CHAPTER 4
CONCLUSIONS

Over the course of 2000-2001, the Department conducted a Research Project to determine if MSW composting merits further serious study as a waste-management strategy for New York City.

The Research Project consisted of sending samples of New York City waste, for five days, to a municipal-solid-waste (MSW) composting facility and closely analyzing the process, as well as the resulting compost. Before sending the samples to the MSW-composting facility, the Department conducted a waste-characterization study, which enabled the Department to calculate both the overall facility recovery rate, as well as the specific recovery rate for the degradable fraction of the waste stream.

In addition, the Department commissioned a survey of four, successfully operating MSW-composting facilities in North America, which involved site visits and reports, management questionnaires, and compost sampling. The laboratory that conducted the compost-quality tests structured the sampling protocol so that the results could be analyzed to infer if the differences observed among facilities were statistically significant. This chapter synthesizes the findings of the Research Project and extrapolates lessons for New York City.

Summary of Key Findings

The most important findings of the Research Project relate to the following:

Compost Quality: The Research Project demonstrated that the Department, like other municipalities utilizing MSW composting, produced a compost that met New York State Department of Environmental Conservation (DEC) Class I compost standards (in effect during the time of the Trials), as well as current DEC standards (effective March 2003). For a summary of results, see Chapter 2.

Odor Control: The Department determined that it is possible to operate an MSW-composting facility without generating nuisance odors. Each of the facilities surveyed employs sophisticated and effective air-handling systems that safeguard against odor emissions. As the facilities are generally located well within a mile of their neighbors, they could not continue operations if this were not the case.

Management of Non-Degradable Items: While the above findings speak to the successes of MSW composting, the Department learned that improvements could be gained by placing more emphasis on removing non-degradable materials *before* they go through the composting digester drums. Beyond the bulk items that facilities routinely remove (such as hoses and cords that cause “hairballs” in the drums), facilities should focus especially on removing problematic materials, such as:

- *Film plastics* (primarily plastic bags), which accumulate moisture in the drums, bind screening equipment, and break up into tiny, hard-to-remove pieces

- *Glass,* which tends to break into small pieces during materials handling and tumbling through the drum, making it difficult to screen away
- *Textiles,* which soak up a lot of moisture in the drums, becoming heavy and more expensive to discard
- *Metal cans,* which can become packed with immature compost in the drums, leading to lost compost and more expensive residue

Air-Floor Quality: It is on the air floor, not in the digester drums, where the significant decomposition of degradable items in the waste stream occurs. A quality air floor—with regular and automated turning, good air flow, and the ability to add moisture—allows a facility to attain the following important goals:

- *High loss of mass,* which is the most cost-effective means of achieving a high, facility recovery rate
- *More complete degradation,* which leads to a better overall compost product
- *Moisture control,* which allows a facility to achieve the optimal moisture range for effective final screening
- *Odor reduction,* which is achieved through maintaining aerobic conditions and minimizing volatile organic acid production

Air-Floor Capacity: By all measures of compost quality, a product is not mature after only 21 days, even on a well-designed air floor. Compost needs at least 50 days of turning and some additional type of aeration in order to lose mass and moisture, as well as attain maturity.

Based on the above findings, the Research Project concludes that MSW composting warrants further serious consideration as a waste-management strategy for New York City. However, in order to determine what it would cost per ton to process City waste through MSW composting, it is necessary to outline a theoretical New York City facility. The remainder of this chapter describes the components of a successful MSW-composting facility, based upon the Department's findings from its MSW-Composting Research Project. These in turn inform the conceptual design of the pilot facility presented in Chapter 5.

Components of a Successful MSW-Composting Facility

In addition to the important compost-quality data, the Research Project provided the Department with a greater understanding of the MSW-composting process itself, and insight into where possible improvements could be achieved.

In very general terms, successful MSW-composting facilities maximize recovery rates by increasing "desirable" outputs (quality compost, marketable recyclables, loss of mass) and decreasing "undesirable" outputs (residue requiring disposal). Table 4-1 summarizes how the four facilities surveyed for the Department's MSW-Composting Research Project, as well the facility used for the NYC Composting Trials, fared according to these measures. (For a description of the NYC Composting Trials, see Chapter 1.)

