

SINGLE-STREAM AND DUAL-STREAM RECYCLING: COMPARATIVE IMPACTS OF COMMINGLED RECYCLABLES PROCESSING



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EXECUTIVE SUMMARY

The MPCA contracted with Tim Goodman & Associates to undertake a study to examine the issue of single-stream and dual-stream recycling, focusing specifically on the processing of collected materials and the marketing of those materials to end-markets. The primary goal of this project was to gain a better understanding of Minnesota's changing recycling infrastructure and in doing so identify both policy and procedural opportunities for increasing the recovery of recyclables, improving the marketability of recovered materials, reducing recyclables processing residuals, and increasing overall recycling rates.

To accomplish this goal a three-prong approach was utilized for collecting information on the processing and marketing of recyclables including conducting on-site visits/interviews with four major, privately-owned material recovery facilities (MRFs) serving the Minneapolis/St. Paul metropolitan area, conducting on-site visits/interviews with major end-markets, and conducting interviews with recycling equipment/system vendors. The focus of these visits/interviews was to observe operations and collect operating data related to:

- Processing of commingled recyclables;
- Amounts and estimated composition of processing residuals;
- Quality of recovered materials delivered to markets;
- End-market operational issues and concerns; and
- Availability and relative effectiveness of materials separation/handling equipment.

MRF Information Review Key Findings

Of the four MRFs selected for inclusion in the study, only one agreed to participate fully. However, some information is known about the others through previous reports, general public information and other limited data shared by the facilities. Based on the information gathered and reviewed:

- Glass breakage in single-stream and dual-stream collection programs can be reduced through the use of collection vehicles and collection methods designed to minimize glass breakage.
- Glass breakage is more prevalent in single-stream processing systems.
- The amount of processing residuals (including mixed, broken glass) generated at the single-stream facilities serving the Minneapolis/St. Paul metro area varies significantly from approximately 2% of throughput up to 17% of throughput.

End-Market Interview Key Findings

- Over 70% of the end-markets interviewed reported they are seeing more contamination in their recycled feedstock today than they were five years ago.
- The most noticeable feedstock contaminants reported by the end-markets include:
 - o Plastic bags/film and unacceptable paper grades (paper mills).
 - o Glass and metal (plastic recyclers)
 - o Ceramics, pottery, and mixed glass (glass manufacturer)
- The most problematic contaminants reported by the end-markets include:
 - o Glass, plastic bags/film, and unacceptable paper grades (paper mills)
 - o Glass and metal (plastic recyclers)
 - o Ceramics, pottery, and mixed glass (glass manufacturer)
- Most of the mills and all of the plastics recyclers cited single-stream recycling as a contributing factor to the decline in feedstock quality.

- Other significant contributing factors for decreased feedstock quality reported by the mills include contaminated loads from dual-stream MRFs, feedstock demand/pressures from overseas markets, reduction in public education efforts, and MRF emphasis in pushing out product quantity versus an emphasis on product quality.
- Over 85% of the end-markets interviewed, said that making blanket statements regarding the feedstock quality coming from single-stream MRFs and dual-stream MRFs is inaccurate. They have received exceptionally clean loads from single-stream facilities and very dirty-loads from dual-stream facilities.
- Export markets are currently driving the demand for recycled fibers, while the domestic paper industry is in a state of flux with regard to industry consolidation and mill closings.
- There has been a dramatic decrease in the quantity of clean, color-separated glass cullet available locally to the glass container manufacturer with the major cause of this decrease being the move to single-stream recycling collection and processing.
- Feedstock contaminants and problem loads of glass are just as likely to come from dual stream MRFs as from single-stream MRFs.

Recommendations:

An expanded version of all the recommendations can be found in Section V of the report. The major recommendations coming out of this study include the following:

- 1) It is recommended that the MPCA:**
 - o **Develop educational materials to help local decision-makers understand the advantages and disadvantages of various collection and processing methods.**
 - o **Sponsor workshops for municipalities and others focusing solely on the issue of source-separated, dual-stream, and single-stream collection and processing including the potential impacts on various end-use markets.**
- 2) With the maturation of the recycling industry and the sophistication of the new generation of MRFs, it is recommended that a registration or certification process be applied to MRFs. As component of this registration or certification process, MRFs should be required to report certain operational data to the state for monitoring purposes. This information should include at a minimum:**
 - o **Amounts and types of recyclables delivered to the facility;**
 - o **Amounts and composition of processing residuals;**
 - o **Amounts and types of materials processed and marketed on an annual basis; and**
 - o **Amounts and types of materials downgraded or rejected by markets.**
- 3) The Solid Waste Management Tax exemption language contained in Minnesota Statute 297H.06 should be clearly articulated to all stakeholders to ensure that though the beneficial reuse of glass as landfill cover or for use as leachate collection system media may be approved on a case-by-case basis, it is not considered recycling. As a result, it cannot be used for meeting the 85% volume reduction at recycling facilities allowing those facilities to be exempt from the Solid Waste Management Tax.**
- 4) The MPCA should conduct further research into the technical, economic, and marketplace feasibility of utilizing optical sorting technology for the further processing and recycling of three-mix glass at local MRFs. If determined to be feasible, the State should partner with the private sector for the construction and operation of the facility (public/private partnership).**

I. INTRODUCTION

A. PROJECT BACKGROUND AND OBJECTIVES

During the early part of this decade, there has been a nationwide trend to move residential recycling programs away from source separated and dual-stream recycling collection/processing to single-stream collection/processing. Single-stream recycling (also known as fully commingled) refers to a system in which all paper fibers and containers are mixed together in a collection truck versus being separated into individual commodities (i.e., newspaper, cardboard, plastics, glass, etc.) or commingled into two streams (fibers and rigid containers). The move to single-stream recycling is believed to offer economic savings, especially on the collection end. However, it has also led to questions regarding the quality of the recovered materials (especially fibers) and the amount of residuals requiring disposal after processing.

Over the last couple of years, the Minnesota Pollution Control Agency (MPCA) has received a number of enquiries from public and private sector entities regarding downstream impacts associated with single-stream and dual-stream processing of recyclables. Of major concern to these entities is the conflicting information they're receiving regarding the quality of recovered materials, how this is impacting the end-markets (i.e., paper mills, glass recyclers, plastics recyclers), the amount of material recovery facility (MRF) residuals generated during the processing of recyclables, the availability of the residuals for further processing and recovery of targeted materials, and how these changes are effecting overall recycling rates.

The MPCA has a stake in expanding recycling efforts statewide and improving the cost-effectiveness and operational efficiency of the recycling infrastructure. In 2001 through 2002, the then Office of Environmental Assistance (OEA) provided grant funding for conducting a number of MRF optimization studies designed to assist local communities improve efficiencies at their MRFs. In 2003, this project culminated with the preparation of a MRF optimization guide.

Using the MRF optimization project as a base, the MPCA felt it was necessary to undertake a study to examine the issue of single-stream and dual-stream recycling specifically focusing on the processing of collected materials and the marketing of those materials to end-markets. The MPCA's intent in conducting this study is not to promote one method over another but rather to provide hard data on Minnesota programs as a way to assist communities to cut through the rhetoric and base their recycling decisions on more objective data.

The primary goal of this project is to gain a better understanding of Minnesota's changing recycling infrastructure specifically as it relates to the processing and marketing of recyclables. By doing so, both policy and procedural opportunities can be identified for:

- Increasing the recovery of recyclable materials;
- Improving the marketability of recovered materials;
- Reducing recyclables processing residuals; and
- Increasing overall recyclables recovery rates.

To accomplish this goal, a three-prong approach was utilized to collect information on the processing and marketing of recyclables including conducting on-site visits/interviews with regional MRFs, conducting on-site visits/interviews with major end-markets such as paper mills, a container glass manufacturer, and plastics recyclers, and conducting interviews with recycling equipment/system vendors. The focus of these visits and interviews was to observe operations and collect operating data related to:

- Processing of commingled recyclables;
- Amounts and estimated composition of processing residuals;
- Quality of recovered materials delivered to markets;
- End-market operational issues and concerns; and
- Availability and relative effectiveness of materials separation/handling equipment.

B. FRAMING THE ISSUE: THE SINGLE-STREAM AND DUAL-STREAM RECYCLING DEBATE

Over the last 20 years there has been an evolution in the types of materials collected in residential recycling programs and the way those materials have been collected curbside. Early programs focused on newspaper, glass (sometimes mixed and sometimes separated by color), tin cans, and aluminum cans. These materials were usually placed at the curb as separate commodities – newspaper, glass bottles & jars, and metal cans.

Collection was often done either using garbage trucks equipped with side bins for holding the different materials (usually seen in early recycling programs with newspaper as the only recyclable commodity collected) or in a new generation of collection vehicles specifically designed to pick up source-separated recyclables. These vehicles often were split into multi-compartments (anywhere from 3 to 7) each designated for a specific product.

Though a good start to modern day curbside recycling, this method of separation and collection had its' drawbacks including:

- Putting more responsibility on residents for preparing and separating the various materials to be collected. This was often seen as a barrier to getting widespread public participation as it required more effort on the part of the participants and attracted only those individuals that were already motivated to recycle;
- Limitations as to the types of materials that could be collected. As more materials were targeted for collection (i.e., cardboard, mixed paper, plastic containers, etc.) the number of separate compartments on collection vehicles increased reducing the capacity for any one material. This added to the cost of designing and/or modifying collection vehicles; and
- Higher costs for collection as it required two-person crews, more time spent at each stop, and shorter times on the collection route since once one compartment was full the truck would have to leave the route to dump its' load even if the other compartments still had capacity.

Early recycling centers had minimal processing equipment and what sorting was required was generally done manually. Unacceptable grades of paper were hand-sorted, as were different colors of glass containers. Ferrous and aluminum containers were either hand-sorted or

separated using simple ferrous recovery equipment. Processing equipment were typically balers, magnetic head pulleys, overhead belt magnets, and glass crushers.

The next stage in the evolution of curbside recycling collection and processing was dual-stream (or commingled) recycling. This method offered a variety of benefits over source-separated curbside recycling including:

- Participation for residents was made more convenient with the only separation requirement being all paper in one bin and all containers in another;
- It allowed for the addition of other materials to curbside recycling programs and it was during this phase of the evolutionary process that plastic containers and other types of paper grades were added to residential recycling programs; and
- It made collection easier as all that was now needed was a two-compartment truck – one for paper and one for mixed containers. Though it still required two-person crews, the time spent at each stop decreased significantly and trucks could stay on their routes longer as they only had to balance the capacity of two compartments.

This evolution, however, did create some issues around contamination of materials and required more attention to be paid to processing of materials. With greater participation by residents, greater amounts of contaminants and non-recyclable materials were placed in recycling bins. With all paper mixed together, sorting paper by different grades became a necessity and more sorting of containers – beyond ferrous recovery efforts – became a major component of materials processing. The more sophisticated materials recovery facility (MRF) became standard for many communities and required a combination of manual and mechanical processing of materials in order to produce a high quality commodity for end markets.

In the late 1990s another step was taken in the evolution of collecting and processing recyclables. Single-stream recycling refers to a system in which all paper and containers are mixed together in a collection truck versus being separated into individual commodities or commingled into two streams. This push, spurred on primarily by the larger waste management companies, is believed to offer several benefits including:

- Participation for residents was made even more convenient in that they could now put all recyclables in one cart. Not only does this add the next step of convenience but with one larger recycling cart there is an expectation that the amount of recyclables setout by residents would increase;
- Collection companies could more easily convert their recycling collection routes to automated collection. This, in turn, allows for the use of one-person collection crews, reducing labor costs;
- By going to automated or semi-automated collection, drivers no longer have to get out of their trucks and manually empty recycling carts resulting in less chance of injury and a reduction in worker compensation claims. Worker comp claims can be a significant cost to a collection company;

- The number of vehicles servicing a route could potentially be reduced in that now a one compartment truck could be used for alternating garbage and recyclables collection or a dual-compartment truck could be used to collect garbage and recyclables simultaneously (garbage in one compartment and recyclables in another); and
- Less vehicles servicing a route and more time spent on the route (as opposed to leaving the route to dump their loads) translates to lower labor and fuel costs.

With regard to bullet number one, a number of surveys point to the fact that residents do find it more convenient and like the simplicity of having one cart for recyclables (especially if it's on wheels and can easily be rolled to the curb). Additionally, it would appear that the amount of recyclables placed in the larger cart does increase.

In addition to the benefits listed above for both dual-stream and single-stream recycling, there are also some disadvantages associated with switching from source separated recycling to dual-stream recycling, or switching from dual-stream recycling to single-stream recycling. These include:

- Greater levels of contamination of materials when they are mixed together including glass breakage and the contamination of paper and plastic with broken glass;
- An increase in residuals generated at MRFs due to the larger amounts of contaminated materials and non-recyclable broken glass;
- A deterioration in recovered paper stock due to an increase in Outthrows¹ and Prohibitive Materials²;
- Greater loss of recoverable product (due to contamination or off-spec materials) including glass, paper, and plastic containers; and
- Increased costs for processing as a result of the required investment in more sophisticated separation equipment.

In 2001, Eureka Recycling, in partnership with the City of St. Paul and the OEA, undertook a study of curbside recycling collection methods³. This study tested five different recycling collection scenarios, one of which was single-stream collection. Based on the results of the study, Eureka reported that the two-stream, bi-weekly 35-gallon cart recycling method netted the highest diversion rates of all the tested methods. The report also indicates that dual-stream MRFs average a 6.4% residual rate while single-stream MRFs average a 27.7% residual rate. The average residual rate for single-stream MRFs, however, is based on results from a national study conducted by Governmental Advisory Associates and did not include data from local MRFs.

¹ The term Outthrows is defined as all papers that are so manufactured or treated or are in such a form as to be unsuitable for consumption as the grade specified.

² The term Prohibitive Materials is defined as any materials, which by their presence in a packing of paper stock, in excess of the amount allowed, will make the packaging unusable as the grade specified or that may be damaging to equipment.

³ "A Comparative Analysis of Applied Recycling Collection Methods in Saint Paul", Eureka Recycling, May 2002.

There are perhaps two things that can be stated with relative certainty regarding the national discussion on single-stream and dual-stream recycling. First, the national trend is by and large moving in the direction of single-stream recycling. Though some communities are choosing to continue with dual-stream recycling programs, many more are shifting to single-stream programs. This is partly evidenced with the continuing trend of new mega-MRFs being predominantly single-stream in design as well as the modification of older MRFs either converting fully to single-stream facilities or adding a single-stream processing line to be more competitive with the larger waste industry companies.

Second, because of this trend and continued investment in single-stream collection programs, this method of collection and processing of recyclables is not going away anytime soon. As a result, what problems do exist with single-stream processing (loss of recoverable product and end-market concerns regarding the degradation in quality of commodities) will need to be addressed as the industry moves further toward single-stream recycling.

The next several sections explore some of the challenges and opportunities associated with the changing recycling infrastructure locally and some of the end-markets serving Minnesota.

II. MATERIAL RECOVERY FACILITY REVIEW AND ASSESSMENT

One component of this project was to conduct site visits and interviews with major MRFs serving the Minneapolis/St. Paul metro area. The MRFs selected for inclusion in this study are all privately owned and operated. These MRFs included:

- Waste Management Recycle America LLC (Minneapolis)
- BFI (Minneapolis)
- Eureka Recycling (Minneapolis)
- Tennis Sanitation (St. Paul Park)

A survey regarding MRF operations was developed for gathering information from these companies. A copy of the survey form is provided in Appendix A.

Of the companies listed above, only one agreed to participate fully in the study. However, some information is known about the others through previous reports, public information and other limited data shared by the facilities. As there was no confidential information shared by any of the companies, there is no need to disguise the identity of the facilities. This information is summarized below.

A. BFI MINNEAPOLIS RECYCLERY

BFI initially indicated they would consider participating in the study but completed only a portion of the survey citing concerns about the sensitive nature of some of the information requested. Their concern was that some of the questions were marketplace sensitive. Despite assurances that efforts would be undertaken to keep this information confidential, they were still uncomfortable in sharing this information.

The BFI Minneapolis Recyclery is located at 725 44th Avenue N. in Minneapolis and began operation in 1992. It receives recyclables from residential (60%) and commercial (40%) sources. Currently, approximately 50% of the materials it receives are from dual-stream collection programs, 20% from source separated programs, and 30% are dedicated loads of product from commercial sources. BFI has recently added a single-stream processing line to this facility to allow for greater flexibility in processing materials collected on single-stream routes. Like their major competitors they feel this will help them be more competitive in the local marketplace. The single-stream line was not operational during the course of this study.

BFI declined to give any information on the annual throughput of materials they handle at the Recyclery but did say that they are seeing an estimated contamination rate in incoming materials of approximately 5%. They also indicated this hadn't changed significantly over the last 5 years.

