ENVIRONMENTALLY BENIGN LINERLESS SELF-ADHESIVE COIL STAMPS: R&D AND RECYCLING STUDIES

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ABSTRACT

The USPS sells billions of stamps every year to consumers, small businesses and bulk mailers; currently these stamps are predominately self-adhesive, on a liner (over 82%). For stamp users, these self-adhesive stamps on a liner have been easy and quick to use, and have offered consistent adhesion. For recyclers, however, these adhesive stamps have caused concern for their paper recycling processes. In addition, there is the issue of the stamp construction which consists of a liner which may not be recyclable (the USPS estimates there is 60-65 billion square inches of liner used in PSA stamps annually).

Under an R&D contract with the USPS, 3M has developed an "Environmentally Benign Linerless Self-Adhesive Coil Stamp". This stamp construction is similar to a roll of tape in that it is coiled and has no liner. In addition, the adhesive was specifically formulated so that it would not interfere with the paper recycling process. This paper will offer information on the development of the linerless self-adhesive coil stamps, and the recycling studies performed during this development.

I. INTRODUCTION

3M has investigated and developed many different types of adhesives used in a whole range of products, and is a recognized leader in the adhesives industry. Therefore the USPS contract to develop an "environmentally benign" linerless self-adhesive coil stamp, one that would not adversely affect the environment or interfere with recyclers and repulpers, presented a wonderful challenge. The product that was developed is very similar to a roll of adhesive tape; it is coiled, with no liner.

II. DEVELOPMENT OF THE ENVIRONMENTALLY BENIGN LINERLESS SELF-ADHESIVE COIL STAMP

a. USPS Research and Development Contract

The linerless self-adhesive coil stamp was developed under R&D contract with the United States Postal Service. This new stamp was introduced at the MEGA Stamp Event in New York City, New York on March 14, 1997, and test marketed in 14 Northern Virginia Post Offices immediately following the introduction. In an independent market research study it was found that consumer response to the new

linerless stamp is very positive, partially because of the linerless feature of the product, which is perceived as more "environmentally friendly" to the consumer.

b. Adhesive Evaluation Approach

Three different classes of adhesives were investigated, all of which are currently used in existing products. These three classes are:

1. Water Insoluble Adhesives
2. Water Soluble Adhesives
3. Dispersible Adhesives

Water insoluble adhesives are hydrophobic in nature and tend to agglomerate in the repulping process and do not typically associate to any great extent with the paper fibers. Many water insoluble adhesives will break up into a wide distribution of particle sizes, resulting in some adhesive particles being large enough to be removed in the screening process and some being small enough to pass through the screening and into the paper stock. Those particles that are not filtered out can still be large enough to cause processing or clean-up problems and imperfections in the formed sheet.

Water soluble adhesives dissolve or break down into very small particles which cannot be filtered out of the wet pulp stream. Some of the solubilized adhesive particles will end up in the formed paper sheet and this is not considered to be a concern to the paper producers, based on decades of sales of successful commercial products. The rest of the solubilized adhesive particles will end up in the effluent: the chemical processing used to treat the effluent has proven to be more than adequate to precipitate the adhesives out of the solution to be discarded.

Dispersible adhesives are particulate adhesives that retain their discrete structure during the repulping process. The adhesive particles are not soluble, and do not agglomerate in the repulping process. The particles are small and cannot be typically captured by filtering techniques. If so additional separation techniques can be utilized (washing, chemical treatment); the particulate adhesive will end up partially in the formed paper sheet and partially in the waste water stream.

Block co-polymers/synthetic rubbers were identified to be the best candidate for the environmentally benign linerless self-adhesive stamp, from the class of water insoluble adhesives.

