# Quantification of Pressure Sensitive Adhesive, Residual Ink, And Other Colored Process Contaminants Using Dye and Color Image Analysis

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## ABSTRACT

The USPS Image Analysis (IA) protocol recommends the use of hydrophobic dyes to develop contrast between pressure sensitive adhesive (PSA) particles and cellulosic fibers before using a dirt counter to detect all contaminants that have contrast with the handsheet background. Unless the sample contains no contaminants other than those of interest, two measurement steps are required: before dying to detect dirt and after dying to detect both dirt and dyed contaminants. The difference between these two measurements can be used to estimate the level of dyed contaminants present. To complement the efforts of the USPS, a new computer image analysis system that measures in full color was developed that is able to measure and classify on the basis of color, residual ink, colored contaminants, and dyed particles in a single analysis step. The theoretical foundations and the practical details of the IA system are discussed. Results obtained for mill stock samples containing PSA's using both the USPS protocol with standard dirt counting and an abbreviated protocol using color image. analysis are compared. The data suggest that the two methods give very similar results.

## INTRODUCTION

The image analysis procedure we have developed is intended to allow mill operators to more fully characterize contaminants in pulp samples. Some of these contaminants are visible such as dirt, residual ink, colored remnants of printed matter, shives from ground wood and TMP. Another class of contaminants that tend to cause serious run-ability problems are stickies, which have may have no visible distinguishing characteristic to separate them from other contaminants. Stickies include thermoplastics that will melt on the machine and become tacky, and PSA's that are tacky at room temperature.

The automatic measurement of stickies has been an elusive goal. The problem has been finding a measurable property that identifies them as a sticky without actually touching them. In pursuit of this goal, methods have been developed using controlled heat and pressure to melt and cause them to flow into surrounding the fibers (1). Subsequent wetting or dying of the handsheet then changes the optical characteristics of the unaffected fibers causing the fibers that are not "waterproofed" by the melted stickies to visibly contrast with the "waterproof" areas. This technique is limited to those stickies that will melt and flow and, because it distorts the original contaminant, does not lend itself to quantification but is a good indicator of quality.

Other techniques using a powdery surface that will stick to the surface of the stickies require the washing away of the powder. This action also often washes away the sticky. It does not find stickies that are tacky at machine temperatures but are not actively tacky under the conditions the powder is applied (2). Other procedures have many steps and activities that require long dwell times. Several of these have been presented at various TAPPI Recycle symposia and are cited below.

One of these procedures is the dye method developed at the prompting of the USPS as part of the benign adhesive project. This method is described in condensed form by William Scholz in his paper "A Summary of Stickies Test Methods" (3) and in detail elsewhere in these proceedings. The dye method has been essential for evaluating PSA compatibility with the recycle fiber recovery process. Attempts to apply this dye method in the highly contaminated mill environment has led to the development of an alternate dye method coupled with color image analysis. The authors believe this technique can be implemented as a recycle mill process quality control protocol to report: 1- stickies (PSA's), 2- dirt, and, 3- other colored contaminants present in one image analysis step.

## DYE METHODS

There are many contaminants that can cause run-ability problems on modern paper machines using recovered fibers. One of these is stickies. Stickies problems are difficult because they are often mixtures of many different polymers. Wax coatings, enamel coatings, window scaling materials, labels, stickers, and stamps are only a few of the potential sources of stickies in a recycled fiber line. The one common property of all these materials is that they tend to be hydrophobic. In fact, many of the deposition methods developed for measuring stickies (6) use hydrophobic substrates to collect materials for quantification. The dyes used in the USPS protocol also probe the surface chemistry if the contaminant particles. Since the fibers are hydrophilic, these hydrophobic dyes tend to preferentially adsorb on surfaces of hydrophobic particles. Figure 1 shows the chemical structures of two dyes used to quantify PSA particles.

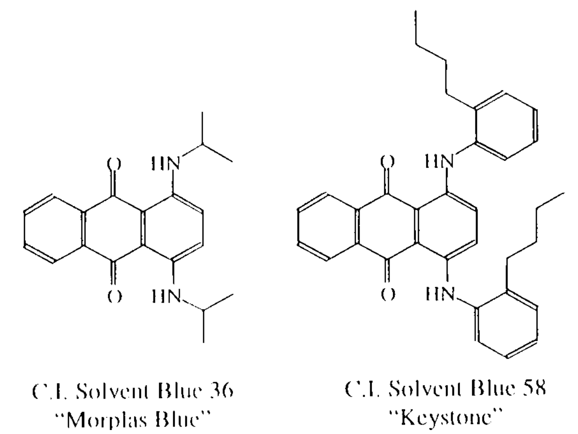



Figure 1: Chemical structures of the hydrophobic dyes used in this study

The USPS Image Analysis protocol, which can be found elsewhere in these proceedings, specifies the use of Solvent Blue 58 in an isopropanol/toluene solution. The handsheet is dipped in the dye solution and then allowed to dry. After it is dried the excess dye is removed by washing the handsheet in methanol. These anthraquinone dyes have strong affinities for hydrophobic surfaces. So when a polar solvent such as methanol is used, dye molecules weakly bound to cellulose fibers are removed, but dye molecules strongly bound to particle surfaces are not removed. The result is a white or slightly tinted sheet with darkly stained PSA particles.

