An evaluation of quantification methods for plastics

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ABSTRACT

The objective was to investigate and compare methods for quantifying the concentrations of different plastics in stock samples. Five types of plastics were added to clean, bleached, hardwood pulp stock. The plastics concentrations in the stock samples were 0.10%, 0.50%, 1.0%, and 2.0%, based on the oven-dried weight of the pulp. Samples were processed and analyzed by four quantification methods: image analysis, screening, passage through a hydrocyclone, and vacuum flotation. Screening was the most efficient and reliable method for quantifying plastics.

Application:

As recyclers delve deeper into the waste stream to recover fiber, they will need efficient methods for quantifying the amounts of plastic contaminants in the recycled wastes.

PLASTICS ARE TROUBLESOME contaminants in paper recycling. Plastics not only scratch the sheet but may also cause breaks in the pressing and drying section if they are not removed from the sheet *(1)*. These contaminants are difficult to detect and remove from recovered stock. The need to measure plastics content and then to remove the plastics poses a technical dilemma in paper recycling.

To measure the concentrations of plastic contaminants in wastepaper pulps, technicians need quantification methods that yield accurate and reproducible results through trials that are readily performed. At present, no one method has been widely accepted or adopted for quantifying plastics. Several reports have been published on various techniques for quantifying stickies *(2-5)*, and one report has been published on quantifying plastics *(6)*. A number of factors contribute to the complexity of finding a method that would gain wide acceptance. The many grades of wastepaper contain heterogeneous and ever-changing contaminants, and the many paper grades made from wastepaper vary in tolerance for contaminants. Also, contaminant-measuring methods are used by different groups (such as those engaged in manufacturing, technical service, or equipment development), and each group has different measuring requirements.

We investigated different methods for quantifying plastics. To limit variability, we used clean, white hardwood pulp and controlled the amount, size, and types of plastic contaminants added. Of course, the size of the contaminants did not reflect the wide range of sizes found in wastepaper mill furnishes. However, our focus was on comparing the quantification methods, and using a standard size of contaminants helped in comparing the methods.

METHODS

Preparation

The stock consisted of dried, bleached hardwood pulp provided by James River Corporation. Sheets were pulped for 45 min at 46°C in a 50-L Voith pulper at 12% consistency.

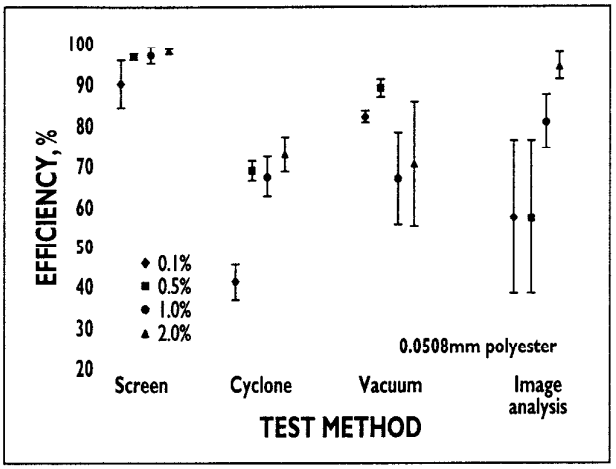
The plastic films used were 0.051-mm polyester, 0.051 mm high-density polyethylene (HDPE), 0.127-mm polyvinyl chloride (PVC), 0.127-mm polystyrene, and 0.076-mm polyacetate. Films were disintegrated by a hammermill with the accepts passing through a 6.35-mm screen. The hammermill was equipped with a rotating set of stainless-steel bars that were 76.20 mm long and 6.35 mm thick.

The shredded plastic samples were fed through a shaker, which is a series of stacked vibrating screens. The screens were allowed to vibrate for 10 min for each plastic sample. The samples were then collected between the screen with holes measuring 4.76 mm in diameter and the screen with holes that were 3.18 mm in diameter. As a result, all the plastic material added to the stock samples was relatively uniform in size. Again, this relatively selective size range was used to make it easier to compare the various quantification methods.

