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# RECYCLABILITY OF LINERLESS PSA STAMPS

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## ABSTRACT

Pilot-scale separation sequences were used to assess the recyclability of postage stamp material. Several different levels of pressure-sensitive adhesive (PSA) stamp material were investigated. The process involved preparing the paper stock, removing contaminants, and measuring contamination level throughout the process. Stock was prepared by shredding and high consistency pulping, which involved diluting the pulp, screening, cleaning, flotation deinking, and washing. The efficiency of contaminant removal was evaluated by dirt count of dyed handsheets. The results indicated that the linerless stamped material could be pulped to free the pulp fiber from the adhesive and ink. The release coating in the material did not cause any problems and could not be detected. Much of the ink was removed in the forward cleaner, which is typical of inks with a density greater than that of water. Conventional screening and cleaning processes were satisfactory for reducing the adhesive levels in the material. However, high levels of contamination required additional processing steps. Future work will include investigations into new technologies such as the use of enzymes and high-shear field separations.



## INTRODUCTION

As the need for recycling of paper increases. the quality and type of paper being recycled will significantly change. An increase in the overall level of paper recycling will require the utilization of less homogeneous and lower quality wastepaper sources. One such source is mixed paper, which contains a variety of paper types. Some of these papers—corrugated paper, newsprint, and office paper—are often sorted out by consumers. Certain other types of paper, such as postage stamps, are concentrated in the remaining mixed paper. The effects of these papers on the recycling process and the quality of the final pulp and paper products have not been well studied.

In 1989, the U.S. Postal Service (USPS) and industry collaborated on specifications for pressure-sensitive adhesive (PSA) postage stamps. The specifications state that the stamps must (a) adhere strongly to the envelope, (b) be repositionable in the first 10 s after application, (c) be resistant to humidity and temperature changes, (d) be capable of being archived for about 5-10 years, (e) prevent the adhesive from bleeding through to the stamp face, (f) be water-removable for recyclability, and (g) be easy to peel off, but not come off by themselves.

By 1994, the demand for PSA stamps had risen dramatically because they are convenient and easy to use, more sanitary than lick-and-stick stamps, not affected by humidity, and adhere well to various envelope materials. However, environmental concerns have been raised regarding the recyclability of PSA stamps. The PSAs contribute to the formation of stickies during the recycling process. Stickie contaminants impede the effectiveness of papermaking equipment and have a negative effect on the quality of the paper.

The work reported here was part of an initial study to evaluate the recycling potential of linerless PSA postage stamps. The U.S. Department of Agriculture Forest Service, Forest Products Laboratory (FPL) and the USPS recently signed an interagency Cooperative Research and Development Agreement (CRADA) through which the FPL will conduct research and pilot plant runs in the area of recycling and repulping of USPS materials. These materials include papers coated with PSAs. undelivered business bulk mail, holographic papers, labels, and tape. In addition, the FPL will test and evaluate USPS papers. This information will be useful for developing a strategy for removing PSA from the pulp during deinking operations.

## BACKGROUND

Although the amount of used postage stamps is small compared to the amount of wastepaper recycled in the United States, the rate of wastepaper recycling can be increased by new technology for removing adhesives and inks from stamps in the recycling process. A research and development effort of this kind provides Federal agencies with a special opportunity to address their agency objectives while advancing the field of wastepaper recycling.

Overcoming the major barriers of removing synthetic adhesives (stickies) and ink (deinking) requires research in contaminant separation technology. The specific needs are as follows:

- New process configurations for contaminant separation equipment, such as equipment that relies on force fields other than gravity.
- Knowledge about and control of interracial phenomena; for example, development of an instrumental technique for studying fluid-solid interfaces.
- More energy-efficient contaminant separation technology; for example. reducing energy use by combining processes.

The FPL has a background in contaminant separation research that includes the development of equipment and biotechnology applications.