III. RECYCLING STUDIES OF THE LINERLESS SELF-ADHESIVE COIL STAMP AND CONCLUSIONS

Recycling studies were done both independently of the USPS development contract. and in conjunction with it as well. All studies were made at the Forest Products Laboratory in Madison, WI.

a. Description of Recycling Lots

Table 1. Group I: Independent Recycling Study

Trial#	Description	Stamp Amount (%)	
Control	100% Copy Paper	0	100
1	Stamp Stock (Synthetic Rubber)	5	95
2	Current PSA Stamp (Acrylic)	5	95

• stamp stocks were laminated to Georgia Pacific Ardor Bond paper (approx. 1:1) for processing

Table 2. Group II: Pilot Scale Study

Trial#	Description	Stamp Amount (%)	Copy Paper (%)
1	Control	none	100
2	Non-adhesive stamps (release coating and printing	20	80

	only)		
3	Stamped Envelopes (post-consumer waste)	30 (stamps consisted of 0.35% by wt)	70
5	Linerless Stamps	20	80
4	Linerless Stamps	10	90
6	Linerless Stamps	10	90
7	Linerless Stamps	5	95

Table 3. **Group III: Laboratory Recycling Study of Linerless Stamps**

Trial#	Description	Stamp Ampunt (%)	Copy Paper (%)
100% Copy Paper	100% Copy Paper	0	100
A	Post-Consumer	5	95
A*	Post-Consumer (pulped and screened at higher temp)	5	95
B	Post-Consumer	1.5	98.5
B**	Post-Consumer (pulped at higher temp)	1.5	98.5

Table 4. Group IV: Pilot Scale Recycling Study of Linerless Stamps

Trial#	Description
	copy paper only
106	5% Linerless PSA Stamp Stock
107	5% Linerless PSA Stamp Stock
110	5% Linerless at High Temperature (60 C)
109	Standard PSA Stamp Stock w/out liner
108	Standard PSA Stamp Stock w/liner

Note: Trial 106 and 107 are the same except the second screening for Trial 106 used 0.30 mm slots

b. Recycling Process and Sampling Locations Used for Evaluation

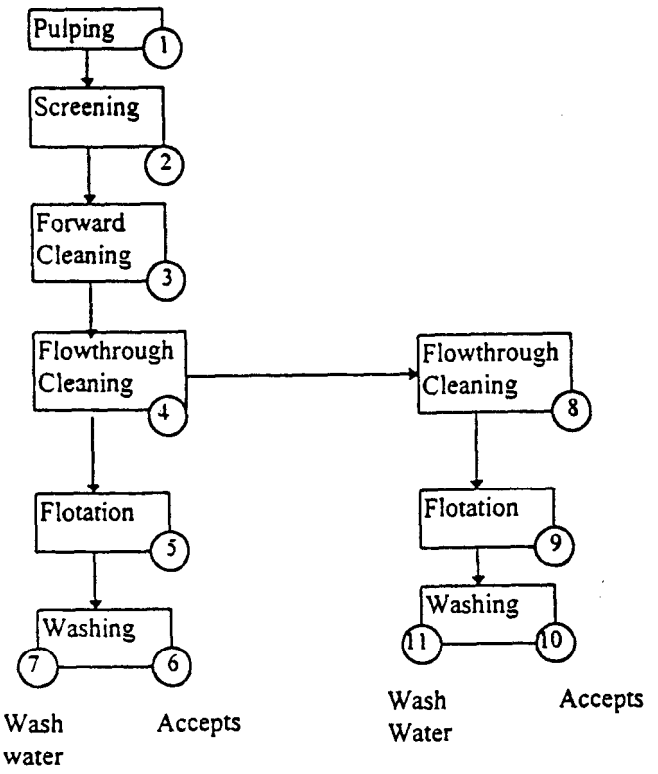


Figure 1.

Notes:

Group I: Independent Recycling Study; these trials only utilized one screening step using a 0.3mm (12-cut) flatscreen; two passes through the Flowthrough Cleaner were made

Group II: Pilot Scale Recycling Study; Trials 1-4 had only one pass through the Flow-through Cleaner; Trials 5-7 had two passes through the Flowthrough Cleaner; all trials had two flatscreening steps, one through the 0.3 mm screen, and a second through a 0.15 mm screen

Group III: Laboratory Recycling studies used two steps of pressure screening; only steps 1 and 2 were utilized in this study (pulping and screening)

