CHAPTER 1
THE NEW YORK CITY COMPOSTING TRIALS

Summary

This chapter describes the 2001 New York City Composting Trials DSNY conducted at the Bedminster Marlborough MSW-composting facility in Marlborough, Massachusetts. The chapter begins by outlining the waste characterization that the Department performed on representative samples of the New York City waste sent to Marlborough for the Composting Trials. Tables summarize the weights of all inputs to, and outputs from the process, which in turn determine the recovery rate achieved during the Composting Trials. A discussion of Marlborough facility operations serves both to introduce the MSW-composting technology, as well as to explain the sampling procedure used to determine the quality of the compost produced in the Composting Trials.

Research Questions

As part of its research to determine if MSW composting merits further, serious study as a waste-management strategy for New York City, the Department set out to answer the following questions:

- What quality of compost might DSNY expect to produce by composting samples of New York City residential and institutional waste (referred to as New York City waste or City waste throughout the report)?
- What is the potential recovery rate of New York City waste through MSW composting?

In answer to the first question, the compost produced from samples of New York City waste would meet New York State Department of Environmental Conservation (DEC) pollutant-limit and product-use criteria. (Chapter 2 presents the actual compost-quality results.)

Regarding the second question, the NYC Composting Trials achieved a 50 percent solid-waste–recovery rate, which is in line with recovery rates achieved by the other MSW-composting facilities surveyed for this report. (Chapter 3 contains the results of this survey.)

In addition to this research, the Department worked with a local, environmental consulting group who received a grant from the Empire State Development Environmental Services Unit to perform an economic and technical viability study for composting New York City's commercial waste through a similar MSW-composting process. Appendix D contains the final report to the State summarizing the commercial-waste portion of the Composting Trials conducted at the Marlborough facility.

New York City Composting Trials

To answer the research questions posed above, DSNY sent 50 tons a day, for five consecutive days, of residential and institutional waste that it collected on Staten Island to the Bedminster Marlborough (Marlborough) MSW-composting facility.[1]

New York City Municipal Solid Waste

DSNY selected the Marlborough facility for its MSW Composting Trials for several reasons. As Marlborough is only four hours away from New York City, the proximity of the plant facilitated both shipping waste and providing direct project oversight, including continuous monitoring of the entire process. Additionally, Marlborough facility management was willing to dedicate one of its two composting drums (also referred to as digesters or digester drums in this report) for City waste exclusively, as well as space on the aeration floor for the resulting compost. This dedicated capacity was essential in order to keep New York City material separate from local material throughout the Composting Trials.

Photo 1-1: New York City waste used for the MSW Composting Trials

Photo 1-2: Removing samples for waste characterization
Under supervision of the sampling coordinator, a front-end loader removed one to two samples from each pile.

Photo 1-3: Sorting and characterizing samples of New York City waste
Workers sorted samples of waste into 13 categories.

Obtaining representative samples of the entire New York City waste stream was not operationally feasible for the limited scale of the Composting Trials. Therefore, the Department chose to take representative samples of waste from one Sanitation District—Staten Island District 2 (SI 2)—that it felt were in some way typical of City waste. Comprising the middle section of Staten Island, SI 2 (coterminous with SI Community Board 2) had a recycling diversion rate of 23 percent, close to the citywide average of 20.1 percent at the time of the Trials. Similar to other City Sanitation Districts, SI 2 also contains a mix of multi- and single-family residences, as well as the types of educational and religious institutions from which the Department routinely collects waste. In addition, SI 2 was also a convenient District to work with, as it is geographically proximate to the Fresh Kills landfill, the location for waste characterization and transfer to long-haul vehicles during the Composting Trials.

The capacity dedicated to New York City waste at the Marlborough MSW-composting facility was approximately 50 tons per day for five days.[2] This represents seven to eight DSNY collection vehicles per day, for a total of 37 truck loads. In order to obtain representative samples of the City waste from SI 2, DSNY worked with a consultant specializing in waste-characterization work, to select the seven or eight trucks that would be used for each day of the Trial. The following factors influenced the selection process:

- The relative quantities of residential and institutional waste generated in the four subsections of SI 2 during the previous year (2000)
- The distribution of DSNY's 105 collection truck routes in these four subsections
- Analysis of census-block-group data for the district

The consultant's final report to the Department, attached as Appendix A, describes the truck sampling methodology in greater detail.

Once trucks from the targeted routes were full and back at their garage, the Department instructed a relay driver to divert the load for the Composting Trials, rather than tip at their assigned transfer station. This way the collection drivers did not know that there was anything special about the waste, and did not bias its collection.

For the five days of the Trials, the drivers tipped their loads directly onto an asphalt pad (Photo 1-1) at the Fresh Kills landfill (Fresh Kills). The drivers unloaded material to form discrete piles, which were then recorded as to their origin (i.e., the section of SI 2 and the collection route). Under direct supervision of the consultant's sampling coordinator, a front-end loader removed one to two samples from each pile (the average sample size was 313 pounds) and placed them on a tarp (Photo 1-2). Workers pulled the tarp into an equipment maintenance building at Fresh Kills, where they sorted materials into 13 primary categories (Photo 1-3). Over the course of the five days, workers sorted a total of 70 samples, totaling 21,934 pounds. Table 1-1 summarizes the waste-characterization results. The consultant's final report

Table 1-1
Composition of the New York City Waste Used in the MSW Composting Trials

Waste Category	Average Percentage Composition by Weight
Paper	32.1%
Food Waste	15.9%
Yard Waste[1]	1.6%
Other Compostables[2]	6.0%
All Compostables	**55.6%**
Bulk Wood	3.4%
Plastic[3]	15.4%
Textiles	5.3%
Glass & Ceramics[3]	3.3%
Metal	3.1%
Large Composite Items	1.0%
Non-Compostable Fines	3.5%
Other Non-Compostables	5.1%
All Non-Compostables	**40.1%**
Unclassified Fines	4.3%
Total	**100%**

1. This characterization took place at the end of February, so it is logical that there is little yard waste. The annual citywide average for yard waste is estimated to be 4.1%.
2. "Compostable" is interchangeable with the term "degradable" in this report. This category includes readily degradable materials that do not fit in the paper, food-waste, or yard-waste categories, such as disposable diapers, sanitary napkins, animal feces, cut flowers, etc.
3. As this characterization took place before the suspension of glass and plastic recycling in July 2002, these numbers would now be proportionally higher.

(Appendix A) presents the sorting procedures and the waste-characterization process in further detail.

After representative samples of the waste had been removed and characterized, the remaining waste was loaded into long-haul, 100-cubic-yard, tractor trailers and transported directly to the MSW-composting facility in Marlborough, Massachusetts. The tractor trailers could haul approximately 20 tons each, so the Department loaded and sent three trailers to Marlborough for each day of the Trials to ensure that at least 50 tons would be available for composting.

The Bedminster Marlborough, LLC Facility

Bedminster Technology

The MSW-composting facility in Marlborough, Massachusetts (population approximately 37,000) was built in 1998/99, under contract with the City of Marlborough. At that time, Marlborough was in need of a new processing facility for its sewage sludge (biosolids), as the previous, unenclosed, biosolids-composting facility had been shut down under court order due to persistent odor complaints. Marlborough sought an alternative to paying for transportation and disposal of its biosolids. After evaluating MSW-composting plants employing the Bedminster Bioconversion Corporation (Bedminster)[3] technology in Tennessee and Georgia, Marlborough officials proceeded to negotiate a contract to develop a Bedminster facility to process all of Marlborough's biosolids in combination with its MSW.[4] At the time of the NYC Composting Trials, the facility was also processing municipal biosolids from several other towns, as well as solid waste from several commercial-waste haulers servicing college cafeterias, supermarkets, and grocery stores.

