PILOT-SCALE EVALUATION OF ENVIRONMENTALLY BENIGN PSA STAMPS

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ABSTRACT

Along with the increased use of pressure-sensitive adhesive products, concerns have emerged about their environmental impact. To address these concerns, the U.S. Postal Service initiated an environmentally benign pressure-sensitive adhesive (PSA) program to develop postal stamps that do not adversely affect the environment. As part of this program, experimental adhesives were evaluated for stamp performance specifications, laboratory recycling, and pilot-scale recycling. Laboratory and pilot-scale recycling trial results are presented in this paper. Synthetic rubber or acrylic-type experimental PSAs were repulpable, and adhesive levels were removed satisfactorily by screening, cleaning, and flotation processes. Compared with synthetic rubber or acrylic-types. dispersible acrylic-type experimental PSAs produced adhesive levels that were not as effectively removed in pilot-scale recycling trials.

INTRODUCTION

For many years, the U.S. Postal Service (USPS) has tried to improve the adhesives used for stamps. These efforts have addressed both conventional gummed adhesives and the newer pressure-sensitive adhesives (PSAs). Although the PSA stamp was first issued in 1974, it was the second issue in 1989 that resulted in a dramatic increase in usage. Since then, it is estimated that the USPS uses more than 3.9 million m^2 PSA stamps and labels per year. This equates to about 14% of the total U.S. label market (I).

Along with the increased use of PSA, concerns about the increased use of PSA stamps adding to the amount of PSA entering the recovered paper recycling stream have emerged. The USPS has a clear commitment to recycling, waste reduction, use of nontoxic adhesives and inks, and use of recycled-content materials in stamp production. To help meet this commitment, the USPS initiated a program to develop PSA postage stamps that do not adversely affect the environment or negatively impact recycling. The intent of the program is to develop PSA stamp and label products that can be successfully and economically recycled into paper products.

The environmentally benign PSA program focuses on both pre- and postconsumer stamp products in the waste stream. Preconsumer stamp product waste is derived from stamp paper production, printing and finishing operations, and out-of-specification stamp materials. Postconsumer waste consists mainly of stamps and labels on envelopes in the home and office paper waste. Mill-scale trials will be conducted for mills that currently supply pulp for printing and writing grades of paper in the industry.

Not only must the PSA be recyclable, but the entire stamp product must meet all performance requirements specified in USPS-P-1238 (2). These requirements include permanent adhesion to envelope substrates and archival ability (long-term aging). Suppliers of the USPS were solicited for candidate PSA stamp stocks. As part of the PSA program, test protocols for evaluating the recylability

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Depamnent of Agriculture of any product or service.

of the candidate stamp adhesive materials at the laboratory and pilot scales were developed by Springborn Testing and Research (STR) and the USDA Forest Service, Forest Products Laboratory (FPL); an image analysis protocol was also developed. The USPS is developing a protocol for mill repulping. Input from all parts of the industry was solicited to help develop these protocols.

Industry consisting of paper manufacturers, PSA producers, converters, paper recyclers, and adhesive and chemical suppliers are working with the USPS to develop PSAs that can be removed from the recycling stream. To achieve this, the basic chemistry of the PSA is modified or the physical properties of the adhesive are changed (3). Teams were formed by industry to tackle the problem of developing new "repulpable" PSAs that deal with the problem of stickies (4). Team members exchanged their expertise and knowledge in a given field to develop an improved PSA.

Experimental PSAs were submitted to STR for evaluation of stamp performance. Those stamps that met the performance requirements were evaluated for laboratory and pilot-scale recycling. Those deemed acceptable will then undergo extensive convening, printing and finishing trials, mail processing test procedures, and recycling trials. After all protocols are finalized, the USPS will issue paper specifications that will include recycling requirements. The USPS will mandate that all future stamp products conform to these new requirements.

This paper examines the results of the pilot-scale recycling trials conducted at the USDA Forest Service, Forest Products Laboratory (FPL). The adhesives are compared based on their chemical composition. In addition, results of the laboratory and pilot-scale trials are discussed.

LABORATORY EVALUATIONS

Springborn Testing and Research evaluated the adhesive stamp materials on the basis of two main criteria: performance and recycling (2). Twenty-seven PSAs were evaluated for performance properties. Those adhesives that passed the PSA performance testing were selected for recyclability evaluation at the laboratory and pilot scales. The postconsumer configuration was 95% copy paper and 5% unprinted stamp stock by weight. The preconsumer configuration was 90% copy paper and 10% unprinted stamp laminate.

PSA Performance

The PSA performance requirements were based upon established test methods in the USPS-P-1238 stamp specification. Three main properties were examined:

- Permanence of adhesive bond between stamp and envelope substrate
- Aging (visible or physical changes) of stamp materials in three environments
- Ability of stamp to be removed from the envelope by soaking in water

Laboratory Recycling

The PSA unprinted stamp stock material was stained with Morplas blue dye so that the adhesive particles would be highly visible throughout the process (5). The dyed stamp face was then laminated to either copy paper or release liner to simulate pre- and postconsumer waste stock. The laminated stamp stock was then pulped in a l-lb (0.45kg) pulper (Adirondack Machine Model 450H) at 15% consistency, 46°C, and pH 10 for 8 mm. The pulped sample was passed through a 0.30-mm (12-cut Valley flat screen; the accepts were then screened with 0.15-mm (6-cut) slots. Handsheets (1.2 g) were made according to TAPPI T-205 om-88 at the pulper and from each screen accepts stream. Handsheets were then scanned using an HP flat-bed scanner and an Optomax Speckcheck Dirt Counter system to determine the level of contaminant having an area >0.02 mm^2.

PILOT-SCALE EVALUATIONS

The PSA stamp material was pulped in a Voith high-consistency pulper, model HC-1.5, at 15% consistency, 43°C, and pH 10 for 20 min. The pulp was then pressure screened (Voith MULTI-FRACTOR model 00) through 0.30-mm slots followed by 0.15-mm slots. Accepts were sent through

a forward cleaner, two passes of a through-flow cleaner, and a flotation cell, and over a sidehill screen. Sidehill accepts were pressed and shredded for storage for future paper machine trials.

For all accepts streams, 1.2-g handsheets were made according to TAPPI T-205 om-88, except that one (2-min) pressing was done. Handsheets were then dyed with Morplas blue dye in heptane and scanned on an Optomax Speckcheck Dirt Counter to determine the level of contaminant having an area >0.02 mm^2. The removal efficiency of each unit operation was calculated by using the ratio of contaminant level expressed in parts per million (ppm).

DISCUSSION

Experimental Adhesives

Preconsumer and postconsumer.

Results of the pilot-scale recyclability trials are given in Tables 1 and 2. In the preconsumer configuration, the release liner either increased, decreased, or had no effect on the stickies count (ppm).

An example of release liner increasing stickies would be adhesive C. When initially pulped, adhesive C had an average ppm of 2700 and count/m^2 of 6800. As adhesive C went through the pilot recycling protocol trial, the contaminants were removed until a final average ppm of 8 and count/m^2 of 230 were obtained. With the addition of the release liner, the contaminant level in the pulper was increased to an average ppm of 3900 and count/m^2 of 13000 for adhesive C. The release liner caused an increase in the number of particles generated. The pilot recycling protocol, because the final average ppm was 170 and count/m^2 was 1700, did not effectively remove these increased particles. Additional processing of the adhesive would be needed to reduce the ppm value. There was only one adhesive, adhesive L, in which the release liner improved the recyclability of the adhesive. With the addition of the release liner, the final average ppm value was reduced from 160 to 27 and the final count/m^2 was reduced from 2100 to 500.

Comparisons of the laboratory and pilot-scale recycling trials from the pulper to the second screening stages are given in Figures l-12. Some experimental adhesives had good correlation between laboratory and pilot-scale recycling (Fig. 1). Not all adhesives correlated (Fig. 11). This could be a result of the differences in equipment (STR used a Valley flat screen and FPL used a pressure screen), difference in pulping temperatures, or the type of adhesive.