Group IV: Pilot Scale Recycling studies used pressure screening

Table 5. Process Conditions:

p H	10
Consistency	10% (14% for Group III)
Temp	120 F (115 F for Group III)
Repulping Time	Until broken up

Table 6. Equipment used for Adhesive Group I and II Studies

Equipment	Manufacturer	Description
Pulper	Voith	High Consistency; Model HD-0.05
Flatscreen *	Impco	Atmospheric 6-plate bronze vat
Forward Cleaner	Bauer	76 mm (3 in) Model 600-N 3.2 mm (0.125 in) tip opening
Flowthrough Cleaner	Black-Clawson	76 mm (3 in) X-clone
Floatation Unit	Denver	90-L Laboratory, Model 8
Sidehill Screen	FPL	70 mesh, 60 degrees

Table 7. Equipment Used for Adhesive Group III Study

Equipment	Manufacturer	Description
Pulper	Adirondack	Model 450H, 1-pound pulper
Pressure Sceen	Valley	flatscreens with 0.30 mm (12 cut) and 0.15 mm (6 cut) slot sizes

Table 8. Equipment Used for Adhesive Group IV Study

Equipment	Manufacturer	Description
Pulper	Voith	High consistency: Model HD-1.5
Pressure Sceen	Voith	Multi-fractor Model 00; baskets with 0.15 mm (0.006 inch) and 0.3 mm (0.012 inch) slots
Flatscreen	Aminco	6-plate vat flatscreen w/0.2 mm (0.008 inch) slotted plates
Forward Cleaner	Bauer	76 mm (3 in) Model 600-N 3.2 mm (0.125 in) tip opening
Flowthrough Cleaner	Beloit	Uniflow HF 100 mm (4 in) nominal diameter
Floatation Unit	LaMort	5000-L 2-stage laboratory cell
Sidehill Screen	FPL	70 mesh. 60 degrees

C. Test Methods Used for Evaluation

Standard handsheets were made with samples at each of the sampling points. according to TAPPI T205. 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 analyzed for dirt count using an Optimax Speckcheck instrument.

d. Results of Different Recycling Lots

Group I

In this study, two commercially available PSA stocks were investigated. The “stamp stock’ sample utilizes the same synthetic rubber-based adhesive used for the linerless self-adhesive stamp construction. The “current PSA stamp” sample is material used for many PSA stamps on the market today; it was found to consist primarily of n-butyl acrylate. The copy paper used in this study was supplied by Georgia Pacific under the trade name Ardor-Xerocopy. The basis weight of this paper is 75 grams/square meter. The two adhesive stamp stocks were laminated onto Georgia Pacific Ardor Bond paper (60#) for easier processing; the adhesive stamp stockbond paper ratio was 51:49.

Samples were shredded to sizes 0.25”-1.0” in width and 103 feet in length. The pulping was performed in a Voith high consistency pulper; pulping time was approximately 30 minutes for each lot of 5 kg of paper stock. During pulping it was apparent that there was some intertwining and/or agglomeration of the synthetic rubber-based adhesive used in linerless PSA stamps. No evidence of agglomeration was observed with the current PSA stock material.

Figure 2 depicts the level of adhesive contamination on a panicle-per- 10-sheet count basis. This data represents only primary (l-time) cleaning through the flow-through cleaner. The synthetic rubber adhesive used in linerless stamps has a count level approximately the same as the control at the steps preceeding the flowthrough cleaning; this level ranges from 100-300 particles per 10 sheets. The current stamp stock has a much higher particle count level prior to flowthrough cleaning with a count basis ranging from 300-1100 particles per 10 sheets. Both adhesives realized a reduction in particle dirt count after going through the secondary flowthrough cleaning (Figure 3); the linerless stamp synthetic rubber adhesive drops to about 100 particles per 10 sheets and the current stamp stock material has a count of approximately 500 particles per 10 sheets. After the whole process, the linerless adhesive has a particle count of 158 and the current stamp stock has a particle count of 435 (control is 120), per 10 sheets. (Data for Figures 1 and 2 can be found in Table 9.

Figure 2.

