that were deemed necessary for their completion.

Phase I: Planning

The benefits of composting food waste are many and proven very important as exposed in the literature review in chapter II. But, just like any other process or enterprise, before reaping the benefits of a food waste composting network, serious planning must take place.

Management. A decision needs to be made as to who is going to manage the food waste composting network, not only during the planning phase but after the network is up and running. Because all aspects of the planning phase are interconnected, having a management group in charge of all aspects of the planning phase is completely necessary to ensure its success.

It is very important that the organization or group of people in charge of managing the network are in constant communication with stakeholders and the community to make sure the plans and goals of the composting network reflect their input.

Market assessment. In the early stages of planning, a market assessment is needed in order to properly identify end users. A market assessment will show potential stakeholders and consumers and their compost requirements, and it will also increase the likelihood of the long term success of the composting network. Moreover, a market assessment will help estimate revenues and what equipment will be needed, and it will help decision makers in all phases of the planning process. Plus, it can help maximize the use of compost once the network is up and running (EPA, 1994).

Food waste classification: quantity and quality. Before starting to design any kind of composting network it is necessary to calculate the amount of available food waste that will be diverted from the landfill and to have an accurate understanding of the municipal waste stream (EPA, 1994). In other words, it is necessary to know where the food waste is produced, the type of food waste and how much of it is in the waste stream. Calculating the amount of food waste will allow the estimation of the savings and cost-effectiveness of the network, the possible amount of compost to be produced, and will also spark interest in potential stakeholders. The calculation of the amount of food waste available should be made using the same unit that the waste handling service uses to charge for waste disposal, usually cubic yards (volume) or tons (weight). If stakeholders measure their food waste in different units, a conversion method should be developed to have all waste measured under one unit to facilitate calculations (University of Colorado Recycling Services [UCRS], 2002).

To properly understand the available feedstock going into the mixture and to gauge the quality of the compost, it is very important that every type of food waste going into the composting network is measured. There are two types of food waste, pre-consumer food waste and post-consumer food waste. Pre-consumer food waste is produced in food preparation and supermarkets. On the other hand, post-consumer food waste is food left over after being prepared and/or served (UCRS, 2002). Furthermore, food waste quality and quantity can be affected by factors such as the state of the economy, demographics, regional differences and type of businesses being serviced by the composting network, putting more emphasis on the need to completely know and understand the waste stream (EPA, 1994). Moreover, a critical step in the quantifying and qualifying of the food waste is communication. Stakeholders need to properly communicate and train employees to make them understand the importance of what is being done and why it is being done. Encouraging workers to participate in the measuring process will allow the stakeholder to obtain valuable results (Cornell Waste Management Institute, 1996).

Additionally, at this stage in the planning process, goals should be set for the network. Goals such as determining the quantity of food waste that will be diverted from the waste stream, the size of the food waste composting network, complying with state and federal regulations, extending the life of landfill facilities, etc are good examples (EPA, 1994). Setting goals is important because it will help to identify the technical and economical aspects of the composting network.

Lastly, decision makers and stakeholders should determine what materials will or will not be composted. The Cornell Waste Management Institute (1996) listed the most commonly composted materials from kitchens and supermarkets as follows:

- tea bags
- egg shells and paper cartons
- dairy products such as cheese, yogurt, ice cream
- frozen foods
- leftovers or pieces of leafy vegetables, spoiled fruits, vegetables, salads
- day old breads and pastries, excess batter, spoiled bakery products
- meat trimmings and seafood
- wet or lightly waxed corrugated cardboard
- coffee grounds and filters

- waxed paper, napkins and paper towels, paper plates and cups, paper trays, paper food wrappers
- Floral waste and trimmings plants
- Leftovers that cannot be served again
- Bio-degradable service ware

Operational plans: source separation, collection and composting method. The collection method chosen to gather the food waste for the composting network is a very important element in the planning process. The cost, effectiveness, and ease of implementation of the composting network are directly affected by the collection and separation methods, therefore their importance. Food waste and other accepted biodegradables should be separated at the source from non compostable materials, and the separation and transportation of the compostable materials to the collection point should be as convenient and simple as possible. This is very important because the quality and effectiveness of the separation process will directly affect the quality of the compost and will also affect the food waste diversion rate. This step should be consciously studied by the stakeholders to properly identify the separation, collection and transportation methods that better adapt to their specific needs (Cornell Waste Management Institute, 1996).