Of the contamination they are seeing in incoming materials they estimate that 90% is non-recyclable items such as plastic toys and household goods, garbage, junk, etc. Another 10% is potentially recyclable items that currently have no market. An example might be #3 – #7 plastics.

As far as equipment used for sorting materials much of the existing system dual-stream system was provided by CP Manufacturing one of the leading companies in recyclable separation technologies. One of the pieces of equipment BFI has is a CP Trom-Mag, which is a combination smooth-bore steel trommel with 2-inch holes and a magnetic separator. According to CP Manufacturing literature small glass shards and dirt are removed, and the steel cans and ferrous materials are separated. An air classifier system follows the Trom-Mag where the light fraction (aluminum and plastic containers) are separated from the heavies (glass). The lights are blown through an enclosed duct and dropped onto a sort line. Plastics are manually sorted and aluminum is separated using an eddy current separator. They also indicated they have sort lines for fiber and glass.

The amount and percentage of the residuals generated during the sorting/separation process, and the composition of this material, was not reported by BFI. They did indicate that processing residuals generated at the MRF are not further processed for recovering recyclables or for beneficial use.

In 2002, BFI submitted a grant proposal to the former Minnesota Office of Environmental Assistance (OEA) to install an optical glass sorter for processing mixed broken glass at their Minneapolis Recyclery. In that proposal, they specified that they were sending approximately 1,000 tons per month (12,000 tons per year) of broken glass to a local landfill.

In a meeting between MPCA staff and BFI representatives in February 2005, BFI stated their intention to market their mixed broken glass to a sandblast media manufacturer. BFI confirmed that approximately 9,000 tons per year of the recyclable glass they collect is sold to Anchor Glass. After further follow-up, MPCA staff has learned that BFI is sending some of the mixed broken glass to a sandblast media market and stockpiling the rest until the market can take more. At this time, it is unclear how much mixed broken glass they are sending to this market.

B. WASTE MANAGEMENT RECYCLE AMERICA

Waste Management Recycle America LLC (formerly Recycle America Alliance) also indicated they would consider participating in the study but, like BFI, ultimately chose not to. They also cited concerns regarding confidentiality of information.

The WMRA Minneapolis MRF has been in operation since 2002. Prior to this, Waste Management had a fiber processing line in St. Louis Park, MN and a container processing line in St. Paul. Those operations were shuttered with some of the equipment being moved to their new facility located at 1800 Broadway NE in Minneapolis. Combining existing equipment with new state-of-the-art processing equipment the MRF processes approximately 14,000 tons of recyclables per month with the majority of this coming from residential recycling programs. The WMRA Minneapolis MRF processes both single-stream and dual-stream collected recyclables.

The single-sort process system was supplied by Bollegraaf/Lubo and consists of dual news screens and dual angle (finishing) screens for the mechanical sorting functions. There are also dual manual sorting lines preceding the news screens for initial sorting. The materials sorted out

manually on the sort lines include OCC, mixed fiber (boxboard, kraft bags, etc.), unrecoverable items (plastic bags, bulky items, etc.), and scrap steel.

The news screens are used to sort newspaper from other paper and containers. Paper separated by the news screens proceeds to another set of sorting lines for post-screenings quality check sorting. The angle screens separate containers from paper with paper proceeding to the post screening lines. Figure 1 shows Lubo's Angled Sorter Screen.



Figure 1: Lubo's Angled Sorter Screen

On the post-screenings sorting line, paper from the screens are checked and sorted as necessary to separate materials into the appropriate grades. Containers are allowed to move through this process to a tipping floor for processing on separate sorting equipment. Paper mixed with the containers that are not separated by the screens is hand sorted. According to WMRA the following categories represent materials produced/sorted from the single-sort process system:

- OCC
- Mixed Paper
- Unrecoverable material (residue)
- Scrap Steel
- Newspaper
- Containers

The container processing system was supplied by CP Manufacturing. Typically, the containers fall from an elevated conveyor on the single-sort process equipment onto a pile of other containers on the tipping floor. A wheeled loader moves containers to an infeed conveyor for the container process system. The sorting methodology for the container process line includes:

- Hand sorting for bulky items and unrecoverable materials;
- Mechanical screening (trommel) of broken glass and fines;
- Mechanical removal (ferrous magnet) of steel and tin cans;
- Separation of light and heavy containers using an air classifier. Glass falls through the air stream and plastic bottles/aluminum cans are blown in another direction;
- Plastic bottles and aluminum cans separated by the air classifier move on to a perforator screen which screens fines, perforates plastic bottles, and splits the total flow of materials onto two parallel sorting lines;
- Plastic bottles are manually sorted into three categories – PET, natural HDPE, and pigmented HDPE;

- Eddy current magnets remove the aluminum; and
- Remaining materials on the line fall off the end as residue.

Recovered materials coming from the container processing line include:

- Ferrous metals including tin cans and scrap steel;
- Aluminum cans;
- Plastic containers (PET, natural HDPE, and pigmented HDPE); and
- Color sorted glass (amber, clear, and green)

WMRA also considers mixed broken glass and fines a recovered product and have been utilizing it as a beneficial use material at their landfill. In late 2005, WMRA upgraded their container line at the Minneapolis MRF. It's unclear at this time how their new line is configured.

Both sorting systems have integral storage bunkers for holding the sorted materials prior to baling. The bunkers for both the single-sort and container processing systems employ the same concept of feeding directly to an infeed conveyor that conveys the materials to a baler. This is how paper, steel cans, aluminum cans, and plastic bottles are managed. Glass products (including fines) are stored in bunkers on the exterior of the facility where it is normally loaded in bulk fashion into open-top trailers for shipment to end-users.

On October 18, 2003 WMRA conducted a single-sort constituent test to calculate a mass balance on materials from single-sort collection and processing at their Minneapolis MRF. A report on the test was prepared by WMRA entitled "*Summary – Single-Sort Constituent Test*". Single-sort materials from some of Waste Management's single-stream collection routes were delivered to the MRF and segregated for processing. Only materials collected in a fashion representing Waste Management's definition of single-sort in the Twin Cities market were delivered. The key points in this definition include:

- Materials are designated for recycling by the resident and separated from waste items;
- Materials are placed in a cart for collection. The cart may be of differing size (32, 64, and 96 gallon) depending on the preference of the resident (all carts have integral lids);
- Materials are collected in either an automated or semi-automated collection vehicle; and
- The collection vehicles have one chamber for the combined materials with a compaction rate of four to one.

Materials were collected in this fashion on 14 of their single-stream recycling routes, representing nine communities, and delivered to the MRF. All materials were weighed in upon delivery and all process materials were collected and weighed to determine makeup.

In conducting this test, the tipping floors and feed pits for the single-sort process system (fiber line) and container process system (container line) were emptied and cleaned. All systems' storage bunkers and enclosures were also emptied prior to beginning the test. All material was processed in the facility according to normal operating procedures. Staffing levels were consistent with normal operations and no additional sorters were added to improve sorting operations.

Based on the results of the test as reported by WMRA, the percentage of residue coming off the fiber line represents 1.73% of production. This material is comprised mainly of items not targeted for recycling such as film plastics and miscellaneous plastic items. The percentage of residue coming off the container line represents 4.22% of production for a total of 5.95% residue as defined by WMRA.

However, another 11.2% of production is in the form of mixed glass. As noted above, broken glass and fines are mechanically screened out by use of a trommel. Though much of this material has been going to WM's landfill for state-approved beneficial use, it cannot be counted as recycling. Thus, including this material in process residue amounts, the facility residual number goes up to approximately 17%. At this time, it is unclear how much, if any, of the mixed broken glass is going to the landfill as a beneficial use material.

In addition to measuring the mass balance of the process, four newspaper bales were selected randomly for testing. In consultation with its paper mill customers, the MRF has set a production standard of 1.5% (average) or less for total outthrows and prohibitives for its marketed newspaper grade. It was the purpose of tearing down these bales to measure the percent of outthrows and prohibitives. Sampling of these bales confirmed production at 1.5% quality standard.

One thing to be noted regarding this study is that it was not witnessed by an independent third party. The on-site performance review and report write-up was done by the former facility manager and by a financial analyst employed by WMRA. As a result, there is no independent verification of the test results or the methodology used.

Two other items in the report are noteworthy of mention.

- During normal daily operations, the containers fall from an elevated conveyor associated with the single-sort process line onto a pile of other containers. WMRA states that this helps cushion the fall and prevents some breakage of glass bottles. Since there was no pile of containers for the falling containers to land on, for purposes of the test a bucket loader was used to catch the falling containers. When the bucket was full the loader would deliver its' load to the infeed conveyor for the container process line allowing containers coming off the elevated conveyor to fall directly to the floor. WMRA indicated that this procedure mimics the actual operating conditions. Though a pile of containers will provide some cushioning for the falling containers, there may still be significant glass breakage. Also, when the pile of containers on the floor is moved to the infeed conveyor for the container process line, the incident of glass breakage will inevitably increase due to a lack of cushioning.
- Once on the container process line, the second operation on the line is for the material to go through a trommel for mechanical screening of broken glass and fines (the first operation is a hand sort for bulky items and unrecoverable materials). The rotation and agitation created when materials go through a trommel will result in additional glass breakage yet no mention is made as to what additional glass breakage occurs by using the trommel.

On a final note, it is not known at this time how much of the mixed, broken glass generated at the WMRA Minneapolis MRF is still being used in landfill applications such as aggregate for roadbed, aggregate for the methane gas recovery system, and alternative daily cover. According to MPCA landfill permitting staff, mixed, broken glass coming from the WMRA Minneapolis MRF is (or was) being used for alternative daily cover at Waste Management's Spruce Ridge Landfill in McLeod County. Over 16,600 tons of glass had been shipped to the Spruce Ridge Landfill in 2004 to be used as daily cover. Additionally, in 2003, the Waste Management Burnsville landfill used approximately 3,900 tons of mixed, broken glass as alternative daily cover.

MPCA staff met with WMRA staff in February 2004 to discuss other options for marketing mixed broken glass. WMRA reported that some of their residual glass was being used in a paving project in Dakota County, made into sandblast media in Fargo, and used in leachate collection systems and as daily cover in Waste Management landfills. Their mixed broken glass was being sent to Chicago for processing and then sold to Anchor Glass, but WMRA stopped this practice because Anchor stopped purchasing their processed glass.

With regard to the landfill applications of mixed broken glass, Waste Management is permitted by the MPCA to utilize the mixed glass in these ways. However, this material cannot be counted toward recycling. In a September 2, 2005 letter from Cathy Berg Moeger (MPCA) to Jennefer Klennert (Waste Management) she states that although the state of Minnesota has accepted alternative materials to be used in a landfill, the state of Minnesota has been consistent in stating that alternative daily cover is not considered recycling.

C. EUREKA RECYCLING

Eureka Recycling's MRF is located at 2828 Kennedy Street in Minneapolis, MN. The facility was built in 2003 with operation beginning in 2004. Unlike BFI or WMRA this facility is a dual-stream recycling facility only and processes up to 5,000 tons per month. The facility processes primarily residential recyclables although commercial accounts are growing. Eureka has a 10-year contract with the City of St. Paul to handle that city's recyclables and has added several other cities (Lauderdale, Maplewood, and Roseville) to their stable of contracts.

Eureka Recycling declined to participate in the study. No further information on this facility is available.

D. TENNIS SANITATION

Of the companies contacted to participate in this project, only Tennis Sanitation agreed to let the consultant visit their MRF, observe operations, and ask questions of them. The site visit was conducted on Tuesday, November 1, 2005.

Tennis Sanitation provides solid waste and recycling collection services as well as processing of the recyclables they collect. Their MRF, located in St. Paul Park, Minnesota was originally designed to process the source-separated recyclables the company collected from their residential accounts. Facing growing competition from Waste Management and other haulers providing

single-stream collection, they changed over to a single-stream collection and processing service earlier this year.

For recycling collection vehicles they utilize semi-automated side loaders (Figure 2) and allow their customers to either go with new, larger carts or to continue using the recycling bins they've been using. The collection vehicles they use have a maximum payload of approximately 10 compacted tons but Tennis does not utilize the compaction unit so the typical payload is about 2 to 2 ½ tons. This means lighter loads and having to come off the routes sooner but it also results in less contamination of materials especially since glass breakage is minimized.



Figure 2: Tennis Sanitation Recycling Collection Vehicle

The MRF processes approximately 500 tons of residentially collected recyclables per month. According to Tennis Sanitation, since they've shifted to a single-stream collection and processing method they've seen an increase of approximately 25% in collected recyclables.



Figure 3: Dump Height of Recyclables From Truck

Utilizing the vehicles that they do also lessens the breakage of glass, as the height at which the recyclables are dumped into the truck's compartment requires a fall of only 2 ½ to 3 feet. This is in comparison to many vehicles used for single-stream collection, particularly front-loaders, where the drop into the compartment may be in excess of 8 feet. Additionally, because of the design of the side-loaders they use, dumping of materials on the MRF tipping floor involves a drop of approximately one foot from truck to floor (Figure 3).

Bulk Handling Systems (BHS) provided much of the mechanical sorting equipment including its Debris Roll Screen® and its NewSorter®. Other separation equipment include an overhead belt

magnet to recover ferrous on the container line and an eddy current separator to recover aluminum on the container line. Three balers are utilized for further preparing materials for

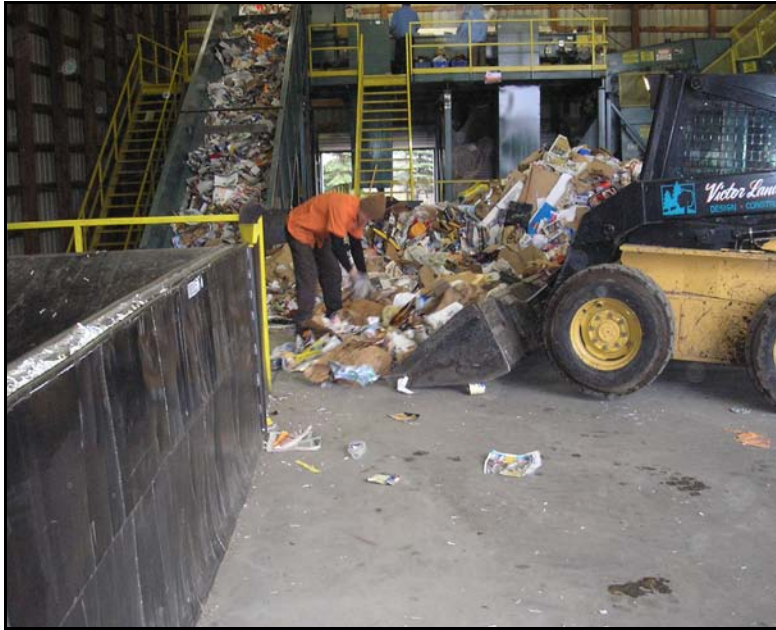


Figure 4: OCC Recovery and Conveyor Feed System

markets including an Economy (OCC), a Harris Badger (#6 ONP), and a Marathon Gemini (mixed plastic containers). Metals are shipped loose to a local market. The process starts when a load of recyclables is dumped on the tipping floor. A skid steer spreads out the materials while OCC is manually pulled from the load and thrown into the hopper of the Economy baler (Figure 4). The baler itself sits on a lower level below the tipping floor. Once the OCC is pulled, the skid steer pushes the remaining materials onto a below grade in-feed conveyor leading to an inclined conveyor which feeds the first sort line. Originally, the OCC was to travel up the inclined conveyor and be pulled off on the sort line but most of the OCC is too large and bulky to make this trip. As a result, the OCC baler was installed and a pre-sort for OCC was created on the tipping floor.

Once the materials reach the top of the inclined feed conveyor it's discharged to the first sort line. The sorters pull off plastic bags/film, other non-recyclables, and OCC that was missed on the tipping floor. Also pulled out are phone books, magazines, and wet-strength fibers (beer and pop cartons) as the fiber market utilized by Tennis Sanitation discourages these materials in the mix. The remaining fibers and containers fall off the end of the sort line onto the BHS Debris Roll Screen® where a 2" minus mechanical sort occurs.

Tennis Sanitation has two problems with the Debris Roll Screen® (Figure 5) they are attempting to resolve. First, the drop from the sorting conveyor to the screen is approximately 2 to 2 ½ feet. As the triangular rotating discs are bare metal (a composite disc would not withstand the wear and tear) this is one area where



Figure 5: BHS Debris Roll Screen®

glass breakage is noticeable. The second problem is that Tennis Sanitation feels the incline of the screen is too steep and containers have a tendency to roll back adding to the length of time they are on the Debris Roll Screen®, which in turn adds to the potential for further glass breakage and paper contamination.

Raising up the receiving end of the Debris Roll Screen® and structural housing would lessen the distance materials have to drop as well as reduce the steepness of the incline that materials need to travel up. This could help reduce glass breakage though by how much is not known. To do this, however, would require some re-engineering and equipment modifications.