An alternative technique, described in the Appendix, was adapted from the USPS protocol. It was developed to provide a rapid testing method that could be used by the paper mill production quality control lab and market pulp producer concerned with the control of PSA's and other stickies in the process and final product. This method also uses a hydrophobic dye, Morplas Blue, to stain the stickies, but the excess dye is removed by absorbing it into a blotting paper rather than washing, which results in a handsheet that has an overall blue tint, but the PSA particles are dark blue.

## THE MEASUREMENT SYSTEM

The objective of this development was to design a fully automatic image analysis instrument that would measure and classify by type the various contaminants present in hand sheets prepared using the alternate dye method in a single step. Such an instrument would be useful to the recycle process operator for quality and process control.

Ideally the system would be simple to use, be rapid, respond to a single command, measure the degree of visually contrasting contamination of any type, and, finally, provide the process engineer timely control information about dirt, residual ink, and stickies in one measurement step. We know that in addition to stickies, the recycle process stream includes colored and black residual ink, dirt, and colored fibers like unbleached fibers and ground wood. It is our task to design an image analysis system that could extract from the prepared specimen handsheet this information for each, the type, quantity and size classification, based upon the color and shape characteristics.

After dying and visual inspection, these are the contaminants and their characteristics:

| Contaminant | Dominant Color | Shape |
|---|---|---|
| Residual Ink | Black | Roundish |
| Dirt | Various Dark Colors | Roundish |
| Print | Various Lighter Colors | Roundish Ragged |
| Shives & Fibers | Brown, Red | Roundish Clumps to Fibrous |
| PSA's & Light Colored Plastics | Blue, Dyed | Roundish to long |

**Picture Points, Polychromatic Pixel Color**

The common property that differentiates these contaminants is color, and, thus a color image analysis system should be able to separately quantify them.

Visual dirt in process specimens has often been automatically detected and measured using a scanner or camera based automatic dirt counter. Dirt counters generally operate using gray scale images because gray images are small, one third the size of a comparable color image, and can be processed by an older PC that has limited memory. Furthermore, desktop scanner manufacturers have designed their gray scale to conform to the National Television Standards Committee (NTSC) standard for gray images. Which means, by default, most of the desktop scanners, even though, they are often able to acquire a full red, green and blue color image, acquire an image composed primarily using the green sensor. (Note many early scanners had a green bulb and a nom-color selective sensor.)

**Measuring Polychromatic Image Objects**

Inside the scanner the color image is acquired with a CCD camera that has three rows of sensors (RGB) arranged in ranks one above the other. The individual RGB sensors are compacted horizontally to a density defined as the resolution expressed as points per inch (ppi). When an image acquisition session is complete, the scanner driver is given the task of mathematically realigning the RGB picture point sensor rows so they ore dimensionally superimposed one upon the other before the image is filed away, displayed on screen, or transferred to the image analysis software.

The color sensors create three separate images that record, as a numeric value, the intensity of the light striking the sensor dedicated to that pixel location. In all image processing the three values are kept separate so they can be reproduced as a print or video screen display that our eye will sense as a color image. The difficulty with any color analysis that requires separation based upon the specific shades is the sensors are only in red, green, and blue. Most colors are usually always polychromatic blends containing a portion of each sensed color. It is anticipated the contaminants to be detected will likewise be polychromatic.

To measure the image object based upon specific color properties the image analysis system will combine these three sensed color intensity values in ways that will amplify a selected sensed color in relation to another sensed color. The amplification will identify the color component in the object thus marking it for measurement and inclusion in a class. As each color contaminant is classified it is eliminated from the image. This elimination process continues in an orderly fashion until no classifiable objects remain in the original image. This orderly progression assures that any contaminant that contains a blend of colors, i. e. red and blue to make a magenta that could possibly be counted in either color class, will be classified only once.

The red, green, and blue CCD sensors create separate images composed of picture points. The luminance values (LV) of these picture points range from 0 LV to 255 LV in an 8 bit system (24 bit color) and from 0 LV to 4096 LV in a 12 bit system (36 bit color). The 8 bit system is the most common and the easiest to implement. In it the lowest luminance valued level, 0 LV, represents the lowest level of reflectivity, that point where the sensor detects no reflected light of that color and 255 LV the highest level of reflectivity for that color. At a specific pixel location in the image the luminance values of each of the separate bands combine to determine the color displayed on the video, printed on the printer, or used in a computation. If each sensor reports saturation of their color, i.e. 255 LV, then the resulting pixel shade, when displayed, is white. And the converse, when they all report no reflected light, i.e. 0 LV, the displayed pixel is black. Any other combination will show a recognizable color. For instance, a medium dark color purple will result if the averages shown for the "Entire Area of Red Speck #1" in Table 1 or Chart 2 were combined at a single video pixel location.