## EXPERIMENTAL PROCEDURE

Seven trials were performed. each with a different furnish. Each trial consisted of a series of processing steps: high-consistency pulping, screening through 0.3-mm (0.012-in.) slots to remove large particles, 76-mm (3-in.) forward centricleaning to remove high density particles, one to two stages of flowthrough centricleaning to remove low density particles, flotation deinking in a 90-L laboratory-sized cell to remove residual ink, and washing using a 70-mesh, 60° sidehill screen to remove ash and very small particulate. A flowchart of this process and sampling points are shown in Figure 1. Test equipment is described in Table I. Details of each processing step are described in the following text.

### Stamp and Paper Preparation

The USPS supplied eight rolls of PSA linerless stamps for the trials: seven rolls with adhesive and one roll without adhesive. The stamps consisted of the stamp paper, printing ink, pressure-sensitive adhesive, and release coating. The purpose of the release coating is to prevent the stamps from adhering to underlying stamps in the linerless coil.

All rolls were shredded upon receipt into 6.4-mm (0.25 -in.) width by feeding random lengths (about 30 to 38 cm [12 to 15 in.]) into a heavy-duty shredder. Commercial business envelopes with one stamp each were similarly shredded in a post-consumer-use trial. The stamp material was diluted to the proper concentration by adding shredded commercial copy paper. This paper was selected since it contains fillers and is similar in composition to envelopes. Since flotation is affected by filler content, material for "preconsumer" trials would have the same approximate filler level as that for "post-consumer" trials. Stamp concentrations used in this study are shown in Table 11.

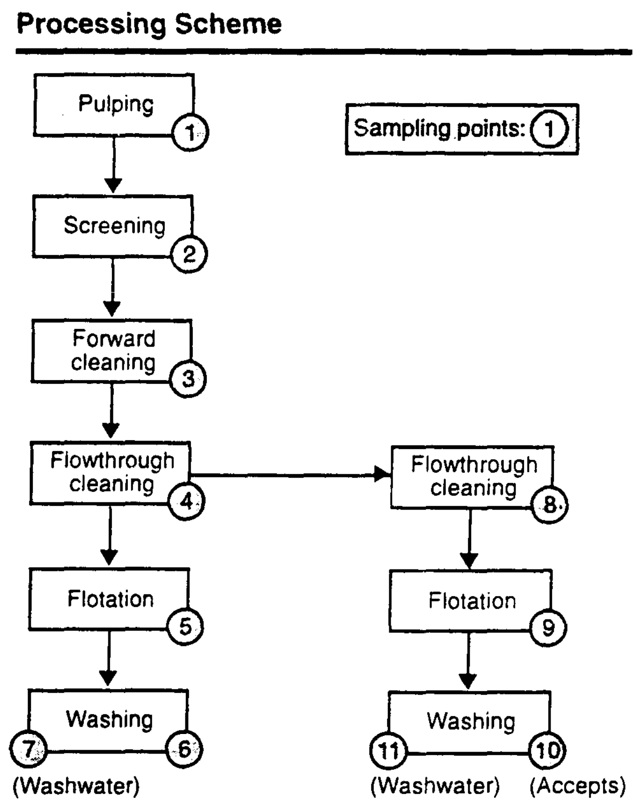


Figure 1. Flowchart of test process.

Table I. Equipment for separation trials

| Equipment | Manu-facturer | Description |
|---|---|---|
| Pulper | Voith | High consistency, laboratory-type, model HD-0.05 |
| Flatscreen | Impco | Atmospheric, 6-plate bronze vat |
| Forward cleaner | Bauer | 76-mm (3-in.), model 600-N, 0.3-mm (0.125-in.) tip opening |
| Flowthrough cleaner | Black-Clawson | 76-mm (3-in.), X-clone |
| Flotation unit | Denver | 90-L, laboratory-type, model no. 8 |
| Sidehill screen | FPL | 70-mesh |

### Pulping

Nine to 12 batches of feedstock were pulped per trial to provide sufficient pulp for the subsequent cleaning steps. The target pulping time was 10 min per batch. However, when feedstocks included adhesives (Trials 4–7), 20 min of