Once the materials fall off the end of the Debris Roll Screen® they fall onto the NewSorter®. This specialized screen utilizes triangular-shaped composite discs operating at various speeds and angles to separate large fiber (primarily ONP) from small fiber and containers. The material going over the top of the NewSorter® lands on a conveyor feeding the Harris baler. This baled material is sold as a #6 ONP. The NewSorter® “unders” roll or fall down to the bottom of the screen onto another conveyor taking the materials to the container sorting line.



Figure 6: Manual Sorting of Glass

color (Figure 6) – clear, amber and green – with the final step being an eddy current separator (Eriez) before residue falls off the end of the line into a dumpster.

Facility residue is running approximately 2 tons per week or, on average, less than 9 tons per month. With a monthly throughput of approximately 500 tons this represents less than 2% of throughput. Of the 2 tons per week of residue, Tennis Sanitation estimates that about 50% of this is mixed glass. The remaining residue is largely plastic film, plastic bags, and scrap paper.

When Tennis Sanitation was collecting and processing source-separated materials they were getting close to 100% recovery of glass. Since switching to a single-stream system they estimate their glass recovery is now closer to 80 – 85%.

On the container sorting line several manual sorts take place. The first two sorters pull off any remaining fibers, much of which are placed on a short conveyor behind the sorters to be mixed with the #6 ONP prior to baling. Also pulled off the line at these stations are mixed plastic containers, which are thrown directly into a hopper, feeding the third baler. The plastics are marketed as a mixed plastic product (plastics #1 through #7). Remaining materials on the line (metal cans and glass) travel under an overhead belt magnet (Eriez) that pulls off the ferrous. Glass is then manually sorted by

One thing that is contributing to this high capture rate is the collection method they employ for curbside pickup. As noted previously, the material collected at curbside does not have to fall a long distance when being loaded into the truck compartment nor do they compact the materials on the collection route. Additionally, the dumping height from truck to tipping floor is minimal. In observing the dumping of materials on the tipping floor there was very little glass noticeable as much of it was mixed in with other materials which provided cushioning for the bottles and jars. Once the materials were spread on the tipping floor by the skid steer, glass bottles became more noticeable. Almost all the glass containers observed were intact.

As noted previously, the one area where glass containers appeared to be getting broken was at the Debris Roll Screen®. Broken glass and other 2” minus materials fall on a separate residue conveyor below this screen and are conveyed to a small container, which is currently combined with other facility residue and disposed. A small overhead magnet has been installed on this conveyor to capture small ferrous items and a fan at one end of the conveyor can be utilized to blow off lighter debris (paper scraps, small pieces of plastic, etc.) into a separate residue container. Tennis Sanitation, is considering doing a sort on this conveyor picking off any remaining debris and amber glass (there appears to be a lot less broken amber glass on this conveyor as compared to clear and green glass). The remaining materials (primarily broken clear and green glass) would then fall off the end of the conveyor where a final gleaning of contaminants would allow for the glass to be mixed with the green glass destined for market.

On a final note, the materials awaiting delivery to markets were examined. The glass to be delivered to market, as well as the plastic bales to be delivered to their plastics market, were very clean with very little, if any, contamination visible. OCC bales were also very clean. The #6 ONP bales observed appeared to be generally of good quality. A couple of bales showed some noticeable plastic bags/film but at least three other bales showed no signs of contaminants. Though none of the paper mills contacted for this study would comment on the quality of materials coming from specific MRFs, both the glass and plastic container markets doing business with Tennis Sanitation commented that they receive high quality material from them. Over the last several years, and since they’ve switched to a single-stream system, Tennis Sanitation has not had any loads delivered to any of their markets either downgraded or rejected.

E. SUMMARY OF MRF REVIEW KEY FINDINGS

Though a more thorough assessment of most of these facilities was not completed, there appears to be enough available information to make a few general observations in comparing local dual-stream and single-stream recycling systems. Based on the information gathered and reviewed:

- **Glass breakage in single-stream and dual-stream collection programs can be reduced through the use of collection vehicles and collection methods designed to minimize glass breakage.**
- **Glass breakage is more prevalent in single-stream processing systems.**
- **The amount of processing residuals (including mixed, broken glass) generated at the single-stream facilities serving the Minneapolis/St. Paul metro area ranges significantly from approximately 2% of throughput up to approximately 17% of throughput.**

III. END-USE MARKET INTERVIEWS

Another component of this project was to conduct site visits and/or interviews with a variety of end-markets for some of the recovered materials generated in Minnesota. The purpose of this activity was to gather further information on how product quality has changed over the last five years, what they believe is the cause of any observed change, and how it has impacted their operation. Seven end-markets were selected for inclusion in this study, all of which receive recycled feedstock from Minnesota and the Upper Midwest. These end-markets, as can be seen in Table 1.1, include four paper mills, two plastics recyclers, and a glass container manufacturer. To provide for some anonymity, the end-markets were assigned letters based on market type. These market types are paper mill (PM), glass container manufacturer (GCM), and plastics recycler (PR).

**Table 3.1
End-Market Descriptions**

Market	Market Type	Recycled Feedstock	Manufactured Product
PM-A	Paper	ONP, Coated Paper	Newsprint
PM-B	Paper	ONP, OMG ⁴	Newsprint, Kraft
PM-C	Paper	OCC, ONP, Office Paper, Mixed Paper	Corrugated, Boxboard
PM-D	Paper	OCC, Mixed Paper	Liner Board
GCM	Glass	Container Glass	Glass Bottles
PR-A	Plastic	HDPE, PET, PP	Plastic Beads & Flakes (Lumber, Pipe, & Carpeting)
PR-B	Plastic	HDPE, LDPE, PET, Mixed Resins	Plastic Lumber

In interviewing and visiting with the end-markets, a number of questions were posed to each of them regarding their operations. Much of the focus was on such things as the quality and quantity of feedstock received, how this feedstock is processed into the final products that they manufacture, what operational concerns they're having with processing the feedstock, and how this is affecting the quality of the final product.

Though a variety of information was gathered on each end-market, there were essentially five key questions posed to each of them. These questions include:

- Have you seen more feedstock contamination over the last five years?
- What types of contaminants are you seeing in your feedstock?
- What do you believe are the contributing factors to the increase in contamination, if any?
- What types of contaminants are the most problematic for your operation?

⁴ Also takes in pre-consumer grades such as coated sections, coated fly.

- What types of operational problems are these contaminants causing?

A brief description of each of the end-markets, along with their responses (aggregated by market type) to key questions, is provided below.

A. PAPER MILLS

1. Paper Mill A Description

PM-A is a paper mill that purchases old newspaper (ONP) and coated papers as a feedstock, and manufactures newsprint. In producing the newsprint, they use up to 40% recycled pulp in their manufacturing process. This mill has two paper machines. Annual production capacity for newsprint is 192,000 metric tons (approximately 211,642 short tons). This represents approximately 79% of production with the remainder being value added fiber. The consultant was unable to visit this facility and there was no written description of the process flow for this mill provided. As a result, a description of their operation is not included in this report.

In terms of where they get their feedstock, they estimate that approximately 40% comes directly from dual-stream MRFs, 20% from single-stream MRFs, and 10% from MRFs processing a source-separated paper stream. The remaining 30% they purchase from brokers and it's not known what types of MRFs or industries this material comes from.

In July, PM-A announced that in October 2005 it would be closing down one of their paper machines at this mill permanently and the other would be indefinitely idled. As of October 22, the smaller paper machine has been shut down permanently and the other idled indefinitely. One reason for the shutdown is high production costs with energy costs being a major component of their balance sheet. At this time they're no longer accepting recycled paper at this location.

2. Paper Mill B Description

PM-B is one of the largest suppliers of recycled content newsprint in North America with about 97% of its output shipped to customers throughout the U.S. Their recycled fiber feedstock consists of post-consumer ONP and old magazines (OMG) as well as pre-consumer paper grades. They manufacture newsprint and Kraft paper with a recycled fiber content of 30 – 40% depending upon the customer specifications. They also run two paper machines and have an annual capacity for newsprint of 534,000 metric tons (approximately 588,628 short tons). This represents approximately 49% of their total annual production with the remainder being market pulp (50%), and coated and specialty paper (1%).

The recycled feedstock delivered to the mill is comprised of approximately 30% magazines and 70% newsprint. The used paper is shredded, mixed with water and fed into the repulpers. As part of the repulping process, the fiber is “detrashed” to remove plastic and other major contaminants. Dense contaminants such as staples, fine sand, and glass shards are removed in high-density cleaners and screens. The pulp is de-inked using soap and air flotation. After de-inking the pulp is screened, cleaned and pressed, and then on to storage prior to being pumped to the paper machine blend chest.

The paper machines each have their own blend chest, which combines the different pulps to meet customer specifications. This “furnish” is diluted, screened and pumped through a paper machine headbox onto the forming wire where 15% of the water is removed by natural drainage and vacuum pumps. The rolls in the press section account for another 30% reduction in moisture.

From here, the paper sheet goes into the dryer section where heated cylinders evaporate the moisture down to approximately 8%. The sheet is then “calendered” (ironed) to its final thickness in the calendar stack. The paper sheet is then wound onto reels each holding a roll of newsprint weighing approximately 33 air dried short tons. Using a winder crane, the reels are removed and the paper is rewound and cut to specific width, diameter, and length depending on the customer’s specifications. These rolls are then wrapped, labeled, coded and loaded directly into rail cars and trucks for shipping to customer’s business.

PM-B estimates that over 30% of its recycled fiber comes from Minnesota but says it’s difficult to know with absolute certainty how most of the material is collected and processed.

3. Paper Mill C Description

The third fiber market (PM-C) is one of the largest consumers of scrap paper in the country and handles all grades of recovered paper including OCC, ONP, office paper, and mixed paper. Their mill that serves the Minnesota market manufactures 100% recycled content corrugated and boxboard including cereal boxes and other cardboard containers. They take in about 1,000 tons per day of recycled paper and utilize a total of four paper machines (two producing clay-coated white recycled paperboard and two producing corrugating medium) to make new product.

The daily flow of mixed paper is sorted on-site with the non-OCC fibers being separated by hand on a conveyor belt. This material is then cleaned and pulped to be used later as part of a white topcoat that is applied to the new production of paper.



Figure 7: Debris Removed From Recycled Paper Slurry

The remaining loose papers are conveyed to a 12-foot wide cylinder full of water and equipped with a mechanical drive wheel that whips the papers to a pulp much like a household blender. Additionally, the facility has two hydro-pulpers that perform a similar function.

From this blending process, the slurry is piped into screens and cleaners, which are engineered to remove all non-paper items and debris (i.e., paper clips, staples, Styrofoam, wet-strength fibers, bits of plastic, etc.). The resulting sludge, from which most of the water has been filtered, is very thick and sticky (Figure 7).

Once the recycled pulp has been cleaned, it travels to one of the four paper machines where it is deposited onto felt blankets that circulate through a series of rollers, coaters and dryers to form the paper. Like the product made at other mills, the paper is wound into rolls and cut to size according to customer orders.

Like PM-B, they don't track what types of facilities they get materials from (though there are some MRFs they deal with directly), so by and large they do not know how much of what they get comes from single-stream versus dual-stream versus source-separated MRFs.

4. Paper Mill D Description

The last paper mill visited and interviewed (PM-D) handles over 100,000 tons of OCC. It also receives some mixed paper which it can blend in with its' OCC but in much smaller amounts. The end product they manufacturer is a liner board, which is used for corrugated packaging, folding cartons, and tubes. PM-D has one papermaking machine that can produce up to 1.2 million square feet of linerboard per hour.

Baled OCC and mixed paper are taken from the receiving warehouse into the mill and placed on a conveyor using a forklift. This conveyor transports the bales to a hydropulper. Inside the hydropulper, a long rope (the ragger) pulls out contaminants such as baling wire, tape, staples, old clothing, and other non-fiber materials (Figure 8).



Figure 8: Hydropulper and Ragger

In the hydropulper, water and OCC are blended together to form a pulp slurry. Material caught by the ragger is discharged from the hydropulper for disposal while acceptable materials continue through the process.

The pulp is piped from the pulper to the pulping screens where coarse contaminants (i.e., rocks, staples, etc.) remaining in the pulp are removed. From the pulping screens, the pulp next moves to a series of cyclones, which use centrifugal force for further separation of fibers and contaminants. In the first cyclone, heavy materials fall to the bottom, while lighter paper fibers flow to the top. In the second cyclone, the paper fibers are the heavier material and they fall to the bottom. Lightweight plastics and other materials move upward and are rejected.

After cycloning, the paper fibers travel to a disk thickener, which thickens the stock before sending it on to the refiner. Once the stock has been refined it is divided with pulp used to make the bottom ply of the paper going to the headbox of the papermaking machine. Pulp to be used on the top ply passes through another set of cyclones for additional cleaning before it is sent to

the headbox. In the headbox, the pulp and water mixture are sprayed onto a moving screen. As the pulp is screened and pressed it loses much of its moisture (about 40% moisture loss) before going into the dryer where steam-heated rolls dry the paper to approximately 7% moisture. As the paper reaches the end of the dryer section, it passes through a set of calendar rolls that give it a smooth finish.

The finished paper is wound on a reel, which weight 25 tons when full. This finished reel is moved by crane to the floor, where it is rewound on smaller rolls (approximately 3 tons each). These rolls are banded and labeled according to type, size, and weight, and moved to the warehouse where they are stored until shipping.

PM-D did not provide an estimate of what percentage of the recycled paper/pulp they purchase from Minnesota facilities come from single-stream MRFs, dual-stream MRFs, source-separated MRFs, or independent brokers citing that this information was proprietary. They did say, however, that very little of their material (less than 10%) comes from single-stream MRFs.

5. Paper Mill Responses to Key Questions

Table 3.2 on the next page summarizes the responses of the interviewed paper mills to the questions previously listed. As can be seen from the table, three of the four mills reported that they've seen an increase in the level of feedstock contamination over the last five years. The one mill indicating they've not seen an increase in contamination rates takes in primarily #11 OCC. This grade of paper is generated primarily by the commercial sector and is either delivered directly to them by the generator or, if it goes to a MRF first, is usually collected separately by haulers and/or separated out early in the processing stage. As a result, contamination levels are relatively low since it is not often collected commingled with other recyclables and when it is, it's usually mixed only with other fibers and is easy to separate at a MRF.

In response to the second question, the answers were somewhat of a surprise. There has been a lot of discussion within the industry of the problems glass is creating at paper mills. This is still a concern (as discussed later) but all the mills interviewed mentioned plastic bags and plastic film as one of the most significant contaminants they're seeing in the feedstock they get from MRFs, brokers, and directly from large quantity commercial generators. Other paper grades not acceptable at particular mills was cited by three of the four mills including one mill who indicated they periodically receive loads of plastic coated paper.

A bale of plastic coated paper was observed at the mill and it looks very much like a high-grade white paper. When you try to tear it, however, it is very difficult to tear with your hands (it resists tearing and stretches instead). In the past, when they've fed this material into their process, it's resisted pulping and got caught on their contaminant screens. Small amounts of it that have gotten as far as the paper machine have affected the quality of that paper run (appearance and printability issues). They are now much better at detecting this material when it's delivered.

Food, broken glass and glass pieces, metal (everything from paperclips and staples to cans and automotive parts), and plastic beverage containers were other contaminants that were mentioned by two of the four mills (not necessarily the same mills).

Table 3.2
Paper Mill Responses

Questions	Responses
Have you seen more feedstock contamination over the last five years?	Yes (3) No (1)
What types of contaminants are you seeing in your feedstock?	Plastic Bags/Films (4) Food (2) Other Paper Grades (3) Metal (2) - OCC/Boxboard (2) MSW (2) - Plastic Coated Paper (1) Plastic Containers (2) Glass (2)
If you have seen an increase in contamination, what do you believe are the contributing factors to this contamination?	<ul style="list-style-type: none"> • Single-stream recycling systems (3) • Dual-stream recycling systems (2) • Feedstock demand/pressures from overseas markets (2) • Reduction in public education efforts (2) • MRF emphasis on quality over quantity (2) (performance/employee incentives) • Transient workforce at MRFs (1) • Local/regional weather conditions (1)
What types of contaminants are the most problematic for your operation?	Plastic Bags/Film (4) Metal (2) Other Paper Grades (3) Plastic Containers (2) Glass (3)
What types of operational problems are these contaminants causing?	<ul style="list-style-type: none"> • Plastic bags/film clog screening equipment resulting in higher maintenance costs. • Glass and metal cause more wear & tear on pulping, screening, and cleaning equipment resulting in higher equipment maintenance and replacement costs. • Contamination deposits on paper machines and related equipment. • More downtime due to operating problems caused by contaminants. • Increased handling and disposal costs for residues and rejects. • Additional manpower needed to deal with issues. • Increased safety issues. • Decreased yield of the fiber stock. • Sheet quality and appearance negatively affected. • Twine and plastic causing more problems with product consistency and flow. • Customer complaints (glass in trailers, “stickies” on sheet, pressroom breaks, printability issues).