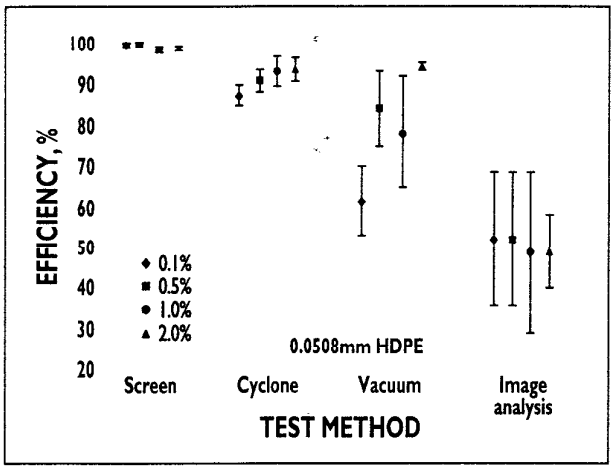
Stock samples were prepared at 0.10%, 0.50%, 1.0%, and 2.0% concentrations based on the oven-dried weight of the pulp. Samples were analyzed in triplicate by four quantification methods: screening, passage through a hydrocyclone, vacuum flotation, and image analysis. For each method, the mean and standard deviation were calculated. The error bars in the figures reflect the 95% confidence intervals of the measurements.

Screening

Each stock sample at 12% consistency totaled 0.454 kg of oven-dried pulp with a known concentration of oven-dried plastic. Samples were mixed by an air-induced agitator for 3 min and were added to a 0.15-mm slotted valley screen. The screen, which vibrates, was allowed to operate until the pulp passed through it. The material retained on the screen, consisting of plastic only, was collected by being washed into a bucket with water. The collected



1. Efficiencies of the five methods using different concentrations of polyester.



2. Efficiencies of the five methods using different concentrations of HDPE.

sample was filtered and dried in an oven to remove all residual water.

Passage through a hydrocyclone

Fifteen liters of stock sample at 0.30% consistency were prepared for each plastic sample at each test concentration. The stock was pumped through a 25.4-mm-diameter hydrocyclone at a pressure of 414 kPa. The overflow, which contained plastics and fiber, was collected in a washbox. A 0.15-mm slotted screen was used to separate the plastics from the fiber. Collected plastics were dried as described, and the removal efficiency of the hydrocyclone and screening system was determined.

The efficiencies for the hydrocyclone were corrected for any plastic lost as a result of using the slotted screen as a separator. This correction was made by applying the efficiency of the screen determined in the previous test for each particular plastic in a material balance of the hydrocyclone-screen system. Thus, the efficiency of the hydrocyclone itself was reported.

KEYWORDS
Bleached pulps, contraries, evaluation, hardwood pulps, plastics, quantitative analysis, reclaimed fibers, recycling, screening, stickies, test methods, waste papers.

Vacuum flotation

Three liters of stock sample at 0.30% consistency were added to a conical flask containing the concentration of the plastics under investigation. After the sample was stirred, a vacuum was applied. The sample was allowed to stand for 1 h. Vacuum was used to remove the bottom two-thirds of the sample. The top one-third, which contained the light contaminants, was collected to a washbox.

Collected solids were added to the 0.15-mm slotted screen and were collected and dried. The efficiencies were corrected for any plastic lost while using the slotted screen as a separator, as was done for the hydrocyclone.

Image analysis

High-resolution image analysis was performed with a Cambridge Instruments Quantimet 970. Five handsheets for each concentration of plastic were prepared for the analysis. The handsheets were analyzed on both sides, with six fields per side. The handsheets (60 g/m^2) were prepared according to TAPPI Test Method T205 *(7)*.