Table 4-1
Summary of Annual Facility Data: Four Surveyed Facilities and NYC Composting Trials

Parameter (% of total facility input)	Conporec	Edmonton	Marlborough	Rapid City[1]	NYC Trials[2]
Recovery Total Facility[3]	75	61	64	64	65
Recovery Solid Waste[4]	72	50	48	60	50
Compost Output	45	29	48	33	37
Recyclables	3	0[6]	0[6]	1	0
Loss of Mass[5]	28	32	16	29	24
Residue	25	39	36	36	39

1. All aspects of the Rapid City facility are not yet complete; figures are projected estimates.
2. The NYC Composting Trials were conducted at the Marlborough facility. See Chapter 1 for more information.
3. Based on solid and liquid inputs. Recovery rate includes loss of mass during composting.
4. Based on solid-waste inputs only.
5. Calculated by subtracting compost output, recyclables, and residue output from total inputs. Loss of mass is attributed to loss of moisture and CO_2 during composting.
6. This facility does recover some scrap metal, but the quantities are negligible as a percentage of the total facility input.

The following sections review the outputs (compost, recyclables, loss of mass, and residue) from each facility surveyed and how these contribute to the overall success of facility operations.

Quality Compost Output

Compost is obviously one of the primary output streams of an MSW-composting facility. The most import aspect of compost output is that it meet certain quality standards. As explained in Chapter 2, the compost produced through the NYC Composting Trials, as well as at the four surveyed facilities, met New York State Department of Environmental Conservation compost standards in place during the time of the Research Project. These standards regulate compost quality with regard to:

- *Pollutant and pathogen levels,* such as heavy metals, PCBs, fecal coliform, and *Salmonella*
- *Physical properties,* such as particle size and inert levels (i.e., small pieces of glass and plastic in the final compost product)
- *Horticultural/agronomic properties,* such as ammonia, pH, and nitrate levels

In order for an MSW compost to be used within New York State, the product must meet pollutant, pathogen, and certain physical-property limits set by the DEC. For the horticultural/agronomic properties of an MSW compost, the DEC requires that a facility regularly report levels for designated parameters, but does not provide set limits for a product to meet.

A successful MSW-composting facility will aim to produce a consistent-quality compost with regard to pollutant, pathogen, and physical contamination limits, as well as agronomic properties. The pollutant levels of the compost from all of the surveyed facilities, as well the compost produced in the New York City Composting Trials, were well within the current DEC limits. (See Appendix H and F, respectively, for data.) However, removing non-degradable materials before they go through the composting process not only improves overall compost quality, but also lessens the chance that certain pollutants will find their way into the final compost product.

Pathogen-kill requirements are standard in many State and federal requirements pertaining to the composting of biosolids. For example, the DEC mandates that for the composting of MSW and biosolids, the material must exceed 55°C (131°F) for three consecutive days to make sure pathogens are eliminated. The New York City Composting Trials demonstrated that this is possible and that pathogen limits were met. (See Appendix C for temperature data sheets and Appendix F for pathogen data.)

Physical contamination levels refer to the non-degradable materials (generally small pieces of plastic and glass) in a final compost product. As explained in Chapter 2, the DEC has set a limit of two percent (by weight on a dry-weight basis) for these materials in a compost. Measuring these small, non-degradable items (referred to as "inerts" throughout this report) is a new lab procedure, for which there is no standard methodology. With regard to inert levels, the New York City Composting Trials demonstrated that it was possible to meet the two-percent limit, but the Marlborough facility final screen removed a lot of compost in the process as well.

However, one of the surveyed facilities (Conporec) was able to overcome the problem of losing too much compost through the final facility screen by adopting the following procedures:

- **Reducing moisture levels in the compost before sending it to the final screen.** Drier compost screens more easily, facilitating the separation of compost from inerts. A facility can achieve this both by adjusting the ratio of liquid to solid-waste inputs, as well as aggressively composting material on the air floor to make sure that as much moisture as possible is lost (as vapor).
- **Sending final screen overs back through the composting process.** In order to meet the DEC particle size requirements (less than 10mm), the final facility screen must be very small. At this setting, even with drier material, compost will inevitably pass over the screen, as well as under. Sending final screen overs back through the composting process, rather than disposing of them as residue, leads to less overall residue.
- **Pulverizing final screen unders.** Pulverizing final screen unders serves to crush any remaining tiny pieces of glass in the compost into sand, as well as reduce the size of small pieces of wood, stone, and other inert materials that do not count towards physical contamination levels.

