Recycling Audits & Composition Studies:
Protocols for Success

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This guide is designed to help Massachusetts communities gain a better understanding of how best to measure contamination and the composition of their recyclables. The guide is broken into four sections: Common Terms, Contamination and Composition Audits, Recycling Composition Studies, and Example Material Categories.

Section 1. Common Terms

The following are recommended definitions for common terms used for contamination audits and composition studies.

Acceptable Recyclables: Refer to *Smart Recycling Guide*.

Composition Audits. See below.

Composition Studies: See below.

Contamination: Materials that are mixed with a community's Inbound material which do not meet the definition of Acceptable Recyclables and are collected along with Acceptable Recyclables.

Contamination Audits: See below.

Materials Recovery Facility (MRF): A specialized facility that receives, separates, and prepares Acceptable Recyclables for marketing to end-use manufacturers.

Inbound: Materials tipped at the MRF prior to any processing, sorting, or mixing with materials from other communities.

Outbound: Materials leaving the MRF either as Recovered Material or Residue. Outbound materials are an aggregate of materials from all sources of Inbound material.

Recovered Materials: Outbound materials that have been separated and prepared for sale or distribution and which may include small amounts of Contamination.

Recyclable Containers: Metal food and beverage cans, plastic bottles/jars/tubs/jugs, glass bottles and jars, clear plastic hinged containers (clamshells), clear plastic cups, and clear plastic egg cartons, including labels and caps. The list of Recyclable Containers may be expanded or reduced from time to time as determined jointly by the Municipality and Contractor.
Note: see www.RecycleSmartMA.org and Waste Disposal Ban requirements (310 CMR 19.017 and https://www.mass.gov/guides/massdep-waste-disposal-bans).

Recyclable Paper: Papers, newspapers, magazines/catalogs, paperbacks & phonebooks (covers ok), corrugated cardboard, and paperboard, including paper clips, staples, and metal spirals. The list of Recyclable Paper may be expanded or reduced from time to time as determined jointly by the Municipality and the Contractor.
Note: see www.RecycleSmartMA.org and Waste Disposal Ban requirements (310 CMR 19.017 and https://www.mass.gov/guides/massdep-waste-disposal-bans).

Recyclables: Materials collected by a community consisting primarily of materials designated for recycling by the community or otherwise jointly agreed to be acceptable by the community and its processing facility. Recyclables can include contamination.

Rejects: Contaminants removed from Inbound materials when received and prior to being processed at a MRF.

Residue: Outbound materials that have not been converted into Recovered Materials and which are destined for disposal. Acceptable Recyclables and Recovered Materials cannot be classified as Residue due to commodity market conditions.

Section 2. Contamination Audits and Composition Audits

What is a contamination audit and when is it used?
A **contamination audit** entails weighing a sample of inbound recyclables, sorting it into two categories (acceptable and unacceptable materials), weighing the unacceptable materials, and calculating the weight-based percent of contamination. An audit of an individual load can be used to decide whether or not that load should be rejected for exceeding a contamination limit. A series of contamination audits can be used to estimate average contamination in a community's inbound recyclables. Contamination audits can lead to financial consequence, e.g., load rejection costs and excessive contamination surcharges. It is very important that Massachusetts communities establish clear agreements with their recycling facilities on how audits are planned and implemented.

What is a composition audit and when is it used?
A **composition audit** is similar to a contamination audit, except in this case the recyclables are sorted into specific materials categories (e.g., newspaper, mixed paper, cardboard, PET, HDPE, aluminum cans, steel cans, container glass, etc.). A series of composition audits can be used to estimate average composition of a community's inbound recyclables. However, composition audits are not as reliable as a composition study (see below), and therefore are not the recommended basis for financial payment or revenue share.

What are the limitations of contamination audits and composition audits?
Contamination and composition audits are less rigorous than a composition study and may not provide an accurate measure of the overall content of a community's recyclables. To make them as reliable and transparent as possible, audits should be based on the following requirements.

Basic protocol checklist for contamination and composition audits:
1. Schedule and Location:
   - ✔ Community must be notified in advance and encouraged to be present during the entire audit, i.e., from pulling the sample to sorting and weighing the materials.