RESULTS AND DISCUSSION

Screening

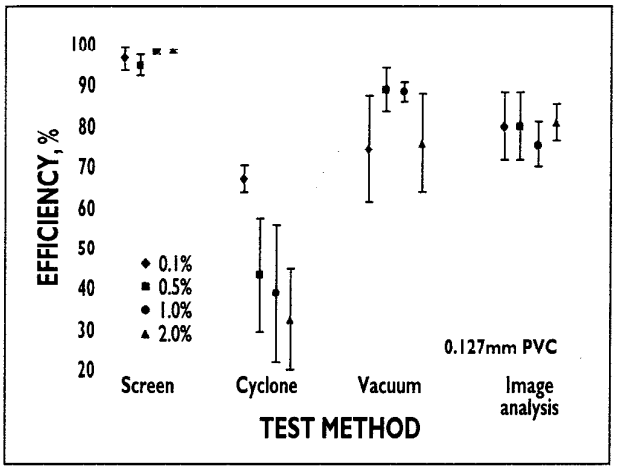
As a quantifying method, screening relies on the shape and size of the material that is being measured. This method is a common industry practice for concentrating and quantifying contaminants *(8)*.

In the initial runs, the screen was observed to quantify 90% or more of most of the plastics tested, as shown in **Figs. 1–5**. The low standard deviations indicate that the method has good repeatability between the replicate tests that were performed. The figures show a slight increase in performance at the higher plastics concentrations, which could be caused by the formation of a mat on top of the screen. With increasing concentration of plastics, the mat increased in size, thus increasing screen retention.

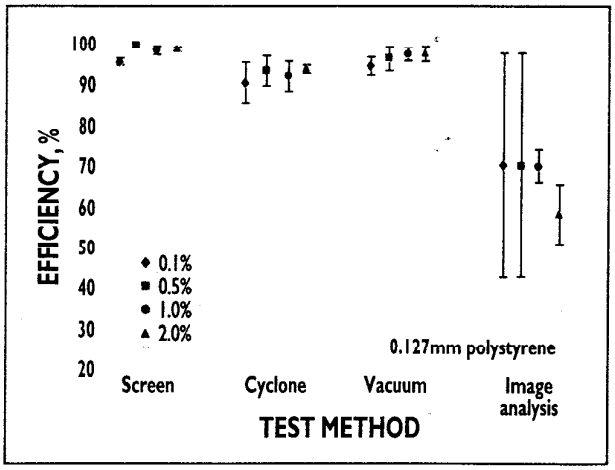
One material that was difficult to screen was polyacetate. The recovery was below 65%--on the high end of the mean for all concentrations studied (Fig. 5). Polyacetate was less rigid than the other samples at room temperature. We postulate that this property of polyacetate must have allowed it to slide through the slots of the screen, resulting in low screening capacity. However, the screening rejects were not analyzed for the uncollected plastic material.

Passage through a hydrocyclone

The hydrocyclone could be used as a quantifying method because it is able to use density differences to separate material. The samples used to investigate this equipment consisted of a fixed size and density.



3. Efficiencies of the five methods using different concentrations of PVC



4. Efficiencies of the five methods using different concentrations of polystyrene.

The hydrocyclone performed exceptionally well for the HDPE and polystyrene samples. This result was expected because the specific gravity of these materials is nearly equal to or less than that of water. The HDPE and polystyrene were recovered in the light fraction of the collection, where at least 90% of the plastic material was concentrated, as shown in Figs. 2 and 4. The other plastic samples were primarily collected in the heavy fraction of the collection as a result of their greater specific gravities. The performance of the hydrocyclone was not as good for these samples as it was for the two lighter plastics studied. The specific gravity values of the plastic samples are listed in **Table I**.

For all plastics, recovery rates may have been hindered by the consistency of the pulp samples. Doshi found that any consistency above 0.10% may be too high and may influence the performance of the hydrocyclone *(8)*. Our use of a higher consistency may have decreased the quantification of the plastics under investigation. Repeating the experiment at a lower consistency of 0.1% would probably result in more accurate quantification.