Table 1-2
North American MSW-Composting Facilities Utilizing Bedminster Technology

Location	Opened	Design Capacity
Big Sandy, Texas	1971	30 tpd (20 tpd MSW + 10 tpd biosolids)
Pinetop-Lakeside, Arizona	1991	15 tpd (10 tpd MSW + 5 tpd biosolids)
Sevierville, Tennessee	1992	340 tpd (240 tpd MSW + 100 tpd biosolids)
Cobb County, Georgia	1997	450 tpd (300 tpd MSW + 150 tpd biosolids)
Sumter County, Florida	1997	250 tpd (175 tpd MSW + 75 tpd biosolids)
Marlborough, Massachusetts	1999	150 tpd (100 tpd MSW + 50 tpd biosolids)
Nantucket, Massachusetts	1999	120 tpd (80 tpd MSW + 40 tpd biosolids)
Edmonton, Alberta, Canada	2000	1,043 tpd (715 tpd MSW + 328 tpd biosolids)

All biosolids data in this report are given in wet tons, which is standard nomenclature when discussing the weight of biosolids in relation to composting. The wet weight represents what the material actually weighs inclusive of water. The wastewater treatment industry will generally refer to the weight of biosolids using dry tons, which is what the material would weigh exclusive of water.

In addition to the Marlborough plant, Bedminster technology is employed in seven operating plants in North America, with two additional facilities under development. Table 1-2 lists all of the North American facilities utilizing Bedminster drums, and provides information on their respective design capacities.

Annual Capacity and Site Size

The Marlborough facility began receiving waste in August 1999. Table 1-3 shows Marlborough's annual processing capacity and rate. Designed originally to process a total of 54,000 tons per year (tpy), at the time of the NYC Composting Trials the facility was handling approximately 51,000 tpy, comprised of 35,000 tpy of solid waste and 16,000 tpy of biosolids. Of the solid-waste component, residential material accounted for 13,000 tpy; commercial sources generated the other 22,000 tpy.

The facility is situated on a six-acre site, adjacent to the City of Marlborough's Easterly Wastewater Treatment Plant and a capped sludge landfill. Located in the vicinity of other commercial operations such as a golf driving range, a restaurant, and a small shopping mall, the facility is only a half-mile from a residential area, containing some of the most expensive homes in Marlborough.

The actual facility footprint is approximately 2.3 acres, which includes the following components:

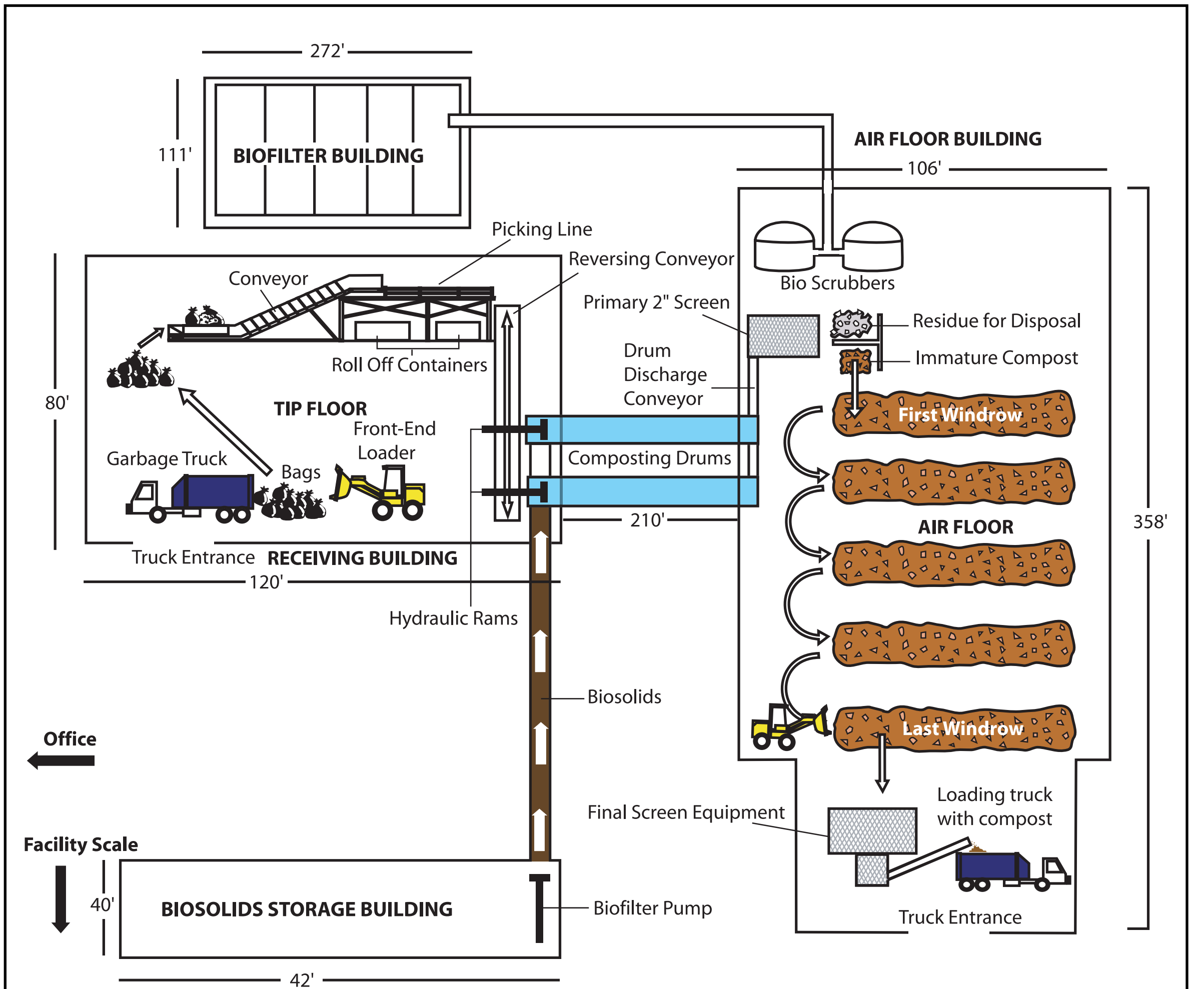
- Receiving building (including tip floor)
- Biosolids storage building
- Two composting drums
- Primary screening area and aeration floor
- Final screening area
- Biofilter building
- Other (scale, parking, office, vehicle maneuvering)

See Illustration 1-1 for a schematic drawing of the Marlborough facility. For more details on the respective area of each of these components, see Chapter 3.

Table 1-3
Marlborough Facility Annual Processing Capacity and Rate

Maximum Annual Processing Capacity	Current Annual Processing Rate
36,000 tons solid waste 18,000 wet tons biosolids	13,000 tons residential solid waste 22,000 tons commercial solid waste 16,000 wet tons biosolids
= 54,000 tons total	= 51,000 tons total

Illustration 1-1
Marlborough Facility Layout



Total facility footprint is 99,812 square feet (not drawn to scale)

Photo 1-4: Long-haul trucks delivering NYC waste to the Marlborough facility
After weighing in, trucks hauling solid waste enter a fully enclosed receiving building and dump their contents onto the tip floor.

Marlborough Facility Operations and the New York City Composting Trials

Receiving Solid Waste

At Marlborough, trucks delivering solid waste and biosolids cross the weigh scale, both upon entering and exiting the facility. After weighing in, trucks hauling solid waste enter a fully enclosed receiving building and unload their contents directly onto the tip floor (Photo 1-4). At this stage, a front-end loader (FEL) and three laborers remove bulky materials for disposal, such as carpet, wood, furniture, and other durable goods (Photo 1-5). After helping to remove the large, bulky contaminants, the FEL pushes the waste into a live floor hopper, (Photo 1-6) from which waste is conveyed to a manual sort line. The three laborers move from the tip floor to the sort line, in order to remove additional wood, metal, textiles, and other non-degradable items for disposal. Once the waste passes by this sort line, it continues on the conveyor to a hopper, where a hydraulic ram pushes it directly into one of the two composting drums.

Photo 1-5: Close-up of bulky items in the NYC waste stream
Workers at the Marlborough facility remove bulky items for disposal, such as the mattress, bulk wood, and furniture shown here.

Photo 1-6: Tip floor at the Marlborough facility
From the tip floor, a front-end loader moves waste to a conveyor, which feeds to a manual sort line.