All experimental PSAs were divided into two major chemical types: synthetic rubber elastomers or acrylic polymers. We divided the acrylic polymers into an additional type, dispersible acrylic, because of its difference in behavior from the acrylic PSA in the laboratory and pilot trials. Each type of PSA behaved differently through each unit operation in the pilot trials. For ease of comparison, data from each adhesive type were compiled and averaged to make composite-size distribution graphs for postconsumer configurations (Figs. 13-36).

Acrylic.

In the pulper, the acrylic PSA formed a combination of large and small particles (Fig. 13), having a mean particle area of 0.61 mm^2. As shown in Figures 14 and 15, through two stages of pressure screening (0.30 and 0.15 mm), the mean ppm was reduced from 1900 to 36 and the count/m^2 was reduced from 3200 to 400, with a mean particle area of 0.10 mm^2. As shown in Figure 15, large adhesive particles were still present in the pulp. This may have been due to the adhesive particles being disc or plate-like (6) and/or deforming and passing through the pressure screens. The forward cleaners and through-flow cleaners, indicating that the remaining acrylic adhesive particles may have had a near-neutral specific gravity, removed a small number of particles. Also, the remaining particles had a small diameter because the mean particle area was 0.01 mm^2. Flotation removed a portion of

small particles present, reducing the mean ppm from 22 to 7 and the count/m^2 from 240 to 95 from the cleaning stage. At the flotation step, the mean particle area was 0.006 mm^2. The acrylic-type PSAs had a 99.5% removal efficiency.

Synthetic rubber.

The synthetic rubber PSA formed a combination of large and small particles (Fig. 21), with a mean ppm of 1400, a count/m^2 of 2900, and a mean particle area of 0.50 mm^2. After 0.30-mm and 0.15-pressure screening (Figs. 22 and 23), the mean ppm was reduced to 44 and the count/m^2 to 700, with a mean particle area of 0.07 mm^2. Some particles were present that had a size >0.15 mm, indicating that some particles were either deforming through the screens and/or had a disc or plate-like shape similar to the acrylic type adhesives. After forward cleaning (Fig. 24), a small reduction of particles was obtained with a mean ppm of 38 and count/m^2 of 578 and a mean particle area of 0.05 mm^2. Through-flow cleaning reduced the mean ppm to 14 (Figs. 25 and 26), which indicated that portions of the particles were lightweight. Flotation further reduced the mean ppm to 7, a count/m^2 of 150, and a mean particle area of 0.05 mm^2. A final mean ppm of 7 and count/m^2 of 120 were obtained. A removal efficiency of 99.5% was obtained for the synthetic rubber-type PSAs.

Dispersible acrylic.

The dispersible acrylic PSAs generated a large amount of small particles in the pulper (Fig. 29). In the pulper, the mean ppm was 5200 and count/m-was 21,000, with a mean particle area of 0.22 mm^2. As shown in Figures 30 and 31, particles with a size >0.15 mm were still present in the pulp. After the forward and through-flow cleaning (Figs. 32-34), a large amount of small particles were still present in the pulp. After cleaning, the mean ppm was 1500 and count/m^2 was 6400, with a mean particle area of 0.16 mm^2. A slight reduction in ppm and particle count was obtained with flotation. However, flotation was not very effective. This may have been due to the particle size of the stickies, the chemistry of the stickies, or to other factors. A final ppm of 1400, a count/m^2 of 4800, and a removal efficiency of 72.7% were obtained for the dispersible acrylic-type adhesive.

Protocol Changes

Since this phase of the project involved unprinted stamp material, it was easy to distinguish the adhesive particles in the handsheets produced. The handsheets were stained with a blue dye. The adhesive particles present in the sheet stained a darker blue than did the surrounding pulp fiber handsheet. In the next phase of the work, printed stamp material will be used. A new image analysis protocol will need to be developed that will take into account the ink factor. A new staining technique will be explored so that a white background with a dark blue adhesive color can be obtained. Currently, a light blue background is obtained. When comparing results with STR, the same detection level could be used for both laboratories.

CONCLUDING REMARKS

The combined efforts of the U.S. Postal Service (USPS), Springborn Testing and Research (STR), and the USDA Forest Service, Forest Products Laboratory (FPL) resulted in a product evaluation process that covers the performance, laboratory recyclability, and pilot-scale recyclability of pressure-sensitive adhesives (PSAs). The USPS program will provide a wealth of information about PSA performance. Information obtained from laboratory and pilot-scale recyclability trials will help manufacturers to improve their adhesive products for the paper recycler.

Experimental PSA can be repulped and adhesive levels satisfactorily reduced by pressure screening, cleaning, and flotation processes. The dispersible, acrylic-based adhesive was not effectively cleaned by pressure screening, cleaning, and flotation processes. With the introduction of the silicone release liner, some experimental PSAs will require additional processing to further reduce the contaminant level.

REFERENCES

1. Peng, J., "Environmentally Benign Pressure Sensitive Adhesive R&D Program," 1998 TAPPI Recycling Proceedings.

2. Thoma, L., "Benign Adhesive R&D Contract and Phase III Efforts and Results," Proceedings, USPS Conference on Environmentally Benign PSA for Postal Applications, July 7–9, 1997.

3. Scholz, W.F., "Summary of Stickies Test Methods, Paper Recycling Challenge," Vol. I Stickies, p. 67-70, 1997.

4. Webster, D. "Environmentally Benign PSA Development," Proceedings, USPS Conference on Environmentally Benign PSA for Postal Applications, July 7–9, 1997.

5. Donermeyer, D., "Laboratory Pulping Test Protocol and Data Analysis," Proceedings, USPS Conference on Environmentally Benign PSA for Postal Applications, July 7–9, 1997.

6. Hodgson, K.T., "Surface Science and Process Factors Affecting Removal of Sticky Contaminants," Paper Recycling Challenge, Vol. I Stickies, p. 71-75, 1997.

Table 1. Pilot recyclability of experimental adhesives[a]

Sample adhesive	Initial pulped slurry		Accepts: 0.30 mm pressure screen		0.15 mm pressure screen		Forward cleaner		Through-flow cleaner 1st pass		Through-flow cleaner 2nd pass		LaMort flotation		Sidehill washing		Pressing/ shredding	
	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²	ppm	Ct/m²
A[b]	2800	8400	600	4900	130	2100	85	1600	71	1200	100	1800	49	670	110	1100	100	950
A[c]	1600	3600	200	1700	72	990	70	1100	34	560	11	230	7	140	2	44	7	100
B[c]	400	760	34	370	23	300	14	170	9	210	13	230	8	150	21	280	16	190
B[b]	700	1400	24	190	13	270	4	50	10	94	3	44	3	50	7	88	2	50
C[b]	3900	13000	1100	9200	300	4900	200	3700	140	2600	210	3000	100	1200	160	1400	170	1700
C[c]	2700	6800	380	3100	96	1500	76	1200	41	610	18	350	6	190	8	230	8	230
D[b]	2800	5700	140	930	36	570	26	490	25	500	23	470	21	440	14	300	16	360
D[c]	800	1000	4	38	5	82	0	6	1	19	3	82	2	38	2	25	4	44
E[b]	2700	8100	530	4300	87	1500	57	1100	48	870	58	1100	20	260	42	490	45	490
E[c]	1400	2400	78	660	26	440	28	440	9	200	15	300	11	220	1	44	2	50
F[b]	4600	16700	2200	13400	440	5400	93	1600	150	2000	140	2200	130	2000	240	2800	230	3000
F[c]	2300	4500	450	2900	41	610	18	350	25	300	31	470	18	140	21	170	31	260
H[b]	5400	22400	3400	21900	1200	10500	610	6700	620	4500	650	4800	510	2700	880	3600	680	3200
H[c]	2600	6000	700	3800	100	1200	170	1600	60	660	140	1100	48	380	190	890	120	590
I[b]	5600	10900	1500	6600	250	2500	140	1800	160	1700	140	1500	63	560	120	910	140	1000
I[c]	1100	150	130	740	39	480	42	380	34	280	24	160	4	120	4	100	3	100
J[b]	2600	5900	850	3000	42	410	24	280	58	260	13	160	14	70	12	120	12	110
J[c]	2100	3700	420	1600	35	440	13	280	23	280	23	270	1	20	8	60	8	88
K[b]	3700	7900	1600	6700	210	1300	200	2000	230	1500	250	2100	140	1100	240	1400	110	990
K[c]	1800	2700	120	450	20	270	17	280	33	220	14	130	1	38	8	63	9	63
L[b]	520	11400	260	5900	160	3800	96	2300	43	1100	91	2100	17	260	33	470	27	500
L[c]	840	12900	1200	20200	640	10900	340	6700	360	6600	260	4500	180	2300	200	2600	160	2100
M[b]	7100	18900	5200	17800	1200	7500	1200	8600	750	4300	690	4100	510	2200	610	2300	480	2600
M[c]	7000	22400	3700	16200	1100	7600	1000	7900	470	3100	290	2200	230	920	360	1300	260	1400
N[b]																		
N[c]	7700	28400	5000	21500	5600	20900	4100	17700	3300	10500	3800	12600	3100	8700	3700	10500	2900	10900

[a]Data obtained from 10 Morplas blue dyed handsheets.
[b]Denotes configuration of 90 copy paper/10-stamp laminate.
'Denotes configuration of 95 copy paper/5-stamp stock.