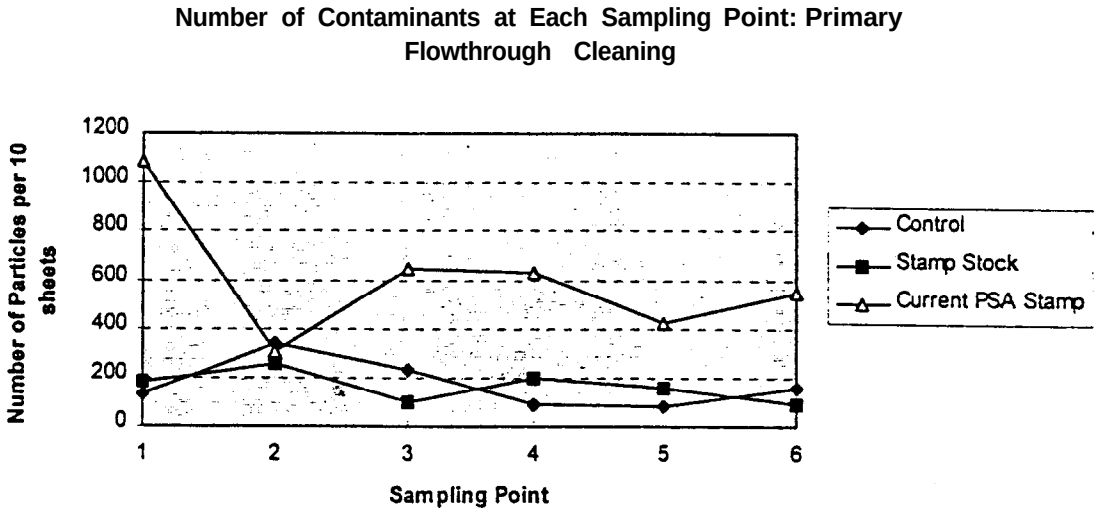


Figure 3.

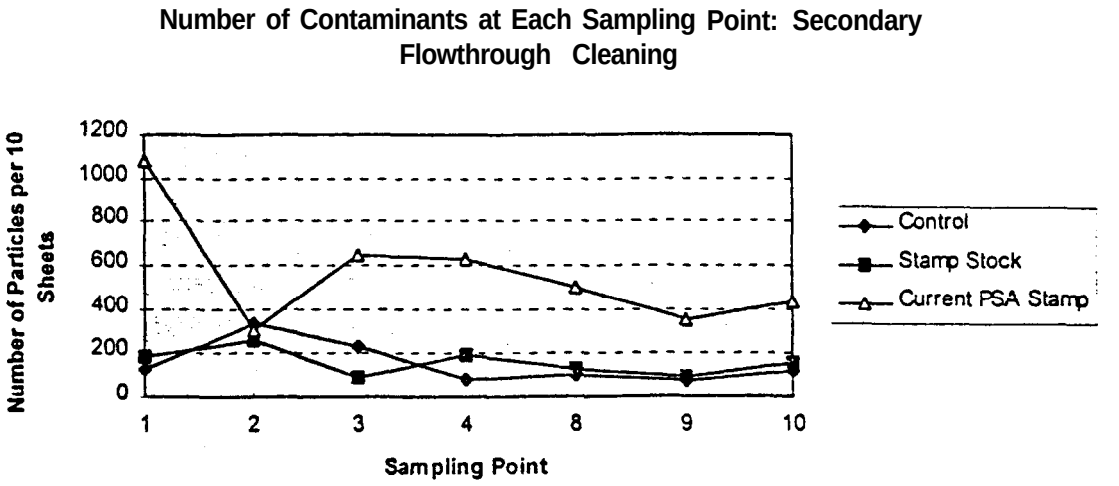


Table 9. Data for Figures 2 and 3

	Sample Collection Point								
	1	2	3	4	5	6	8	9	10
Control	132	336	231	87	85	157	101	74	120
Stamp Stock	186	254	96	195	157	95	125	89	158
Current PSA Stamp	1084	309	649	626	423	549	502	354	435

Group II

In this study, pilot scale sequences were used to assess the recyclability of linerless PSA postage stamp material. Several different levels of PSA stamp material were investigated (see Table 2 above), at both pre-consumer and post-consumer waste levels. All material was shredded into 0.25 inch width strips; input lengths were 12-15 inches. The stamp material was "diluted" by adding shredded commercial copy paper which contains fillers and is similar in composition to envelopes. Nine to 12 batches of feedstock were pulped per trial to provide sufficient pulp for the subsequent process; target pulping time was 10 minutes, however, trials 4-7 required 20 minutes.