For further discussion of compost-moisture levels and final screening in general, see the *Residue Reduction* section later in this chapter. (For the inerts characterization data for the New York City Composting Trials and the four surveyed facilities, see Appendix F and H, respectively.)

Finally, with regard to agronomic/horticultural properties, a successful facility will consistently produce a compost product with certain useful properties, which can be labeled appropriately and marketed to end users. Even if limits for these parameters are not set by the DEC as law, a facility must pay utmost attention to producing a consistent, quality product and working with a laboratory, or other certification agency, to arrive at a recognizable soil-amendment product designation. This reduces the “guess-work” for compost users, increasing user confidence in the product, and making it possible for the facility to target specific end-use markets. *An MSW-composting facility must be in the business of creating quality compost, not just handling a municipality’s waste.*

In addition to compost quality, there are other factors relating to compost that are important to take into account. Table 4-1 shows the amount of compost produced (as a percent of total facility input) at each of the surveyed facilities, and during the NYC Composting Trials. These numbers should be viewed cautiously, however, since in terms of compost, quality is as important as quantity.

High-compost output is desirable only when it accompanies high loss of mass and low residue. The Conporec facility, with its 45-percent compost output, 28-percent loss of mass and only 25-percent residue, represents the ideal in this case. Marlborough, on the other hand, has high-compost output (48 percent), but low loss of mass (16 percent), indicating that the compost might not be fully mature and still retains a lot of water weight from the biosolids. Edmonton’s low compost-output number (29 percent) is positive in the light of its high loss of mass (32 percent), but negative in terms of its high residue rate (39 percent). For more information on loss of mass during composting, see the *High Loss of Mass* section on the next page.

Recovery of Recyclables

Recyclable or reusable, non-degradable materials represent another potential output stream from an MSW-composting facility. In order to increase recovery rates and keep residue rates low, MSW-composting facilities should ideally recover non-degradable recyclable items, in addition to the degradable materials that they recover as compost. However, as Table 4-1 reveals, the four surveyed MSW-composting facilities recover very little (0 to 3 percent) non-degradable, recyclable material.

All four of the municipalities that send their refuse to the MSW-composting facilities surveyed for this report offer curbside collection of source-separated recyclables such as paper, metal, glass, and plastic. (See Chapter 3 for more information.) Designers of MSW-composting facilities assume that most non-degradable recyclables will be handled through this separate curbside collection, or that the cost associated with recovery outweighs the cost associated with disposal.[1]

MSW-composting-facility operators, however, often have a different perspective than facility designers. Operations managers from both the Marlborough and Edmonton facilities expressed the desire to have greater ability to remove recyclables before they enter the digester drums. They both reported that even with a separate curbside collection in place, there are still significant quantities of recyclables in the incoming MSW. These recyclables become soiled and entrained with compost in the digesters and lose much or all value as commodities. Facility operators, therefore, not only lose this potential revenue stream, but must pay to dispose of the recyclable items after they are discharged from the digesters.

Furthermore, some of these recyclable items, such as tin cans, become solidly packed with immature compost in the digesters to form what one facility manager called “hockey pucks.” To his annoyance, he noted that by not removing these cans before they went to the digesters, he was losing the recycling value of the can, losing the compost, *and* having to pay more to dispose of the residue, as the can was much heavier now that it was filled with compost. A consultant analyzing Marlborough’s primary screen overs determined that 16.7 percent of this material, destined for disposal, consisted of metal and plastic containers that were designated as recyclable, per Marlborough’s recycling law.

The characterization work associated with the NYC Composting Trials, both for the NYC MSW sent to the Marlborough facility, as well as for the material passing under and over various post-digester screens, did not specifically identify what non-degradable material was recyclable. For instance, the waste-characterization consultant and the research laboratory both used the category “hard plastic.” This included readily recyclable plastics, such as polyethylene terephthalate (PET), as well as those without well-established recycling markets, such as acrylonitrile butadiene styrene (ABS).

Without hard numbers, one way to calculate how much recyclable material is in the New York City municipal-solid-waste stream is to consider the capture rate achieved by the City’s recycling program (before the suspension of plastic and glass recycling in July 2002). The Department estimated that of the total amount of designated recyclable material in the waste stream, New York City residents captured (set out for separate collection) about 40 percent. This means that 60 percent of the items that the City designated as recyclable were still in the waste stream. As it is unlikely that residents will ever set out 100 percent of the materials designated for recycling, it makes operational sense for MSW-composting facilities to be equipped to recover this material. This is the case whether curbside recycling programs are in operation or not.