Table 2. Adhesive removal efficiency of experimental adhesives[a]

ample lhesive	Initial pulped slurry (ppm)	Unit efficiency (%)								
		0.30-mm pressure screen accepts	0.15-mm pressure screeen accepts	Forward cleaner accepts	Through-flow cleaner accepts 1st pass	Through-flow cleaner accepts 2nd pass	LaMort flotation accepts	Sidehill washing accepts	Press/ shredding accepts	Total efficienc (%)
A[b]	2738	77.8	79.2	32.5	16.5	−43.7	52.0	−126.5	10.8	96.4
A[c]	1622	87.8	63.6	2.8	51.4	67.6	38.2	70.6	−265.0	99.5
B[c]	378	91.1	31.3	39.1	39.3	−52.9	40.0	−169.2	23.8	95.8
B[b]	722	96.7	45.8	73.1	−185.7	70.0	3.3	−137.9	75.4	99.8
C[b]	3896	72.4	72.4	33.7	27.4	−46.2	49.8	−49.5	−10.8	95.5
C[c]	2682	85.7	75.0	20.8	46.1	56.1	65.6	−21.0	−12.0	99.7
D[b]	2822	95.2	73.3	27.8	3.8	8.0	8.7	33.3	−14.3	99.4
D[c]	787	99.5	−14.0	95.9	−300.0	−287.5	45.2	−11.8	−105.3	99.5
E[b]	2720	80.7	83.5	34.5	15.8	−20.8	65.5	−110.0	−7.1	98.3
E[c]	1364	94.3	66.7	−7.7	68.2	−68.5	26.7	87.3	−50.0	99.8
F[b]	4581	51.0	80.5	78.7	−57.0	2.1	7.0	−76.7	3.8	95.1
F[c]	2277	80.1	91.0	56.1	−38.9	−24.0	41.9	−16.7	−47.6	98.6
H[b]	5358	36.7	66.0	46.8	−1.10	−4.0	20.6	−69.8	22.4	87.4
H[c]	2578	72.8	84.9	−61.3	64.9	−135	66.0	−290	38.5	95.5
I[b]	5564	73.1	83.6	41.1	−11.6	13.1	55.1	−97.4	−9.8	97.6
I[c]	1065	88.3	68.4	−5.8	19.5	29.9	80.9	6.5	20.5	99.7
J[b]	2623	67.4	95.1	42.9	−142	77.6	−7.7	14.3	0.0	99.5
J[c]	2120	80.0	91.7	62.9	−76.9	0.0	95.7	−700	0.0	99.6
K[b]	3697	56.8	86.5	8.8	−19.4	−4.7	42.9	−67.9	54.0	97.1
K[c]	1754	93.4	82.8	15.0	−94.1	57.6	92.9	−700	−12.5	99.5
L[b]	516	50.3	38.4	39.0	55.2	−110.8	81.5	−96.3	17.3	94.7
L[c]	843	−44.7	47.4	46.7	−4.2	27.5	29.6	−11.7	20.4	80.8
M[b]	7128	26.7	77.6	−1.2	36.9	8.2	25.4	−18.6	21.3	93.3
M[c]	6968	47.4	70.5	4.0	54.8	38.7	20.5	−55.0	26.8	96.3
N[b]										
N[c]	7738	35.1	−12.2	27.9	18.2	−14.4	19.5	−20.7	20.1	61.9

[a]Removal efficiency determined by ppm ratios.

[b]Denotes configuration of 90 copy paper/10-Stamp laminate.

'Denotes configuration of 95 copy paper/5-stamp stock.

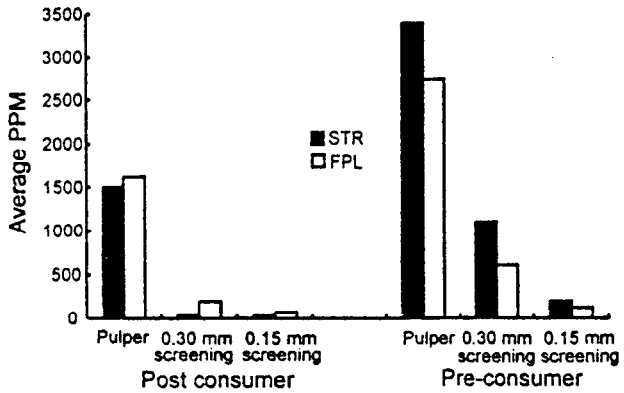


Fig. 1. Screening comparisons of Adhesive A.

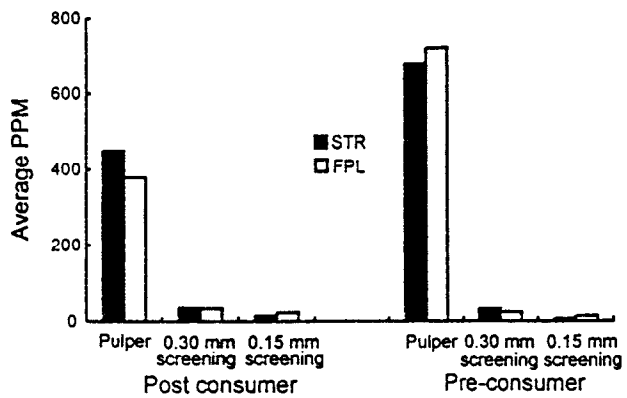


Fig. 2. Screening comparisons of Adhesive B.

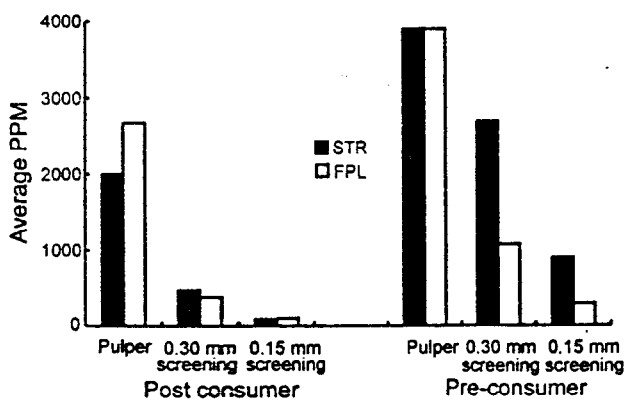


Fig. 3. Screening comparisons of Adhesive C.

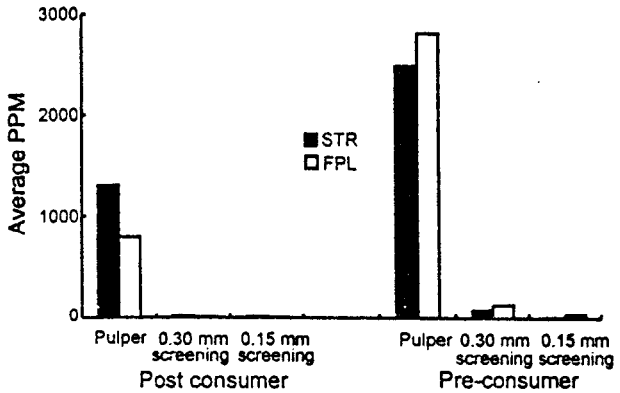


Fig. 4. Screening comparisons of Adhesive D.