This blend of sensed colors in an image object is important to the measurement of the contaminants used in this study. Consider the Red Speck #1 in the image shown in Figures 1 through 7. Table 1 shows the luminance values for separate the RGB sensors. It also shows a comparison of the distribution of the sensor luminance values from the core area to the approximate entire area. There are about five times as many picture points in the full extracted image shown in Table 1 and Figure 2A as in the core sample taken from the same speck as shown in Figure 2B. It is this variation in color intensity distribution that is central to this image analysis method.

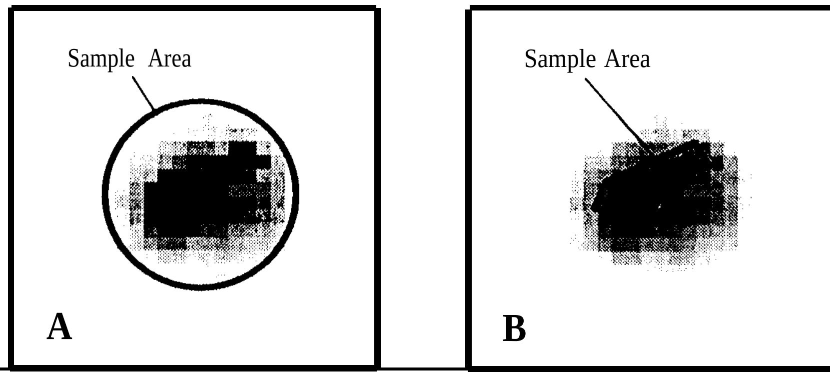



Figure 2: An enlarged view of the red speck #1 shown in Figure 2. This printing is in gray but the actual is full color. "A" shows the sample of almost the entire area of the speck while "B" shows a sampling of the core area of the same speck. The data in Table 1 describe the pixel luminance values within the areas sketched on the images.

| **Table 1** | Color Sensor | | |
|---|---|---|---|
| | **Red** | **Green** | **Blue** |
| **Entire area of Red Speck #1** | | | |
| Average | 140 | 105 | 140 |
| Range: Min - Max | 94 - 182 | 46 - 161 | 74 - 205 |
| **Core of Red Speck #1** | | | |
| Average | 172 | 70 | 96 |
| Range: Min - Max | 164 - 189 | 46 - 105 | 74 - 139 |

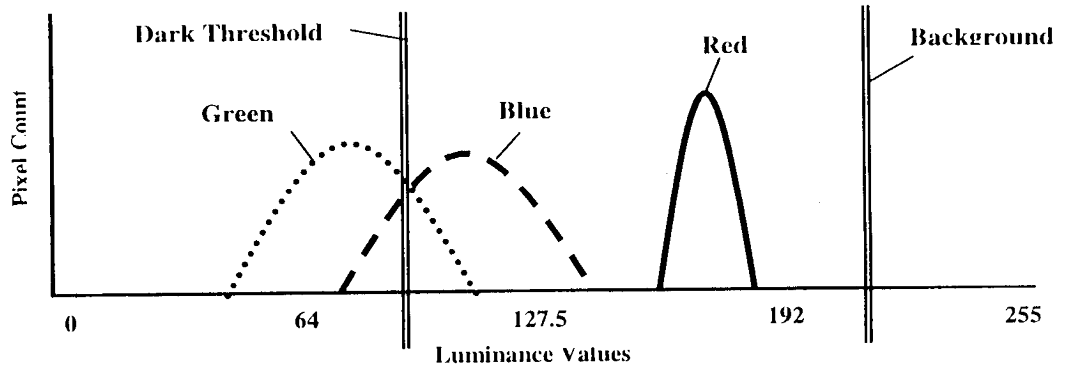
A blue dyed PSA particle has these values:

| **Table 2** Sensors | **Red** | **Green** | **Blue** |
|---|---|---|---|
| **Core of Blue PSA** | | | |
| Average | 98 | 93 | 200 |
| Range: Min - Max | 56 - 148 | 34 - 149 | 164 - 230 |