The separation method chosen should be the one that maximizes the rate of materials going into composting, separates compostable organic waste from non compostable waste (plastic, metal, glass) and minimizes labor and space requirements (Cornell Waste Management Institute, 1996). It is within this step that a decision should be made if meat waste is going to be composted or not. When the collection method includes all types of food waste (including meat and seafood) the capture rate increases since the separation process becomes simpler, but it is necessary to make sure that the selected facility will have the capacity and licensing required to process these kinds of organic waste.

In addition, when the collection method is being selected it is important to keep in mind whether or not food waste is going to be collected with yard waste or if they will be collected independently. Composting facilities that received separated organic wastes (food from yard) can have better control on the mixing of feedstock and therefore more control on the quality of the compost (EPA, 1994). At this point it is important to establish a partnership with the organization appointed to haul or transport the food waste to the composting site. It is necessary to get their input and completely understand the cost and logistics involved in the collection and transportation process.

The composting method to be used should be properly researched in order to find the method that better adapts to the community's necessities, resources, laws and geographical location. At this level, a decision should be made on the composting method to be used (windrows, in-vessel, static piles, etc.), the equipment and personnel needed and where the composting facility will be located. Furthermore, it is necessary to keep in mind that with each composting method brings about different requirements that would need to be satisfied. Each different composting method may require different amounts of equipment and personnel, site size and location, noise and odor control, and environmental protection measures (EPA, 1994). Although, different composting methods can be employed there are six factors that can (positively or negatively) affect the composting process, these factors are particle size, moisture, temperature, oxygen, carbon to nitrogen ratio and pH. Each of these six factors needs to be considered when selecting the composting method to ensure that high quality compost is produced (USCC, 2009).

As explained by the United States Composting Council particle size is important because the smaller the material's size, the faster organisms can break it down, but a proper mix of particle sizes needs to be used since a mix constituted only of small particles will have problems with air circulation (USCC, 2009). The adequate level of moisture ranges between 40% to 60% (EPA, 1994) and needs to be calculated based on the kind of food waste being received, if the mix is too dry the organisms will go dormant, and too wet of a mix could result in turning the composting process from aerobic to anaerobic due to the lack of oxygen. Temperature is an indicator that the organisms are working on breaking down the organic waste and therefore releasing energy. The ideal composting temperature ranges between 55°C and 70 °C, if the composting pile temperature is outside this range the other four factors need to be observed since this is an indication that something is not working well. Oxygen is vital for the survival of composting micro-organisms. Without enough air, the decomposing process can turn anaerobic and undesirable byproducts could be produced. The carbon to nitrogen ratio is an extremely important factor when composting and needs to be properly calculated. Carbon acts as an energy source for the micro-organisms and nitrogen for cell building and reproduction. Without the proper ratio the composting process slows down, odors appear due to the release of ammonia and the composting process is not fully completely. If needed, different feedstock materials can be added and mixed to achieve optimum levels of carbon and nitrogen (USCC, 2009). Finally, the pH of the mixture indicates the acidity or alkalinity of the compost. The pH is measured on a scale that ranges from 0 which is very acidic to 14 which is very basic, with 7 being neutral (Cornell Management Institute, 1996). The closer that the pH is to 7 the more effective the composting process will be (EPA, 1994).