All MSW-composting facilities incorporate varying levels of materials recovery prior to loading waste into the composting drum. Marlborough's FEL operator and manual sort line represent typical pre-drum, materials-recovery efforts at MSW-composting plants currently operating in North America. While some plants employ more sophisticated technology, such as magnets and air classifiers, others do nothing beyond removing bulk items. For more information on materials-recovery efforts at existing MSW-composting facilities, see Chapter 3. For the more intensive materials-recovery system proposed for a New York City Research and Development Pilot Facility, see Chapter 5.

New York City waste was loaded into long-haul vehicles at the Fresh Kills landfill during the day for each of the five Trial days, and delivered to the Marlborough facility (Photo 1-4). New York City loads arrived at night (after the Marlborough material had been loaded into one of the two composting drums) to avoid cross-contamination on the tipping floor. Table 1-4 presents the weights of the incoming New York City waste to the Marlborough facility. (Appendix B contains

Table 1-4
Weight of Incoming NYC MSW at Marlborough MSW-Composting Facility

Date	Weight of NYC MSW (tons)
February 26, 2001	49.23
February 27, 2001	54.64
February 28, 2001	53.99
March 1, 2001	51.96
March 2, 2001	49.23
Total	**259.05**


Photo 1-7: Sort line at Marlborough facility
Following standard operations, workers at the Marlborough facility removed non-degradable items on the sort line before the NYC waste entered the composting drum.

copies of the scale receipts from the trucks hauling the New York City waste to the Marlborough facility, as well as those of local trucks removing all process residue from the facility.)

As per standard operations, workers removed bulk items from the incoming loads on the tipping floor and additional, non-degradable items on the sort line before the waste entered the composting drum (Photo 1-7). Together, these two streams are referred to as “front-end residue.” Table 1-5 shows the percentage of New York City’s waste that was removed for disposal as front-end residue during the Composting Trials.

The Composting Trials did not allow for measurement of the percent of front-end residue that could be recycled. However, Chapter 6 shows estimates of what could potentially be recovered by the proposed Research and Development Pilot Facility. Those estimates come from the waste characterization performed for the Composting Trials described above, combined with an analysis of existing materials-recovery technologies and systems.

Receiving Biosolids and Liquid Waste
Biosolids refers to treated sewage sludge that has been dewatered to increase solidity, thereby making it easier to handle and transport. Before dewatering (using presses or centrifuges), the sewage sludge generally goes through a process of microbial digestion at the wastewater treatment plant. Biosolids make an excellent feedstock for composting due to their homogeneity and stability. In fact, approximately 13 percent of the biosolids produced in New York City are currently composted by a private contractor based in Pennsylvania. See the *Biosolids* section of Chapter 2 for a brief

Table 1-5
Percentage of NYC MSW Disposed of as Front-End Residue

Date	Weight of Front-End Residue (tons)	Percent of Total Incoming NYC MSW
February 26, 2001	7.21	14.6%
February 27, 2001	7.16	13.1%
February 28, 2001	6.86	12.7%
March 1, 2001	6.97	13.4%
March 2, 2001	5.98	12.1%
Average	**6.84**	**13.2%**
Total	**34.18**	**13.2%**

description of this operation, as well as laboratory results from the compost made with New York City biosolids.

The high paper content of MSW typically makes it too dry and low in nitrogen for optimal composting conditions. Most MSW-composting facilities therefore incorporate municipal biosolids at the start of the composting process, to provide the moisture and nitrogen necessary for optimal decomposition conditions. In the case of at least one facility surveyed for this report (see Chapter 3), moisture and nitrogen are provided by other organic, industrial liquid wastes, such as out-of-date juices, dairy waste, and wastewater from slaughterhouses and an organic glue factory.

The amount of biosolids or other liquid waste that facilities use ranges from 10 to 50 percent of the total input material. Liquid wastes are handled separately from solid waste, and are pumped directly into the digester drums. Facility operators can also pump water, if necessary, into the drums to achieve the optimal moisture range, which is generally between 50-55 percent.

As noted, the Marlborough MSW-composting facility is located next to the town's wastewater treatment facility. From the biosolids storage building at the wastewater-treatment facility, a large hydraulic ram pumps this material directly into the composting drums. In general, for every 60 tons of solid waste, Marlborough facility operators add approximately 30 tons of biosolids, which have been previously dewatered by the wastewater-treatment facility to contain about 16 percent solids (84 percent moisture).

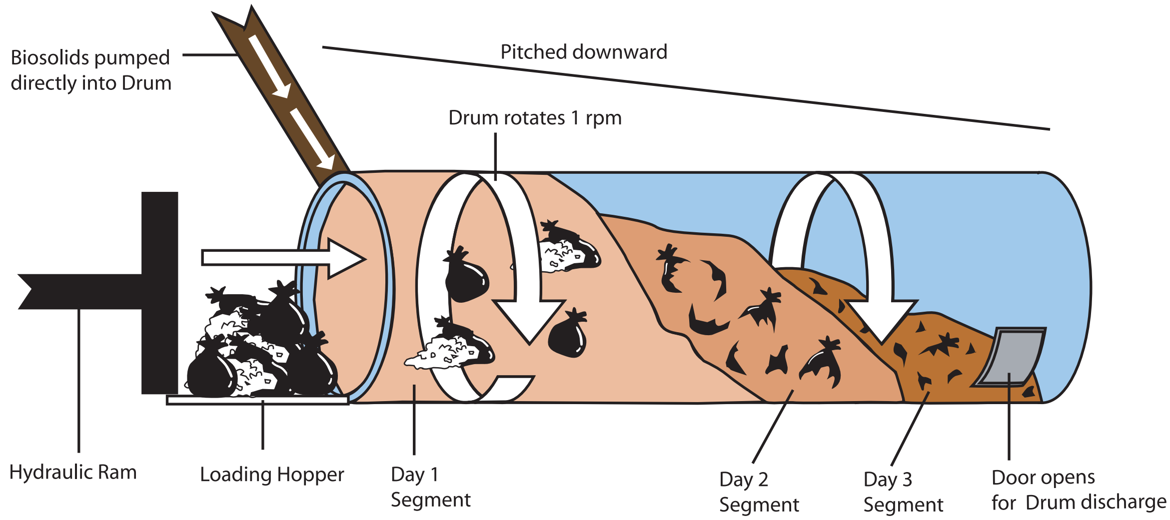
The New York City Department of Environment Protection (DEP) currently creates 1,200-plus tons of biosolids per day, dewatered on average to 26 percent solids. Private haulers remove this material at a cost of $112 per wet ton. The City's biosolids are either pelletized into a fertilizer (42 percent), directly land applied to crops (37 percent), composted (13 percent), or alkaline stabilized into an agricultural liming agent (8 percent). Due to logistical constraints, the New York City Composting Trials did not use biosolids from New York City. Instead, the Trials utilized Marlborough biosolids, samples of which were sent to a laboratory for analysis. Chapter 2 presents the results of Marlborough biosolids analysis and, for comparative purposes, also includes the results of routine testing that the DEP performs on New York City biosolids.

Digester Drums

The rotary digester drum represents the central element of the MSW-composting process. Fabricated from steel, the digesters (resembling elongated cement kilns) are divided into chambers, separated by interior baffles, which aid in retaining material for the desired amount of time. Facility operators feed and discharge material from the drum on a daily basis, with actual retention times varying between facilities anywhere from 24 hours to four days. Digester size is variable, depending on the technology, the amount of solid and liquid wastes processed per day, and the desired retention time. Illustration 1-2 shows the basic conceptual workings of a digester drum.

The Marlborough facility employs two proprietary, Bedminster digesters, each measuring 12.5 feet in diameter and 185 feet long, which retain material for two to three days. In addition to providing the ideal environment for the microbial populations that consume degradable waste,

Illustration 1-2
Basic Workings of a Digester Drum



the tumbling action of the rotary drum serves to homogenize liquid and solid waste, and break open garbage bags, exposing the degradable fraction within. At Marlborough, the digester exterior is insulated, and only the ends are enclosed in a building; the loading end is located in the receiving building, and the discharge end in the air floor building (Photos 1-8 and 1-9). At other facilities, the drums might be entirely housed indoors. The Bedminster drums are generally pitched slightly downward from loading end to discharge end, and gravity, combined with a slow rotation (at 1 rpm), serves to move the waste along. Air feeds into the digester either by blowers, or via a chimney effect when the discharge door opens. This air flow, along with the tumbling action, creates the conditions necessary for aerobic decomposition. Thermometers record the temperature of material in the drum, which routinely peak around 55°C (130°F).