**Extracting Polychromatic Image Objects**

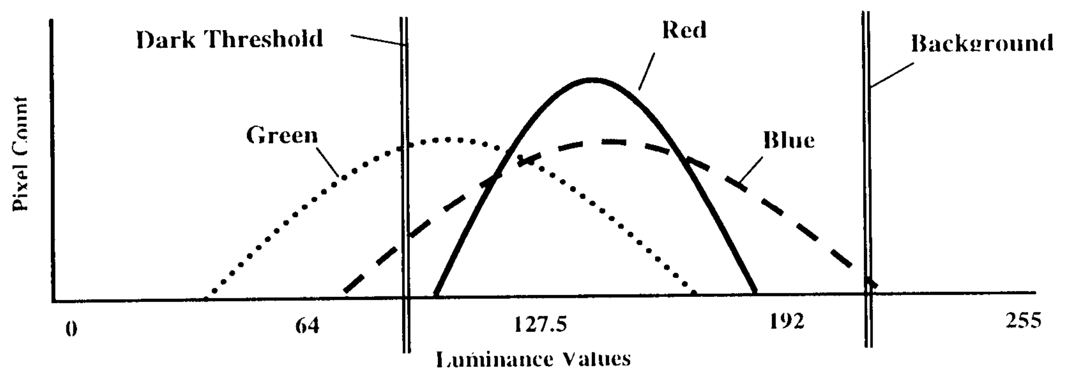
Chart 1 graphically shows the range of luminance intensities present in the pixels making up the core or reddest part of Red Speck #1, Figure 1B. It clearly shows that all three of the color sensors picked up measurable reflection at these picture points.

Chart 2 shows the color intensities present in most of the picture points related to Red Speck #1, Figure 2A. It is apparent there is a higher red intensity in the core area than at the edges and the blue dye is present everywhere. Because there is blue present, and it is so dark, a thresholding technique that used the signal from only the blue sensor would include a high proportion of these picture points that also contained red in a measurement extraction. As a result a blue only extraction would erroneously report the presence ofa blue object when in fact the object is clearly red.




**Core: Red Speck #1**

Chart 1: A schematic showing the relative luminance value distribution of the RGB components in the core of Red Speck #1 shown on Figures 1 to 6. These are the pixels that show the purest red color. As the edges of the speck are approached the blue dye begins the show as a component in the pixel color; see chart 2.




**Entire Area: Red Speck #1**

Chart 2: A schematic showing the relative luminance value distribution of the RGB components in the entire area shown in side the circular area of interest in Figure 1. These pixels demonstrate the pervasiveness of the blue dye. It covers a broad range of intensities and will be present in almost every picture point location.

To separate those objects containing a higher proportion of colors other than blue the image analysis program designed by Verity IA LLC for this application separates those polychromatic picture points from the main image by calculating the ratio of the red luminance intensity to the blue intensity at each point. This ratio is then multiplied by a constant, usually 128, and the resulting value is placed in a new image containing the exact arrangement of picture points as the original.

**New Pixel Luminance = 128* R / B**

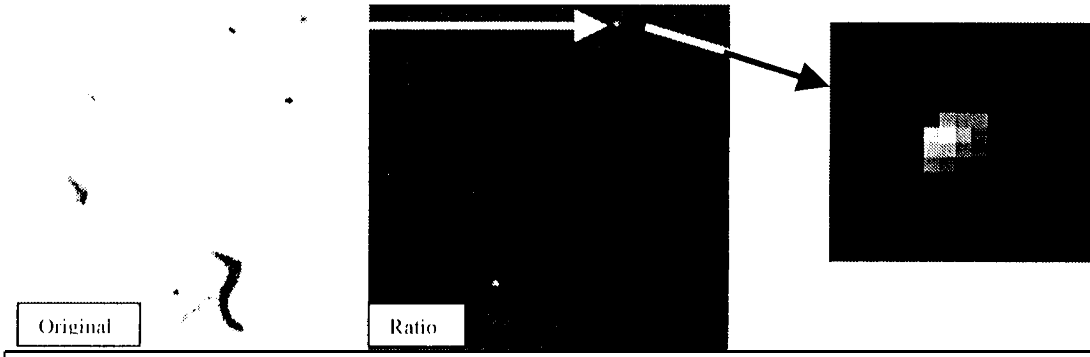



Figure 3: Transition from Full color image to a gray tone image using the ratio of red intensity to blue intensity. The arrow is pointing to the specific transition of Red Speck #1 to a light gray while dominated area. The final view is magnified

[The first image is full color not reproduced here. See the Color Image Addendum.]

This produces a gray tone image illustrated in Figure 3 that has significantly lightened those pixel containing both red and blue measurable intensities and, where the ratio of' red to blue intensity is 2 or greater, has turned them while.

At each point in the original image the luminance value (LV) of the color of interest (red) was divided the base color(Blue) and multiplied by 128 LV (The mid LV). If the ratio is 1 then the resulting new image picture point has a value of 128 LV, a medium gray. When the content of the color of interest becomes less then the result becomes darker. In the example case the original in Figure 3 contains a very high proportion of blue in the overall background and very little red thus the resulting "Ratio" image is very dark overall, much less than a medium gray. And the dyed PSA's become almost black. At the opposite extreme the red speck has turned white and very light gray.