High Loss of Mass

One of the most cost-effective ways of maximizing recovery rates is through loss of mass. By aggressively composting the degradable fraction of the waste stream the material loses mass, primarily in the form of water, discharged as vapor. The water in organic (degradable) materials is what makes municipal solid waste heavy, and therefore expensive to transport. Composting the degradable fraction of the waste stream not only recovers this material for recycling, but also significantly reduces the weight of the remaining items requiring disposal.

With respect to every measurement of composting efficiency, the statistical analysis performed by the laboratory in association with the Research Project demonstrated that those facilities with mechanized, highly regulated air floors outperformed those without. This was true regardless of the “compostability” of the input recipe. In essence, a good air floor can compensate for the shortcomings of facility operator negligence, or inexperience, when formulating a recipe to load into the composting drums. Conversely, failure to maintain optimum conditions after drum discharge not only results in the decomposition rate slowing down, but can actually prevent the process from happening at all.

The initial emphasis in MSW-composting facility design (at least in North America) focused on the digester drums. The drums were considered the heart of the process, where the "real" composting occurred, and the air floor was deemed secondary, as the place where the material cured and stabilized (some facilities referred to the post-digester space as a "cure floor"). This may have resulted from the fact that drum designers originally envisioned longer material-retention times than what was practicably possible, given the value of high facility throughput.[1]

The Research Project firmly concluded that while the digester-drum stage is important, it is the post-digester, composting process that is essential to producing a quality product. After three days, for example, in the digester drum, the material requires additional time to both compost and cure. While the exact number of days that a facility should actively manage decomposing material on the air floor is unknown, an extended, mechanized, post-drum process remains crucial. The DEC's requirement that MSW compost be produced from a process with a *minimum* detention time of 50 days (including composting and curing) seems very reasonable in light of the findings of the Research Project.

Looking at the loss-of-mass data in Table 4-1, it is interesting to compare the Edmonton and Marlborough facilities. Both facilities compost MSW and biosolids, employ a similar pre-drum, non-degradables removal strategy, as well as utilize similar digester drums. Both facilities also detain their material on the air floor for 21 days. However, during those 21 days, Edmonton employs a mechanized system that turns the material daily and adds water as needed. Marlborough, on the other hand, forms its compost into piles and turns them weekly, flipping the piles with a front- end loader. It is not surprising then that Edmonton's material loses twice as much mass as Marlborough's. As Chapter 3 noted, the reason that the NYC Trials material lost more mass on the Marlborough air floor than Marlborough's own material is possibly due to the fact that Marlborough facility operators turned the NYC Trials' material more frequently than they would typically turn their own.

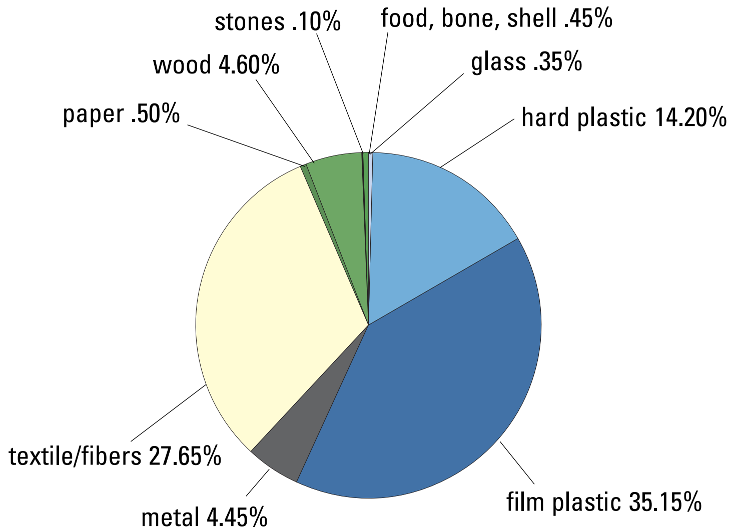
Residue Reduction

The initial thinking of MSW-composting facility planners and operators was that everything could go into the composting digester drums, with all non-degradable items (residue) removed by a series of subsequent screens, post drum-discharge. This is true for the most part. However, two problems arise from this approach:

- Non-degradable items saturate with moisture and immature compost in the digester, making the resulting residue much heavier and therefore more expensive to dispose.
- Small pieces of non-degradable items (such as tiny shreds of glass and plastic) are very difficult to screen away and remove completely without losing substantial compost to residue in the process.