To the three mills that indicated they’ve seen an increase in feedstock contamination, the question was posed to each of them as to what they believe are the reasons they’re seeing this increase. All three indicated the switch to single-stream collection and processing was a

contributing factor to this increase (one mill indicated it was the source of most problems). They all felt, to one extent or another, the commingling of fibers and containers during collection and the processing required to separate the materials once delivered to the MRF, has increased the contamination level of the paper.

Having said this, at least two of the mills indicated that not all single-stream MRFs are created equal, and that they are getting some exceptionally high-quality fiber from some of the single-stream MRFs that are delivering them paper. Even when they've had problems with some of the larger single-stream MRFs they contract with (MRFs not only in Minnesota but in other locations) the problems have not been with all loads (or even most of the loads) coming from those MRFs.

Another contributing factor to increased levels of contamination mentioned by two mills was the switch from source-separated to dual-stream MRFs. According to these mills they've received some very dirty loads of paper from dual-stream MRFs including paper containing plastics, metal, glass, and MSW.

In fact, one of the mills said that it's not so much the type of facility they have a problem with as it is the attitude of facility management. How a facility responds to a problem load tells them a lot about the commitment of that MRF to working with the mill on resolving problems and sharing in the responsibility of finding solutions to prevent future occurrences.

Other contributing factors mentioned by the interviewed mills include:

- Increasing feedstock demand/pressures from overseas markets: With the demand for fiber at near record highs and the entrance of foreign competitors (especially China), there is greater competition for recycled feedstock. As a result, mills have been scrambling to find the feedstock they need to continue operating.
- Reduction in public education efforts: Over the last five years there has been greater pressure on municipalities and others to reduce costs. Often it is the community recycling efforts and other "soft programs" that bare the brunt of these cost reductions. Many times the cost reduction in municipal recycling programs comes at the expense of promotional and educational efforts. Without these types of continuing public educational programs there can be deterioration in the quality of the feedstock set out at the curb or deposited at drop-off sites. Regardless of the type of commingled collection and processing program a community has, some of this contamination will carry over to the product shipped to end-markets.
- MRF emphasis on quality over quantity: MRF management focus, especially at privately owned facilities, is oftentimes related to production levels (quantity) versus quality of materials. Performance or employee incentive/bonus programs are many times tied to production versus customer satisfaction.
- Workforce at MRFs: Sorters and laborers at MRFs are generally low-skilled and low-wage positions. As a result, turnover can be high and consistency in quality of performance can be low unless a lot of time and energy is put into a training program.

- Local/regional weather conditions: This plays a part in several ways. First, during collection the condition of the curbside materials may be impacted by weather conditions (i.e., rain, snow, mud, etc.). Such moisture laden materials can impact the efficiencies of mechanical separation equipment especially at single-stream MRFs where processing equipment may be more sensitive to moisture. Weather conditions may also come into play if product awaiting shipment to mills is stored outside or in a warehousing environment that is susceptible to moisture.

When asked what types of contaminants are the most problematic to their operations, all four mills mentioned plastic bags and film plastics. With all the focus being on glass contamination and glass shards in baled paper, it was surprising to learn that plastic bags and film plastic showed up on everyone's radar as problematic. Unacceptable paper grades mixed in with the purchased feedstock was also high up on the list (three mills mentioned this) as was glass (three mills). Metals and plastic containers were brought up by two of the mills interviewed.

Two of the three mills that brought glass up as being problematic indicated that this was not a minor problem. They stressed that broken glass and glass shards mixed in with the delivered recycled feedstock cause a number of operational problems (see below). They did say, however, that plastic bags and film mixed in with the recycled feedstock also causes them a number of operational and end product quality problems, and it's an issue that hasn't been as widely publicized as the glass issue.

As noted previously, one of the mills uses #11 OCC as their primary feedstock. With much of this material originating with commercial businesses, the preferred method of collection is usually in dedicated vehicles, dumpsters, and compactors. Though some of this OCC may be collected commingled with other fibers, very little, if any, is collected in single-stream collection programs. In visiting with this mill they did express concerns that if single-stream collection began being applied to commercial business accounts on a large scale they anticipated seeing an increase in unacceptable items including OCC contaminated with glass fragments. At this time, however, they have not seen this.

Finally, when asked what types of problems are these various contaminants posing to mill operations and product quality, the mills cited a number of issues including:

- Wear and tear on equipment leading to increased maintenance and equipment replacement costs;
- Increased labor costs and safety issues;
- Increased disposal cost for residue and less fiber yield;
- More downtime; and
- A variety of product quality issues and customer complaints.

Other pertinent comments offered by the mills include the following:

- Some single-stream MRFs provide better quality materials than others (they're able to meet specs). The same can be said for dual-stream MRFs.

- Our single-stream assessment is based on general information in the market. Mills will need to invest in additional capital to manage higher contaminant levels. The real question is who will pay for the additional cost.
- We work continuously to improve our fiber yield. There is ongoing consideration on whether existing equipment is operating properly and whether there are new ways of capturing more fiber. We work under “continuous process improvement” conditions.
- We believe quality control extends beyond the rejection or downgrade of a load received. Communication with suppliers on a consistent basis is critical to our quality control program and in maintaining good supplier relationships. Our preferred approach is to work with suppliers when challenging material is received, as best we can, utilizing a proactive approach of diverting potentially challenging material prior to arriving on site. This has been found to be very effective.
- Our experience has been that quality issues arise with all single-stream processors however not all the time. This is due to volume as well as quality sensitivities (adjustment requirements on equipment, maintenance, operating conditions, manpower, weather and moisture).
- Government agencies and program coordinators need to understand the mill dynamics – where the market is going, which grades will be required for the long term, etc. Suppliers need to understand each mill’s requirements and specific tolerances, appreciating that they are usually very different.
- The need to increase the supply of waste paper in order to meet the feedstock demand of mills here and abroad has been acknowledged within the industry and creates, perhaps, an artificial environment of what is or will be acceptable (in terms of quality) going forward.
- Supply assurance and supplier relationships are tested when quality issues arise. Who is ultimately responsible for quality assurance?

B. GLASS CONTAINER MANUFACTURING

1. Glass Container Manufacturer Description

GCM is a glass container manufacturer that recycles container glass into new containers. Glass accepted for recycling must be color separated (green, clear and amber) although they can take small amounts of colored glass mixed with clear (green/clear and amber/clear) to make new green glass containers and amber glass containers, respectively. In the past they’ve taken in 86,000 + tons annually of recycled cullet for manufacturing new glass containers. However, this is down by approximately 50% due to some of the changes currently taking place within the recycling industry (discussed later in this section).

Recycled cullet delivered to GCM is dumped in front of outside storage bunkers designated by color. An individual running a bucket loader will first inspect the materials pulling out large contaminants that may be in the load. The materials are then pushed into their respective bunkers.

From the bunkers, the glass is put on a conveyor system that runs under a ferrous recovery unit to pull out ferrous that may be in the load and then on to a glass crusher to ensure the cullet is of a uniform size for melting down. The recycled cullet is then fed into a melt furnace along with sand, soda, ash, limestone, and other raw materials in a predetermined mix. With temperatures between 2,300⁰ and 2,800⁰ F the mixture is turned into a molten glass.



Figure 9: Sheering of Molten Glass

The Refiner distributes the molten glass to the fore hearth, which brings the temperature of the molten mixture to a uniform temperature level. From here a shear cuts the molten glass into uniform gobs (Figure 9) and sends them to the forming machine that forces the gobs into the mold shape. At this point the temperature has dropped to below 2,100⁰ F. The formed glass containers leave the machine, crossing a cooling plate and begin cooling rapidly to approximately 900⁰ F.

Once the glass containers are further conditioned, the temperatures are further reduced to between 225⁰ and 275⁰ F. Cold end sprays then apply an exterior coating to the bottles to increase line mobility and reduce abrasions. This helps maintain the inherent strength of the container.

The fast cooling section brings the container temperatures down to approximately 100⁰ F. The manufactured containers pass through a series of instruments that physically and optically test the containers. Rejected containers are recycled back into the furnace while acceptable containers move on to an automated Case Packer, which packs the containers in corrugated cases for shipment. At the request of the customer, the new containers can be labeled at the manufacturing plant (using an automated labeling machine) or can be shipped as is for labeling at the customers facility.

2. Glass Container Manufacturer Responses to Key Questions

The glass container manufacturer participating in this study was asked the same or similar questions as the paper mills. Responses are presented in Table 3.3 on the next page.

As noted in the table, the overall issue has not been with contaminants or the mixing of different color of glass as much as it's that the quantity of delivered recycled glass has dropped considerably. In recent years there has been an approximate 50% drop in quantities of color-sorted glass. As a result of this situation they have been forced to use more raw materials in the

production of glass containers. This has resulted in them running a 30% mix of recycled cullet in their production versus the 50 – 60% they were previously using.

The contaminants they typically do see are ceramics, pottery, and Pyrex or Ovenware type of materials. Mixed colors of glass, especially amber/green/clear or amber/green, can sometimes be problematic but they work with their suppliers closely to minimize this. As noted previously, they can accept small amounts of clear/green mixed glass or clear/amber mixed glass to make green or amber bottles. The quality of recycled glass cullet received from local MRFs has largely been good with one local single-stream MRF (Tennis Sanitation) providing them with exceptionally good materials.

**Table 3.3
Container Glass Manufacturer Responses**

Questions	Response
Have you seen more feedstock contamination over the last five years?	No, but delivered quantities have dropped significantly.
What types of contaminants are you seeing in your feedstock?	Ceramics, pottery, Pyrex, and mixed glass.
If you have seen an increase in contamination or a decrease in quantity of recycled cullet, what do you believe are the contributing factors to this contamination/decrease?	<ul style="list-style-type: none"> • Single-stream collection and processing • Competition from other markets and end uses (construction aggregate, sandblast media, drainage media, landfill cover, etc.).
What types of contaminants are the most problematic for your operation?	Ceramics, pottery, Pyrex, and mixed glass.
What types of operational problems are these contaminants causing?	<ul style="list-style-type: none"> • Uneven melting causing machinery to jam and shut down leading to higher maintenance costs and loss of production. • More frequent maintenance on the melt furnace and other pieces of equipment to remove clinkers and slag. • Off-spec bottles (glass content and/or color).

With regard to the significant reduction in the amounts of color-separated glass cullet they’re receiving, they cite single-stream recycling as the biggest factor for this decline. They’ve seen a significant drop in the color-separated glass coming from those companies that utilize single-stream recycling methods noting that much of the glass is broken and mixed during the collection and/or processing of the materials.

As MRFs throughout Minnesota have searched for new outlets for their mixed glass, they’ve also seen greater competition from other markets and end uses such as construction aggregate, sandblast media, drainage media, and landfill cover. This trend will likely continue for the foreseeable future.

When contaminants such as ceramics, pottery and other similar materials do get through the screening process at the glass container manufacturing facility, it is likely to cause a couple of problems. First, because of the different physical and chemical characteristics of these materials compared to bottle glass they melt at an uneven rate or in some cases don’t melt at all. This

causes problems in the melt furnace (formation of clinkers and slag) that can carry over into the Refiner. When the molten glass containing un-melted chunks of ceramics or other materials comes through the sheer, the sheer blades can get jammed stopping that part of the operation. The entire manufacturing line has to come to a stop in order to repair or un-jam the sheer causing a shutdown of production. Equipment needs to cool down in order to correct the problem and then be started up again. Though this unexpected downtime can often be minimized to less than 30 minutes such events typically happen 3 to 5 times per week causing a significant amount of accumulated downtime.

A second problem caused by contaminants getting into the operation is the production of an off-spec run of containers. Off spec may be either due to physical flaws in the container (foreign materials other than container glass) or the color of the container (foreign materials or mixed color container glass). When a batch of off spec glass containers are made, very often it will require disposing of the batch and require a new run to replace the off spec containers. Again, this all adds up to higher costs and lost production time.

According to the glass container manufacturer, mixed glass generated at the WMRA single-stream MRF was going to an optical sorting operation in Chicago and then being sold to the container manufacturer at a higher price than what they would've paid had it not been mixed in the first place. Since this was not cost-effective they discontinued purchasing this material from WMRA. As a result, WMRA stopped shipping their mixed glass to Chicago and began using it for other purposes including construction aggregate, leachate collection system drainage media, and landfill cover at their local landfills.

In a recent conversation with Waste Management staff (November 8, 2005) MPCA staff report that Waste Management indicated to them that they've stopped using glass as landfill cover and are once again sending this material to the Container Recycling Alliance (CRA) optical sorting operation in Chicago. CRA is a subsidiary of Waste Management and operates eleven beneficiating facilities across the country. According to Waste Management, the optically sorted glass is being marketed to the glass container manufacturer's facility in the Chicago area. However, it is unclear as to how much glass is currently being sent to Chicago for processing.

On a final note, the local glass container manufacturer has looked at putting in an optical sorter as a way to take in mixed glass from the region, process it, and utilize it in their manufacturing process. At this time, they've decided against this, as this option was cost prohibitive.

C. PLASTICS RECYCLERS

1. Plastics Recycler A Description

The first plastic recycler visited (PR-A) doesn't actually make a product but rather processes plastics to sell to other companies as a raw material in their manufacturing process. In this particular case, their markets are manufacturers of plastic lumber, plastic pipe, and synthetic fiber carpets. The types of plastics accepted and processed at PR-A include HDPE (natural, pigmented, and mixed), PET, and PP (natural, pigmented, and mixed). The types of plastics processed are kept separate to meet specific market requirements.

The baled plastics delivered to PR-A are inventoried and warehoused until needed. Processing of the plastics is pretty straightforward. The bales are broken open with wires and other contaminants removed. The plastic is cleaned and then sent to a shredder (Figure 10) to make plastic flakes or a pelletizer to make beads depending on the application. The shredded and plastic beads are discharged into Gaylords for delivery to markets.



Figure 10: Plastics Shredder

PR-A reported that they get their post-consumer raw materials from source-separated MRFs and independent brokers. They also accept post-industrial plastics from manufacturing facilities (e.g., off-spec plastic containers). They minimize what they take in from both dual-stream and single-stream MRFs due to the contamination problems they've had with this material.

2. Plastics Recycler B Description

PR-B makes plastic lumber from a variety of recycled plastic feedstock including HDPE (natural, pigmented, and mixed), LDPE (natural only), mixed PET, and other mixed resins (1 through 7). Their lumber is 100% recycled plastic. They declined the site visit or to provide a description of their process citing competitive reasons. They did, however, complete the questionnaire pretty thoroughly and were responsive to most of the follow up questions. PR-B estimates that 50% of their feedstock comes from independent brokers, 40% from source-separated and dual-stream MRFs, and approximately 10% from single-stream MRFs.

3. Plastic Recyclers Responses to Key Questions

Table 3.4 shows the responses of the plastics recyclers interviewed/visited for this study. Both recyclers interviewed indicated greater levels of contamination than in the past and two of the biggest offenders in this respect are glass and metal. One of the recyclers also indicated that other plastic container grades were a problem since his operation is focused on very specific grades. The other takes in a wide variety of plastic container grades. In addition, one facility responded that much of the material they get from MRFs (regardless of the type) contain a lot of dirt and grit. As a result, they spend a lot of time cleaning soiled feedstock prior to processing.

When asked what they attribute the increased contamination to, both plastic recyclers said single-stream recycling systems are the main culprit. One facility now refuses to accept plastics from single-sort recycling programs whereas the other one still accepts plastics from these MRFs but

scrutinizes the loads closely. However, this latter facility did say that not all single-stream MRFs are a problem and indicated they get exceptionally clean loads from one local single-stream facility (Tennis Sanitation).

Table 3.4
Plastics Recyclers Responses

Questions	Response
Have you seen more feedstock contamination over the last five years?	Yes (2)
What types of contaminants are you seeing in your feedstock?	Glass (2) Unacceptable Plastic Grades (1) Metal (2) Dirt/Grit (1)
If you have seen an increase in contamination, what do you believe are the contributing factors to this contamination/decrease?	<ul style="list-style-type: none"> • Single-stream recycling systems (2) • Poor operating and storage practices at MRFs (1)
What types of contaminants are the most problematic for your operation?	Glass (2) Unacceptable Plastic Grades (1) Metal (2)
What types of operational problems are these contaminants causing?	<ul style="list-style-type: none"> • Blades in grinders and shredders wear quicker or break due to metal and glass. • More sparking when cutting lumber due to metal content. • Excessive wear on screens, grinders, extruders, and motors due to glass and metal in feedstock. • Glass gets into bearings under conveyor belts. • Glass and metal in end product. • Higher maintenance costs and greater downtime due to repairs/cleaning (downtime has been as high as 50%).