Table 1-6
Amounts of New York City MSW and Marlborough Biosolids Loaded into the Marlborough Digester Drum

Date	New York City MSW (tons)	Marlborough Biosolids (tons)	Total Input to Digester Drum (tons)
February 26, 2001	42.02	18.01	60.03
February 27, 2001	47.48	23.12	70.60
February 28, 2001	47.13	23.61	70.74
March 1, 2001	44.99	21.91	66.90
March 2, 2001	43.25	19.80	63.05
Average	**44.97**	**21.29**	**66.26**
Total	**224.87**	**106.45**	**331.32**

During the Composting Trials, an empty, dedicated composting drum at the Marlborough facility received daily inputs of the New York City municipal solid waste along with the Marlborough biosolids. Table 1-6 shows the tonnage of each loaded into the drum during the five days of the Composting Trials. The material entering the drum was discharged three days later. This means that the majority of the material loaded into the drum on Monday, February 26 was discharged on Thursday, March 1; the material loaded on Tuesday, February 27 was discharged on Friday, March 2, and so on for the remaining three days of the Trials. Facility operators took daily thermometer readings in different sections of the drum to ensure that the material reached temperatures necessary to achieve pathogen kill. Appendix C contains these temperature record sheets.

Photo 1-8: Digester Drum at the Marlborough Facility
MSW loaded into the digester drum from the receiving building is discharged two to three days later in the air floor building.

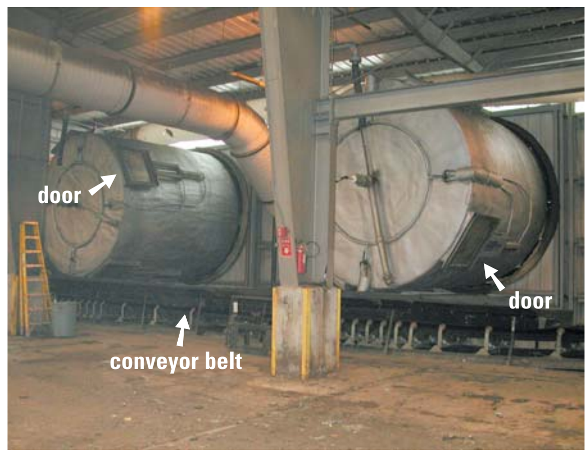


Photo 1-9: Discharge end of the composting drums at the Marlborough facility
After the two- to three-day retention time, operators discharge material from the drums onto a conveyor belt.

Drum Discharge

Most MSW-composting facilities perform a primary screening of the material after discharging it from the digester drum. Before describing the results of the primary screening of the New York City material, it is helpful to understand how material actually discharges from the drum and moves to this first screen.

Each day, hydraulic rams push new material into the drums. Each day's worth of material forms a discrete segment inside the drum (although in actuality some mixing between days inevitably occurs). The action of the rams loading new material displaces the previous day's segment and forces it forward through the drum (see Illustration 1-2). This daily displacement, combined with gravity's pull (resulting from the slight downward pitch of the drum), means that each segment takes about two to three days to reach the discharge end of the drum. The more material operators load into the drum, the fewer days each segment takes to reach the end of the drum.

Facility operators do nothing to actively discharge material from the composting drums. To discharge material, facility operators simply open the door located on the discharge end of the drum. Material that has collected there falls through the door and onto a conveyor belt below, as the drum continues to rotate (Photo 1-9).

Photo 1-10: Conveyor belt leading to the two-inch, primary trommel screen
After discharge from the drum, material moves via convey belt to a two-inch trommel screen mounted above (not in view).

Photo 1-11: Two-inch trommel screen "overs"
The two-inch overs, comprised of broken plastic bags and other large, non-degradable items, fall into a concrete bay, and are moved by front-end loaders into containers for disposal as residue.

Photo 1-12: Two-inch trommel screen "unders"
The two-inch unders, consisting primarily of immature compost, as well as smaller, non-degradable items, get transported to the air floor for further composting.

After two to three days of tumbling through the hot, moist, and tightly packed conditions inside the composting drum, the degradable portion of the waste stream no longer appears recognizable as the paper towels, phone books, leftovers, etc. that were loaded into the drum. Due to the intensive physical and chemical decomposition occurring inside the drum, the degradable fraction of the waste stream discharges from the drum as very immature compost, resembling a rich topsoil.

However, despite appearances, these degradable materials have actually only partially undergone the complex decomposition process. This immature compost requires an extended period of active, aerated composting and curing (stabilization) in order to become a mature, usable, final product. Before the immature compost moves to this next stage, it must first pass through the **primary screen** to separate out the larger, non-degradable items.

Primary Two-Inch Screen
The conveyor belt running under the drum discharge door moves the newly discharged material to the primary trommel screen (Photo 1-10). The screen at Marlborough separates out two fractions: material over two inches in size ("overs") and material under two inches in size ("unders"). While most MSW-composting facilities employ this primary screening step, actual screen sizes vary between facilities.

At Marlborough, the **two-inch overs**, comprised of broken plastic bags and other large, non-degradable items, fall into a concrete bay, and are moved by a front-end loader into containers for disposal as residue (Photo 1-11). The **two-inch unders** consist primarily of immature compost, as well as smaller, non-degradable items from the waste stream, such as bottle caps, shreds of plastic bags, and broken glass (Photo 1-12). Front-end loaders move this material to the aeration floor for further composting. The smaller, non-degradable items will be removed with subsequent, finer screens later in the process.

Table 1-7
NYC Material After Passing Through Marlborough's Primary Two-Inch Screen

Date of Discharge	Two-Inch Screen Unders (tons)	Two-Inch Screen Overs (tons)	Total Discharge: Unders and Overs (tons)	Overs as Percentage of Total Discharge
March 1, 2001	45.36	14.14	59.50	24%
March 2, 2001	58.50	14.83	73.30	20%
March 3, 2001	36.56	15.63	52.19	30%
March 5, 2001	45.00	18.19	63.19	29%
March 7, 2001	52.80	15.17	67.97	22%
Average	**47.24**	**15.59**	**63.23**	**25%**
Total	**236.22**	**77.96**	**316.18**	**25%**

Table 1-7 summarizes the results of the primary two-inch screening of the New York City material after Marlborough facility operators discharged it from the drum. Again, the two-inch overs are generally residue and the two-inch unders are immature compost. Appendix B contains the daily facility scale tickets with the weight of the overs leaving the facility, as well as the derivation of the weight of the unders as front-end loaders formed this material into windrows (elongated piles) on the Marlborough air floor.

Three points should be noted about the data in Table 1-7. First, as the far right column indicates, a quarter of the inputs to the drum are screened away at this point for disposal as residue. The primary, post-drum screen, therefore, represents the point in the current MSW-composting operations where the largest separation of degradable from non-degradable items occurs. Chapter 4 of this report, which critiques MSW composting as a whole, will elaborate on the significance of this point.

Second, it is interesting to note that on some days it appears that more material was discharged from the drum than was initially loaded. For example, the total inputs to the drum on February 27 weighed 70.60 tons (Table 1-6). Three days later (March 2), when the bulk of this day's material should have moved through the drum, 73.30 tons discharged from the drum. This illustrates that although material does generally move through the drum in the discrete segments described earlier, some mixing does occur. Furthermore, heavier items tend to tumble through the drum faster and therefore might discharge in less than three days.

Finally, while 331.32 tons of material went into the drum (Table 1-6), only 316.18 came out. Some of this 4.5 percent loss occurred during material handling and weighing, but the majority is due to moisture and carbon dioxide lost during the initial decomposition process, which has already taken place inside the drum.