**Thresholding, Colored Object Extraction**

To measure an object the image analysis system must first identify those picture points that satisfy an intensity range criterion. In an 8 bit system these intensities will range between 0 LV and 255 LV. To identify those picture points of interest a minimum and a maximum intensity level is set; i.e. 90 LV and 130 LV and any picture points having an intensity included between these two limits would be extracted, tagged, or foregrounded for further analysis. In this case, if the image were monochrome, the extracted pixels would be a medium gray.

The thresholding limits can also be exclusive in which case the picture point intensities in the example would either be very dark or very light; below 90 LV and above 130 LV.

To extract the picture points contained in the newly created image shown in Figure 2 the threshold limits are inclusive with the top limit being white or 255 LV. The resulting image background is also a function of the blue content in the original image. The typical background LV is the statistical mode of the frequency distribution of the image LV's. The lower threshold limit is then set automatically to be a preset constant or offset LV's above the background statistical mode.

The image analysis software will determine which picture points that fall in the threshold range are connected or touch at any point. It will attempt to close a perimeter around an image object and, when it does, it can include all those picture points within the perimeter to perform other operations such as extracting them all or assigning new luminance values to them. After measuring the size of the light gray object that indicates a red speck the system will then binarize the entire image. Binarization is achieved by assigning 255 LV (White) to the very light gray picture points above the lower threshold value and 0 LV (Black) to the picture points below the lower threshold value. Figure 7 shows this result.

**Establishing Mutually Exclusive Color Classes**

The primary requirement of this analysis is the segregation of the contaminants into discrete categories separate from one another based upon their color.

Because most reflected colors contain a blend of the primary luminance components measured by the scanner, red, green and blue, the analysis should provide assurance any objects extracted from the image and categorized would not be double counted. In order to do this the image analysis system requires many operations upon a single color scan image of the handsheet.

To establish mutually exclusive color classed the method used by the image analysis system is pixel arithmetic, that is, using the image itself to keep track of the analysis progress by eliminating from it the various objects as they are measured and classified. In this way a hierarchy of measurement can be constructed that eliminates the objects that contain the most absorptive color concentrations colors, i.e. Black and other Dark objects, and then to the lighter blended colors containing Red and Green. Done properly, this elimination will leave the blue as the only remaining color.

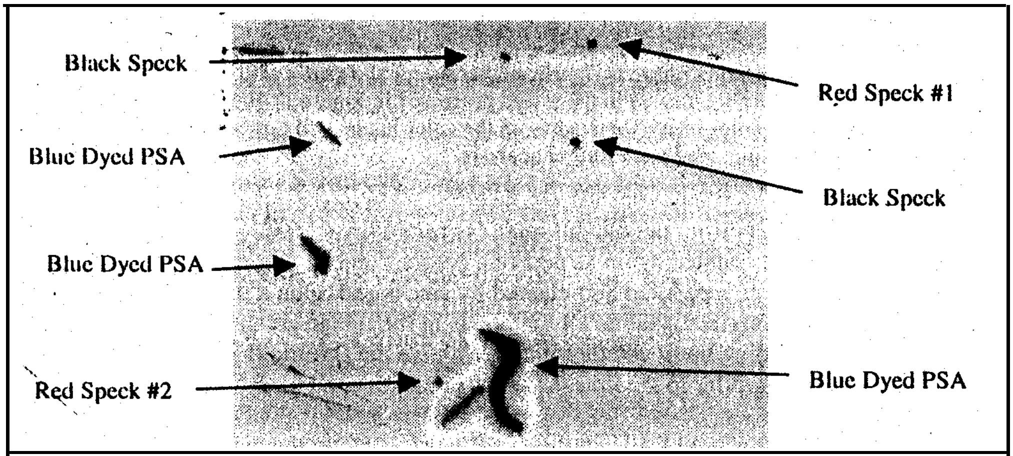



Figure 4: This is a gray image of a full color image made by the image analysis system of the blue dyed specimen. The contaminants arc labeled by the color they are in the original image. The background is also blue and shows here as a gray. The white area that shows around the blue PSA's is in the handsheet. It may be caused when the dye is attracted to the PSA.

This image is made as a conversion from and RGB color image by averaging together the RBG color bands and thus the red specks show as lighter gray.

The automated steps in the process are explained in the following:

1. Acquire an image in full red (R), green (G), and blue (B) tri-stimulus color, at sufficient resolution to reliably report the contaminant size. A discussion of the level of resolution required for the acquisition of a high quality image meeting these requirements is beyond the scope of this examination. The reader is referred to several papers on this subject: Bibliography references 5 & 6.

   The image is sufficiently large to cover the entire handsheet in one scan. This means the image file size can be quite large, in excess of 12 x $10^6$ bytes in size at 600 ppi full color resolution. (Increasing the resolution exponentially increases the tile size. These large images are no problem in the modern PC where computers routinely have 64 x $10^6$ bytes of memory just to play games.)