Another factor contributing to feedstock contamination is poor operating and storage practices at some MRFs. In this case, one of the recyclers indicated he sees this problem in a wide-variety of MRFs including dual-stream and source-separated processing facilities. Not paying enough attention to the sorting process (lackadaisical manual sorting), not having the right separation equipment (ferrous and aluminum recovery systems), and storing materials outside where they can pick up contaminants or be degraded by weather conditions (i.e., rain, snow, sunlight, etc.) are all contributing factors in this case.

As one might expect the contaminants that are the most problematic include glass and metal. Unacceptable plastic grades can be sorted out relatively easily though it is much more difficult to remove glass shards and metal pieces embedded or mixed in with the plastic containers. Among the types of operational problems these contaminants cause are:

- Wearing and breakage of blades in grinders and shredders due to metal and glass;
- More sparking when cutting lumber due to metal pieces in the extruded lumber;
- Wearing on screens, grinders, extruders, and motors resulting in higher maintenance costs;
- Glass getting into bearings under conveyor belts;
- Pieces of glass and metal in the end product leading to product quality issues; and
- Overall higher maintenance costs and greater facility downtime due to repairs and cleaning.

D. SUMMARY OF END-MARKET REVIEW KEY FINDINGS

The end-markets contacted for this study were very open through the course of the dialog. Though there were some questions they did not feel comfortable answering (primarily due to competitive reasons or because the information requested was proprietary) clearly they wanted to weigh in on the issue of how current recycling trends are effecting their operations as well as how other industry trends (the paper industry in particular) are also contributing to the changes in the marketplace. Based on the information presented above, as well as other comments and thoughts that came up during the course of the discussions, some key findings coming from the market interviews include the following:

- **Over 70% of the end-markets interviewed reported that they are seeing more contamination in their recycled feedstock today than they were five years ago.** The one paper mill that said it wasn't experiencing this primarily uses OCC as their feedstock and this material is primarily generated in the commercial/industrial sectors where single-stream recycling is less common (mostly collected in dedicated compactors or with other fibers). The other market not reporting an increase in feedstock contamination was the glass container manufacturer.
- **The most noticeable feedstock contaminants reported by the end markets include:**
 - **Plastic bags/film and unacceptable paper grades (paper mills);**
 - **Glass and metal (plastic recyclers); and**
 - **Ceramics, pottery, and mixed glass (glass manufacturer).**
- **The most problematic feedstock contaminants reported by the end-markets include:**
 - **Glass, plastic bags/film, and unacceptable paper grades (paper mills)**
 - **Glass and metal (plastic recyclers); and**
 - **Ceramics, pottery, and mixed glass (glass manufacturer).**
- **Most of the mills and all of the plastics recyclers cited single-stream recycling as a contributing factor to the decline in feedstock quality.** The one mill that isn't reporting an increase in contamination expressed concern that if single-stream recycling were to be adopted widely in the commercial sector they would likely see an increase in contamination.
- **Other significant contributing factors to the decrease in feedstock quality include:**
 - **Contaminated loads from dual-stream recycling systems (2)**
 - **Feedstock demand/pressures from overseas markets (2)**
 - **Reduction in public education efforts (2)**
 - **MRF emphasis in pushing out product quantity versus an emphasis on product quality (2)**
- **Over 85% of the end-markets interviewed said that making blanket statements regarding the feedstock quality coming from single-stream MRFs and dual-stream MRFs is inaccurate. They have received exceptionally clean loads from single-stream facilities and very dirty-loads from dual-stream facilities.** There are many variables that will contribute to the quality of an end product coming out of a MRF. On the collection side, the type of vehicle used and whether or not the loads are compacted will have some influence on the outcome. Once at the MRF, a number of other factors come into play. The age of equipment, its operating efficiency, design/layout of the MRF, the quality and dedication of

the sorters, and the management philosophy and attitude of those who own and operate the MRF.

- **Export markets are currently driving the demand for recycled fibers, while the domestic paper industry is in a state of flux with regard to industry consolidation and mill closings.** The domestic paper industry is a low-margin industry with an aging infrastructure. Upgrading aging mills with new equipment for speeding up paper production or for dealing more effectively with contamination is hard to justify when external overhead costs (i.e., taxes, health & pension benefits, regulatory costs, energy costs, etc.) are rapidly rising. If they make this investment the question comes back as to who will pay for it. Because of where the international paper industry is, most domestic mills are not in a position to pass those cost increases on to their feedstock suppliers.
- **There has been a dramatic decrease in the quantity of clean, color-separated glass cullet available locally to the glass container manufacturer with the major cause of this decrease being the move to single-stream recycling collection and processing.** As noted above, it is not an increase in contamination that is a problem for this market, but rather a decrease in supply. Over the last several years, the glass container manufacturer has seen their local supply of color-separated glass cullet cut in half.

With the advent of single-stream collection and processing there has been a noticeable increase in the quantity of residue generated at MRFs with much of this increased residue being broken, mixed glass. This has significantly decreased the supply of clean cullet for the glass container industry. Again, though, there are exceptions to every rule and at least one local single-stream hauler/processor is able to minimize glass breakage largely due to the methods they are using for collecting and processing the glass,

- **Feedstock contaminants and problem loads of glass are just as likely to come from dual-stream facilities as from single-stream facilities.** The glass container manufacturer participating in this study is getting some very clean loads of color-separated glass from single-stream MRFs while at the same time is having some problems with loads coming from dual-stream facilities. They are currently in the process of resolving this issue.

What is the current state-of-the-art in separation and sorting equipment? Are there ways to mechanically enhance the recovery of materials collected in commingled (both single-stream and dual-stream) recycling systems? Some of the leading processing equipment/system vendors were contacted to find out what types of separation and sorting equipment is currently available for getting better recovery out of commingled streams. These are discussed in the following section.

IV. SEPARATION AND SORTING EQUIPMENT TO ENHANCE THE RECOVERY OF COMMINGLED RECYCLABLES

A. SELECT PROCESSING EQUIPMENT/SYSTEM VENDORS

There are a number of equipment manufacturers providing sorting and separation equipment for the recycling industry. Some provide particular pieces of equipment for processing a specific type of material while others manufacture a wide variety of processing equipment and provide turnkey recovery systems. There appear to be five industry players that either through their own equipment, or through partnerships and arrangements with other equipment vendors, currently dominate the North American recycling industry. These include:

- Bulk Handling Systems (BHS)
- CP Manufacturing
- Machinex Industries
- Van Dyk Baler Corporation/Bollegraaf Recycling Machinery
- Lubo USA

Representatives of these companies were contacted to find out more about the separation and sorting systems they offer (both single-stream and dual-stream). The following descriptions and discussions of the various companies and their equipment is not meant to give detailed information or equipment operating reviews, but rather to provide a summary of the processing equipment that is currently being used in many of the larger MRFs around the country. It should also be noted that by referencing these vendors and their equipment it is not the author's intent to endorse any one vendor or piece of processing equipment.

Appendix B lists the design function, throughput capacity, and removal efficiencies of most of the equipment discussed below.

1. Bulk Handling Systems

Bulk Handling Systems (BHS) was founded in 1976 and is based out of Eugene, Oregon. It quickly gained a foothold in supplying conveying and screening equipment to the forest products and power generation industries and in 1989 diversified into the solid waste and recycling industries. Since 1989, BHS has designed, manufactured, and installed a variety of separation and sorting equipment to the recycling industry as well as designed and constructed fully integrated MRFs most of which are dual-stream facilities.

Over the last several years they've begun adapting some of their screening systems to process single-stream collected recyclables. They are, along with the other equipment vendors discussed here, one of the leading designers and suppliers of single-stream processing equipment with over 13 systems currently operating throughout North America and Europe. As previously noted, much of the screening equipment used at the Tennis Sanitation single-stream MRF was developed by BHS.

Systems that are designed and manufactured by BHS incorporate custom tailored screening units to meet specific processing requirements and utilize discs or star screening technology to achieve material separation. Some of the screens that BHS has designed include the OCC Separator®, the Debris Roll Screen®, the NewSorter®, and the Polishing Screen.

The OCC Separator® screen was designed for mechanically separating corrugated containers from mixed fiber streams. Mixed fibers are conveyed to the screening deck via an infeed conveyor. The rotating discs on the OCC Separator® creates a wave-like action into the fiber stream as it flows over the screening deck. This aggressive screening action liberates smaller fibers and contaminants, which fall through the screening surface. The unique compound disc configuration reduces the loss of smaller OCC through the screen, resulting in higher recovery rates.

Another screen offered by BHS is the Debris Roll Screen® (DRS). The DRS is designed to remove small miscellaneous contaminants, such as grit, paper clips, bottle caps, glass shards, etc. It is designed for more rugged applications such as the screening of MSW, C&D waste, wood waste, and tires. It can also be highly effective in separating out contaminants from fiber streams. Though typically installed at the infeed end of the sorting conveyor, the unit can also be placed at the end of the sort line to remove small contaminants from the negatively sorted paper mix, improving the product quality. At the Tennis Sanitation MRF it's installed after the first sort line and prior to the materials going to the NewSorter® (see Figure 5 in Section II). Though it is effective in this application for removing small contaminants, it does add to glass breakage. According to a BHS representative, it is highly effective of getting glass out of mixed fiber streams but it was not designed for sorting out whole bottles from commingled streams. In this application it functions more like a glass breaker screen.

The NewSorter® (Figure 11) is a specialized screen that utilizes tri-shaped, urethane discs mounted on rotating shaft assemblies. The NewSorter® operates at varying speeds and angles to separate large fiber, primarily newsprint, from small fiber and containers. There is an interface opening between each disc on the same shaft assembly as well as between each reciprocating shaft assembly that allows small containers, glass shards, bottle caps, and small grit to be removed from the fiber material.



Figure 11: BHS NewSorter®

Operating at an extreme screening angle, the NewSorter® causes containers to roll backward off the unit. At the same time, the rotating discs cause a wavelike action, which carries newsprint up and over the top of the screen.

For processing single-stream recyclables after the NewSorter® has removed newsprint and large fibers, BHS makes the Polishing Screen. The Polishing Screen creates three material fractions mechanically – mixed fiber, containers, and fines. Mixed fiber is conveyed over the screening deck while containers roll off the back of the screen and are captured for sorting. The fines (i.e., broken glass, bottle caps, dirt, grit, small fiber, etc.) fall through the screening surface and are consolidated for disposal.

The BHS De-Inking Screen™ provides mechanical separation of fibers that create problems at paper mills producing de-inking grades. This screen is designed to separate out cardboard, kraft, and other similar materials.

On a final note, BHS also manufactures a glass-breaking screen. This unit is designed to break glass containers present in curbside recyclables early in the processing of commingled containers. Doing so releases broken glass along with fines, while carrying plastic, aluminum and tin containers forward for sorting

2. CP Manufacturing

CP Manufacturing was incorporated in 1977 and for more than 25 years has been one of the leading manufacturers of recycling equipment in the nation. Much of CP Manufacturing's earlier work in this industry was in the design and manufacturing of conveyors for such firms as BFI and Waste Management. They still do quite a bit of work for BFI and have provided much of the equipment that is in BFI's Recycleries serving the metro area. They have since broadened their product line and now offer an array of sorting and separation equipment for MRFs (dual-stream and single-stream).



Figure 12: CP Paper/Container Sorting Screen

CP's OCC screen has a unique design for separating OCC from other fibers, containers, and residuals. Serrated elliptical discs in two screening sections rotate off-center to create a side-to-side bouncing action. The serrated edge grabs the OCC and throws it forward while shaking other materials loose, which fall through the screen.

CP Manufacturing also makes a couple different screens for separating newspaper from mixed paper and commingled containers (the CP NEWScreen) and for

separating mixed paper from commingled containers (the CPScreen). Both of these screens use unique two-piece, square-shaped molded rubber or urethane discs with metal inserts that allow easy maintenance, disc changes, and disc spacing adjustments (Figure 12). CP claims that the square-tube steel shaft resists the metal wrapping that tends to collect on round shafts.

The V-Screen™ Separator (Figure 13) is designed for single-stream processing with the discs running at 90° angles to the product flow. Better quality control can be achieved by adjusting the angle of the disc arrangement, the angle of the total machine, and the speed of the discs. The V-Shape also minimizes the footprint of the screen allowing for a higher capacity throughput in a limited space.



Figure 13: CP Manufacturing V-Screen™ Separator

Among the potential benefits offered by the V-Screen™ Separator, CP lists the following:

- Dual-separating decks providing twice the throughput;
- Up to 3 times the effective screening surface;
- Lower maintenance costs as the design allows for easier cleaning and routine maintenance;
- Multiple screen-angle adjustments;
- Improved container egress path resulting in better screening and less glass breakage; and
- Produces a very clean container stream.

Other sorting and separation equipment offered by CP Manufacturing include:

- Glass Cleanup System: This system is designed to remove paper, dirt and debris from mixed and broken glass using screening and air separation equipment. If a market can be found for the mixed, broken glass, or if it can be put to beneficial use, tonnages going to landfills are decreased.
- Trom-Mag: The Trom-Mag is a combination smooth-bore steel trommel with 2” holes and a magnetic separator made of stainless steel tubing welded to the end of the trommel. A magnetic field is created through the stainless steel tube attracting the ferrous materials to the inside of the tube and transporting them to a chute where the magnetic field weakens and the ferrous materials drop down the chute into a bin. As mentioned in Section II, the Minneapolis BFI Recyclery uses a Trom-Mag on their container line.

Though the Trom-Mag may be an effective tool for liberating ferrous metals from the container stream and capturing them before they leave the trommel, the problem with such a unit is the increased glass breakage occurring because of the agitation caused in the rotation of the trommel and the mixed containers being bounced around as they make their way to the other end.

In 2003, CP Manufacturing acquired MSS, Inc. of Nashville, Tennessee. MSS, Inc. is a manufacturer of optical sorting equipment for the recycling industry and is one of the leading companies providing fully automated optical sorting equipment for identifying and removing plastic, glass, and paper from mixed materials streams.

3. Machinex Industries

Machinex Industries was founded in 1970 in Plessisville in eastern Quebec. In the early 1980s, Machinex became the first company in Canada to design machinery for MRFs, establishing themselves as a leader in the Canadian recycling industry. In recent years they've begun marketing their equipment and processing systems in the U.S. Locally, their sorting and separation equipment can be found in the front-end processing system recently installed at the Pope-Douglas Solid Waste Management Authority's waste-to-energy facility.

Machinex offers a full-line of separation and sorting equipment including the following:



Figure 14: Machinex Mach Two News Screen

- **Mach Two News Separator:** Designed to separate various news grades from curbside collected materials. The Mach Two News Separator features adjustable twin decks (Figure 14) for complete sorting of news and other fine paper grades.
- **Mach OCC Screen:** A fully automated system that separate OCC from other paper streams;
- **Mach One Single Stream Separator:** This unit is specifically designed for processing a commingled paper and containers stream. Machinex reports that

their simpler design results in a significantly reduced breakage in glass while improving fiber/container separation.

- **Mach One Finishing Screen:** Used in conjunction with the Mach One Single Stream Separator, the Mach One Finishing Screen can help reduce residuals while providing a cleaner stream to down-stream sorters. According to Machinex, with the adjustable spacing between discs, the finishing screen can remove a greater percentage of the fiber from the containers while at the same time screen out the fines.

All of Machinex Industries screens are designed with inclined screening surfaces with hydraulically adjustable angles, adjustable spacing between discs for better sorting flexibility, variable speed controls on the sorting decks, and split-disc design making removal and spacing adjustment more efficient and cost effective.

Machinex also offers a variety of other processing equipment including conveyors, air separators, magnetic and Eddy current separators, and glass pre-cleaning systems. Machinex has a partnership arrangement with Pellenc Selective Technologies, a French manufacturer of optical sorting equipment.

4. Van Dyk Baler Corporation/Bollegraaf Recycling Machinery

Van Dyk Baler Corporation was founded in 1984 and has been heavily involved in the manufacturing of residential and industrial recycling technology from the beginning. Van Dyk Baler Corporation is the exclusive North American distributor of Bollegraaf Recycling Machinery (Appingedam, Netherlands) and provides sales and service for all of Bollegraaf's equipment including their balers, sorting systems, shredders, conveyors and screens.



Figure 15: Bollegraaf PaperStar

One of the sorting systems manufactured by Bollegraaf is their PaperStar (Figure 15). The PaperStar is a star screen used for mechanically separating cardboard from paper. Star screens are screens that have specially shaped rotating discs fitted to a shaft system.

Star screens sort according to fraction size, weight and stiffness of the material. In this particular application, the PaperStar is fitted with square rotating discs over which the cardboard moves while magazines and newspapers fall through. The PaperStar can be adjusted for the type of materials being processed by changing the distance between the shafts, by varying the spacing between the discs, or by adjusting the rotational speed of the shafts.