- ✔ Audits should not be performed during holiday weeks or major community events.
- ✔ Audits should be performed during hours when a community representative can easily attend, (e.g., between 8:00am and 5:00pm Monday through Friday).
- ✔ Audit site should be determined prior to initiation, clear of debris, and separated from operational activities.

2. Load and Sample Selection:
   - ✔ If being used to estimate average contamination or composition, the loads must be representative of the community's recyclables. If a community has multiple collection routes, loads should represent the diversity of them.
   - ✔ Determine how many loads to evaluate based on community-specific factors, including the size of the community, the types and diversity of generators, the range of collection methods, and seasonal fluctuations. As a general guideline, even small community audits should be based on at least 6 samples to ensure results are representative. Larger, more diverse communities may need at least 24 samples to obtain a statistically valid confidence interval.
   - ✔ For smaller communities that generate few loads, it may be acceptable to pull up to 3 separate samples from a single load, provided that each load is truly representative of the whole community.

3. Load Sampling:
   - ✔ Methodology for pulling all samples should be clearly articulated to municipal officials.
   - ✔ The composition varies significantly from place to place within a load. To avoid bias, the sample should be randomly pulled from the load in a manner that makes it representative of the entire load, i.e., not just from one part, or the surface, of the load. It is recommended that loads be gently mixed prior to sampling and that samples be taken from a cross section of the pile.
   - ✔ A sample size of approximately 150 to 200 pounds is recommended regardless of community size.

4. Sample Sorting:
   - ✔ The definitions of recyclables and contamination must be clear, mutually agreed to in advance by both parties, and not changed during the audits.
   - ✔ The definition of contamination must clearly establish how common points of disagreement will be treated (e.g., recyclables in bags, wet paper, containers with residual food and liquid, and interlocked materials like an aluminum can crumpled with a newspaper).
   - ✔ The methodology must describe how small particles and outliers (e.g., bowling balls or tire rims) will be handled. It is generally recommended that all materials that do not fall through a ½ inch screen be sorted. The parties must also agree whether the small pieces and outliers will be counted as contamination, split proportionally, or not included due to being outliers that are not representative of overall composition.

5. Results and Analysis:
   - ✔ Results need to be complete and transparent so that all parties can review the raw data and replicate the calculations made to determine the results.
   - ✔ Raw data should include for each load and sample: load identity, time and date, load weight, sample weight, photo documentation, and weight for each material in the sample.
   - ✔ Calculations should include: separate percentage calculations of materials in each sample and average for all samples.

- ✔ When calculating the results from multiple samples, the average percentage should be a weighted average based on the weight of each load from which samples were taken.

Section 3. Recycling Composition Studies

What is a recycling composition study and when is it used?
Recycling composition studies (RCSs) are a statistically valid method for identifying the average composition of a community's recyclables stream, and detailing weight-based percent of all constituent materials. They are a recommended tool for defining financial compensation terms for contractual agreements. This allows pricing to be based on an individual community's inbound recyclables not on outbound materials that are a composite from multiple sources and impacted by the unique means and methods of how the processing facility decides to operate.

What are the limitations of a recycling composition study?
The major limitation for a RCS is the time and level of effort required to conduct it. While contamination audits typically require one or two inspectors, an RCS is best performed with a crew of workers to sort recyclables into multiple categories. These studies require more planning and data analysis to ensure the results are statistically valid and can lead to higher costs if utilizing a third party. To make them as reliable and transparent as possible, a RCS should be based on the following requirements.

Basic protocol checklist for recycling composition studies:

1. Planning:
   - ✔ RCSs should be performed by an independent third party.
   - ✔ The parties must establish a mutually agreeable schedule, sampling plan, and sort protocol before the actual RCS takes place.

2. Schedule and Location:
   - ✔ Both the community and its processor must be notified in advance and encouraged to be present during the study, i.e., from pulling of samples to the separation and weighing of the materials.
   - ✔ RCSs should not be performed during holiday weeks or major community events, which can have short term impacts on generation, composition, and participation.
   - ✔ RCSs should be performed during hours when both parties can easily attend, e.g., between 8:00am and 5:00pm Monday through Friday.
   - ✔ Audit site should be determined prior to initiation, clear of debris, and separated from operational activities.