Sampling
After the primary two-inch screen, the Department selected the first samples of New York City material for laboratory analysis. Department personnel (and/or a consultant to the Department) sampled the material directly to ensure accuracy and veracity of reporting. The laboratory

provided the sampling methodology, which consisted of taking shovels of material at various locations and combining them to fill two, five-gallon containers, labeled A and B (Photo 1-13). For each sample testing point, the lab performed analyses on both the A and B sample to form paired data for each point.

The laboratory specified two-inch unders and overs sampling as follows:

- Collect two, composite, five-gallon samples (**A** and **B**) for the **first**, **second**, and **third** day of two-inch **unders**, as generated by the primary screen.
- Repeat the procedure for the two-inch **overs**.
- On the fourth day, combine and mix all of the **A** sample **unders** (15 gallons) and send five gallons of this mix to the laboratory. Repeat the procedure for the **B** sample **unders**.
- Repeat the process for the **A** sample **overs** and the **B** sample **overs**.
- Repeat the entire process for the **third**, **fourth**, and **fifth** day of discharge. The third day was sampled twice to account for the mixing in the drum.

Photo 1-13: Samples taken from the NYC two-inch unders (right) and overs (left) piles
For each of the five days of drum discharge, DSNY took samples from the two-inch unders and overs piles.

Photo 1-14: Windrow pile at the Marlborough facility
Forming windrows on aerated floors represents one of the ways that MSW-composting facilities maximize decomposition rates and minimize odors.

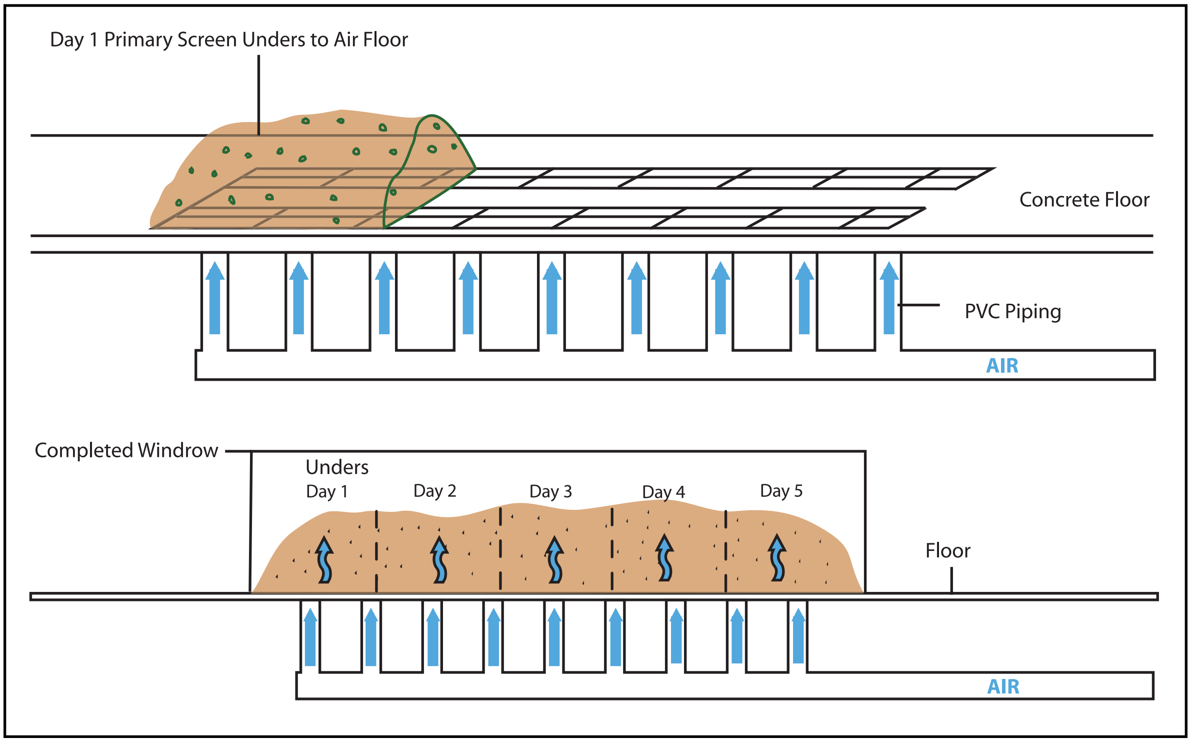
Therefore, the laboratory received a total of eight, composite, five-gallon samples at this point in the process. On the laboratory data sheets attached in the *Facility Data* section of Appendix F, the samples are labeled as follows: *Day 1-3 Unders, Sample A; Day 1-3 Unders, Sample B; Day 3-5 Unders, Sample A; Day 3-5 Unders, Sample B* (and likewise for overs).

Aeration Floor/Active Composting
Air flow is essential to the aerobic decomposition process. As any gardener knows, if a compost pile does not receive enough air, the pile turns anaerobic and starts to produce unpleasant, sulphurous odors. To maximize decomposition rates, as well as to minimize odors, all MSW-composting facilities must ensure that material discharged from the composting drum gets enough air. This stage of managed decomposition, when the material is still hot and needs oxygen, is referred to as "active composting." The material is still actively breaking down. After this active stage of composting, the material will require additional time to "cure" or stabilize.

Aeration strategies generally fall into two categories: **windrows** with forced aeration and

Illustration 1-3

Detail of Windrow and Aeration Trenches on Marlborough Air Floor



periodic turning (the strategy employed at Marlborough), or **aerated agitated bays**. In either case, active composting occurs inside a building with a system in place to capture and treat process air through a biofilter in order to minimize odors.

The **windrow** approach entails building large, elongated piles of the immature compost on an aeration floor (Photo 1-14) with embedded PVC piping, which functions to circulate air through the pile. Every few days facilities will use a front-end loader or windrow turner to move and mix the piles. Illustration 1-3 shows how the system of windrows and aeration trenches works on the Marlborough air floor.

The **agitated bay** approach[5] relies on the same basic principles for aerating the material, except rather than building piles, the facility operators place the material into aerated concrete channels, or bays. An automated agitator then moves down the length of the bay (either on a bridge crane, or rails set into the tops of the bays), and turns the composting material. This serves to introduce oxygen, chop up any remaining large pieces, and move the material towards the opposite end of the bay, where it is unloaded. Some facilities are also designed to allow the addition of moisture during active composting, if needed.

Meeting pathogen-kill requirements represents another function of the aeration floor. Most States mandate that compost made from MSW and/or biosolids exceed temperatures of 55°C (130°F) for a minimum number of days to kill harmful pathogens, such as *Salmonella* and fecal coliform. Therefore, MSW-composting facilities must monitor temperatures during this active-composting phase to document compliance with local pathogen-kill regulations. Appendix C contains the temperature monitoring sheets documenting the temperatures achieved by the New York City material both as it moved through the Marlborough facility digester and then onto the air floor. Chapter 2 presents pathogen-level (*Salmonella* and fecal coliform) data.