Figure 16: Bollegraaf Paper Spike

Another piece of equipment that Bollegraaf offers is the Paper Spike (Figure 16). The Paper Spike is designed to capture cardboard and boxboard and would typically be placed after other screens to remove this material. According to Bollegraaf, material is fed in a single layer into the Paper Spike. The papers and cardboard are then pierced or snagged on the belt spikes. The cardboard, being more rigid than other papers, sticks onto the spikes whereas the paper drops off the spikes. The cardboard is transported to the end of the line where it is peeled off and placed in separate bins.

5. Lubo USA

Lubo USA is a sister company to Van Dyk Baler Corporation and was founded in 1991. It is the sole distributor for Lubo Screening and Recycling Systems B.V. and the TiTech VisionSort optical sorting technology.

Like Bollegraaf, Lubo Screening and Recycling Systems B.V. is located in the Netherlands (Emmen, Netherlands). They have also developed a patented Starscreen™ that can be used in a number of applications including screening and separation of construction and demolition materials, green waste, organic waste, sludge processing, wood processing, incinerator slag processing, and of course commingled materials recycling.

According to the company literature there are a number of advantages with their Starscreen™ technology including:

- The screen deck pulls apart and spreads the material, then screens it;
- The screen decks provide high processing capacity, particularly with difficult and sticky materials;
- They have the ability to process wet and high moisture content materials very well;
- Screens can be mounted in series so that a number of sizes can be screened simultaneously;
- A patented cleaning finger keeps the screening deck clean during the screening process; and
- Various screening dimensions can be achieved just by varying the rotating speed of the stars.

Their OCC Starscreen™ transports cardboard over the screening deck with the smaller materials such as paper and garbage falling through the screens. Lubo News Screens are used to automatically separate out newsprint from commingled streams (fiber or fiber/containers). Lubo has Single Deck News Screens and Double Deck News Screens.

Double Deck News Screens (Figure 17) are used exclusively in the large single-stream MRFs designed by Lubo USA. These screens separate the #8 ONP out of the single-stream collected materials at a very high rate. They can also be employed in paper operations to separate the #8 ONP automatically, with the mixed paper being screened.

Two other pieces of equipment made by Lubo are the Angled Sorter Screen and the French Banana Screen. Both of these are used for screening mixed materials.



Figure 17: Lubo Double Deck News Screen

For example the Angled Sorter Screen (see Figure 1 in Section II) is used in single-stream MRFs to separate mixed paper from containers after the materials have gone over a News Screen. Three streams come off of the Angled Sorter Screen including paper, containers, and fines. As the name implies, angles of this screen are adjustable from front to back and from left to right. To increase effectiveness, offset axles are used to vary star heights and increase agitation. The French Banana Screen was first installed in a MRF in France. It also separates paper from containers with a third fraction of mixed broken glass.



Figure 18: Lubo Fines Screen

One other Lubo Starscreen™ should be mentioned here – the Lubo Fines Screen. The Fines Screen (Figure 18) is designed to remove grit and mixed broken glass out of a stream of commingled containers. This screen works well for this task but because of the metal rotating discs, it's hard on whole glass containers adding to the amount of mixed broken glass generated at a MRF.

For processing glass, Lubo offers two other pieces of equipment. The first is the Lubo Glass Breaker Screen. It was developed for a fraction of the material stream that still contains glass. This screen breaks the glass and makes it possible to remove this fraction from the material flow. The remaining fractions (i.e., plastic containers, tin

cans, aluminum, etc.) can be screened out in a subsequent screening deck. Lubo offers single, double, and triple deck Glass Breaker Screens. In a triple deck system, the first screen breaks the glass, the second screens the glass, and the third separates small plastics and aluminum from larger items.

The Glass Breaker Screen offers the advantage of higher throughput, elimination of maintenance on air separation equipment, and elimination of glass sorters. Unfortunately, the downside is the loss of glass as a marketable commodity to the glass container recycling industry unless optical sorting is implemented.

Other options for processing the broken glass coming out of this system are to clean it up using Lubo's Topaas Screen and selling it as construction aggregate or crushing it into sand. WMRA has recently added a Lubo Glass Breaker Screen to their Minneapolis MRF.

The second piece of equipment is the Topaas Screen, which is billed as a glass cleaning unit. This unit can be added downstream of the Glass Breaker Screen to process the 2" minus glass

coming off that system. The material to be sorted (glass, paper, and other materials) typically goes through a two-step process. First, small particles such as fine glass are separated out using a star screen. The second step separates the paper particles from the glass particles and other heavy materials. The paper is blown away and collected in a container or bunker while the glass particles fall into the bunker under the installation or are removed via a belt conveyor. The Topaas Screen works with very small but precisely calibrated volumes of air.

B. SELECT OPTICAL SORTING EQUIPMENT VENDORS

One of the detrimental side effects of single-stream recycling is that during the collection and processing of materials glass containers get broken with the various colors mixed together. This causes two problems – the contamination of other materials (primarily paper) with glass shards and a significant decrease (at least in most cases) of clean, color separated glass available for the glass container recycling industry. Over the last few years there has been a move to look at optical sorting technology as a way to recover this mixed, broken glass.

The technology for sorting materials via optical scanning has been popular throughout Europe for more than a decade and only recently has it been gaining popularity in the U.S. In the early 1990s, optical sorting equipment was adopted by recyclers to process whole plastic containers. The units enabled plastics to be sorted by resin type and by color. In the mid-1990s, optical sorters were beginning to be adapted for sorting glass by color and to remove ceramic contaminants from glass streams. The optical sorting technology was then modified further and is now being applied in some instances for differentiating between various paper grades. What is currently holding back the widespread adoption of optical sorters for separating mixed broken glass is the cost of the equipment and that very few optical sorting equipment vendors in the U.S. have experience in sorting mixed, broken glass (both of these are discussed later in this section).

Optical sorting technologies fall into two general categories – singulated feed systems and mass feed systems. Singulated feed systems require objects to be fed to the sensor one-by-one while mass feed systems require that the materials to be sorted be spread out in a single-layer fashion over the width of the feed belt. In either case, the overall sorting concept is the same. Materials flow under a reflective near infrared (NIR) sensor, which shoots a beam of light at the materials passing under the sensor. Depending on the type of sensor and how it's calibrated, it can differentiate between different density and types of resins (e.g., PET plastic containers versus HDPE containers) or between different colors of materials (e.g., green glass fragments versus clear glass fragments). The sorter is programmed to shoot a stream of air toward the targeted material (green glass for instance), which blows it off the conveyor into a bin while the clear glass continues on, running off the end of the conveyor.

Mass feed systems, which are the focus of this discussion, have higher throughputs than singulated feed systems and generally require less maintenance. However, at least one sensor is typically required for each type of material to be sorted (e.g., PET containers, natural HDPE containers, pigmented HDPE containers) adding to the cost and complexity of the sorting system.

Companies that manufacturer optical sorting equipment for the recycling industry include:

- Rofin Rapidsort (Melbourne, Australia)
- Separating & Sorting Technology GmbH (Schönberg, Germany)
- National Recovery Technologies, Inc. (Nashville, TN)
- Binder+Co Group (Gleisdorf, Austria)
- TiTech VisionSort (Oslo, Norway)
- Pellenc Selective Technologies (Pertuis, France)
- Magnetic Separation Systems, Inc. (Nashville, TN)

Of these companies, neither Rofin Rapidsort nor Separating & Sorting Technology GmbH are players in the North American recycling industry. National Recovery Technologies, TiTech VisionSort, and Pellenc Selective Technologies are currently serving the plastics separation market. Though these technologies may be able to be adapted to color sorting glass cullet, this is not the market these companies are currently pursuing, and they have no facilities on-line that are doing glass cullet sorting. Only Magnetic Separation Systems, Inc. and Binder+Co Group have operating systems that are specifically being used for color separation of mixed broken glass. These two companies are discussed below.

1. Binder+Co Group

The Binder+Co Group, based out of Austria, is a mechanical engineering company specializing in processing, environmental, and packaging technology. The company is billed as the world leader in screening technology for hard-to-screen bulk material and for glass recycling. Binder+Co has been dealing with the preparation of glass cullet for the recycling industry for nearly twenty years and offers optical sorting technology specifically for separating ceramics, stone and porcelain (CSP) from mixed glass as well as color sorting the glass fraction.

Their Clarity Plus optical sorter (Figure 19) is a three-way system for color sorting glass for the recycling industry. The technology used in this application is a high-resolution camera system in combination with air jets, all controlled by an automated computer interface. The high-resolution camera can detect and distinguish between different color glass shards down to as little as 0.2 inches in diameter. Clarity Plus units are modular and can be installed into existing glass recycling plants as well as installing multiple units in one facility for increased processing capacity.



Figure 19: Clarity Plus Glass Sorter

In 2001, Container Recycling Alliance (CRA) began operations of a fully automated glass sorting line utilizing Clarity Plus glass sorting equipment. The facility removes foreign materials such as ceramic and metal from three-mix glass. The glass is then color sorted into clear, brown and green. The facility, processes up to 25 tons of three-mix glass per hour (160,000 tons per year) with much of the glass sold to the E & J Gallo Winery who was heavily involved in the planning and implementation of the project. A cost estimate for this system was not obtained.

Information on Binder+Co Group and the Clarity Plus glass sorting system can be found in Appendix C.

2. Magnetic Separation Systems, Inc.

Magnetic Separation Systems (MSS, Inc.) is a company specializing in automated sorting systems for plastics, glass, paper and metals. Headquartered out of Nashville, Tennessee it was recently acquired by CP manufacturing. MSS, Inc. is a pioneer in the design and installation of optical sorting equipment to identify and separate glass, plastic and paper based on the color of the material.

MSS, Inc. manufactures a variety of sorting systems each designed with a particular material or waste stream in mind. Of the six sorting systems they make, only the Glass ColorSort™ is specifically designed for color sorting of glass and ceramic removal of mixed glass streams. Screened, vacuumed and magnetically scalped glass cullet is fed onto a slide by a stainless steel vibrating feeder. Using NIR technology, the degree of opacity and true color of each glass particle is identified. A precisely metered compressed air pulse is activated to eject the selected colors or contaminants. Using computerized controls the amount of glass product loss and carry over can be minimized.

To be effective, glass particle sizes must be in the range of 3/8" to 2". Smaller or bigger than this may either not get detected correctly or because of size will be difficult to eject from the system. The Glass Colorsort™ sorts all shades of green, amber, yellow, and blue colored glass.

There are at least 28 installations in Europe, Japan, Australia and North America (two-thirds of these installations are in the United States and Canada). Of those in the United States and Canada, two-thirds are separating ceramics, amber glass, and green glass from clear glass). The United States installations in this latter group include 2 in Illinois, 2 in Maryland, 2 in Oregon, 1 in Pennsylvania, 1 in Florida, and 3 in unnamed locations.

An example of a typical set up for a Glass ColorSort™ system can be found in Partner's Recycling in Baltimore, Maryland. In 1998, the company acquired about 40,000 tons of mixed broken glass when it purchased a local glass processing company. With this type of inventory, along with glass the company collects from several other area MRFs, they needed a more efficient way to process the glass.

They purchased five optical glass sorters. The first two machines are used to sort amber glass from the stream of amber, green and clear glass. The remaining green and clear glass are conveyed into two more machines where the green glass is optically sorted. The fifth machine is used to perform a quality check and final screening of material.

In talking with a representative from the company, it is common to utilize a series of optical sorters to screen out ceramics and targeted colors of glass since one machine cannot effectively do this simultaneously. Another option is to have one or two machines setup to screen for one color and then running the materials back through these machines to screen out another color.

A ballpark estimate for a Glass ColorSort™ unit is approximately \$120,000. This does not, however, include the auxiliary equipment that is required such as a conveyor system to feed the sorter as well as one to eject materials to. Miscellaneous sizing screens and cleaning equipment is also required. This additional equipment can cost 2 to 2 ½ times as much as the optical sorter itself bringing the cost of a simple system up to \$360,000 to \$420,000. If multiple optical sorters are used it doesn't take long to add up to a system costing in excess of \$2 million.

An information/specification sheet on the Glass ColorSort™ system, including information on throughputs and removal efficiencies, can be found in Appendix D.

V. CONCLUSIONS AND RECOMMENDATIONS

In the Introduction to this report it was stated that the primary goal of this project was to gain a better understanding of Minnesota's changing recycling infrastructure specifically as it relates to the processing and marketing of recyclables. Specific questions to be addressed included:

- What are the differences between single-stream and dual-stream MRFs serving the Minneapolis/St. Paul metro area as it relates to the:
 - Condition of incoming materials;
 - Quality of outgoing commodities; and
 - Generation rate and composition of processing residuals.

- What impacts, if any, are end-use markets observing and experiencing with the recyclable feedstocks they're receiving from MRFs serving the Minnesota marketplace including those in the Minneapolis/St. Paul metro area? Are there noticeable differences between materials coming from single-stream MRFs versus dual-stream MRFs. More specifically:
 - Have they seen more feedstock contamination over the last five years?
 - What types of contaminants are they seeing in the delivered feedstock, if any?
 - What do they believe are the contributing factors to increased contamination?
 - What types of contaminants are the most problematic for their operations?
 - What types of operational problems are these contaminants causing?

- What is the current state-of-the-art in separation and sorting equipment that is being applied to commingled streams (both dual-stream and single-stream systems)? More specifically:
 - Who are the major equipment vendors supplying this equipment to the recycling industry?
 - What are the different types of screening systems and their capabilities for separating mixed streams of recyclables?
 - Who are the major vendors of optical sorting equipment and what capabilities do these systems have for processing mixed streams of plastic containers and/or glass?

The research conducted and the data collected as part of this study barely scratched the surface. However, there are some strong conclusions that can be drawn from analyzing the information presented in this report, and many of the questions posed above can be answered. The study conclusions and recommendations for further policy discussions are presented below.

A. CONCLUSIONS

The conclusions drawn from this study are based on the three main questions forming the basis of the project.

As discussed previously, only one MRF (single-stream) agreed to participate fully in the study. Information on the other MRFs came from previous reports, general public information, and limited data shared by these facilities. As a result, a comparison of MRF empirical data to answer this question was not possible. Some anecdotal information, however, was obtained from end-

use markets as a way to rate the performance of these facilities especially as it relates to the quality of commodities shipped to market. The conclusions drawn from the MRF information reviews and end-market interviews are listed in Sections II and III, respectively. Information on separating and sorting equipment was primarily obtained from vendors themselves, either through telephone interviews or through their Websites. Claims on efficiencies were not verified in the field and no endorsement of any one vendor or type of equipment should be construed by the information presented in the report.

1. What are the differences between single-stream MRFs and dual-stream MRFs serving the Minneapolis/St. Paul metro area as it relates to generation of residuals and the quality of recovered products?

- The generation of residuals at the two single-stream facilities ranged from as little as 2% up to almost 6% by weight. In this latter case, broken glass and fines mechanically screened during processing are being used at a landfill in a beneficial use role. Though approved for use in this application, the material is still considered a processing residual and should be factored into the residual rate. Doing so raises the residual rate from 6% to approximately 17%.
- Residuals generation in single-stream facilities is likely to be a function of collection vehicles and the collection methods used as well as processing equipment (e.g., trommels, hard disc screens, long drops from conveyors, etc.).
- If mixed, broken glass is counted toward residuals, it can account for up to 65% by weight of residuals coming from a single-stream MRF.
- Glass breakage and contamination of materials in single-stream and dual-stream collection programs can be minimized if the proper steps are taken in the collection materials. These steps include:
 - Minimize dumping height from the recycling container into the vehicle body;
 - Provide minimal compaction, or better yet, no compaction to materials in the truck;
 - Utilize collection vehicles that minimize the drop distance from truck to tipping floor in the dumping process; and
 - Once on the tipping floor use care in spreading out the load and pushing materials into conveyor pits so as to minimize rolling-stock from running over materials and breaking glass.
- The quality of observed commodities waiting for delivery to markets at one single-stream facility were generally quite high. Some of the markets talked with verify that this facility provides them with excellent quality materials.

2. What impacts, if any, are end-use markets observing and experiencing with the recyclable feedstocks they're receiving from MRFs serving the Minnesota marketplace including those in the Minneapolis/St. Paul metro area? Are there noticeable differences in the materials coming from single-stream MRFs and dual-stream MRFs?