Legislation and regulatory requirements. The Wisconsin Department of Natural Resources (WDNR) is the organization in charge of the rules and regulations that govern composting of food waste and other organic waste in the state. The regulations imposed by the state have great influence in composting activities and should be thoroughly studied and understood before any composting activity starts. State regulations and local ordinances pertaining to water and air pollution, solid waste management and environmental protection laws are used to control composting and should be followed. Furthermore, federal and state regulations plus local ordinances about zoning, building codes and waste regulations should be considered when defining the location where the food waste is going to be composted (EPA, 1994). The United States Environmental Protection Agency, the WDNR and the local government should be consulted in the planning phase to make sure that the facility selected complies with all laws and regulations including worker health and safety regulations. After a plan and location for the composting facility have been determined they need to be submitted into the WDNR for approval.

Governmental influence and leadership is not only about regulation, governmental agencies also provide incentives. Wisconsin's sales and tax exemptions on waste reduction and composting/recycling machinery is one of the items that decision-makers should study when planning the establishment of the composting network. Also, grants and financial aid are available through state and federal agencies. In addition, state agencies can help with market development for compost products.

It is worth noting that because composting food scraps poses little risk to causing harm to people and the environment, the WDNR does not regulate the quality of compost produced from this organic waste.

Economic planning. First, it is necessary to know the cost of transportation and tipping fees and how much food waste is being produced and collected. Second, the cost of a food waste composting network will vary depending on the available resources and systems. The calculation of the cost of the composting network will also include items such as:

- Local wage levels.
- Number of loads transported.
- Acquisition and/or adaptation of vehicles for transportation of food waste.
- Cost of fuel.
- Depending on the separation and collection method chosen, the cost of containers for food waste.
- The capture rate or landfill diversion achieved.
- Logistics.
- Composting facility design and acquisition.

When calculating the cost of developing the composting network it is important not to forget the savings that can be made elsewhere (Waste Strategy, 2007). Reduction of fertilizer use, prolonging the life of landfill facilities, reduction of waste disposal cost, decreasing fuel expenses and reduction of green house gas emissions (to use as carbon credits in a cap and trade program) are good examples of these savings.

Community support. Community support and participation are vital for the survival and effectives of the food waste composting network. All stakeholders should feel free to voice their concerns and ideas, which in turn will provide a sense of ownership that is necessary for the success of the network. Furthermore, input from all stakeholders will help design a network that better adapts to the community's needs and will also help identify the most economically feasible plan. To gain the community's support clear and consistent communication is needed. All plans, methods, costs and data should be clearly exposed and available for review (EPA, 1994). Designing a system that is simple and easy to use, and maintaining open communication with the community will increase participation and gain their support (Waste Strategy, 2007). It is worth noting that the community support will be affect by cultural influences, cooking habits, environmental awareness, and economic and political concerns.

Composting site location. The composting site's location and size depends not only on the legal requirements and regulations (previously explained in this chapter), but also depend on the amount and type of food and other organic waste to be composted (EPA, 1994). Furthermore, the type of composting process selected (windrow, in-vessel, etc) and the time needed for composting will also affect the area needed for the installation of the facility. In addition, space will be needed for unloading incoming food waste and other organic wastes, storage of finished products and other feedstock like wood chips, and operations such as mixing and curing (UCRS, 2002). Additionally, when selecting the site for the composting facility all environmental precautions need to be kept in mind to prevent environmental pollution and the site needs to be visited and approved by the WDNR.

The compost facility should be located close to the sources of food waste to minimize cost related to transportation and to maximize convenience and efficiency. Also, a well located composting facility will make the distribution of the final product (compost) much easier and cost effective and will encourage participation from stakeholders and the community as a result of the convenient location (EPA, 1994).

A properly located composting facility will help the attainment of the network's goals and will facilitate the smooth running of its operations through time. The facility should be located on a site with the correct topography and soils, and should have an adequate cushion between residential and/or commercial areas and the facility.