After pulping, the blended slurry from the batches was diluted to about 4% consistency for pumping purposes. The slurry was then pumped to a flatscreen where it was further diluted. Accepts were pumped to a stock tank and diluted to about 0.70-0.75%. This stock was sent to the forward cleaners. Afer Trial 4, it appeared that the flowthrough cleaner was overloaded with adhesive, and it was decided that a second pass through the flowthrough cleaner was needed Trials 5-7 therefore, had two passes through the flowhrough cleaners.

Accepts from the first pass through the flowthrough cleaner was transferred to a laboratory floatation unit. A floatation aid (Hercules DI-600) was added at a rate of 0.2% weight on dry fiber. The pulp was aerated for 10 minutes and foam was removed by simple overflow. The remaining stock was allowed to slowly flow by gravity to a sidehill screen where free drainage removed small particles and water.

Table 10 shows the contaminants found per sampling point.

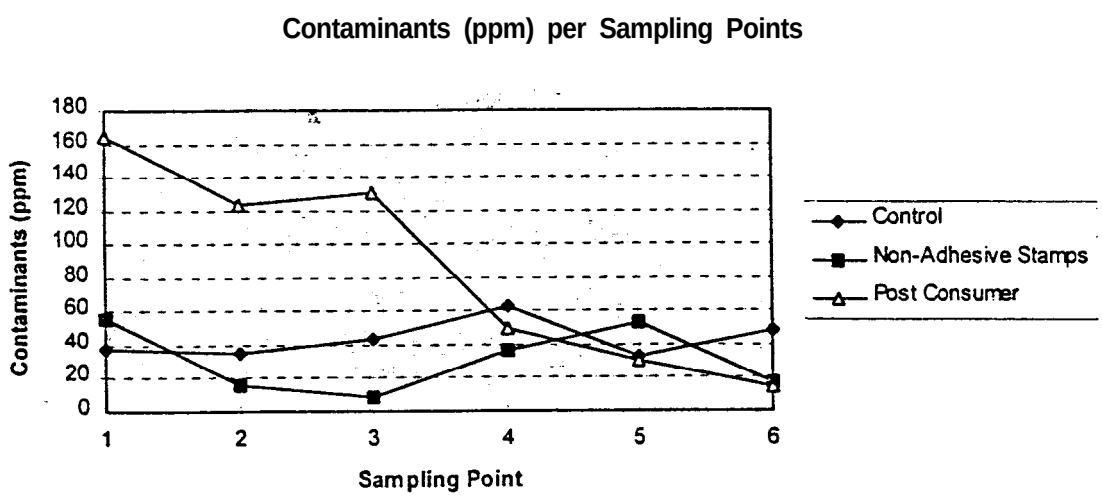
Table 10. Contaminants (ppm) per sampling point.

	Sample Point								
Trial	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	3570	2430	3330	1530	643	706	-	-	-
5	5610	3130	4353	2750	692	743	968	203	191
6	2340	2050	2890	3747	425	524	660	198	262
7	1440	881	1110	683	412	563	418	250	91

Trial 1, the control sample, had very few contaminants at each of the sampling points. Trial 2, non-adhesive stamp material, showed similar results. No adhesive was present in this sample; the only contaminants introduced by this sample were printing inks and release coating. After screening and cleaning (sampling point 3), this 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 release coating did not appear to be a problem.