- Five of the seven end-markets interviewed indicated they are seeing more contamination in their recycled feedstock today than they were five years ago. One of the mills and the glass container manufacturer were the two exceptions.
 - As reported by the paper mills, the most noticeable feedstock contaminants are plastic bags/film and unacceptable paper grades (Outthrows).
 - As reported by the paper mills, the most problematic feedstock contaminants are plastic bags/film, glass, and unacceptable paper grades (Outthrows).
 - As reported by the plastic recyclers, the most noticeable and problematic feedstock contaminants are glass and metal.
 - As reported by the glass container manufacturer, the most noticeable and problematic feedstock contaminants are ceramics, pottery, and mixed glass.
 - Three of the mills and both of the plastics recyclers cited single-stream recycling as a contributing factor to the decline in feedstock quality.
 - Other significant contributing factors to the decrease in feedstock quality include:
 - o Contaminated loads coming from dual-stream facilities;
 - o Feedstock demand/pressures from overseas markets;
 - o Reduction in public education efforts; and
 - o MRF emphasis in pushing out quantity versus quality.
 - There has been a dramatic decrease in the quantity of clean, color-separated glass cullet available locally to the glass container manufacturer. The major contributing factor to this decrease is the growing presence of single-stream recycling programs.
 - Six of the seven end-markets said that it is unfair to make blanket statements about single-stream and dual-stream MRFs. They've received exceptionally clean loads from single-stream and dual-stream MRFs as well as dirty loads from single-stream and dual-stream MRFs.
 - Export markets are currently driving the demand for recycled fibers (particularly China).
 - The domestic paper industry is in a state of flux with a string of consolidations and mill closings. This, along with low margins in the domestic paper industry, impact how much investment in equipment upgrades the paper industry can absorb before they would have to pass on the cost of that investment to suppliers in the form of lower prices paid for commodities.
- 3. What is the current state-of-the-art in separation and sorting equipment that is being applied to commingled streams (both dual-stream and single-stream systems)?**
- The major separation and sorting equipment vendors, especially those that provide total package systems for processing commingled recyclables (both single-stream and dual-stream) include:
 - o Bulk Handling Systems (BHS)
 - o CP Manufacturing
 - o Machinex Industries

- o Van Dyk Baler/Bollengraaf Recycling Machinery
 - o Lubo USA
- These companies, and others, appear to make separation and sorting equipment that can be very effective at mechanically separating fibers from containers, fibers from fibers, and containers from containers with efficiency ratings running from 80% up to 95% + depending on the piece of equipment, the mix of materials going through the equipment, and the type of materials that are being targeted for separation.
- Some of the separation and sorting equipment manufactured by these companies and being installed in MRFs are having a detrimental affect on the quality and quantity of the final product being recovered primarily because of the significant glass breakage that can occur when applying this equipment to material streams containing glass containers. Examples of such equipment include trommels and disc screens designed for removing fines from mixed waste streams.
- There are about a half a dozen companies that make optical sorting equipment being used in the waste and recycling industry. Of these companies there are primarily three that are gaining popularity in the industry because of their affiliation with larger recycling equipment manufacturers. These three companies are;
 - o MSS, Inc. (wholly owned subsidiary of CP Manufacturing).
 - o Pellenc Selective Technologies (exclusive North American partnership arrangement with Machinex Industries).
 - o TiTech VisionSort (North American partnership arrangement with Lubo USA).
- All the optical sorting equipment vendors use near infrared (NIR) technology, high-resolution photography, or both to accomplish the sorting process.
- Though originally designed for sorting different types of plastics (primarily separating whole plastic bottles made of PET and HDPE) optical sorters have recently been adapted for sorting other materials such as fiber and glass.
- Though all vendors say their equipment could be adapted for removing contaminants from glass (e.g., ceramics) or for separating mixed glass by color, only two companies are currently doing this – MSS, Inc. and Binder+Co Group.
- The three leading companies in applying optical sorting to the recycling industry are reportedly achieving Purity Rates (cleanliness of the ejected material expressed in percentage) in the following ranges plastics (90 – 98%), paper (70%), and glass (95 – 98%).
- The ballpark cost for an optical sorter for processing mixed glass is approximately \$120,000 per unit. Adding the necessary sizing screens and cleaning equipment brings the cost for a simple system up to the \$360,000 to \$420,000 range. To remove contaminants (i.e., ceramics, metal, other inerts, etc.) and obtain multi-color separation (amber, green, clear) would likely require adding multiple units. Such a system would likely cost in excess of \$2 million.

B. RECOMMENDATIONS

Based on the findings and conclusions, recommendations include the following:

- 1) Much of the rhetoric on both sides of the single-stream/dual-stream debate appears to be exaggerated making it difficult for municipalities and residents to obtain unbiased information for decision-making. To this extent the MPCA should:**
 - a. Develop educational materials to help local decision-makers understand the advantages and disadvantages of various collection and processing methods.**
 - b. Sponsor workshops for municipalities and others focusing solely on the issue of source-separated, dual-stream, and single-stream collection and processing including the potential impacts on various end-use markets. This last point is crucial as many end-use markets voiced concern that public officials don't understand how choices on the front-end are impacting the ability to actually recycle the materials delivered to the markets.**

- 2) The MPCA should provide technical assistance to MRF owners/operators for improving facility performance with the objective being to increase the amounts of materials recovered, decrease the amount of contaminants in marketed end products, and decrease the amount of processing residuals produced.**

- 3) Currently in Minnesota, recycling facilities (MRFs) are permitted under the "permit-by-rule" designation. As a result, there is very little state oversight on facility design and operation yet the state has a vested interest in establishing and implementing statewide policy on recycling. With the maturation of the recycling industry and the sophistication of the new generation of MRFs, it is recommended that a registration or certification process be applied to MRFs. As a component of this registration or certification process, MRFs should be required to report certain operational data to the state for monitoring purposes. This information should include at a minimum:**
 - o Amounts and types of recyclables delivered to the facility;**
 - o Amounts and composition of processing residuals;**
 - o Amounts and types of materials processed and sent to end-markets on an annual basis; and**
 - o Amounts and types of materials downgraded or rejected by markets.**

- 4) The Solid Waste Management Tax exemption language contained in Minnesota Statute 297H.06 should be clearly articulated to all stakeholders to ensure that though the beneficial reuse of glass as landfill cover or for use as leachate collection system media may be approved on a case-by-case basis, it is not considered recycling. As a result, it cannot be used for meeting the 85% volume reduction at recycling facilities allowing those facilities to be exempt from the Solid Waste Management Tax.**

- 5) The MPCA should conduct further research into the technical, economic, and marketplace feasibility of utilizing optical sorting technology for the further processing and recycling of three-mix glass at local MRFs. If determined to be feasible, the State should partner with the private sector for the construction and operation the facility (public/private partnership).**

- 6) No reliable, independently verified information regarding the amounts and composition of the MRF processing residuals coming out of the metro area processing facilities appears to be available. Yet, there is a tax exemption benefit available to processors who achieve a volume reduction of 85% or greater. As a result, it's recommended that an independent, residuals composition analysis should be conducted on the residuals generated at all commercial MRFs serving the metro area to determine the true quantities and characteristics of this material.**

- 7) No significant data from the two major dual-stream MRFs serving the metro area were provided. As a result, how these facilities are doing with regard to processing recyclables, the amount and composition of residuals, and the quality of recovered materials sent to markets is difficult to ascertain. To get some sense of how dual-stream facilities in Minnesota measure up to single-stream facilities it is recommended that supplemental information be obtained by studying and assessing larger dual-stream MRFs located in Greater Minnesota.**

- 8) The focus of this study was on the processing of recyclables and the impacts on end-markets. However, many of the problems associated with residuals production at MRFs and the quality of the recovered product to be sold to end-markets starts with the setout of materials at the curb and the methods used for collecting and transporting that material. Carefully examining these issues and identifying best management practices (BMPs) for generator education/participation and on-route operational procedures for minimizing product loss and contamination, regardless if it's a single-stream collection scenario or a dual-stream collection scenario, is strongly recommended.**

APPENDIX A
MRF SURVEY FORM

MRF SURVEY FORM

Name of MRF: _____

Address: _____

Contact: _____ Phone: _____

E-mail: _____ Fax: _____

- 1) How are materials delivered to the MRF and in what estimated percentages? (Check all that apply please make sure numbers add up to 100%)

Source Separated: _____ Est. %: _____

Dual-Stream (Fibers & Rigids): _____ Est. %: _____

Single-Stream (Fully Commingled): _____ Est. %: _____

Other (Please Specify): _____ Est. %: _____

_____ 100%

- 2) What is the estimated percentage of residentially generated versus commercially generated recyclables your facility handles?

- 3) If your company also provides residential collection of recyclables:

A. What types of collection vehicles do you use? (check all that apply)

Dual Compartment Vehicles: _____ Dual Compartment Vehicles: _____
(With compaction) (Without compaction)

Conventional Single Compartment Compaction Vehicles: _____
(Rear packers, front-end loaders, side-loaders, etc.)

Multi-Compartment Vehicles for Curb Sorted Materials: _____

Other (Please specify): _____

- B. If using collection vehicles with on-board compaction, what is the compaction ratio used on rigids (if collection is two-sort) or combined materials (if fully commingled)? How often is the load compacted?

- C. What is the average setout rate (pounds/household) for your:

Single-Stream Routes: _____ Typical Type/Size of Containers: _____

Typical Frequency of Collection: _____

Dual Stream Routes: _____ Typical Type/Size of Containers: _____

Typical Frequency of Collection: _____

Source Separated Routes: _____ Typical Type/Size of Containers: _____

Typical Frequency of Collection: _____

- 4) Once reaching the MRF tipping floor, how are materials unloaded, stored and moved into the overall processing scheme? For example, are there any operational procedures employed to minimize additional glass breakage or to quickly isolate fibers from rigids?

MRF SURVEY FORM (continued)

5) Using the Excel spreadsheets below, please provide monthly materials mass balance for calendar years 2004 and 2005 thru September.

2004 Materials Mass Balance (tons)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total Tons of Delivered Materials													
Recyclables Recovered													
OCC													
Other Fibers													
Aluminum													
Ferrous Metals													
Other Non-Ferrous Metals													
Plastic Containers													
Plastic Film													
Other Plastics													
Clear Glass													
Green Glass													
Amber Glass													
Other Materials (specify below)													
Total Recovered Recyclables	0	0	0	0	0	0	0	0	0	0	0	0	0
Rejects/Unacceptables Disposed													
Residuals Generated													
State-Approved Recycling Use*													
Beneficial Reuse of Residuals **													
Disposal of Residuals													
Total Residuals	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Disposal***	0	0	0	0	0	0	0	0	0	0	0	0	0

* State-approved recycling use is limited to sandblasting media, MNDOT specs for Class 7 roads, and for use in leachate collection systems.

** Primarily mixed cullet used for landfill cover and non-MNDOT construction aggregate.

*** Total of rejects/unacceptables disposed and residuals disposed.

MRF SURVEY FORM (continued)

2005 Materials Mass Balance Thur September (tons)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Total Tons of Delivered Materials										
Recyclables Recovered										
OCC										
Other Fibers										
Aluminum										
Ferrous Metals										
Other Non-Ferrous Metals										
Plastic Containers										
Plastic Film										
Other Plastics										
Clear Glass										
Green Glass										
Amber Glass										
Other Materials (specify below)										
Total Recovered Recyclables	0	0	0	0	0	0	0	0	0	0
Rejects/Unacceptables Disposed										
Residuals Generated										
State-Approved Recycling Use*										
Beneficial Reuse of Residuals **										
Disposal of Residuals										
Total Residuals	0	0	0	0	0	0	0	0	0	0
Total Disposal***	0	0	0	0	0	0	0	0	0	0

* State-approved recycling use is limited to sandblasting media, MNDOT specs for Class 7 roads, and use in leachate collection systems.

** Primarily mixed cullet used for landfill cover and non-MNDOT construction aggregate.

*** Total of rejects/unacceptables disposed and residuals disposed.

MRF SURVEY FORM (continued)

6) On average, what is the estimated contamination rate of incoming materials? Have you received more or less in the last 5 years?

7) Of the contamination rate indicated above, please indicate what percentage falls into the following categories (please make sure numbers add up to 100%)

Non-Recyclables Items _____
(i.e., plastic toys and household goods, garbage, junk, etc.)

Recyclable Items Rendered Non-Recyclable _____
(i.e., mixed broken glass, food-contaminated fibers, etc.)

Potentially Recyclable Items That Currently Have No Market _____
(i.e., # 3 – 7 plastics, etc.)

Other (please specify) _____
_____ 100%

8) Please indicate the types and numbers of mechanical sorting devices used to segregate the materials delivered to your facility.

Fiber and Container Screens: _____

Trommels: _____

Air Classifiers/Knives: _____

Ferrous Magnets: _____

Eddy Current Separators: _____

Other (please specify): _____

9) Please indicate the number of manual sort lines you have and what materials are sorted on these lines.

10) At what points in the collection and processing chain (from curbside pickup to recovered commodity storage and load-out) are residuals or other rejects generated? At what location in the process are they consolidated?

11) Are residuals further processed for recyclables or for beneficial reuse? If so, how?

MRF SURVEY FORM (continued)

12) Please indicate the estimated average composition (%) of your residuals stream **before and after** any additional processing:

Estimated Composition of Processing Residuals

	Glass	Paper	Metals	Plastic Containers	Plastic Film	Other Plastic	Other Materials (specify)	Inerts	Total
Before Additional Processing									100%
After Additional Processing									100%

13) What is your annual cost and cost per ton for disposal of process residuals and rejects/unacceptables?

14) What markets (mills, brokers, other end-markets) are you currently delivering your recyclables?

Commodity Markets

Fibers	Plastics
Glass	Metals

15) In 2004 and 2005, what **types** and **amounts** of materials sent to your markets were rejected or downgraded in value? What were the reasons for these rejections or downgrades?

Rejected and Downgraded Marketed Commodities

Materials	2004		2005	
	Rejected	Downgraded	Rejected	Downgraded
Fibers				
Plastics				
Glass				
Metals				
Totals				

MRF SURVEY FORM (continued)

Additional Comments: _____

Both the OEA and Tim Goodman & Associates realize the potentially sensitive nature of some of the information being requested. To this extent, quantity data reported will either be aggregated with other data for reporting purposes or be presented as percentages (i.e., percent of throughput, percent of residue, etc.). Additionally, none of the MRFs or end-markets participating in this project will be referred to by name in the project report. If there is other specific data that you are concerned about being released please contact Tim Goodman at the number below to discuss your concerns.

Should you have any other questions or comments regarding the nature of the project or the information requested, please feel free to contact Tim Goodman at (952) 544-6005 or at tgoodman1@mn.rr.com. Thank you in advance for your participation in this endeavor.

APPENDIX B
PROCESSING EQUIPMENT SPECIFICATIONS

Fiber and Container Sorting Equipment Specifications

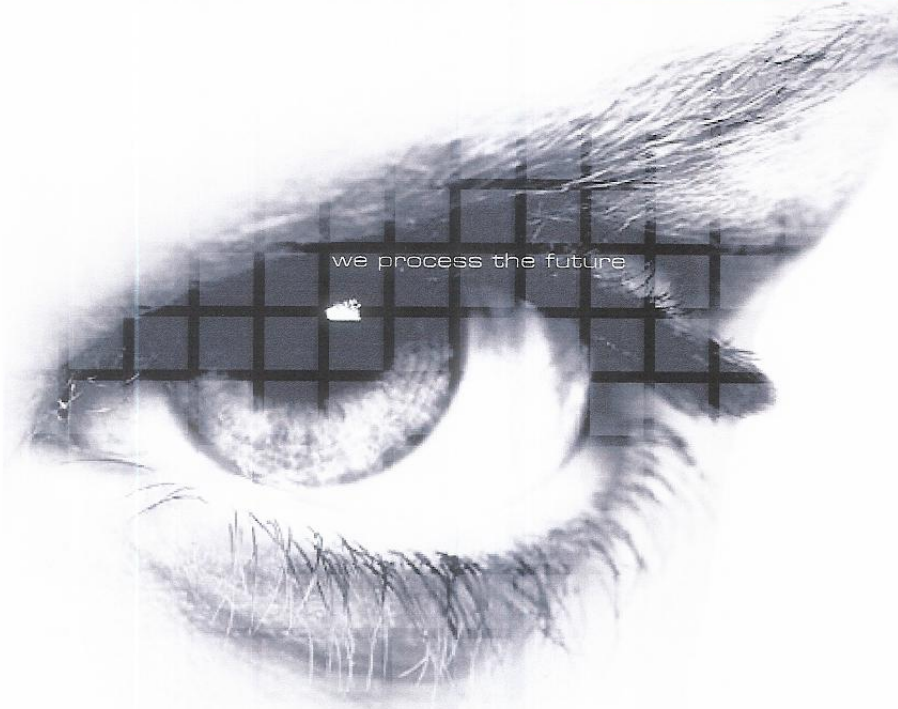
Company	Equipment Name	Designed Function	Throughput Capacity	Removal Efficiency
Bulk Handling Systems (BHS)	OCC Separator®	Separates OCC from mixed fibers	Up to 25 tons/hr.	90 – 95%
	Debris Roll Screen®	Removes small contaminants from MSW and C&D streams	Up to 25 tons/hr.	90 – 95%
	NewSorter®	Separates ONP from small fibers and containers	Up to 25 tons/hr.	90 – 95%
	Polishing Screen	Separates containers, mixed fibers, and fines	Up to 25 tons/hr.	90 – 95%
CP Manufacturing	OCC Screen	Separates OCC from mixed fibers and containers	Up to 30 tons/hr.	N.A.
	NEWScreen	Separates ONP from mixed fibers and containers	Up to 30 tons/hr.	N.A.
	CPScreen	Separates mixed paper from containers	Up to 15 tons/hr.	N.A.
	V-Screen™ Separator	Separates containers from mixed paper	Up to 20 tons/hr.	N.A.
	Glass Cleanup System	Removes paper, dirt and debris from mixed glass	Up to 20 tons/hr.	N.A.
	Trom-Mag	Ferrous recovery after removal of fines	N.A.	N.A.
Machinex Industries	Mach OCC Screen	Separates OCC from mixed fibers	Up to 35 tons/hr.	98%
	Mach Two News Separator	Separates ONP from small fibers and containers	Up to 25 tons/hr.	95%
	Mach One Single Stream Separator	Separates containers from mixed paper	Up to 25 tons/hr.	98%
	Mach One Finishing Screen	Separates containers, mixed fibers, and fines	Up to 25 tons/hr.	98%
Van Dyk Baler Corp/Bollegraaf Recycling	Bollegraaf PaperStar	Separates OCC from mixed fibers	Up to 22 tons/hr.	N.A.
	Bollegraaf Paper Spike	Separates cardboard and box-board from mixed fibers	Up to 8 tons/hr.	N.A.
Lubo USA	OCC Starscreen™	Separates OCC from mixed fibers	14 – 30 tons/hr.	95%
	Single Deck News Screen	Separates ONP from small fibers and containers	20 – 30 tons/hr.	95%
	Double Deck News Screen	Separates ONP from small fibers and containers	20 – 30 tons/hr.	95%
	Fines Screen	Removes grit and broken glass from commingled containers	N.A.	95%
	Angled Sorter Screen	Separates mixed fibers, containers, and fines	8 – 10 tons/hr.	95%
	French Banana Screen	Separates mixed fibers, containers, and broken glass	6 – 9 tons/hr.	95%
	Glass Breaker Screen	Breaks glass for upfront removal	Up to 40 tons/hr.	95%
	Topaas Screen	Removes paper, dirt and debris from mixed glass	7 – 30 tons/hr.	95%