Vacuum flotation

Like the hydrocyclone, vacuum flotation uses density differences to separate and concentrate contaminants. The specific gravities in Table I suggest that this method should give good results for polystyrene since it is less dense than water. The results confirmed this assumption for polystyrene at all levels studied, as Fig. 4 shows. The recovery rate was greater than 95%, with low variation between samples, as reflected by the error bars in Fig. 4. The smaller error bars indicate that vacuum flotation is very repeatable when used as a quantifier for this plastic material.

In all cases, the accepts were the light fractions that were collected. In cases where the plastics tend to be more dense than the water, the bulk of the plastic would be expected to be in the heavy fraction. However, the large variations and the large amount of material in the light fraction for the other plastics indicate that the separation of plastics by density is not "clean."

Image analysis

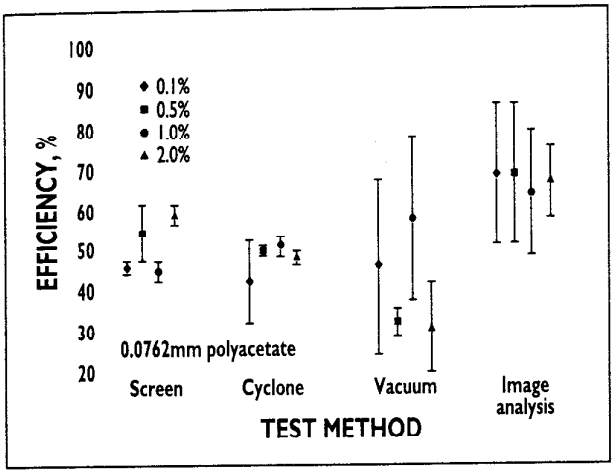
Recent studies have focused on image analysis as a quantification and characterization method for contaminants *(9)*. Because the level of detection and the size of materials detected can be adjusted, this method is regarded as more accurate than methods that use mechanical separations.

We found the performance of the image analyzer to be the poorest of all the methods studied in regard to detecting the amount of plastic known to be in the pulp (Figs. 1-5). One disadvantage is the lack of uniformity for calculating results. The results were calculated by fixing the *actual* concentration of the plastics that should have been on the test handsheets, which relies on the assumption that the initial concentration of plastic had not changed. However, some plastic could have been lost during the preparation of the handsheets.

Furthermore, some plastics were embedded in the handsheet webs and were thus difficult to detect via image analysis. Also, variations in backlighting may have affected the detection of the contaminants. It may be possible to avoid some of these problems by preparing and using handsheets of lower grammage.

CONCLUSIONS

The most effective method for quantifying plastic contaminants, with the exception of polyacetate, is screening. For four of the five plastics, more than 90% of the material was quantified using this method. The advantage of the hydrocyclone is that it can be operated continuously with on-line devices. It can handle high- and low-density materials reliably, and the operator can define the accepts fraction based on the plastic being quantified. Vacuum flotation is somewhat



5. Efficiencies of the five methods using different concentrations of polyacetate.

time-consuming, and it produces results with high variation between samples.

Unlike the other methods, image analysis can provide particle size distributions of contaminants. However, the disadvantages of this technique are in the preparation required (handsheets need to be made) and in the need to correlate the analysis with the amount of plastic in the pulp.

Finally, only bleached hardwood pulp was used as the stock in this study. The presence of longer fibers, or a combination of long and short fibers, may have a dramatic effect on the efficiencies of the quantification methods studied. Similar future studies could be focused on the effect of the furnish—hardwood versus softwood—on the separation efficiency. **TJ**

Plastic	Specific gravity
Polyester	1.85
HDPE	1.06
PVC	1.21
Polystyrene	0.88
Polyacetate	1.18

I. Specific gravity of plastics

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