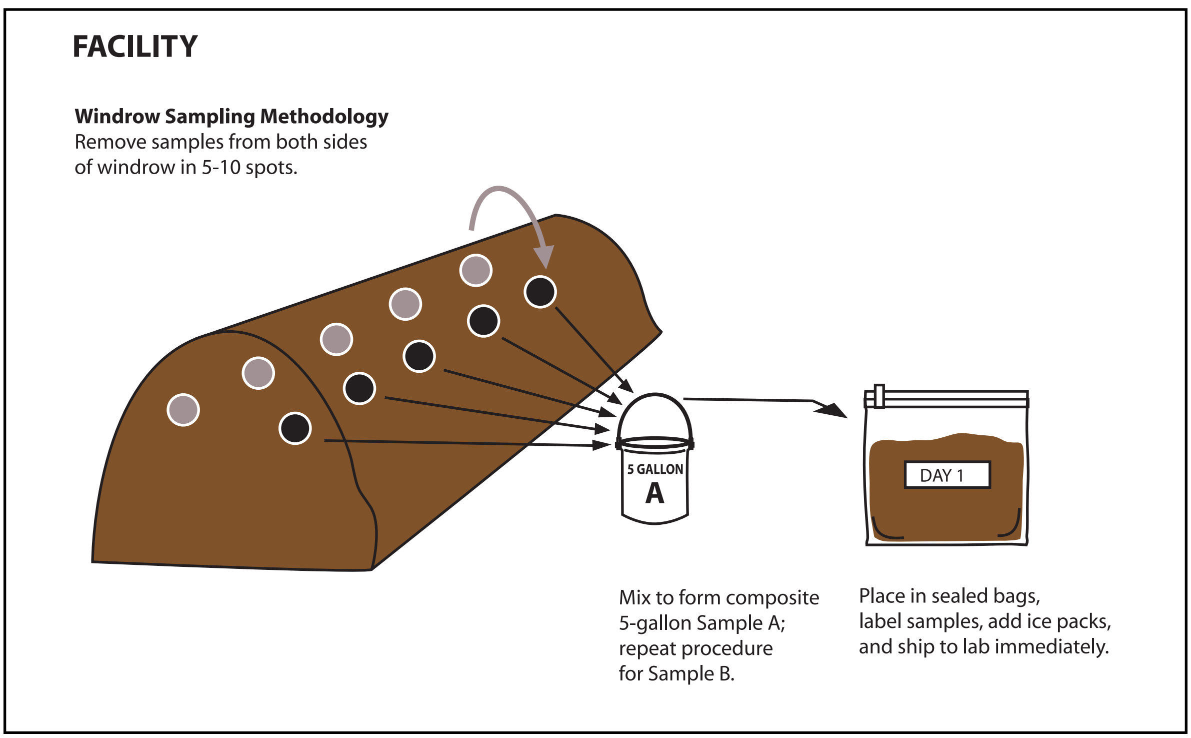
At Marlborough, front-end loaders (FELs) form the immature compost into windrows 90 feet long, 15 feet wide, and four- to eight-feet high. Each windrow sits on top of two lines of aeration trenches built into the concrete floor. The Marlborough facility employs 80 separate aeration trenches. Using computers, facility operators vary the air flow through each pair of trenches based upon the state of decomposition and windrow temperature.

Operators use FELs to turn the windrows every five to seven days. As operators turn the windrows, they transfer them from one aeration trench to the next, effectively moving the material from one end of the aeration floor to the other over the course of about twenty-one days. When a windrow is ready for final screening, it is moved off of the aeration floor (Illustration 1-1).

Per the terms of the Composting Trials, the management at Marlborough agreed to clear a portion of the air floor exclusively for the New York City material. Space was reserved in front of and behind the New York City material (both in the drum and on the air floor), so that there would be no chance of accidental mixing with local material. Each day of the Trials, facility operators discharged New York City material, ran it through the primary screen, and then transferred the unders to the first set of aeration trenches on the air floor.

Illustration 1-4

Windrow Sampling Methodology



After all five days' worth of New York City's material was discharged from the drum, the unders covered one whole set of trenches and the windrow was complete (Illustration 1-3). At this point the Department took the next set of samples, which are labeled "Day 1" (see Illustration 1-4) on the laboratory data sheets attached as Appendix F.[6]

Photo 1-15: Removing samples from the windrows for laboratory analysis
The Department took laboratory samples at different points during the 21 days that the NYC material spent on the Marlborough aeration floor.

The Marlborough facility retains material on the air floor for approximately 21 days. The first windrow is turned after one week, so depending on how long it takes to form this windrow, some material could be on the air floor slightly more or less than 21 days. On Day 1, 7, 14, and 21, the Department took two, composite, five-gallon samples for laboratory testing from the windrow of the New York City material as it moved along the Marlborough air floor (Photo 1-15). For the analysis of these lab test results, as well as a discussion of air floor performance in general, see the *Analysis of Variance (ANOVA)* section in Chapter 3.

Half-Inch Screen

After anywhere from 21 to 60 days in active composting, MSW-composting facilities will move the material to a final processing stage that includes some combination of the following:

- Finer screening at either a half-inch, three-eighths-inch, or an even smaller setting
- De-stoning to remove heavy inert materials, such as pieces of glass or stones
- Air-classification to remove any remaining small plastic shreds

See Chapter 3 for details on actual final-screening operations. Most facilities dispose of the residue from the final processing stage and typically move the remaining compost off-site for additional curing or end-use. Additional curing requirements depend upon end-use options, local regulations, and the length of the active composting stage. Immature compost (generally less than 50 to 60 days old) may be placed in outdoor windrows and turned periodically by an FEL, or it may be blended with sand, clay, or other ingredients to create different topsoil products.

Table 1-8
NYC Material After Passing Through Marlborough's Half-Inch Screen

Half-Inch Screen Unders (tons)	Half-Inch Screen Overs (tons)	Total Half-Inch Screen Unders and Overs	Overs as Percentage of Total
121.36	16.59	137.95	12%

Composting material remains on the Marlborough aeration floor for approximately 21 days, after which an FEL moves it to a **half-inch trommel screen**. Table 1-8 shows the results of the half-inch screening of the NYC material. From this final, on-site screen, the facility disposes of the **overs** (material greater than a half-inch)

Photo 1-16: Cubic-yard sample shipped to lab for additional curing and testing
The sample cured at the lab for an additional 21 weeks. At different points during this period, lab staff removed samples for analysis.

as residue, and moves the **unders** (material smaller than a half-inch) into trailers for transport to an outdoor curing facility (located in another town) for additional curing, screening through a three-eighths-inch screen, and blending for topsoil manufacturing.

Comparing Tables 7 and 8 shows that 98 tons of material was "lost" during the three weeks of active composting. (Operators originally transferred 236 tons of the two-inch unders to the curing floor, but only ran 138 tons through the half-inch screen three weeks later.) While some of this "loss" can be attributed to the invariable displacement that occurs during material handling, the bulk of the reduction results from moisture and carbon dioxide loss occurring during the active stage of composting. The percentage "lost" during the New York City Trials matches the typical loss experienced during regular Marlborough facility operations.

The Department sent a set of paired (A and B), five-gallon samples of both the half-inch unders and overs for laboratory analysis. The Department also sent to the laboratory one cubic yard of the half-inch unders for additional curing and testing. Lab staff removed the sample from the aerated packing crate (Photo 1-16) and formed a pile outdoors at their facility in Maine. They protected the pile with a specialized fabric designed for covering compost, which they removed periodically in order to manually turn the pile and incorporate water as needed. They continued to compost the NYC material in this fashion, and sampled the pile for all further compost-quality testing on Day 59, 70, 80, 91, 105, 125, and 147.

Final Three-Eighths-Inch Screen
The Department's initial Trials protocol did not call for a half-inch screening of the material as described above. Instead, material was supposed to move directly off the air floor to a final

Photo 1-17: Marlborough final-screening equipment
While this equipment successfully removes small pieces of glass and plastic particles, Marlborough facility operators no longer use it because too much usable compost was also passing over the screens and being discarded as residue.

facility screen, involving a combination vibration screen, de-stoner, and three-eighths-inch screen (Photo 1-17). The Department had to alter its protocol in response to operational changes at the Marlborough facility. Namely, the decision by facility management to no longer use the facility final screen, and to run their material instead through a half-inch screen and then move it off-site for additional curing, blending, and screening (as described earlier).

Table 1-9
NYC Material After Passing Through Marlborough's Three-Eighths-Inch Screen

Compost: ⅜" Unders (tons)	Residue: ⅜" Overs (tons)	Total (tons)	Overs as Percentage of Total
95.25	26.11	121.36	22%

This new arrangement was unacceptable to DSNY as it was not possible to provide direct oversight of the New York City material at this satellite location. There was a risk that New York City material might accidentally get mixed with local material. Since the Department still needed a final three-eighths-inch screen in order to produce a finished compost that could meet DEC standards, the Department requested that the facility operators screen the New York City material through Marlborough's on-site, final-screening equipment. See Table 1-9 for the results of this final screening.