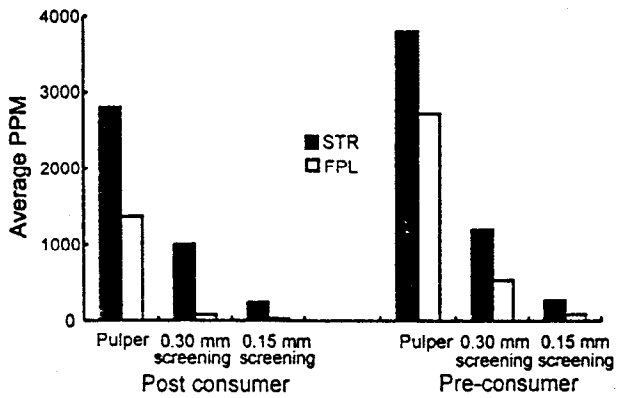


Fig. 5. Screening comparisons of Adhesive E.

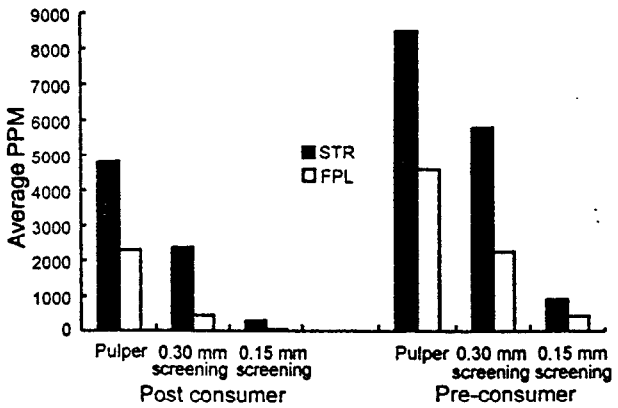


Fig. 6. Screening comparisons of Adhesive F.

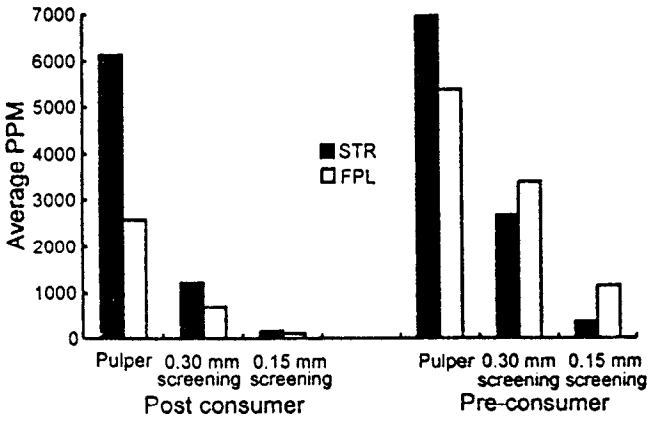


Fig. 7. Screening comparisons of Adhesive H

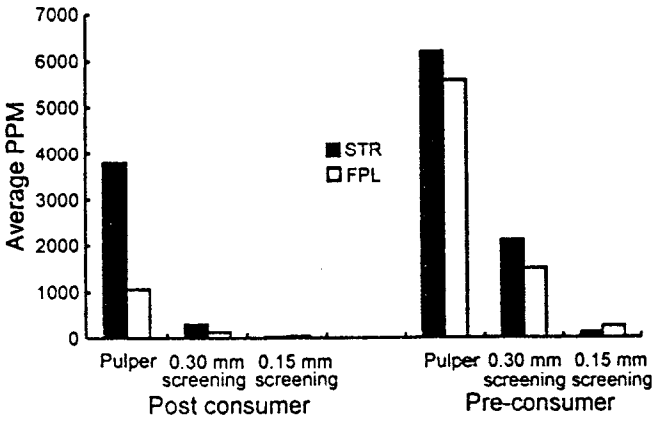


Fig. 8. Screening comparisons of Adhesive I.

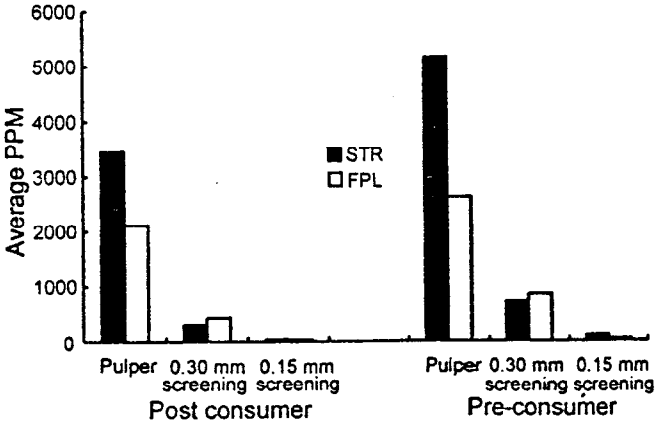


Fig. 9. Screening comparisons of Adhesive J.

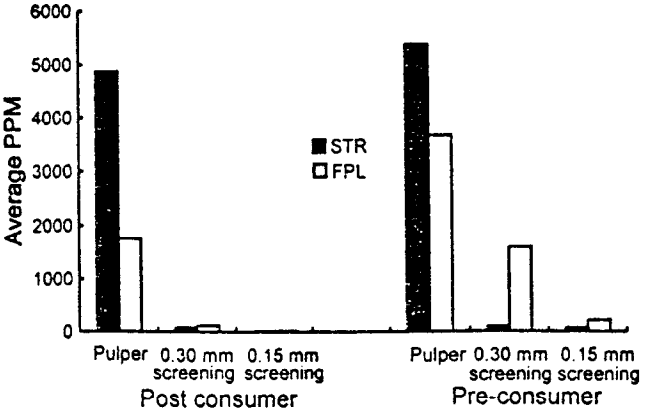


Fig. 10. Screening comparisons of Adhesive K.

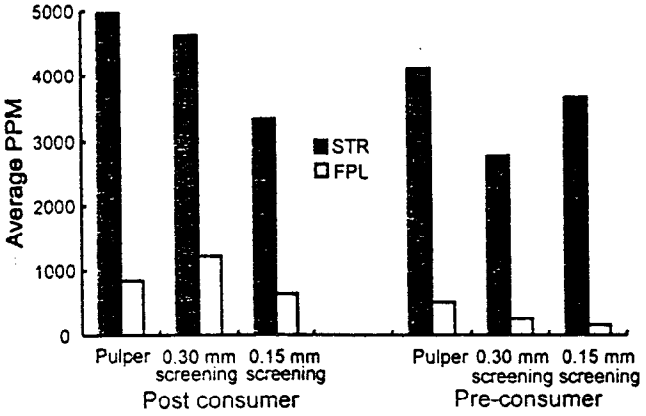
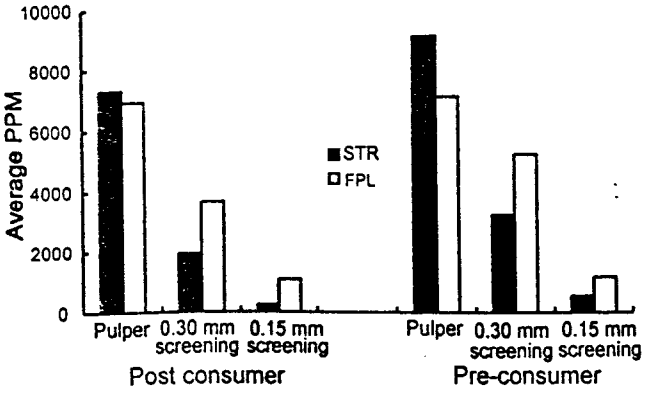


Fig. 11, Screening comparisons of Adhesive L



Fig, 12. Screening comparisons of Adhesive M.