Avoiding Heavy Residue
As part of the NYC Composting Trials (described in Chapter 1), the Department had the laboratory characterize samples of the New York City material that passed over the various Marlborough facility screens, and list the respective weights of each fraction. The composition of the material that passed over the first screen after discharge from the digester drum (meaning

Figure 4-1
Composition and Percent by Weight of Material Passing Over Primary Post-Drum Screen During NYC Composting Trials



Note: Results are an average of two samples (A/B). Data can be found in Appendix F, labeled *NMS Primary Screen Overs (>2")*.

material larger than two inches) is presented as a pie chart in Figure 4-1. Again, this represents residual material that will require disposal.

By far the two heaviest categories of material, as a percent of the total, are film plastic (primarily plastic garbage bags) and textiles (such as discarded clothing and bedding). These items soak up moisture and become entrained with immature compost in the digester drum, making them much heavier than they would be otherwise.

This same process occurs in the laundry—a pair of jeans is obviously much heavier after it comes out of the washing machine than before it went in. In fact, a consultant for one MSW-composting facility weighed a dry pair of pants and found them to be 1.52 pounds. Two similar pairs of pants after they had traveled through the composting digester drum weighed 3.74 and 5.10 pounds, respectively. A dry, plastic, kitchen garbage bag weighed .84 ounce before, and 3.5 ounces after going through the digester (although this bag had not captured any immature compost as many others do).

Since facilities process hundreds of tons of material and pay per ton to dispose of residue, these accretions of weight add up quickly. Therefore facilities can reduce residue disposal costs by removing such non-degradable items *before* loading material into the digester drums. How much can a facility save by doing this? Using the weight gains the consultant derived for textiles and film plastic, the Marlborough facility, for example, could have reduced disposal costs during the NYC Composting Trials by as much as 41% if they had been able to remove textiles and film plastic from the material entering the digester drums.[2]

Avoiding Screening Out Compost with Residue

The current approach to MSW composting, which removes non-degradable items through a succession of smaller post-drum screens, means that the final screen is designed to remove the smallest inerts. This step is particularly important, both for regulatory compliance (in certain States), as well as for visual appearance of the compost from a marketing perspective.

In New York State, even if a facility were to remove non-degradable items before they went through the composting process, as this report proposes, the final screen would still have to be set at three-eighths inch (⅜" or 10mm) in order to meet the DEC regulation that no compost contain *any particles* larger than this size. As noted above, the current DEC regulations also stipulate that inerts must make up no more than two percent of a final, MSW-compost product. In order to get these tiny inert materials out of the compost, the final screen setting at most MSW-composting facilities is very small (generally ten millimeters, or .4 inch, and under). However, with settings this small, the final screens also tend to remove a lot of compost along with inerts.

As presented in the *Quality Compost Output* section above, the Department learned through its Research Project that MSW-composting facilities can overcome this problem by:

- Sending final screen overs back through the composting process
- Reducing moisture levels in the compost before sending it to the final screen

In general, successful facilities will actively compost their material for at least 50 days and drop moisture levels in the compost to about 25-30 percent before sending it to the final screen.

As part of its MSW-composting facility survey, the Department looked at the amount of compost being lost to final screen overs. Table 4-2 presents the percent of compost and other degradable material in the final screen overs (on a dry-weight basis) for the two surveyed facilities that produced a (non-blended) final compost product. These results are more "meaningful" than the New York City Composting Trials results since these facilities run the same compost recipes year-round, as opposed to the limited duration of the Trials.

In the case of both Conporec and Edmonton, about a third of the material passing over the final screens is compost. Given that nearly 80 percent of Conporec's final screen overs is degradable, it makes sense that the facility runs this material back through the composting process rather than disposing of it. Edmonton, on the other hand, disposes of its final screen overs, despite the fact that nearly 40 percent of this material is degradable. This difference contributes to Edmonton's higher residue rate (39 percent), shown in Table 4-1.

Again, sending the overs back through the composting process (i.e., Conporec's approach) ensures that any wood or paper that has not yet degraded, is given a "second chance" to do so. This means that very little degradable material (including compost) is lost to residue.