Table II. Feedstock for trials

| Trial | Stamp content: Type | Stamp content: Amount (%) | Copy paper content (%) |
|---|---|---|---|
| 1 | — | — | 100 |
| 2 | Nonadhesive stamps | 20 | 80 |
| 3 | Stamped envelopes | 30 | 70 |
| 4 | Stamps | 10 | 90 |
| 5 | Stamps | 20 | 80 |
| 6 | Stamps | 10 | 90 |
| 7 | Stamps | 5 | 95 |

pulping was required to achieve adequate disintegration. Each batch contained 5 kg (0.11 lb) paper (air dry) in 50 L total volume (10% consistency). Pulping was performed at 49°C (120°F) and pH 10. Each trial was conducted on the same day as the repulping to minimize any degradation caused by soaking at high pH.

### Screening

After pulping, the blended shiny from the batches was diluted to about 4% consistency for pumping purposes. The temperature was maintained at the pulping temperature (49°C [120°F]) target level. After thorough mixing, a sample was saved for handsheet preparation (Sample 1). The slurry was then pumped to the flatscreen where it was further diluted using about 49°C (120°F) water. Accepts passing through the 0.3-mm (0.012-in.) slots were pumped to a stock tank and diluted to about 0.70%–0.75% consistency at about 49°C (120°F). A 4-L sample of the accepts was saved (Sample 2).

### Cleaning

The 0.70%–0.75% consistency stock was sent to the forward cleaners in parallel at a feed pressure of 276 kPa (40 lb/in$^2$) and back pressure of 93 kPa (13.5 lb/in$^2$). Rejects (3.2-mm [0.125-in.] tip opening) were collected and drained in a screenbox. Accepts were passed to a 600-L (150-gallon) surge tank and then pumped through the flowthrough cleaner at a feed pressure of 207 kPa (25 lb/in$^2$) and back pressure of 69 (10 lb/in$^2$). Rejects (16 mm [0.625 in.] core diameter) were collected and drained in a screenbox. Accepts were pumped to a stock tank where the entire batch was thoroughly blended and a 4-L sample saved (Sample 4). Since the surge tank between the two cleaners could not hold the entire batch, a 10-L sample was collected from the flowing stream of accepts after the cleaner was ruining for about 5–10 min and was at thermal equilibrium (Sample 3). This was the accepts sample for the forward cleaner, and it was assumed to be representative of the entire batch.

After Trial 4, it appeared that the flowthrough cleaner was overloaded with adhesive. We decided that a second pass through the flowthrough cleaner would considerably reduce the residual adhesive in the accepts from this stage. Trails 5, 6, and 7 had two passes through the flowthrough cleaner. A 4-L sample was collected after each pass (Samples 4 and 8).

### Flotation and Washing

When the accepts from the first pass through the flowthrough cleaner were completely mixed, a 70-L sample of the stock was transferred to the laboratory flotation unit. A flotation aid (Hercules DI-600) was added at a rate of 0.2% weight on dry fiber and thoroughly mixed. The pulp was aerated for 10 min, and foam was removed by simple overflow and then manually using a scraper blade. After aeration and mixing, a sample of the cleaned slurry was taken (Sample 5). The remaining stock was allowed to slowly flow by gravity from the same bottom drain to a 70-mesh, 60° laboratory sidehill screen where free drainage removed water and small particulate. Sidehill accepts were saved (Sample 6) as well as a 10-L sample of the washwater rejects (Sample 7). As indicated, each trial had two passes through the flowthrough cleaner. The accepts were subjected to the flotation and washing steps after both the first and second passes (Fig. 1). Samples 8–11 were collected after the second pass.