Fig. 13.
Acrylics Postconsumer
Image Analysis After Pulping and Before Screening
Total Count/m² = 3143 Total Avg PPM = 1862

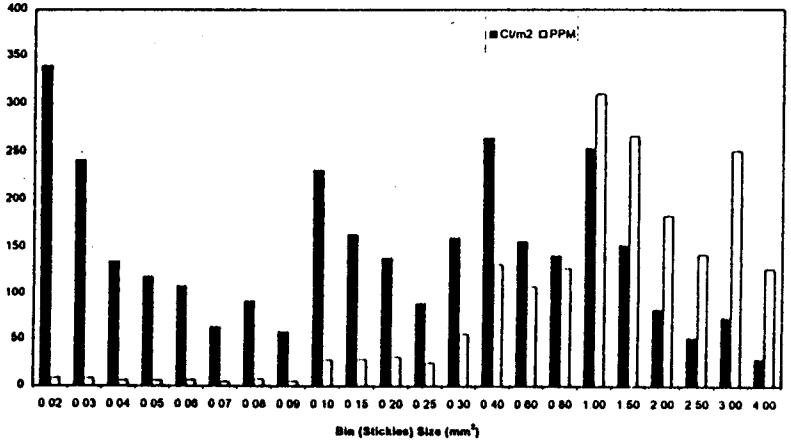


Fig. 14.
Acrylics Postconsumer
Image Analysis After 0.30 mm Pressure Screening
Total Count/m² = 1487 Total Avg PPM = 344

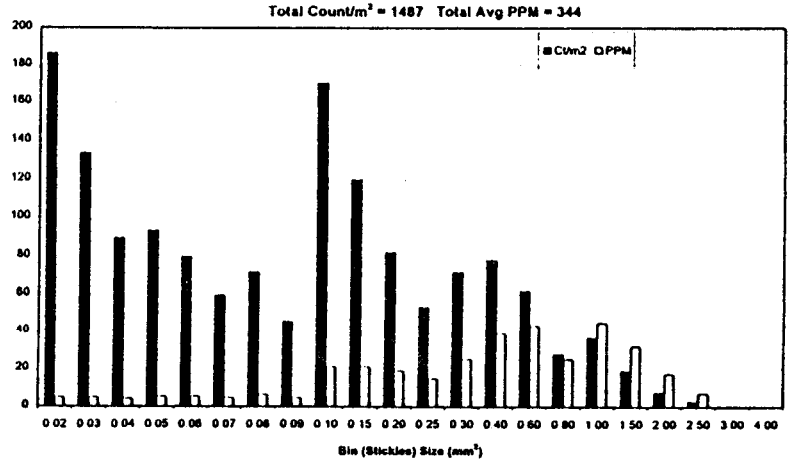


Fig. 15.
Acrylics Postconsumer
Image Analysis After 0.15 mm Pressure Screening
Total Count/m² = 404 Total Avg PPM = 36

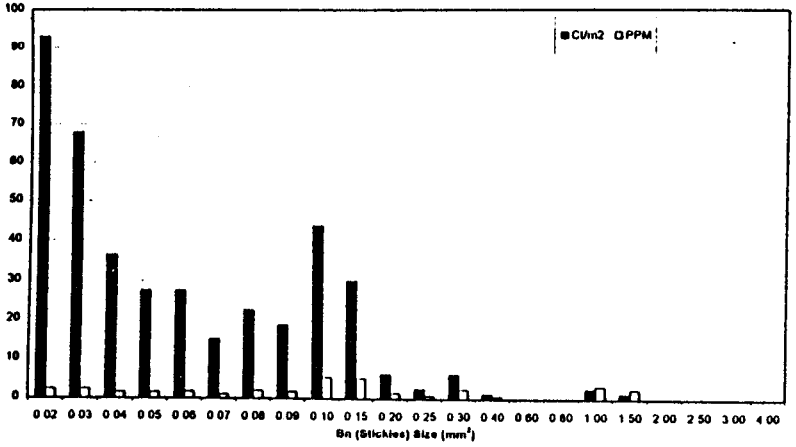


Fig. 16.
Acrylics Postconsumer
Image Analysis After Forward Cleaning
Total Count/m² = 321 Total Avg PPM = 24

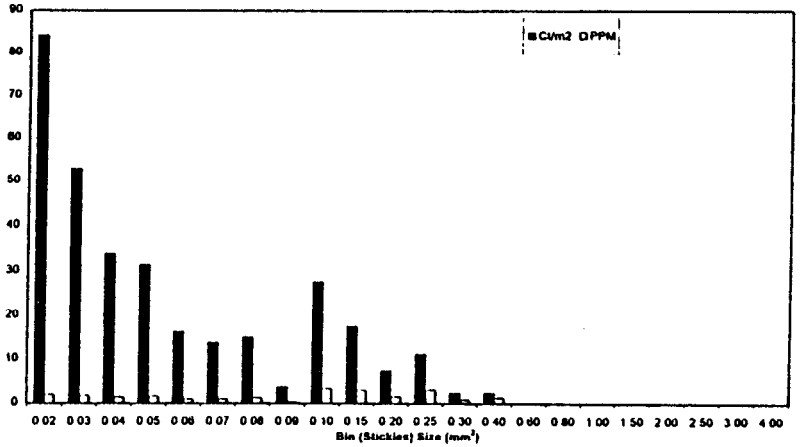


Fig. 17.
Acrylics Postconsumer
Image Analysis After First Through-flow Cleaning
Total Count/m² = 254 Total Avg PPM = 27

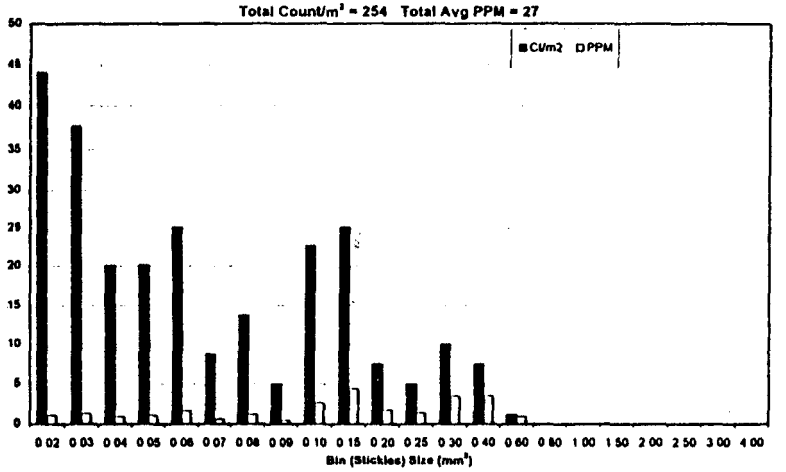


Fig. 18.
Acrylics Postconsumer
Image Analysis After Second Through-flow Cleaning
Total Count/m² = 240 Total Avg PPM = 22

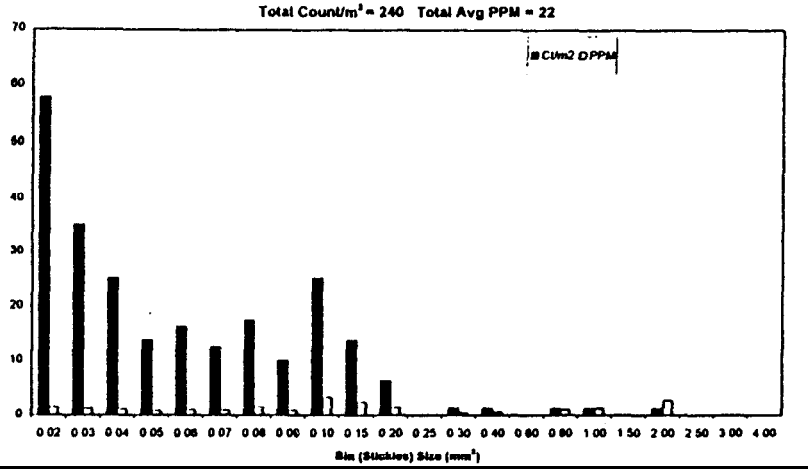


Fig. 19.
Acrylics Postconsumer
Image Analysis After LaMort Flotation
Total Count/m² = 95 Total Avg PPM = 7