APPENDIX C
CLARITY PLUS GLASS SORTER INFORMATION

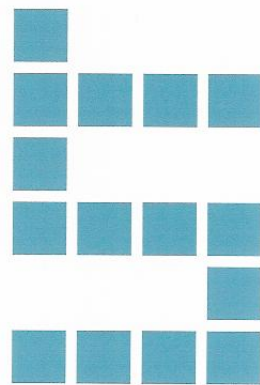
binder+co

clarity PLUS

Revolutionary waste glass processing meeting the highest standards



we process the future



Environmental Technology



TASK

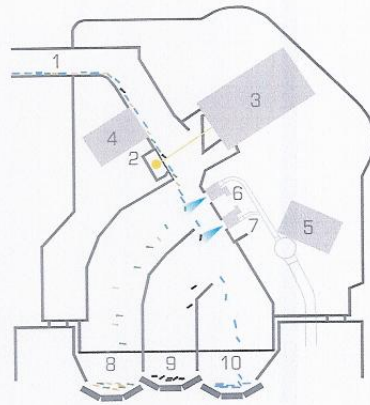


As for the sorting of waste glass, the requirements placed on the sorting accuracy are becoming increasingly stringent, the fractions having to become finer and finer. Material that previously could not be sorted is now additionally subjected to reliable colour sorting before being re-used. As large parts of waste glass will get to the processing plant as cullet, a special machine is required for the fully automatic sorting of these pieces of broken glass, which will guarantee the required colour purity, even in their finest fraction. On the one hand, this is to guarantee a high-quality processing of mixed glass. On the other hand, it also is to increase the colour purity of waste glass that has already been separated according to its colours.





SOLUTION

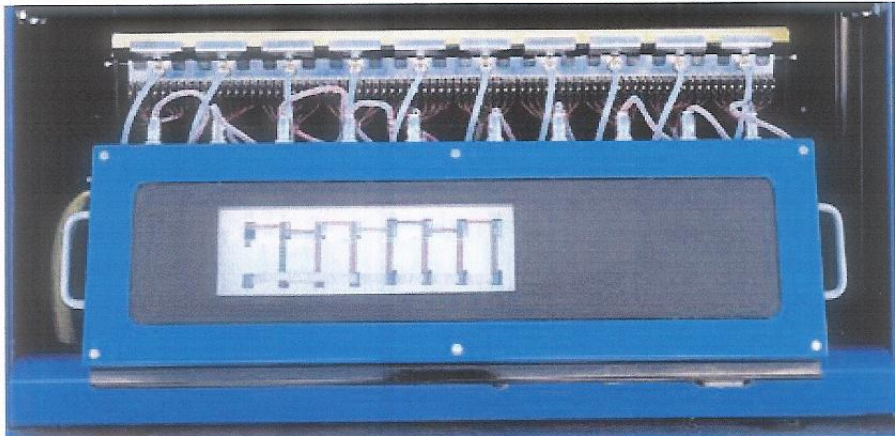


- | | |
|----------------------------------|--|
| 1 - Oscillating conveying trough | 6 - Sorting valves with nozzles (Series 1) |
| 2 - Transmitted light | 7 - Sorting valves with nozzles (Series 2) |
| 3 - Sensor unit | 8 - Ejected Fraction 1 |
| 4 - Metal detection | 9 - Ejected Fraction 2 |
| 5 - Direct valve control | 10 - Fraction passing through |

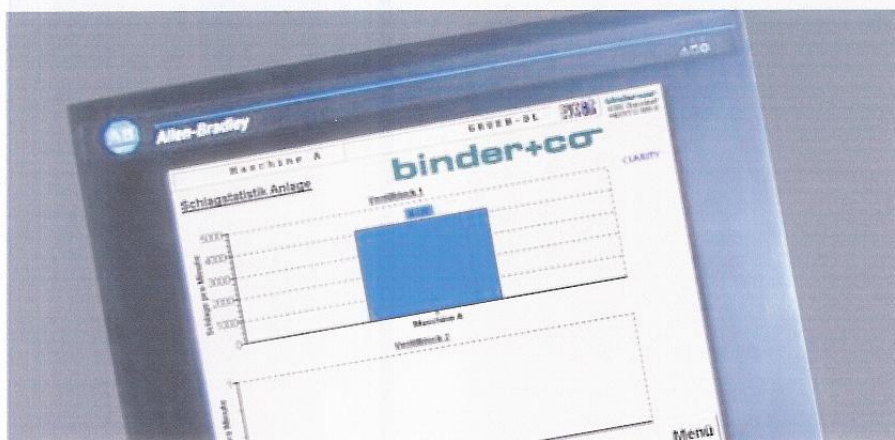
Having had long-standing experience in the processing of waste glass both in connection with the separation of such impurities as ceramics, stone and porcelain and with sorting on the basis of colour; Binder+Co has developed the CLARITY system. CLARITY plus is the first three-way system to meet these high requirements in waste-glass processing. With the help of CLARITY plus, mixed glass processing and colour improvement together with CSP recognition can be guaranteed in unequalled quality.



TECHNOLOGY

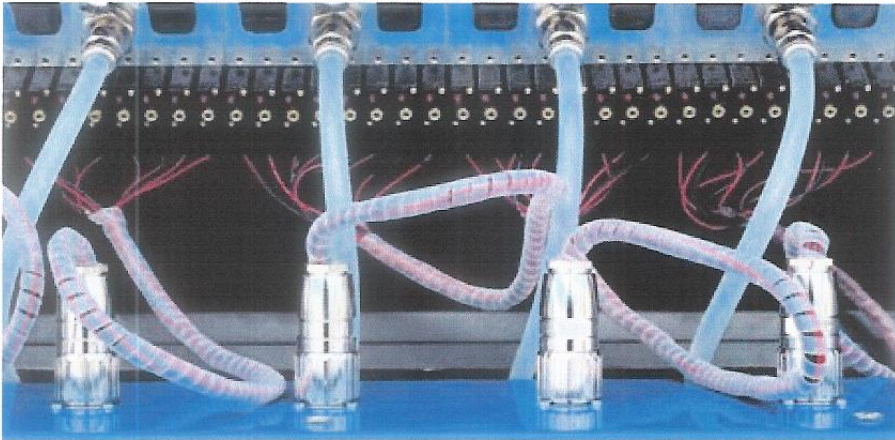


By means of a specially designed slide with an exactly defined inclination, pieces of broken glass with a diameter of 5 mm and more will be fed and separated. In the lower area of the slide, the pieces of broken glass will be exposed to white radiation. A maximum number of seven independent cameras, which can detect up to 16 m. colours, will analyze the obtained information and directly control the valves distributed over two blowing-out strips at the right time. These valves will blow out cullet with the colour defined in the menu or impurities. As the resolution of the detection units is quite high with 0.6 mm – 160 x 3 Pixels on 100 mm – and as there are so many valves with a valve time of less than 5 ms, a maximum sorting quality is guaranteed down to the finest fractions, the colour characteristics of the glass being irrelevant. This guarantees that the pieces having the wrong colours will be sorted out efficiently and reliably without a computer separated from the detection units being required. According to the respective requirements on the unit it is equipped in different widths with a different number of valves. In this context, it is possible to access the slewable valve strips without tools.





TECHNOLOGY



3-Way System. Sorting paths freely selectable.

The sorting parameters will be defined and evaluated by means of a PC with a touch screen. In this context, it is possible to control altogether up to sixteen CLARITY sorting units. This touch screen enables different pre-programmed recipes for combinations of sorting parameters to be activated. Remote maintenance is made possible by a modem and data line, which is particularly advantageous for the sorting quality.

Control station capability.

CLARITY plus has been designed as to make sure that it can be incorporated into central control systems.





OPERATION



The know-how Binder+Co boasts in the processing of bulk and recycling materials is reflected by an intelligent material selection and the matured technical design of CLARITY plus. CLARITY plus has a proven modular design so that it can be installed into existing glass recycling plants without any problems. Thanks to the slewable valve strip, the unit is easily accessible for maintenance and operational checks.

Self-cleaning, the low consumption of operating material and the longevity of the units are still other advantages of the efficient waste glass processing technology offered by Binder+Co. CLARITY does not only excel by its maximum user friendliness but, above all, by its up-to-date design. It is also in aesthetics and the outward appearance that Binder+Co sets new standards for modern industrial products.

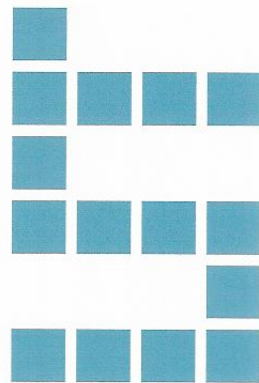
binder+co

- Processing Technology
- Environmental Technology
- Packaging Technology

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The know-how of Binder + Co in the processing of bulk and recycling materials is reflected by an extensive range of special machinery that is used for raw material, building and chemical industries all over the world. The company delivers entire turnkey plants – from planning via design, production, assembly to commissioning. Highly qualified employees transform metal into intelligent machinery and structures. The special asset of the Austrian company is its 50 years' experience in elaborating solutions tailored to specific customer demands.

CLARITY plus is the name of Binder+Co's flagship product in waste glass processing technology. Here, efficient technology meets exciting modern design. CLARITY sets new standards in glass recycling.



Environmental Technology

APPENDIX D
MSS GLASS COLORSORT™ SPECIFICATIONS



Glass ColorSort™

Color Sorting and Ceramic Removal of Mixed Glass

The Glass ColorSort™ provides state-of-the-art color sorting and removal of ceramics, stones and porcelain from dirty three-mix glass.



State-of-the-Art Technology

Turns negative value, contaminated mixed glass into high value, furnace-ready cullet.

Capacity is 20 tons/hr in ceramic sorting mode, 5 tons/hr in color sorting mode.

Automatically identifies and sorts glass particle sizes from 9–50 mm (3/8"–2").

Sorts all shades of amber, yellow, red, blue and green glass including "Georgia Green" and "Half-White".

Employs the latest developments in sensor technology, using high-speed optical detectors and digital signal processing.

A user-friendly color touchscreen with modem provides easy operator controls, setup flexibility and advanced system diagnostics.

Sophisticated software algorithms correct for the effects of dirt and other contamination, resulting in improved separation over troublesome self-cleaning systems which require air and water.

Low maintenance costs due to few mechanical components.

Automatic velocity detectors compensate for any moisture effects in the infeed material.

Requires little space and can easily be integrated into existing facilities and processing systems.

Reliable and proven in more than 50 installations in Europe, Japan, Australia and North America.

The Glass ColorSort™ system is covered with a full one-year warranty on parts, workmanship and performance.

Upgrades
 Dual-Ejection
 Split Configuration
 Metal Detector

Features
 Color Touchscreen
 Modem Access
 Count Statistics

intelligent.automated.sorting



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Glass ColorSort™

Color Sorting and Ceramic Removal of Mixed Glass

ColorSort™ Model	Single-Eject	Dual-Eject	Split Single-Eject	Split Dual-Eject
Feed Width	1,200 mm (48")	1,200 mm (48")	2 x 550 mm (2x22")	2 x 550 mm (2x22")
Feedrate Color Sorting	5 tons/hr	5 tons/hr	2 x 2.2 tons/hr	2 x 2.2 tons/hr
Feedrate Ceramic Sorting	20 tons/hr	20 tons/hr	2 x 9 tons/hr	2 x 9 tons/hr
Removal Efficiency	> 95%	> 95%	> 95%	> 95%
Electrical Requirements	110/220V, 50/60Hz	110/220V, 50/60Hz	110/220V, 50/60Hz	110/220V, 50/60Hz
Power Consumption	2 kW	4 kW	2 kW	4 kW
Air Pressure	7 bar (100 psi)	7 bar (100 psi)	7 bar (100 psi)	7 bar (100 psi)
Dimensions L x W x H	1.9 x 1.7 x 1.8m (73" x 68" x 71")	2.2 x 1.7 x 1.8m (85" x 68" x 71")	1.9 x 1.7 x 1.8m (73" x 68" x 71")	2.2 x 1.7 x 1.8m (85" x 68" x 71")

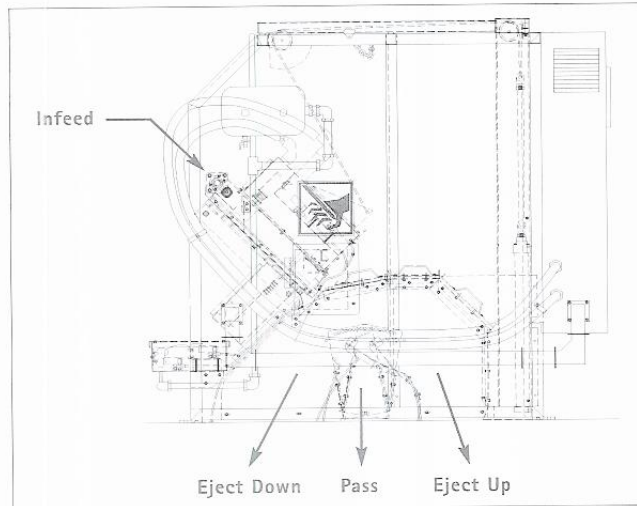
System Description

The screened, vacuumed, and magnetically scalped glass is fed into the module by a stainless steel vibrating feeder. The sensing array identifies the opacity and true color of each glass particle. The computer also activates and controls the precisely metered compressed air pulse to minimize the amount of glass product loss and carry-over during the ejection.

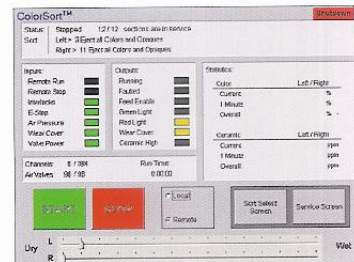
The self-normalizing software compensates for labels and contamination and eliminates the need for an automated cleaning system.

An integral touchscreen provides system diagnostics, sorting statistics, and easy parameter access.

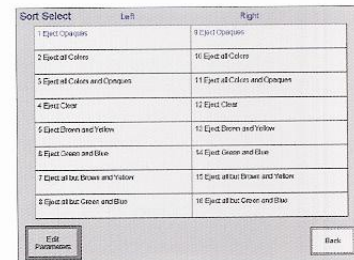
A built-in modem provides for remote diagnostics and monitoring from the factory.



The Dual-Eject Glass ColorSort™ generates three outputs on the standard model, and six outputs on a split machine.



Sorting Statistics are displayed on the main user interface screen.



Sorting programs can be changed by the operator within a few seconds.



Maintenance areas in the Glass ColorSort™ are easily accessible.