### Particle Analysis

Standard handsheets were made according to Tappi T 205. Sheets were conditioned to standard Tappi conditions and dyed with a solution of hexane and Morplas Blue 1003 to highlight the contaminants. The sheets were then evaluated for dirt count using an Optimax Speckcheck, which uses a Hewlett Packard ScanJet IIc flatbed 400-dpi scanner connected to a Dell 486 computer. The particles ranged from 0.02 to 5.0 mm$^2$, the same range as that used on the standard Tappi dirt count (T 437 om-90). These results are reported in Table III as parts-per-million based on area. Table IV shows the number of specks counted in five size ranges, including those smaller than the standard Tappi range. For the purposes of discussion, we assumed that particles smaller than 0.02 mm$^2$ were ink particles.

## RESULTS

This section describes the results of each trial. General conclusions drawn from these results appear in the final section.

### Trial 1. Control, 100% Paper

The control trial represented the amount of dirt and other contaminants present in the copy paper used as dilution for

Table III. Total concentration of contaminants in pulp

| Trial | Contaminants (ppm) per sampling point 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 37 | 35 | 44 | 63 | 33 | 48 | — | — | — |
| 2 | 56 | 16 | 8 | 36 | 53 | 17 | — | — | — |
| 3 | 164 | 123 | 130 | 49 | 30 | 14 | — | — | — |
| 4 | 3,570 | 2,430 | 3,330 | 1,530 | 643 | 706 | — | — | — |
| 5 | 5,610 | 3,130 | 4,353 | 2,750 | 692 | 743 | 968 | 203 | 191 |
| 6 | 2,340 | 2,050 | 2,890 | 3,747 | 425 | 524 | 660 | 198 | 262 |
| 7 | 1,440 | 881 | 1,110 | 684 | 412 | 563 | 418 | 250 | 91 |

the stamp stock. Since this paper is presumed to be cleaned to the appropriate standards, we expected little effect from processing. As shown in Table IV, there was little change in the number of specks at all levels. At the smallest level (ink), the number of specks ranged from 181 to 317, averaging 250 specks per 10 sheets. Likewise, for the next two size ranges, the number of specks did not change appreciably, averaging 87 and 11 for the 0.02-0.1 $mm^2$ and 0.1–1.5 $mm^2$ ranges, respectively. An average of less than three larger particles were present in each of the two larger ranges. On an area basis, 33 to 63 ppm of specks occurred in the 0.02-5.0 $mm^2$ range (Tappi dirt count range), with an average of 43 ppm. These values represent the background dirt that must be subtracted from the other samples with stamped material that contain ink, adhesive, and release coating. We assumed that there were no stickies in this sample and that all the particles detected were probably dirt or ink specks.

In a recent report [1], the specifications for dirt and stickies in commercial deinked market pulp are <20 ppm dirt in the same size range and <150 $mm^2$/kg stickies. However, the methods for measuring dirt and stickies have not been standardized. Therefore. we must measure the dirt and stickies that we consider to be allowable and compare our measurements to published specifications and target specifications. Assuming that each stickie weighs about 1 mg, then the stickie specification is <150 ppm. Assuming that our bond paper control sample was satisfactory in dirt count, then our value of 43 ppm should translate to at least as good as the <20-ppm specification recently published.

**Trial 2. 20% Stamps, 80% Paper**

The sample for Trial 2 was similar to the control except that 20% stamped material without adhesive was substituted for the bond paper. The contaminant added to this trial was ink and release coating. After screening and cleaning (sampling point 3). the sample was as clean or cleaner (in terms of dirt count) than the control at the final sampling point. The screen was effective in removing small particles of materials, which were possibly ink attached to the release coating. The cleaner further removed small particles, which were possibly ink. In any case, after screening and cleaning, the speck levels were reduced to below that of the control. We expected that the cleaner would be able to remove the ink specks because of their high density. Apparently, either the release coating was attached to the ink and removed with it or the release coating particles became so small that they were not detectable. The release coating did not appear to be a problem.

**Trial 3. Stamped Envelopes**

Trial 3 consisted of 30% envelopes with one stamp per envelope. The resulting concentration was 0.35% stamped material on a dry solids basis. We did not expect to observe much difference between this trial and the control. However, after the flotation process, the number of small particles was lower than that of the control. The adhesive in the stamped material apparently acted as a scavenger for the small particles, and these particles were removed by flotation. The result was that the dirt count in the final sampling point for the Trial 3 sample was lower than that for the control at the final sampling point.