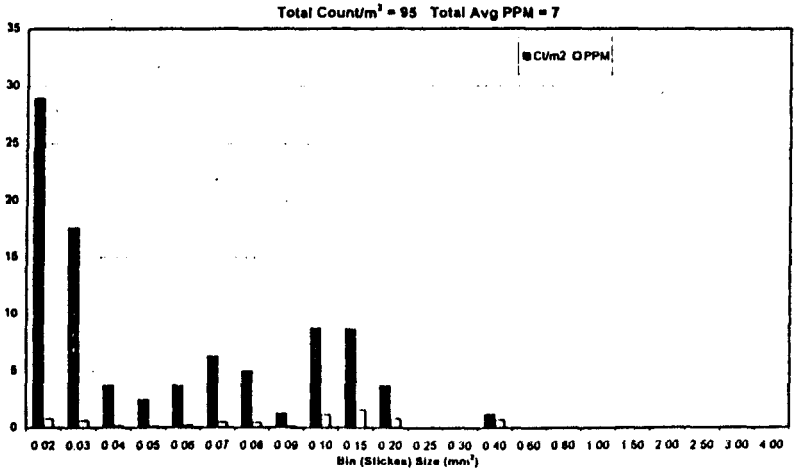


Fig. 20.
Acrylics Postconsumer
Image Analysis After Sidehill Washing
Total Count/m² = 97 Total Avg PPM = 10

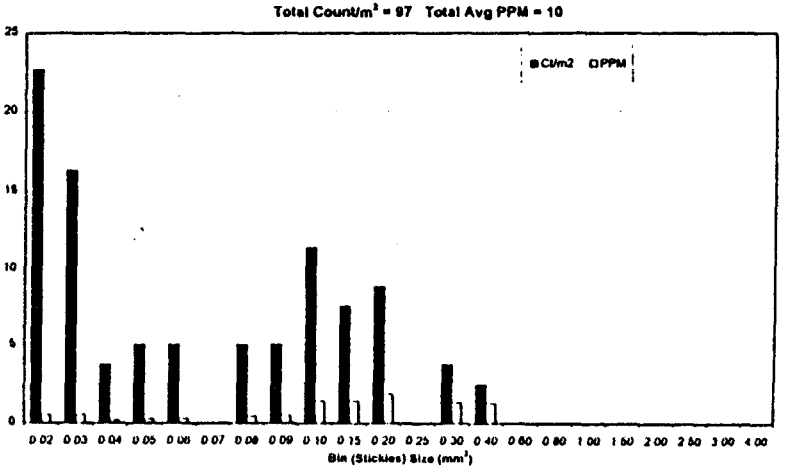


Fig. 21.
Synthetic Rubber Postconsumer
Image Analysis After Pulping and Before Screening
Total Count/m² = 2908 Total Avg PPM = 1366

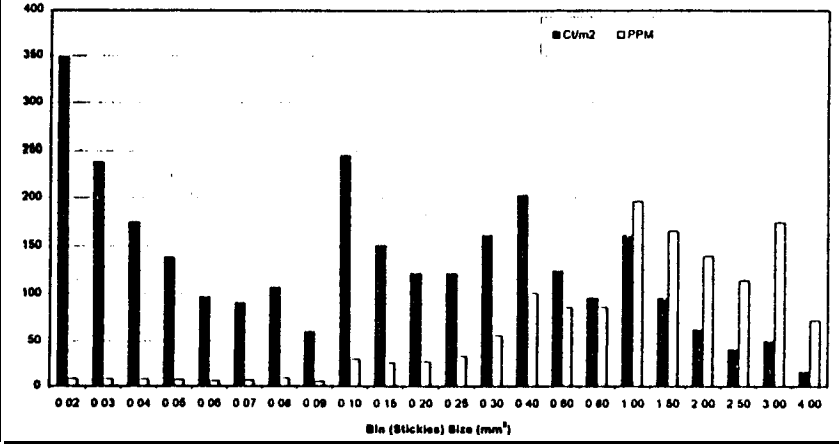


Fig. 22.
Synthetic Rubber Postconsumer
Image Analysis After 0.30 mm Pressure Screening
Total Count/m² = 1167 Total Avg PPM = 139

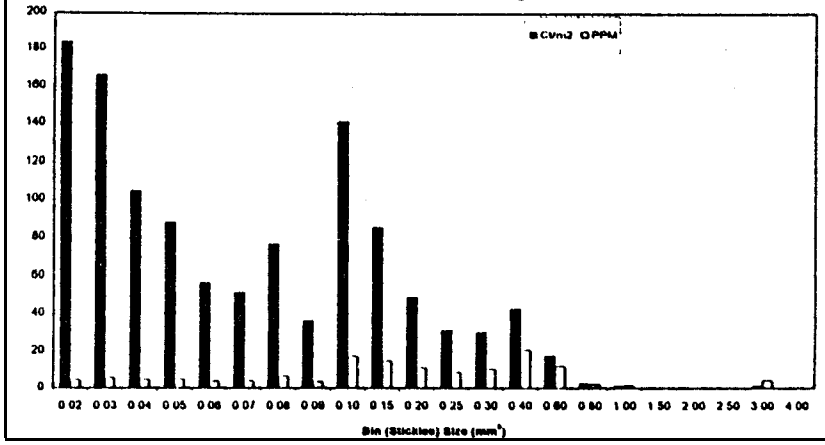


Fig. 23.
Synthetic Rubber Postconsumer
Image Analysis After 0.15 mm Pressure Screening
Total Count/m² = 662 Total Avg PPM = 44

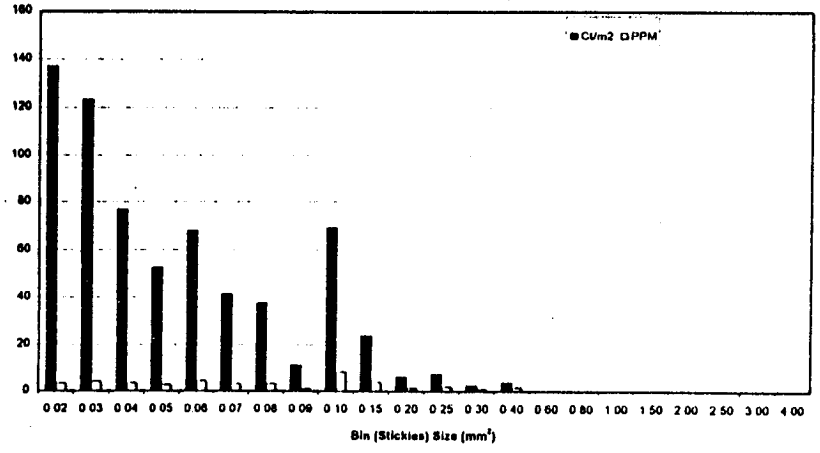


Fig. 24.
Synthetic Rubber Postconsumer
Image Analysis After Forward Cleaning
Total Count/m² = 578 Total Avg PPM = 38

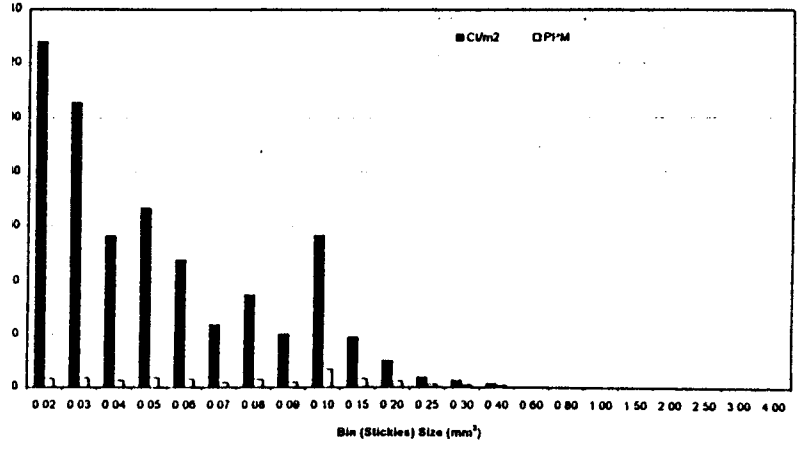


Fig. 25.
Synthetic Rubber Postconsumer
Image Analysis After First Through-flow Cleaning
Total Count/m² = 332 Total Avg PPM = 19