The facility's final three-eighths-inch screening equipment was still functional, but Marlborough facility management had chosen to no longer use it for several reasons. First, due to space constraints at the Marlborough facility, there was nowhere to stockpile material before sending it through the final screen. The screen would therefore have to operate continuously at a fast pace in order to facilitate increased facility throughput. The equipment was not up to this pressure and frequently caused back-ups and delays. Second, while the equipment did an excellent job of removing the small pieces of glass and shreds of plastic ("inerts"), it also removed a lot of compost. This was due to the fact that the compost was immature after only 21 days (and therefore still very wet) and would adhere to the inerts. In essence, facility operators were throwing compost away with the inerts in the final screen residue (bottom Photo 1-18). While similar screening equipment works smoothly in other MSW-composting facilities, the combination of the equipment configuration and space constraints caused facility management to forego using it at Marlborough.

Photo 1-18: Samples of the NYC material passing under (top) and over (bottom) the three-eighths-inch screen
Laboratory analysis confirmed Marlborough facility operators' criticism of the final screening equipment: 64.5% of the material passing over the final screen was compost.

Table 1-10
Characterization of NYC Material Passing Over and Under the Final Three-Eighths-Inch Screen

Amount of Material Passing Through ⅜" Screen:	Material Characterization	Sample of ⅜" Screen Unders	Sample of ⅜" Screen Overs
	Glass	ND	16.60%
	Film Plastic	.20%	1.90%
	Hard Plastic	.10%	ND
Unders: 95.25 tons	Metals	ND	.45%
Overs: 26.11 tons	Textiles	.20%	16.55%
	Total Inerts[1]	**.50%**	**35.50%**
	tonnage estimate	*.48 tons*	*9.27 tons*
	Compost[2]	**99.50%**	**64.50%**
	tonnage estimate	*94.77 tons*	*16.84 tons*
	total tonnage	*95.25*	*26.11*

ND means not detected.
1. Inerts are very small pieces of non-degradable material, such as glass and plastic.
2. Compost includes very small fragments of remaining degradable items, such as paper, wood, stones, bone, and shell, which the DEC does not count towards inerts levels.

The Department sent two, five-gallon samples of both the three-eighths-inch unders and overs for analysis. The laboratory performed a characterization of this material (Photo 1-18), which verified Marlborough's complaint of the final-screening equipment. Table 1-10 shows the results of this characterization. (Table 1-10 incorporates the tonnage numbers from Table 1-9.) The final screen left only .50 percent of inert material in the finished compost, which is an excellent result. However, a large percentage of the material that passed over the screen as residue (64.5 percent) consisted of compost (including small pieces of organic material, such as wood and stone, which are allowable in a finished compost product). For a more detailed discussion of inerts levels, see Chapter 2. The *Inerts Data* section of Appendix F contains the laboratory inerts-characterization data.

Table 1-11 presents a summary of the overall composting process at the Marlborough facility and at what stage lab samples were taken for compost-quality analysis.

Air Handling
Preventing offensive odors from migrating off-site represents one of the most important factors in the success of any composting facility. In order to do this, facilities must achieve the following:

- Maintain aerobic conditions in the decomposing material, since decomposition under anaerobic conditions produces the most offensive odors
- Capture and treat all process air prior to its release outside

Table 1-11
NYC Composting Trials Summary: Description of Composting Stages, Duration, and Lab Samples

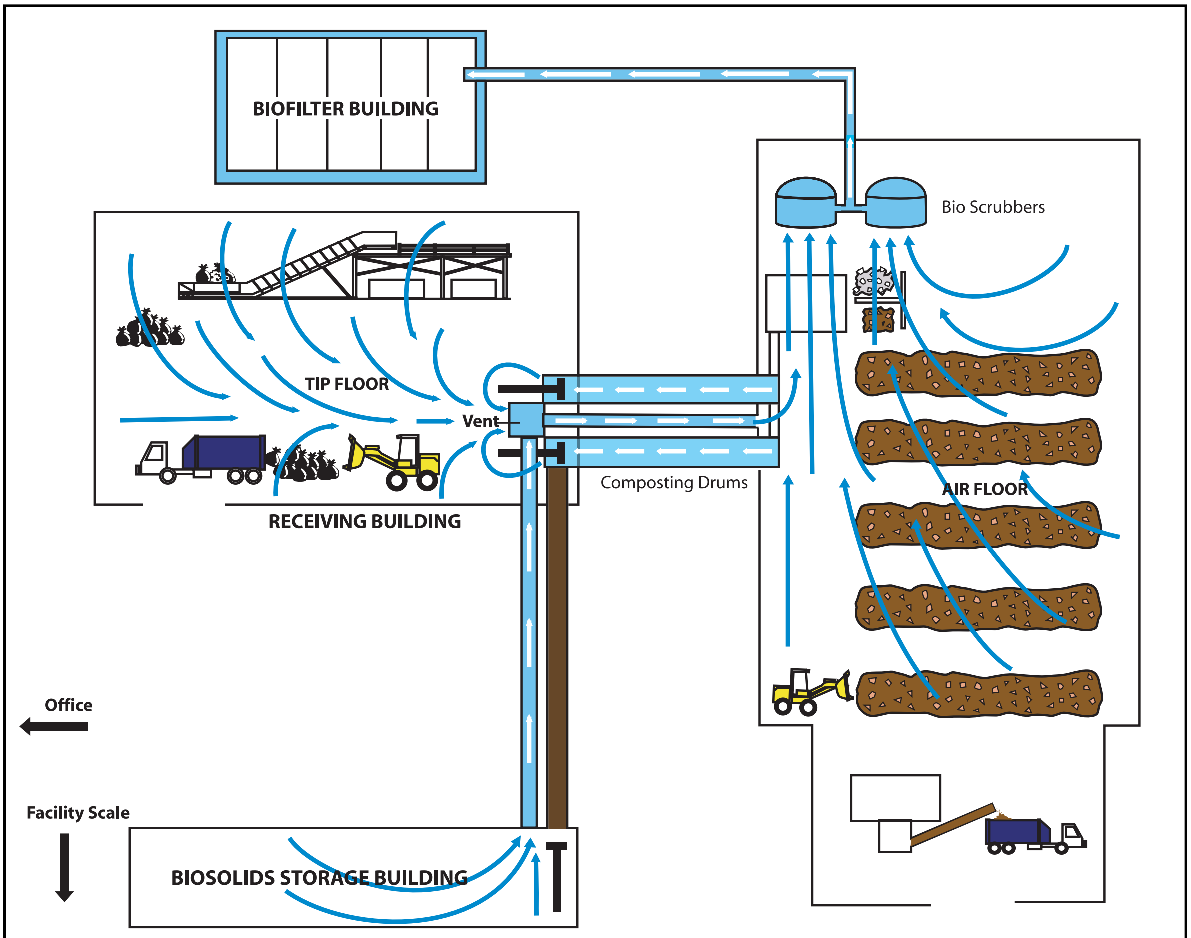
Description	Time/Period Duration	Day Sample Taken	Lab Sample Name[1]
NYC MSW loaded into composting drum	Material loaded each day for 5 days/ Remains in drum for 3 days	None	None
Biosolids loaded into composting drum	Material loaded each day for 5 days/ Remains in drum for 3 days	Every day and then combined into Day 1-3 (A) and Day 3-5 (B)	*NYC Trials Biosolids*
Material passes through primary 2" screen	Directly upon discharge from composting drum	Every day for unders and overs/Combined into Day 1-3 (A&B) and Day 3-5 (A&B)	*NMS[2] Primary Screen Unders* and *NMS Primary Screen Overs*
Active composting of 2" unders	21 days	Day 1, 7, 14, 21	*NMS Day 1 (7, 14, 21) Facility*
Material passes through ½" screen	After 21 days of active composting	Immediately after screening	*NMS Half-Inch Unders* and *NMS Half-Inch Overs*
One cubic-yard sample of ½" unders sent to lab for curing	Approximately 126 days	Day 59, 70, 80, 91, 105, 125, 147	*NMS Day 59 (70, 80,… etc.) WERL[3] Cure*
Material passes through Marlborough facility final ⅜" screen	In the week following the ½" screening and sampling	Immediately after screening	*NMS Facility Final ⅜" Screen Unders* and *NMS Facility Final ⅜" Screen Overs*

1. Lab data is attached as Appendix F.
2. NMS is the code the laboratory assigned to the NYC MSW during the NYC Composting Trials.
3. WERL is an abbreviation for Woods End Research Laboratory, the site of the NMS compost curing.