**Trial 4. 10% Stamps, 90% Paper**

Trial 4 contained 10% by weight postage stamp material. As expected, the initial dirt count after pulping was much greater than that of the control. Two separation processes were effective in reducing the number of specks. The cleaner removed significant specks, especially in the <0.02 and 0.02–0.1 $mm^2$ ranges. Particles larger and smaller than these were not removed. The final number of specks for this sample was much greater than that for the control and was unacceptable for both ink and adhesive levels.

### Trial 5. 20% Stamps, 80% Paper

Additional processing was included for this trial through the addition of a second flowthrough cleaner step. The subsequent processing steps, flotation and washing, were conducted after a single pass and after two passes through the flowthrough (see Fig. 1). As expected, the initial sample after pulping was very high in particle count. As in Trial 4, the cleaner and flotation steps were very effective in reducing particle counts. After the first six steps, Trial 5 resulted in particle counts similar to that of Trial 4, even though the stamp level was double for Trial 5, The additional removal steps resulted in particle counts somewhat similar to that of the control in the smaller particle size ranges, but higher particle counts in the higher size ranges. The final dirt count was 191 ppm, compared to 48 ppm for the control. The dirt count at sampling point 6, with only one flowthrough cleaning pass, was 744 ppm. The reduction in dirt count resulting from additional processing suggests that more separation processing of this type would further reduce particle counts. Additional separation processing is standard for mills that produce printing and writing grades of paper from recycled wastepaper.

### Trial 6. 10% Stamps, 90% Paper

Reducing the level of stamped material from 20% to 10% (dry basis) did not change the results of the particle counts between Trials 5 and 6. The dirt count was 524 ppm at sampling point 6 and 262 ppm at the final sampling point. Again, further processing is indicated.

### Trial 7. 5% Stamps, 95% Paper

Reducing the stamped material from 10% to 5% (dry basis) resulted in particle counts similar to that of the control. Ink and adhesive levels were both reduced to that of the control. Trial 7 resulted in satisfactory removal of contaminants. However, the trial required an additional pass . through the flowthrough cleaner.

## CONCLUSIONS

This study established pilot-scale separation sequences for assessing the recyclability of postage stamp material. Tests involved preparation and processing of paper stock and measurement of contaminants during processing. The significant results were as follows:

- For the stamped material. pulping freed the fiber from adhesive and ink. The release coating was not detected; it probably was released separately or with the ink. The release coating does not appear to cause any problems.
- Much of the ink was removed in the forward cleaner. This is typical for inks with densities greater than that of water.
- Adhesive levels were satisfactorily reduced by conventional screening, cleaning, and flotation processes. Flotation was especially effective for removing adhesive particles in the mid-size range.
- Conventionally available equipment removed ink and adhesive materials from the wood pulp slurry. At high levels of contamination, additional sequences were required for removing contaminants, but this is typical for any contaminated wastepaper pulp.

The trials and data analysis could be enhanced in several ways. First, the sheets could be measured for optical properties and brightness before they are dyed. In our trials, the inks were assumed to be the smaller particles in the speck check data. This speck check analysis was conducted after the sheets (fibers) were dyed to provide contrast with the contaminant particles. Measuring optical and brightness properties prior to dying might provide a better indication of the amount of ink. Second, the data could be used to develop models. The information gathered here for single passes through the system could be used to model systems that have multiple stages of each operation as well as water recycling. The data could be used to extrapolate the findings to conditions found in a production facility.

Another possibility is to develop a stamped material that would be an example for manufacturers of synthetic adhesives that are used for paper and paperboard applications. For example, the Forest Products Laboratory, as well as many other laboratories, is currently developing technology for using enzymes for deinking wastepaper. Recycling of stamped material could be simplified by incorporating a small amount of water-insoluble enzyme-labile material in the adhesive portion of the stamped material. If successful, this development could point the way for reducing a major technical barrier facing paper manufacturers who recycle wastepaper.