Trial 3 was not expected to be much different than the control batch as the resulting concentration of stamps on the envelopes was only 0.35% (dry wt basis). However, after the floatation process, the number of small particles was lower than that of the control. The adhesive in the stamps possibly acted as a scavenger for small contaminants which were then able to be removed by floatation. The dirt count in the final sampling point for Trial 3 was *lower* than the control. Figure 4 shows the dirt count levels for the first 3 trials.

Figure 4. Contaminants per sampling point for Trials 1-3



Trial 4 contained 10% stamp material by weight. As expected. the initial dirt count after pulping was much greater than that of the control. The two cleaning steps reduced this number significantly, but the final number of specks was unacceptable for both ink and adhesive levels. Trial 6 repeated this same batch, but an additional flowthrough cleaning was added. This reduced the dirt count level to 262 ppm at the final sampling point.

Trial 5 has twice as much stamp material than trials 4 and 6. After the first 6 steps, Trial 5 resulted in particle counts similar to 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. After the first flowthrough washing, the dirt count was 743; after the second flowthrough cleaning. the dirt count was reduced to 203. This 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 7 shows that reducing the stamped material to 5% (weight by dry basis) results in particle counts similar to that of the control.

These trials indicate that pulping freed the fiber from the adhesive and ink for the linerless stamped material. The release coating did not cause any problems. Much of the ink was removed in the forward cleaner, and conventional screening and cleaning processes were satisfactory for reducing the adhesive levels in the material.

Figure 5. Contaminants per sampling point for Trials 1, 4-7.

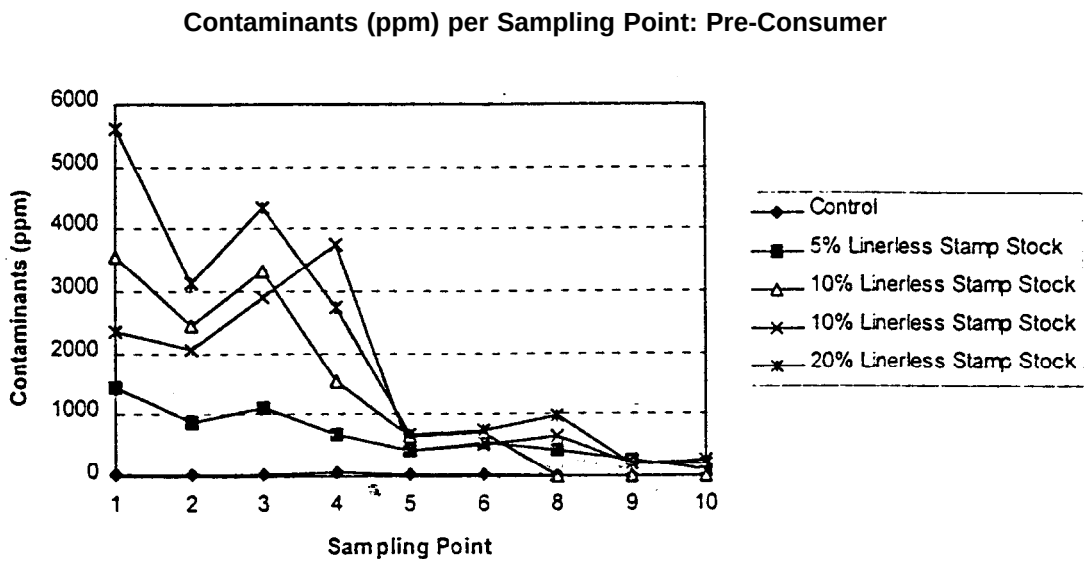
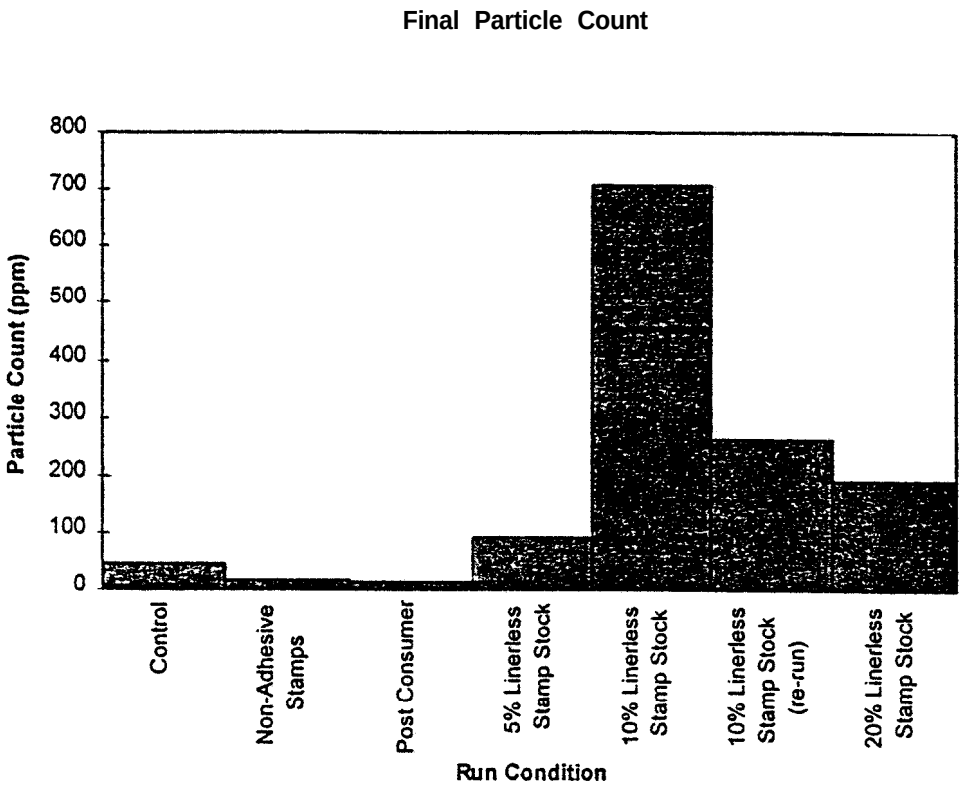