3. Load Selection:
   - ✔ Because the goal of the RCS is to determine the average of an entire community's recyclables stream, it needs to capture the variations of recyclables collected within the community.
   - ✔ The number of loads and diversity of samples will depend on the size and demographics of the community, the community's collection program, the number of collection routes (if applicable), seasonal fluctuations, and the total tons collected.
   - ✔ As a general guideline, even small community composition studies should be based on at least 6 samples to ensure results are representative. Larger, more diverse communities may need at least 24 samples to obtain a statistically valid result.

4. Load Sampling:
   - ✔ The methodology for pulling samples should be clearly articulated in the planning documents prior to conducting the RCS.
   - ✔ The sample should be randomly pulled from the load and done in a manner that makes it representative of the entire load, i.e., not just from one part, or the surface, of the load. It is recommended that loads be gently mixed prior to sampling and that samples be taken from a cross section of the pile.
   - ✔ A sample size of approximately 150 to 200 pounds is recommended regardless of community size.

5. Sample Sorting:
   - ✔ The definitions of recyclables and contamination must be clear, mutually agreed to in advance by both parties, and not changed during the RCS.
   - ✔ The definition of contamination must clearly define how common points of disagreement will be treated, e.g., recyclables in clear bags, wet paper, containers with residual food and liquid, and interlocked materials.
   - ✔ Sorting methods used should address how small particles and outliers will be handled. It is generally recommended that all materials that do not fall through a ½ inch screen be sorted. The parties must also agree whether the small pieces and outliers will be counted as contamination, split proportionally, or not included due to being outliers that are not representative of overall composition.

6. Results and Analysis:
   - ✔ Results need to be complete and transparent so that all parties can review the raw data and replicate the calculations made to determine the results.
   - ✔ Raw data should include for each load and sample: load identity, time and date, load weight, sample weight, photo documentation, and weight for each material in the sample.
   - ✔ Calculations should include: separate percentage calculations of materials in each sample and average for all samples.
   - ✔ When calculating the results from multiple samples, the average percentage should be a weighted average based on the weight of each load from which samples were taken.
   - ✔ In addition to calculating the average, a confidence interval should be calculated for each material category by the party performing the composition study. Confidence interval is the likelihood that the samples are representative of the composition of the community's recycling. A higher confidence interval more accurately reflects the entire community. For example, a 95 percent confidence interval means that there is 95 percent chance that the average of all tons will fall within the upper and lower bounds of the entire community.

Section 4. Examples of Material Categories

When planning and conducting an audit or RCS, the categories of materials need to be based on the specifics of the community's recycling program and its processing facility. On the following page is a sample list of material categories that may be used to develop a community-specific list.

Sample Material Categories

Acceptable Recyclables	
Corrugated Cardboard	Glass Containers
Mixed Recyclable Paper	Tin/Steel Cans
Newspaper	Other Ferrous Metals
Pizza Boxes without Food Residue	Aluminum Cans
PET Containers (#1)	Aluminum Foil and Trays
Natural HDPE Containers (#2)	Other Non-Ferrous Metals
Colored HDPE Containers (#2)	Aseptic Containers/Cartons*
Polypropylene Containers (#5)	Bulky Rigid Plastics*
Other Plastic Containers (#3, #4, #6, #7)	
Unacceptable Materials	
Plastic Bags and Film	Bagged Recyclables
Liquids and Food Residue	Bagged Waste
Shredded Paper	Scrap Metal
Textiles	Small Appliances
Tanglers (hoses, chains, cords)	E-waste
Organic Waste (yard waste & food waste)	Batteries
Expanded Polystyrene	Hazardous Waste
Multi-Laminate Pouches	Aseptic Containers/Cartons*
Materials Smaller than 2 Inches	Bulky Rigid Plastics*

*Depending on the specific community, these items may or may not be accepted and sorted for recycling, which is why they are included under both categories. Please note that this is a sample list; a municipality should customize to meet their needs.

Further information and resources for recycling and waste management provided by MassDEP can be accessed online at www.RecycleSmartMA.org.

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