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Table IV. Dirt counts

| Trial | Sampling point | Number of specks per 10 sheets | | | | |
|---|---|---|---|---|---|---|
| | | <0.02 mm² | 0.02–0.1 mm² | 0.1–1.5 mm² | 1.5–5.0 mm² | >5.0 mm² |
| 1 | 1 | 240 | 89 | 7 | 0 | 4 |
| | 2 | 203 | 80 | 12 | 0 | 5 |
| | 3 | 249 | 91 | 12 | 0 | 1 |
| | 4 | 305 | 110 | 11 | 2 | 0 |
| | 5 | 181 | 63 | 11 | 0 | 2 |
| | 6 | 317 | 87 | 16 | 1 | 4 |
| 2 | 1 | 5,252 | 244 | 13 | 0 | 2 |
| | 2 | 637 | 46 | 5 | 0 | 0 |
| | 3 | 86 | 26 | 2 | 0 | 3 |
| | 4 | 286 | 57 | 12 | 1 | 1 |
| | 5 | 299 | 78 | 10 | 1 | 4 |
| | 6 | 193 | 53 | 5 | 0 | 0 |
| 3 | 1 | 299 | 88 | 26 | 6 | 3 |
| | 2 | 274 | 71 | 27 | 4 | 1 |
| | 3 | 179 | 58 | 21 | 4 | 2 |
| | 4 | 357 | 68 | 27 | 0 | 3 |
| | 5 | 56 | 34 | 18 | 0 | 0 |
| | 6 | 63 | 32 | 3 | 0 | 2 |
| 4 | 1 | 4,724 | 897 | 383 | 126 | 64 |
| | 2 | 6,957 | 1,026 | 317 | 77 | 31 |
| | 3 | 506 | 347 | 413 | 116 | 30 |
| | 4 | 380 | 242 | 234 | 47 | 7 |
| | 5 | 307 | 99 | 41 | 20 | 5 |
| | 6 | 405 | 143 | 55 | 26 | 3 |
| 5 | 1 | 10,612 | 1,661 | 601 | 194 | 152 |
| | 2 | 6,705 | 969 | 441 | 98 | 32 |
| | 3 | 707 | 398 | 602 | 147 | 45 |
| | 4 | 819 | 357 | 439 | 85 | 13 |
| | 5 | 444 | 118 | 61 | 27 | 10 |
| | 6 | 386 | 109 | 52 | 35 | 14 |
| | 8 | 923 | 286 | 183 | 28 | 7 |
| | 9 | 381 | 89 | 16 | 7 | 4 |
| | 10 | 303 | 80 | 25 | 4 | 3 |
| 6 | 1 | 5,063 | 546 | 259 | 82 | 75 |
| | 2 | 2,949 | 414 | 258 | 70 | 18 |
| | 3 | 424 | 242 | 311 | 103 | 33 |
| | 4 | 507 | 273 | 361 | 129 | 36 |
| | 5 | 363 | 131 | 30 | 14 | 10 |
| | 6 | 301 | 99 | 37 | 24 | 7 |
| | 8 | 302 | 133 | 99 | 24 | 3 |
| | 9 | 679 | 220 | 65 | 3 | 5 |
| | 10 | 394 | 170 | 49 | 8 | 6 |
| 7 | 1 | 1,505 | 242 | 122 | 56 | 49 |
| | 2 | 2,656 | 358 | 107 | 17 | 10 |
| | 3 | 466 | 187 | 118 | 30 | 8 |
| | 4 | 292 | 101 | 99 | 20 | 2 |
| | 5 | 267 | 74 | 16 | 21 | 7 |
| | 6 | 196 | 54 | 28 | 27 | 6 |
| | 8 | 336 | 117 | 78 | 12 | 3 |
| | 9 | 799 | 151 | 21 | 6 | 4 |
| | 10 | 375 | 76 | 11 | 2 | 7 |