2. Measure the black and very dark image components. This is the most basic of all the operations. The color image is temporarily converted to a gray image by averaging together the three color components (RGB) of the image. Averaging the raw color image components instead of using the default gray scan mode assures each of the color sensors is equally represented in the resulting gray image. Since it is only the darkest components of

the image that are extracted at this point a fixed threshold luminance value is used to determine which picture points are to be considered as part of the black and dark objects extracted and classed by size. The objects that meet the minimum size requirements are foregrounded (selected).

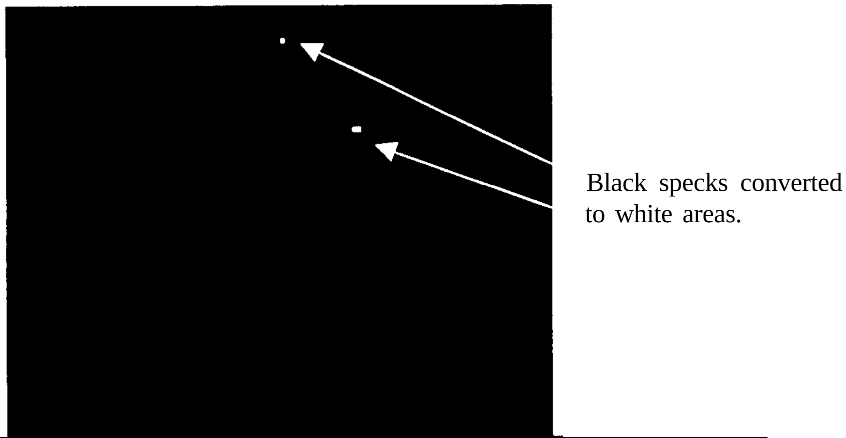



Figure 5: This uninteresting image is significant because it shows the white areas created where the black specks are located in the image processed in Figure 1. When this image is added to the original color image these areas on the color image will turn white and, effectively, will be eliminated from further analysis.

3. Eliminating the extracted objects from the overall image is necessary to assure there is no possibility the black and very dark objects could be counted again as part of a colored object. At this point in the process only the black and dark objects have been measured and classed by size based upon a threshold value. Using this same threshold value the image is binarized, that is, all the pixels in the image are given a value of either 255 LV (white) or 0 LV (black) depending upon whether they are above the threshold value or, at or below it. This creates, in our case, an image similar to the one shown in Figure 5.

   This binarized image of the extracted black and dark objects is added to the original. The result of this addition is shown in Figure 6. The formerly black areas have been turned white in the original.

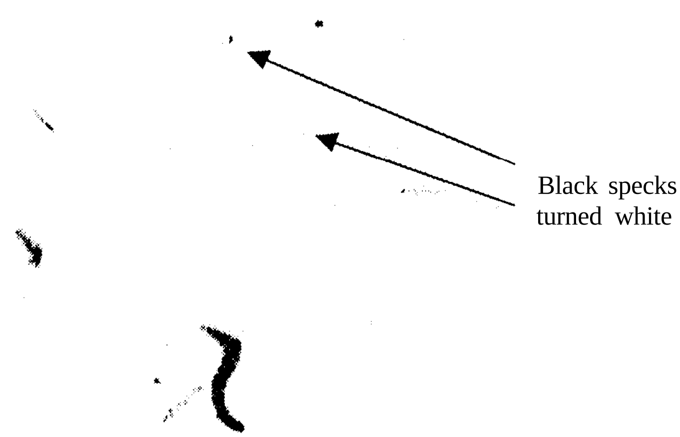



Figure 6: The image after the binarized foregrounded image of the black and dark areas is added to the original. This is shown here as a gray image when in fact it is a very colorful image dominated by blue. [See Color Image Addendum]

4. Each of the color bands is now compared against blue on a pixel by pixel basis as described in the earlier section dealing with the polychromatic object extraction. Once extracted the image is binarized at the threshold luminance value and added to the original as was the black.

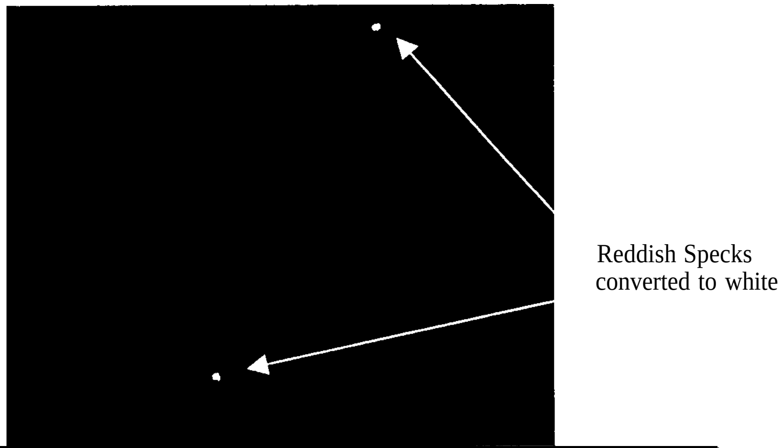



Figure 7: As described in step 5, the binary image of the foregrounded result obtained from the ratio of the red color band to the blue color band at each pixel location.