Maintaining aerobic conditions in the material is a function of supplying adequate oxygen through mixing and turning, as well as moving air through the composting piles. Facilities accomplish the second goal through the design and operation of an air-handling system. Generally, such systems work by keeping buildings under negative air pressure to prevent fugitive emissions, and directing all captured air to a **biofilter—**a living system that "scrubs" odorous compounds from the air passing through it. Some facilities may also employ a scrubber prior to the biofilter to improve the biofilter's performance or extend its life. Typically composed of a blended ratio of compost and wood chips, biofilters may also include soil, limestone, or other ingredients. The biofilter is constructed either above or below ground, over a series of perforated pipes through which process air is pumped and distributed. Biofilters retain air in the media for a specified time to ensure the degradation of odorous compounds.

Marlborough facility operators pay as much attention to *not* creating odors as they do to creating compost. All buildings at Marlborough are kept under negative air pressure. This means that any time workers open a door, fresh outside air is drawn in, rather than odorous facility air escaping out. Additionally, vents draw air from the receiving building, biosolids storage building, composting drums, and air floor building through **scrubbers**, and subsequently through an above-ground biofilter. Illustration 1-5 represents a schematic of Marlborough's air-handling system.
The scrubbers are two dome-like structures housed inside of the air floor building. The domes are filled with small, hollow, plastic spheres (resembling wiffle balls), over which a small stream of water continuously trickles down. The scrubbers serve to humidify and cool the airflow in order to prevent the biofilter from drying out or becoming too hot in the summer. Air stream

Illustration 1-5
Marlborough's Air-Handling System



Arrows represent airflow through the facility.

temperatures above 103°F could potentially damage the mesophyllic bacteria and other organisms at work in the biofilter. Vents draw air off of the top of the domes and pump it through a large pipe to a separate 30,000-square-foot building, which houses the biofilter.

The pipe from the bioscrubbers enters the biofilter building and connects to a network of smaller perforated pipes that lie on an asphalt pad. The biofilter itself sits on top of these pipes and is designed to retain the air for a specified period of time before releasing it. Again, the microbes in the biofilter media serve to "eat" the odor-causing compounds as they rise through it. Marlborough's biofilter consists of five cells, which typically operate together, but are designed to allow air to be directed to a set of three cells, while maintenance occurs on the other two.

Recovery Rate

Definition
The **recovery rate** represents the percent of material actually recovered for beneficial secondary use by the systems in place to accomplish this. For example, the three materials-recovery facilities (MRFs) with which the City contracted to process municipally collected metal, glass, and plastic recovered between 50-70 percent of the incoming material. This means that of the material DSNY brought to the MRFs as part of its source-separated, curbside (blue bag) recycling program, over half was recovered for use as input to manufacturing processes.

The recovery rate should not be confused with the **diversion rate***,* which in source-separated recycling programs represents the percentage of the total waste stream collected for recycling. It is measured by dividing the weight of collected recyclables by the weight of collected garbage plus recyclables.

The recovery rate is also distinct from the **capture rate—**the percent of material set out for recycling, out of the total quantity of recyclable material estimated to be present in the waste stream. The estimated amount of recyclables in the waste stream is based upon waste-composition sampling. Understanding these distinctions allows for better analysis of any waste-management strategy based on recycling.[7]

Recovery Rate Achieved During the New York City Composting Trials
Table 1-12 summarizes all of the inputs and outputs from the NYC Composting Trials, which can be used to determine an overall facility and solid-waste recovery rate. Similar tables can be found for each of the surveyed MSW-composting facilities in Chapter 3, as well as for the proposed New York City Pilot Research and Development Facility in Chapter 6. The loss-of-mass calculation presented here, as well as in the other recovery rate tables, is derived by subtracting the compost and residue outputs from the total inputs. In other words, the difference between the material brought to the facility for composting (MSW and biosolids) and the material leaving the facility (compost and residue) is attributed to loss of mass. Again, loss of mass is due to the loss of moisture and carbon dioxide that occurs during decomposition. This is a rough calculation, but is a standard way of deriving these types of "mass balance" numbers for MSW-composting facilities. As Table 1-12 shows, the overall facility recovery rate is 65 percent. This means that of all the New York City MSW and Marlborough biosolids processed at the Marlborough facility during the Composting Trials, the facility recovered 65 percent, either as compost or through loss of

Table 1-12
Recovery Rate Achieved During the New York City Composting Trials

Material	Tons	Percent of Input Material
INPUTS:		
MSW Input	259[1]	71
Biosolids Input	106[2]	29
Total Inputs	**365**	**100**
OUTPUTS:		
Compost Output	121[3]	33
Loss of Mass[4]	115	32
Residue Output	129[5]	35
RECOVERY		
Total Facility Recovery[6]	**236**	**65**
Recovery of Solid-Waste Fraction	**130[7]**	**50[8]**

Calculations based on compost and residue rates achieved after the ½" screen instead of the ⅜" due to the technical problems previously described regarding the ⅜" screen.

1. From Table 1-4.
2. From Table 1-6.
3. From Table 1-8.
4. Calculated by subtracting compost and residue output from total inputs. Loss of mass is attributed to loss of moisture and CO_2.
5. Sum of residue listed in Tables 2-5, 2-7, and 2-8.
6. Includes compost output and loss of mass.
7. Calculated by subtracting liquid input (biosolids) from "Total Facility Recovery."
8. Based upon solid-waste input.

moisture and carbon dioxide. The recovery rate for MSW alone, exclusive of biosolids, is 50 percent. These numbers are in line with recovery rates achieved at the four surveyed facilities. The actual rates are summarized in Chapter 3, Table 3-1, *Summary of the Four-Facility Survey.*

As discussed, residue refers to all non-degradable material that a facility must remove for disposal, either before it enters the digester drums (through sorting), or after it has gone through the composting process (through screening). It is interesting to note that the 35 percent residue rate from the NYC Composting Trials comes close to the consultant's determination of what is "non-compostable" in the samples of New York City MSW sent to Marlborough (Table 1-1). The waste characterization performed at the Fresh Kills landfill (before long-haul trucks transported the NYC MSW to the Marlborough facility) found that 40.1 percent of the material was "non-compostable." Conversely, the 50 percent recovery rate for the solid-waste fraction makes sense given that the waste characterization indicated that 55.6 percent of the NYC waste sampled was degradable.

To get detailed recovery rate information, it is necessary to have accurate waste-characterization data, which is why the Department performed a waste characterization on representative samples of the material it sent to the Marlborough facility. Such data enables DSNY to accurately determine the recovery rate achieved by the facility during the NYC Composting Trials for the *degradable fraction* of the MSW. As summarized in Table 1-13, the recovery rate for the degradable fraction of the MSW was 90 percent.

Focusing on the recovery of the degradable portion of the solid-waste stream represents another way to assess the performance of MSW-composting facilities. Most municipalities, however, do

Table 1-13
Recovery Rate for Degradable Waste Achieved during the New York City Composting Trials

NYC MSW Sent to Marlborough[1]	Amount of Degradable Material		Recovery Rate: Solid-Waste Fraction[3]		Recovery Rate: Degradable Portion of Solid-Waste Fraction[4]
Tons	Tons	%	Tons	%	%
259.05	144	55.6[2]	130	50	90

1. From Table 1-4.
2. From Table 1-1.
3. From Table 1-12.
4. Calculated by dividing the tons of solid waste recovered (130) by the estimated tons of degradable material in the waste stream (144).

not conduct regular, statistically valid, waste-composition studies owing to the relative time and expense involved. Therefore, the summary of the four-facility survey presented in Chapter 3 compares MSW-composting facilities using "total facility recovery" and "recovery of the solid waste fraction."

Chapter 4 presents the conclusions to the NYC Composting Trials, and discusses the results in the context of the findings from the four-facility survey.