Figure 6. Final contaminant counts,



Group III

In this study, two different levels of linerless stamp material were investigated, at two different pulping temperatures on the laboratory scale. Only the pulping and screening (2 steps) were used in this study. The results of this study are in Table 11.

Table 11. Laboratory Recycling Tests

Image Analysis of Accepts (ppm)				
	Before Screen	After 12 Cut Screen	After 6 Cut Screen	Total Efficiency
100% copy paper	6	4	4.5	
5% Linerless Stamps	990	84	12	99%
5% Linerless Stamps (high T)	1900	310	75	96%
1.5% Linerless Stamps	250	38	9	96%
1.5% Linerless Stamps (high T)	560	170	28	96%

The adhesive used in linerless stamps separates in the form of large tough elastic tacky particles which agglomerate to form a large clump. This suggests that this resin would be suited to recovery by screening techniques. Image analysis confirms that good separation is accomplished by screening techniques.

Group IV

In this study, a pilot-scale separation sequence was used to assess the removal of contaminants from the feed stock which contained linerless PSA material. The linerless adhesive caused no apparent problems; it seemed to break up easily and was easily screenable. Significant amounts of adhesive accumulated on the flatscreens and the final pulp was clean. Table 12 shows the Speckcheck analysis of the contaminants found in the final accepts.

Table 12: Pilot Scale Results

Trial	Contamination Level (ppm)
copy paper only	9.78
5% Linerless Stamps (0.20 mm screen)	1.6
5% Linerless Stamps	5.2
5% Linerless Stamps (high T)	10
Standard PSA Stamp Stock w/out Liner	19
Standard PSA Stamp Stock w/Liner	21

The linerless stamp material had very low contamination after the pilot scale recycling process was completed, even less than the "control" of only copy paper, and also less than current stamp stock material that is currently available and is being used in the current construction of self-stick stamps on a liner.

IV. OVERALL CONCLUSIONS

In all the different recycling studies performed using the linerless PSA stamp, this material has shown to be "environmentally benign", in that it does not cause major problems in the repulping and recycling processes, simulated in the experiments discussed in this paper.

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