5. Similar ratio functions are performed with Green and Blue to extract the Yellowish specks and with Red and Green to extract the Cyan. Each image is foregrounded and binarized separately, and then summed to form a composite as illustrated in Figure 8 all of the Black and other colors except for the Blue. This composite of all is then added to the original image before extracting the blue dyed PSA's. The result is shown in Figure 8.

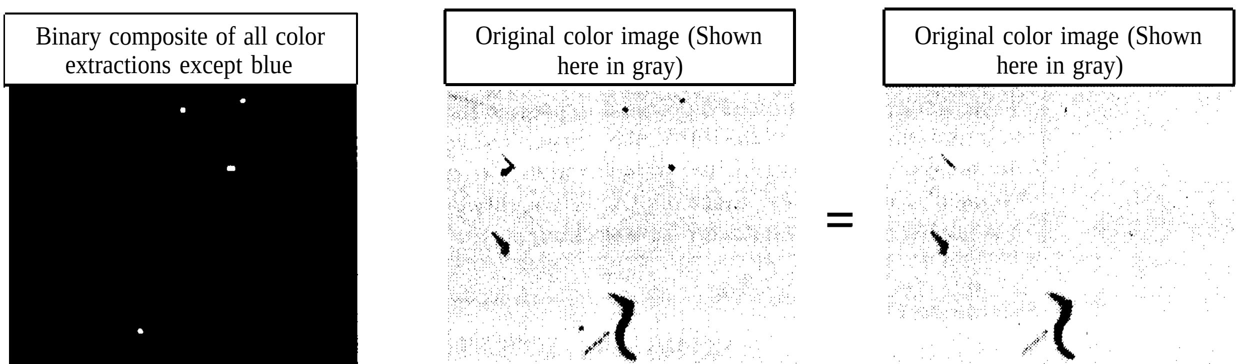



Figure 8: Final image after adding the composite of all color extractions leaves only the blue objects of interest darker than the background.

6. As shown in Figure 7, when this image is added arithmetically to the previous one the areas that have been foregrounded, and given a value of 255, are turned white. In these areas the luminance value now exceeds the possible range of the pixel value luminance scale, 0 to 255. When this occurs these areas are no longer available for analysis because they are now pure white in the image being analyzed and will not be included in any thresholded image using a threshold of 254 or less..

7. Since blue is the dominant color it will be used to ultimately determine the size and classification of the dyed PSA's,

**Results:**

Results using alternate dying method were compared to results obtained using the USPS protocol on the same mill stock samples. This comparison is shown in Tables 3, 4 and 5.

| Alternate Dye Method & Multi - Color IA | | | | | | | |
|---|---|---|---|---|---|---|---|
| Blue offset : | 37 | | | | | | |
| Black threshold : | 120 | | | | | | |
| | Contaminant | | | | | | |
| Sample Pt. | Blue | 95% CI | Black | 95% CI | Other | 95% CI |
| 1 | 1529 | 357 | 261 | 94 | 0 | |
| 2 | 843 | 130 | 53 | 73 | 0 | |
| 3 | 923 | 115 | 3 | 2 | 0 | |
| 4 | 294 | 57 | 8 | 7 | 0 | |
| 5 | 179 | 34 | 1 | 1 | 0 | |

Table 3: Alternate single step dying method coupled with the multi-color IA that measures dark, blue, and other contaminants as separate categories in a single specimen image. In this particular set of specimens there were no contaminants in the "other" category detected.

| USPS Protocol | | | | |
|---|---|---|---|---|
| Threshold 140 | | | | |
| | Contaminant | | | |
| Sample Pt. | Stained | 95% CI | Unstained | 95% CI |
| 1 | 1480 | 294 | 32 | 16 |
| 2 | 740 | 83 | 10 | 6 |
| 3 | 810 | 72 | 10 | 3 |
| 4 | 280 | 55 | 15 | 4 |
| 5 | 140 | 54 | 8 | 7 |

Table 4: Using the full **USPS** protocol to prepare the specimens: each was first measured to detect the dirt as the "unstained" contaminant and then the same set of handsheets was stained and then re-measured to detect the "stained" contaminants. Since the IA system only uses gray scale values, it is unable to differentiate dirt from stickies.

| Calculated Stickies | | | | |
|---|---|---|---|---|
| | Contaminant | | | |
| Sample Pt. | Blue | 95% CI | USPS | 95% CI |
| 1 | 1529 | 357 | 1448 | 294 |
| 2 | 843 | 130 | 730 | 83 |
| 3 | 923 | 115 | 800 | 72 |
| 4 | 294 | 57 | 265 | 56 |
| 5 | 179 | 34 | 132 | 54 |

Table 5: Combining the Single step methods from Table 3 and the USPS protocol from Table 4 after taking the difference between "Stained" "Unstained" results.