Potentially good sites include areas close to recycling drop-off centers, buffer areas of existing or closed landfills and waste water treatment plants. Also sites with an extensive natural buffer zone (trees and shrubs) are good choices due to odor and visual impact reduction. If natural barriers or a buffer zone are not available it may be necessary to build visual screens or plant vegetation and to do some landscaping (EPA, 1994).

Once selected, the manager or managers should decide on the ownership of the composting facility. Different types of ownership should be studied to determine the best option for the community. Is the composting facility going to be owned and managed by the city? Or is it going to be a privately owned facility? Or is the facility owned by the city but the operation will be contracted? Or is some kind of partnership the best option? Questions like these will help decision makers find the most economically effective and feasible alternative (EPA, 1994).

Odor prevention. When selecting the composting facility's site, the type of composting method to be used, the type of food waste to be composted and the local weather conditions such as wind speed and direction, rain amounts and temperature should be taken into consideration to develop a plan to reduce odors. This is important because the prevention and control of odors at any composting facility is closely related to its success. Odors could make the community and users turn their support against the composting facility, and can also indicate that something is wrong with the composting process (EPA, 1994).

Phase II: Implementation

This phase of the study includes information on the practical aspects of the implementation of a food waste composting network such as collection methods, transportation, odor control, sales and quality control.

Collection methods. The collections methods are divided into: interior containers and exterior containers.

Interior containers. The containers to be used to collect the food waste are a critical element for a food waste composting network. Interior food waste containers should be placed near the source and their size should be adapted to the amount and weight of food waste produced (Cornell Waste Management Institute, 1996). Additionally, the size of the containers is important because the ease of handling and cleaning is directly affected by the size, plus an oversized container could hide contamination. Since food waste can be especially heavy when wet the containers should be made of rigid plastic with a lid. Furthermore, the containers should prevent leakage and have a lockable lid to prevent attracting pests and should comply with all laws and regulations (Waste Strategy, 2007). It is imperative that all containers are properly marked to prevent contamination and improve collection. Containers should have tags or labels that include the type of food waste and other organic waste to be composted, this is especially necessary in post-consumer collection areas. Moreover, frequently emptying and cleaning the containers is necessary to eliminate odors and the buildup of moulds and micro-organisms (UCRS, 2002).

The use of liners inside containers makes the collection process more attractive to users and could improve collection rates but adds expenses to the separation process. In addition, liners reduce the need for cleaning and the presence of odors. With the use of liners food waste does not attach to the interior of the container and is more easily emptied from the containers. Moreover, liners prevent food waste and liquids from spilling or leaking. Compostable liners made of materials like corn, paper or potato starch are preferred but usually more expensive than non-compostable plastic bags (Waste Strategy, 2007). Plastic bags utilized as liners require the extra work of empting their content and separating them from compostable materials, plus they end up as garbage in landfills.

Furthermore, as previously mentioned in the planning phase, employee and community training is vital for the proper collection and maximization of the capture rate of food waste in pre and post consumer areas (UCRS, 2002). Education is necessary to ensure participation and the separation of compostable materials for the waste stream.

Exterior containers. Just like internal containers, the size of the external container will depend on the amount and weight of food waste produced, with the addition of collection times. The longer the time between collections the bigger the containers may need to be (USCC, 2009). This issue should be discussed with the agency in charge of collecting the food waste and the food waste producers to find a collection time that is both time and cost efficient.

Exterior containers may also need liners to prevent spillage and/or leaking, and should be made of strong materials (plastic or metal) to withstand weather conditions and collection procedures. Exterior containers need to have a lockable lid to reduce the attraction of vermin and the emission of odors, and to avoid spillage during transportation (Waste Strategy, 2007). Finally, all exterior containers should be properly marked and be in accordance with all ordinances, laws and specifications for handling food waste.

Transportation. Stakeholders need to decide which transportation method is more economically feasible for the network. For some stakeholders it will be less expensive to transport the food waste to the composting facility themselves, for others a contracted hauler is the best option or maybe a mix where the food waste is taken to a collection area and then is picked up by a hauling company is a better option. The volume of food waste produced may determine the type of transportation and the collection method needed (USCC, 2009). The important fact is to find a transportation solution that maximizes the capture rate and is also economically attractive.