As noted above, another means to prevent degradable material from ending up in the residue is to control compost moisture levels. Drier materials are generally easier for final-screening equipment to handle, allowing for a more effective separation of compost from small, inert materials.

Table 4-2

Percent of Compost and Other Degradable Material in Final Screen Overs (on a dry-weight basis)

Material	Conporec	Edmonton
Compost	33.13	32.79
Paper	38.16	2.09
Wood	6.33	2.40
Total	**77.62**	**37.28**

Table 4-3
Moisture Levels in Final Screen Unders: Surveyed Facilities and NYC Composting Trials

Facility	Age of Material (Days)	Percent Moisture (as-is basis)
Conporec[1]	42	21.75
Edmonton[1]	21	34.55
Marlborough	21	55.60
New York City Composting Trials	21	43.40

1. Results are the average of an A/B sample pair.

Table 4-3 shows the moisture levels of the compost passing under the final facility screens from each of the surveyed facilities producing a finished compost, as well as the New York City Composting Trials.

Even with moisture levels as low as 35 and even 22 percent (from Table 4-3), about a third of the material passing over the Edmonton and Conporec final screens is compost (from Table 4-2). However, Conporec remedies this situation by running these organic-rich overs back through the composting process.

What is significant to note here is that after 21 days of composting, the material from the Marlborough facility (both Marlborough's own compost and New York City Trials' compost) is extremely wet. The moisture level in Marlborough's compost (56 percent) is more appropriate for the beginning of the compost process, not the end. This means that Marlborough cannot run its material through a final screen at this stage of the process, let alone worry about losing compost to overs. The facility's decision to stop attempting to run its material through the final facility de-stoning equipment and fine screen (ten millimeters, or .4 inch), at this stage makes sense.

As explained in Chapter 1, the Department decided to run New York City Composting Trials' material through the Marlborough final-screen equipment, in spite of the fact that the facility was no longer using it. As Chapter 1 described, the Department verified the facility's complaint that the equipment was screening out too much compost along with the inert material that it was designed to remove. In addition, the final-screen equipment would jam up, break down, and generally struggle to operate at all. This makes sense given how wet the material from the New York City Trials was at this point.

While the exact moisture levels for ideal de-stoning and final screening are not known, facility operators generally agree that compost should contain less than 40-45 percent moisture in order to screen well. Based on the findings of the Department's Research Project, it is perhaps the case that MSW compost should be even drier when going to the final screen (around 25-30 percent moisture).

Given that Conporec detained its material for 42 days and the other facilities only 21, it is interesting to note how long it took for these other composts to exhibit the "ideal" moisture levels for final screening.

Both Edmonton and Marlborough send their material off-site after 21 days to outdoor areas for additional composting and curing. The Department took samples of the material that each facility considered finished. As explained in Chapter 1, the Department sent the lab a cubic-yard sample of the material from the New York City Composting Trials after it spent 21 days on the Marlborough air floor and was screened through the facility's half-inch screen. The lab sampled this New York City material at Day 59 and performed a full analysis, as this was the material that the Department considered the final product from the Trials. Sampling occurred at this point in order to meet the DEC's 50-day-minimum detention-time requirement, outlined in Chapter 2. Table 4-4 presents the moisture levels in the finished compost products from Edmonton, Marlborough, and the New York City Composting Trials.

Table 4-4
Moisture Levels in Finished Compost: Surveyed Facilities and NYC Composting Trials

Facility	Age of Material (Days)	Percent Moisture (as-is basis)
Edmonton[1]	90+	26.55
Marlborough	60+	20.8
New York City Composting Trials	59	23.5

1. Results are the average of an A/B sample pair.

At the time of the survey, the Edmonton facility was not actively managing the compost at their off-site curing location. They were not turning the material at all, but rather just leaving it in large piles. Marlborough facility operators provided for regular turning at their off-site curing location with a front-end loader. Staff at the laboratory also regularly turned the cubic-yard sample of the New York City Trials compost. It is interesting that with more active management, the Marlborough and the New York City Composting Trials materials lose more moisture in less time than Edmonton's. At 59 days, the New York City material has attained the "ideal" moisture range for final screening.

The next chapter discusses how a facility can systematically incorporate materials recovery with MSW composting, and presents the preliminary layout and proposed components of a theoretical pilot facility. The conceptual design of the pilot facility builds upon the findings from the Department's MSW-Composting Research Project, discussed earlier.