As shown in Table 5 average PPM values obtained using the two methods are highly correlated. The color image analysis method appears to give values that are slightly higher, but this can likely be corrected by adjusting the threshold value used in the dirt counter or dark threshold and the color measurement contrast offset values in the color IA.

## CONCLUSIONS

The alternate dye protocol coupled with the color image analysis method has been shown to give results nearly identical to results obtained using the USPS protocol. Further work will be required to confirm the validity if using the alternate method to quantify the stickie contaminants found in mill stock samples. An added benefit of using the color image analysis method is that contaminants can be separated and quantified in a single measurement step, which should allow operators to better identify the sources of contamination and thereby develop strategies to control them.


## ACKNOWLEDGEMENTS

We would like to thank the USPS for supporting this work and providing the data produced using the USPS Image Analysis protocol.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## APPENDIX

Hydrophobic contaminant identification method

DRAFT 19 Nov 99

**1. Scope**

1.1 This procedure describes a method fix quantifying hydrophobic contaminants in pulp samples. A dye that associates with contaminant particles is used to develop contrast from the pulp background. Computer-based color image analysis can then be used to quantify contamination levels by type based upon color and shade.

1.2 This method is a compliment to TAPPI T 213 "dirt in pulp". It allows for the quantification of hydrophobic contaminants that do not have sufficient contrast with pulp to be identified. Hydrophobic contaminants, i.e., waxes, pressure sensitive adhesives, hot melt adhesives, etc., can contribute to "stickie" problems in recycled fiber mills.

**2. Significance**

2.1 When coupled with automated color image analysis contaminant measurement and classification methods, this method provides a complele quantification of pulp contaminants.

## 3. Apparatus

3.1 Standard handsheet mold as described in TAPPI T 205 sp-95.
3.2 Standard couch roll.
3.3 Standard blotting paper as described in TAPPI T 205 sp-95.
3.4 Handsheet dryer with an operating temperature of 150°C.
3.5 Color image analysis system able to acquire and analyze an image at least 600 ppi resolution and able to automatically set a threshold based on contrast below the statistical mode of the sheet image in each of its three primary colors, Red, Green and Blue. The instrument is able to measure and classify the various contaminants present into Dark (Residual Ink), Blue (Dyed Stickies and Other (Colored contaminants of an undefined nature.) based upon their colors and relative darkness.
3.6 Plastic or metal tray large enough to hold a blotting paper.
3.7 Foam varnish applicator.
3.8 Laboratory timer

## 4. Reagent

4. 1 dye solution 0.67 g of C.I. solvent blue 36 in 1 liter of n-heptane. The dye is also known as Morplas Blue 1003 and can be obtained from Pylam Products Company Inc., 2175 East Cedar Street, Tempe, AZ 85281, (602) 929-0070

## 5. Procedure

5.1 Form handsheets according to TAPPI T 205, except end the procedure after couching. After couching the second wet blotting paper is discarded and a third dry one is placed to protect the handsheet attached to the first blotting paper.

5.2 Place the two blotter papers, with the handsheet between them, on the dryer. The intent is to leave the handsheet firmly attached to the blotting paper until it is dyed. Dry for a set period of time that is recorded and kept constant through a series or as a laboratory standard for the handsheet dryer used and temperature setting.

5.3 Dye the handsheet by applying the dye solution to the back side of the blotter that has a handsheet attached. This allows the dye to uniformly penetrate the handsheet. Furthemore, as the dye solution passes through the blotting paper dye undissolved particles arc filtered from the solution. Typically, dying is done by placing the blotting paper/handsheet with the handsheet side down on another blotting paper in a tray, and then painting the blotting paper with a foam brush that has been dipped in the dye solution. This step of the procedure should be carried-out in a ventilation hood to avoid exposure to heptane vapors. Since the dye is a mild sensitizer, heptane-tolerant gloves are also required.

5.4 Let the heptane evaporate from the blotting paper/handsheets without separating the handsheet from the blotter paper by hanging them with clips attached to the blotter paper in the ventilation hood. Typical drying times are 2-3 minutes.

5.5 With a gloved hand gently peal the dyed handsheet from the blotting paper. Place the side that was towards the blotting paper on the glass of the flat bed scanner. Using a weight with a white surface, hold the sheet flat on the scanner.

5.6 Use the color image analysis software to quantify the number of particles on the sheet. To compensate for sheet to sheet variations in dye intensity, best results are obtained by using a threshold that is automatically set 20 luminance values below the mode of the sheet image picture point luminance value frequency distribution. The software system developed by Verity IA LLC was used in this study. The scanner used was an AGFA Argus II.

## 6. Report

6.1 Results for each class are reported as parts per million of the scanned area. Typically an average and 95% confidence interval for 10-40 standard 1.2 g handsheets is calculated.

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