Depending on the company or companies selected to transport the food waste (and the resources available to them), there are several ways that food waste can be collected; with yard waste, by itself or with other garbage in split bodied trucks. The type of collection vehicles (all should be leak proof), their routes and their operation will directly impact the cost and efficiency of the collection and transportation methods of the network (Waste Strategy, 2007). In addition all vehicles transporting food waste need to comply with all laws and regulations. It is also important to locate a site for the composting facility that is not too far from the sources of food waste since this will directly affect the logistics and transportation costs (EPA, 1994). Finally, the capacity to collect and transport the food waste from the source to the composting facility can be a determining factor to select which sources to start working with (USCC, 2009).

Odor control. A group of people made of community members and stakeholders can be in charge of monitoring odors and communicate their findings to the facility's management so they can take the appropriate actions. This group can determine an appropriate level for odor emissions based on community acceptance and help select odor control methods (EPA, 1994).

Odors can indicate that something is not working well in the composting process. The six factors that make the basic elements of compost (particle size, moisture, temperature, oxygen, carbon to nitrogen ratio and pH) need to be checked to determine if something is out of specifications. If the composting materials are loose and have proper aeration (to allow oxygen to reach all areas of the composting pile), a moisture content between 40% to 60%, the right carbon to nitrogen ratio and a pH level close to 7, odors should not be a problem. Odors can occur when receiving food waste and/or other organic waste and also while executing composting operations, but should be quickly dealt with (USCC, 2009).

Maintaining a clean site can help reduce odor emissions. Daily cleaning of all equipment, cleaning of receiving, loading and composting areas and eliminating excess water and stagnant puddles through proper drainage are simple practices that can help odor control (Cornell Waste Management Institute, 1996). If odors persist after these simple practices have been taken and the composting process has been checked, the use of bio-filters, wet scrubbers or any other odor control method should be studied.

Sales. In order to be sustainable in time and increase the diversion of food waste from landfills it is necessary to sell the compost produced by the network. The group in charge of managing the composting network should review the market assessment performed in the planning phase, and design a marketing plan to increase the use of compost among possible users.

Compost is a very effective soil amendment that can be used by many different industries and users. The users that can benefit from the use of compost and should be part of the marketing plan of the network are:

- The agricultural industry: forage and field crop growers, fruit and vegetable farmers, organic farmers, turf growers.
- The construction industry: land reclamation contractors, landscaping, land developers.
- The forestry industry.
- Greenhouses and nurseries.
- Homeowners.

- Golf courses.
- Discount stores and supermarkets.
- State agencies and departments: public works departments, schools, parks and recreation departments, department of transportation, WDNR, etc (EPA, 1994).

In addition, (as explained in chapter II) compost can also be marketed through its water pollution reduction attributes: storm water management, pollution prevention and bioremediation.

The community should be informed of the environmental benefits of composting and encouraged to use compost as a soil amendment. Local advertisement should be run on local newspapers, local home and garden centers, farmer cooperatives, industry-specific publications, newspapers columns, trade shows, personal website and stakeholders' websites, garden clubs, word of mouth, e-mails and direct mail (Cornell Waste Management Institute, 2004-2005).

Quality control. The physical characteristics of compost (color, texture, structure, porosity, particle size, etc) and its chemical and biological properties are important elements in the measurement of its quality and its marketability and should be controlled to ensure a good quality product. In addition, the quality controls should verify that the compost complies with the regulations set by state and federal agencies pertaining to heavy metal, organic, chemical and pathogen concentrations. Moreover, constant testing should be employed to measure inorganic elements, nitrogen concentrations, organic matter density, metal concentrations, microbial respiratory activity, and plant disease and pathogen levels (Cornel Waste Management Institute, 1996).