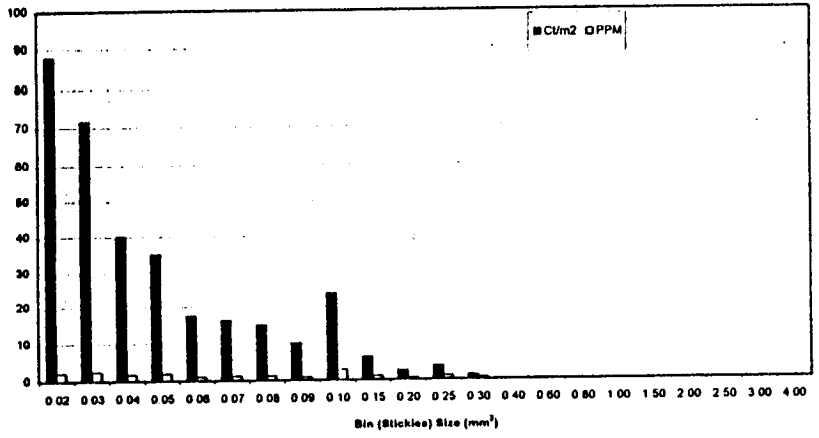


Fig. 26.
Synthetic Rubber Postconsumer
Image Analysis After Second Through-flow Cleaning
Total Count/m² = 225 Total Avg PPM = 14

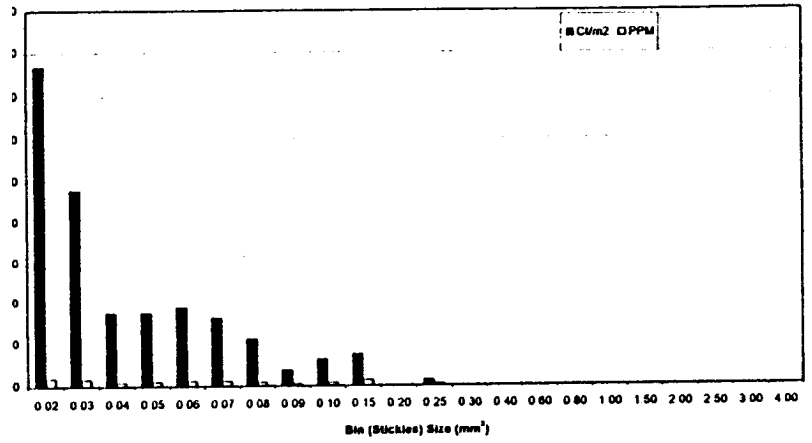


Fig. 27.
Synthetic Rubber Postconsumer
Image Analysis After LaMort Flotation
Total Count/m² = 146 Total Avg PPM = 7

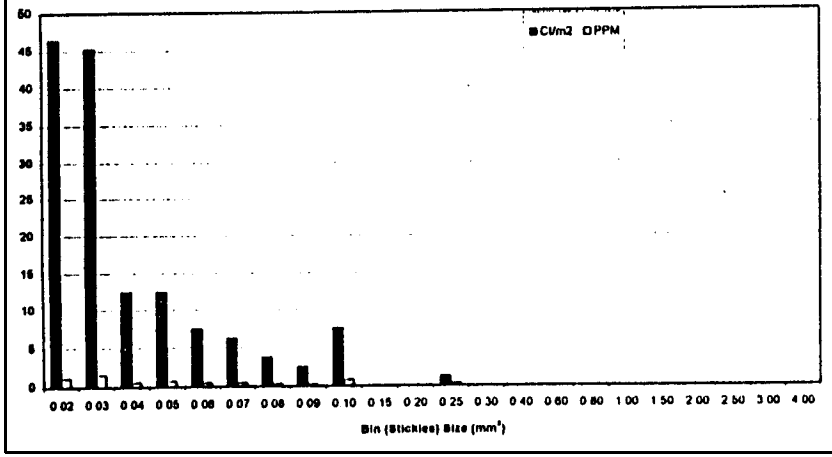


Fig. 28.
Synthetic Rubber Postconsumer
Image Analysis After Sidehill Washing
Total Count/m² = 122 Total Avg PPM = 7

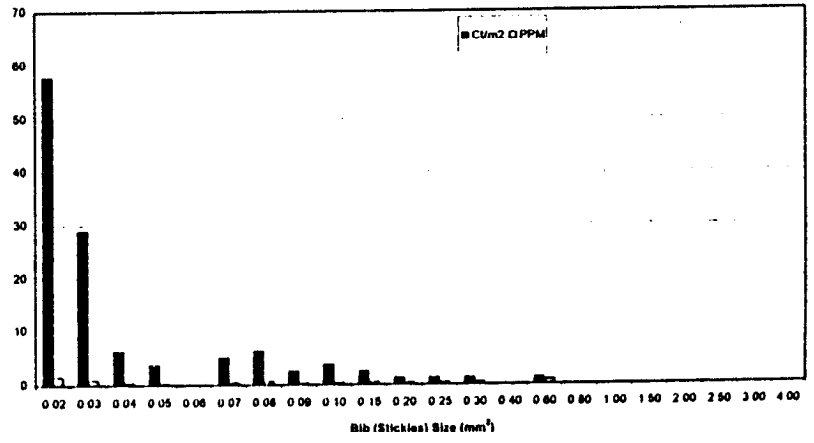


Fig. 29.
Dispersible AcrylicsPostconsumer
Image Analysis After Pulping and Before Screening
Total Count/m² = 21,216 Total Avg PPM = 5183

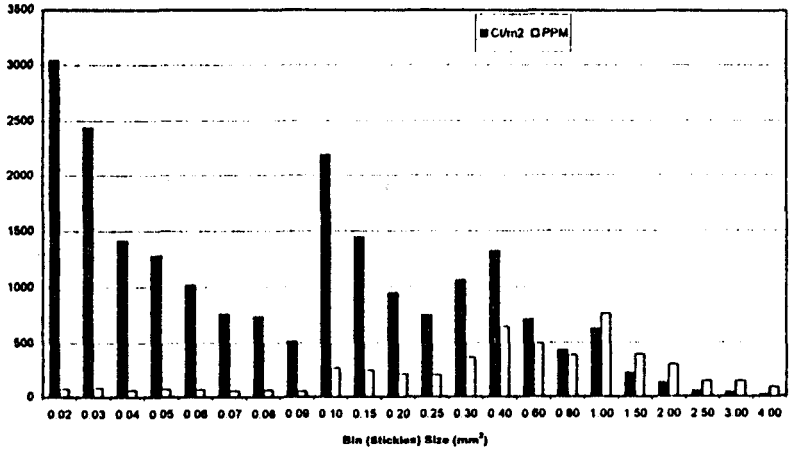


Fig. 30.
Dispersible Acrylics Postconsumer
Image Analysis After 0.30 mm Pressure Screening
Total Count/m² = 19,326 Total Avg PPM = 3302

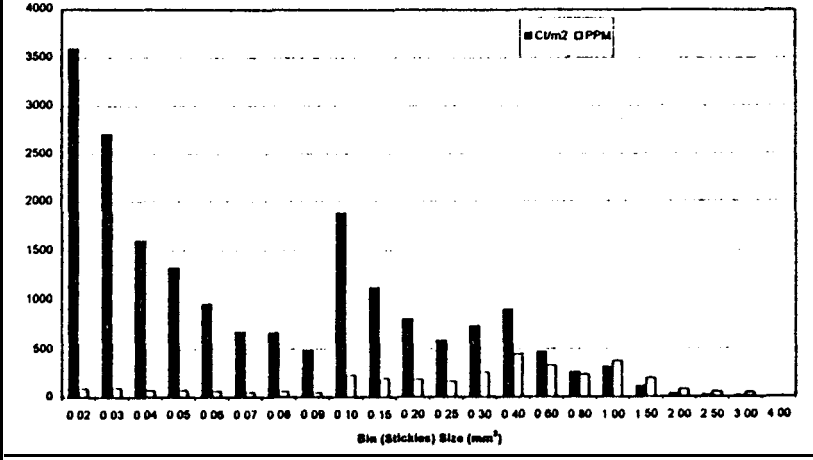


Fig. 31.
Dispersible Acrylics Postconsumer
Image Analysis After 0.15 Pressure Screening
Total Count/m² = 13,133 Total Avg PPM = 2452