Establishing end product quality specifications, quality control and quality assurance programs, and accurate records keeping will ensure the production of consistently good compost (Cornel Waste Management Institute, 1996).

The results shown in this chapter provide a guide for the city of Menomonie, Wisconsin to plan and implement a food waste composting network that will help to minimize the city's environmental footprint and strengthen the community.

Chapter V: Discussion

The purpose of this study was to produce a guide to help lead the creation of a food waste composting network for the city of Menomonie, Wisconsin. The guide was based on the participation of large stakeholders (e.g., restaurants, educational and governmental institutions, hospitals, supermarkets and waste haulers) and the community's support. Currently the city disposes the food waste generated by the stake holders into a landfill, this has severe environmental consequences, as shown in the literature review, and does not help the city move into a sustainable future.

The data collected for this study contains information about the benefits of composting food waste, the environmental impact of disposing food waste in landfills, the benefits of compost as soil amendment and the environmental footprint of synthetic fertilizer. Furthermore, data about existing food waste composting networks and institutional publications about the setup and best practices of such networks were studied to create a suitable guide for the city. The limitations, conclusions and recommendations of this research project are included in this chapter.

Limitations

The study is limited to the information obtained through the literature review. There was no direct interview or survey given to potential stake holders. The study is limited to the city of Menomonie, Wisconsin and is intended to be used as a reference or guidance for the community to create a food waste composting network. Some of the results shown in this study are supported by institutional documents dated more than 10 years ago, however, the elements and principles (with the exception of regulations and governmental incentives) presented in this study are universal and do not change over time.

Conclusions

The literature review shows the environmental consequences of food waste disposal into landfills. These environmental consequences range from water pollution to green house gas emissions. Moreover, the disposal of food waste into landfills represents a waste of energy that could be used to produce compost that can improve soil quality. When food waste is composted with other organic wastes, the compost produced can be used as soil amendment, rather than just letting these organic wastes decompose in landfills with no return.

Compost has been proven to improve the physical, chemical and biological properties of the soil. Furthermore, compost has the ability to increase the soil's capacity to hold and release nutrients and also promotes the activity of earthworms and microorganisms beneficial to plant growth. In addition, compost has been shown to suppress plant diseases and pests, which consequentially promotes higher yields.

The benefits of compost use as a soil amendment can help reduce the dependence and overuse of synthetic fertilizers. The increasing reliance on synthetic fertilizers and its overuse creates water pollution and soil acidification. Moreover, the production and application of synthetic fertilizers generates green house gas emissions, creates more dependence on fossil fuels and does not improve the physical and biological properties of the soil. Therefore, compost represents a sustainable alternative to synthetic fertilizer.

Finally, the creation of a food composting network can provide profitable relationships for the stakeholders. With the savings on waste collections and tipping fees, plus the green advertising generated, stakeholders can strengthen the local economy by making their institutions stronger and lead the local economy towards a sustainable future.

Recommendations

Before planning and setting up a food waste composting network, the first thing the stakeholders need to work on is reducing pre-consumer and post-consumer food waste. Excess food can be given to food shelters and to organizations that feed the hungry. After this, the leftover food can be used as animal feed or as raw material in the rendering industry. Finally, once all food waste reduction measures have been taken, the work on a food waste composting network should start.

Two phases were proposed in chapter four: planning and implementation. These phases and the elements within the phases (e.g., marked assessment, food waste quantity and quality, economic planning), should be divided and researched in-depth with the stakeholders and the community in mind to guarantee the success of the network and its durability over time.

The support of the community and stakeholders needs to be present before the composting network can become a reality. It is necessary that all parts have their concerns and input heard to create a sense of ownership that is vital for the creation and functioning of a composting network.

Research needs to be performed when studying the location of the composting site and the feasibility of the network to ensure that all laws and ordinances are followed since federal, state and local regulation can change overtime.

The economic and environmental benefits of a composting network should be constantly exposed and communicated to the community to spark interest in the stakeholders and to start creating a market for the compost produced.

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