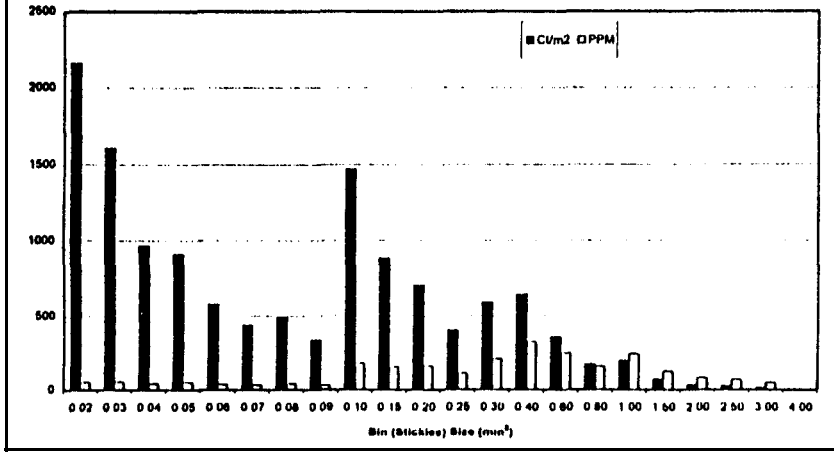


Fig. 32.
Dispersible AcrylicsPostconsumer
Image Analysis After Forward Cleaning
Total Count/m² = 10,792 Total Avg PPM = 1815

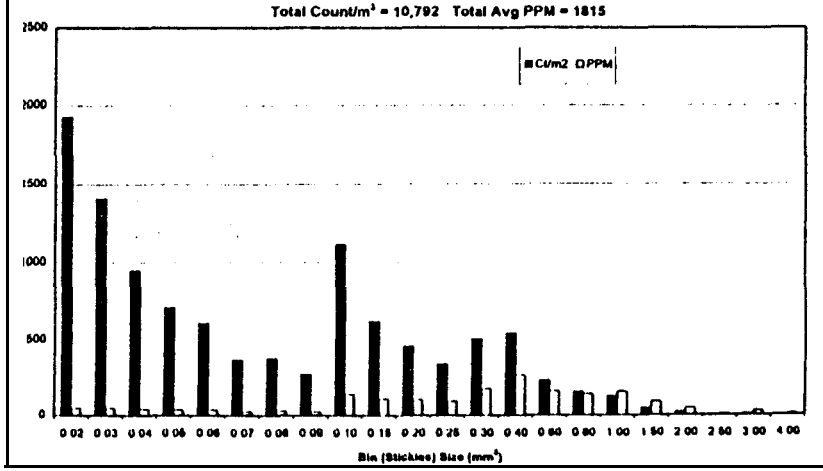


Fig. 33.
Dispersible Acrylics Postconsumer
Image Analysis After First Through-flow Cleaning
Total Count/m² = 6716 Total Avg PPM = 1384

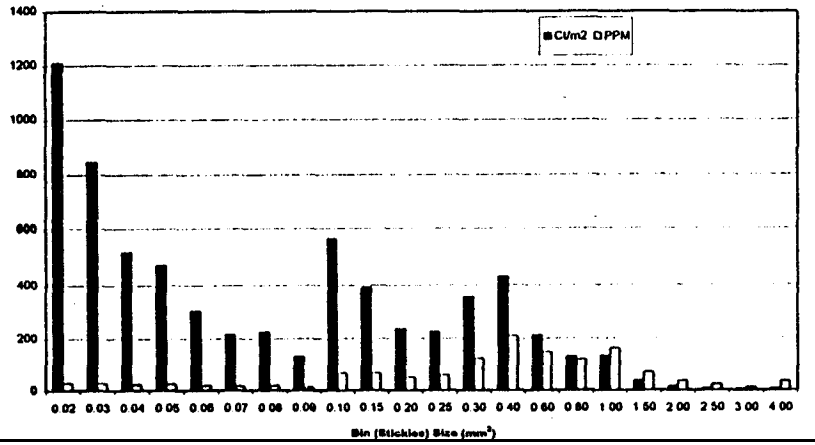


Fig. 34.
Dispersible Acrylics Postconsumer
Image Analysis After Second Through-flow Cleaning
Total Count/m² = 6411 Total Avg PPM = 1450

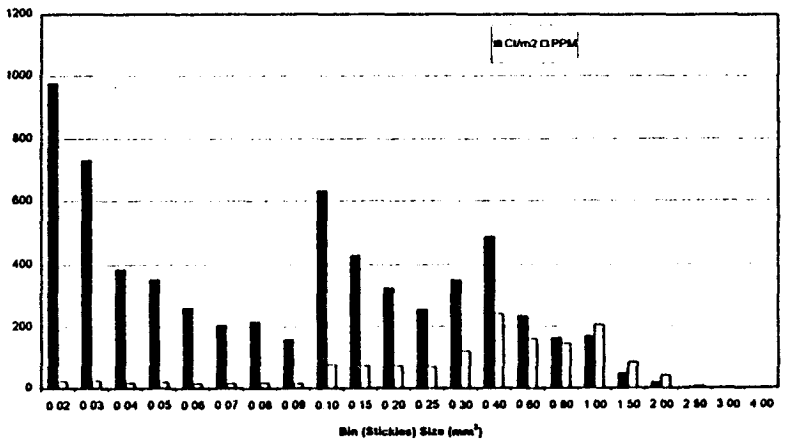


Fig. 35.
Dispersible Acrylics Postconsumer
Image Analysis After LaMort Flotation
Total Count/m² = 3959 Total Avg PPM = 1156

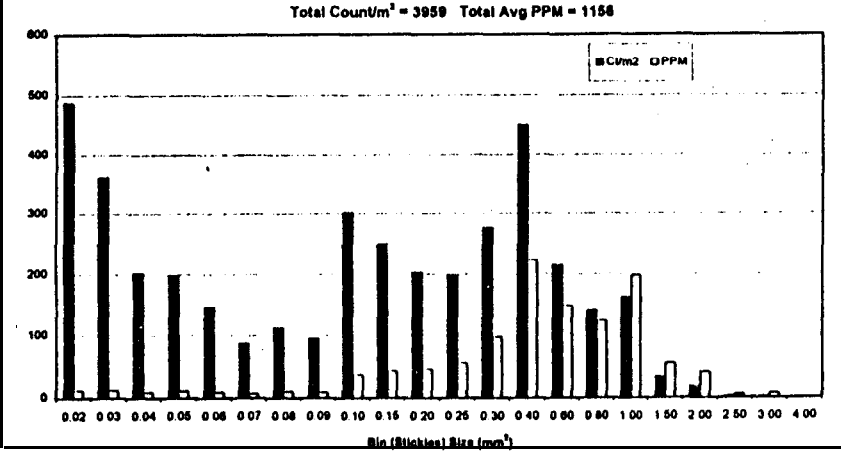
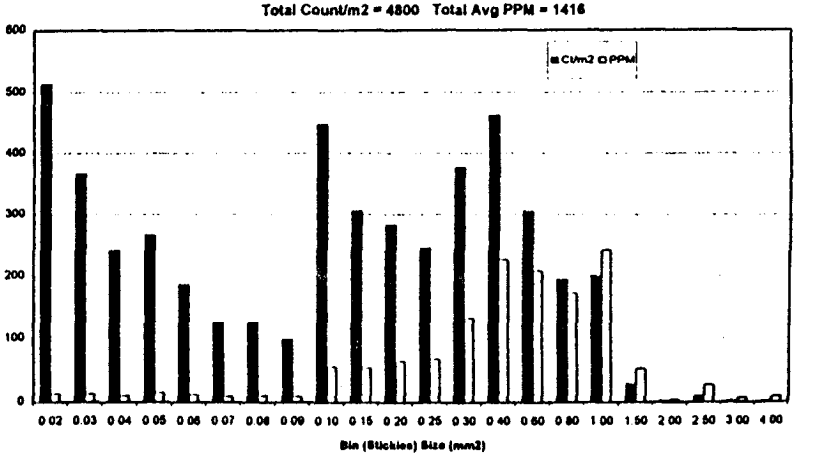



Fig. 36.
Dispersible Acrylics Postconsumer
Image Analysis After Sidehill Washing
Total Count/m2 = 4800 Total Avg PPM = 1416