Paprispec©: a system for monitoring plastic contaminants in pulp

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ABSTRACT

Efficient inspection techniques are required to ensure that pulp sent to sensitive markets meets quality specifications with regard to plastic contamination. The Paprispec© System has been developed to do this where no suitable means had previously existed.

Application:

Pilot plant trials demonstrated that the Paprispec© System can process representative quantities of pulp and capture plastic specks at a high (>70%) efficiency. Mill trials showed how Paprispec© could be used to provide a daily measurement of plastic contaminant levels.

PLASTIC SPECKS ARE AMONG THE most troublesome contaminants found in pulp. They can lower paper quality in several ways *(1, 2)*. Specks will reduce the appearance of the paper and its physical strength. Because plastic specks do not integrate into the paper sheet, they can fall out and leave holes. Even if the specks are retained in the sheet, they may act as sites of stress concentration and lead to sheet breaks. These breaks will cause lost production during the papermaking or printing processes.

Plastic specks can also lead to image quality problems in the printing process. If the speck is removed from the paper sheet during printing, it may transfer to the printing blanket or printing plate, where it will interfere with ink transfer and cause a "hickey," "donut," or other visible defect to appear on the printed image. But perhaps the most serious problem caused by plastic contamination is streaking of coated paper. A speck that is trapped under the blade of a trailing-blade coater will interfere with the uniform transfer of the coating medium. A streak or scratch will result, which will severely degrade the quality of the coated paper. Because many types of plastic are wear-resistant, the speck will not be easily worn away by the moving paper sheet. Thus a single plastic speck can cause a large amount of high-value coated paper to be rejected.

DEFENSES AGAINST PLASTIC CONTAMINATION

The principal defenses against plastic contamination are based on prevention, removal, and detection *(3, 4)*. Prevention has been promoted by mill awareness programs that alert employees to the problem of plastic contamination. Workers can identify and eliminate sources of plastic, such as debris that is inadvertently mixed with the chip supply; packaging materials that are discarded on the mill floor and washed into the floor drains and fiber recovery system; and plastic components of the pulp mill system which abrade and pass directly into the pulp suspension.

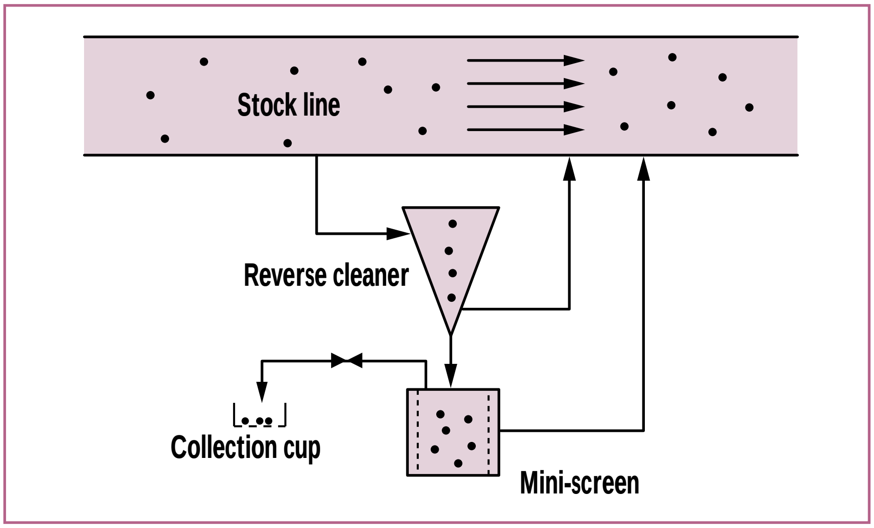
The removal of plastic contaminants may be made on the basis of their size or density. Size separation (i.e., screening) can be accomplished by the chip screens, knotters, or pulp screens. However, screening is not completely effective for the removal of small specks and plastic films or plastic that enters the system after the pulp screens. Also, many of the systems that treat the screen rejects will subvert the action of the screens. The majority of oversize contaminants are fibrous, such as knots and shives. Certain reject treatment systems are designed to reduce these contaminants to fibers and return them to the process stream. Unfortunately, the plastic in the reject stream will also be broken down until it is small enough to pass through the screens. These very small specks may still cause streaking and the various other problems listed above.

Centrifugal cleaners can separate plastic from pulp based on differences in density. There are two problems with this approach, however. First, the most commonly used centrifugal cleaners are designed to remove heavy contaminants such as sand, while the most commonly found types of plastic (polyethylene and polypropylene) are lighter than water. Second, the centrifugal cleaners that are specifically designed to remove lightweight contaminants like plastic are not perfectly efficient. As many as a third of the plastic specks will pass into the accept stream.

Detection is perhaps the most critical tool in dealing with the problem of plastic contamination. Outbreaks of plastic specks are believed to be sporadic but can last for several days. If one knows when an outbreak is occurring, one can, in the case of a pulp mill, direct the pulp to a customer whose process is relatively insensitive to plastic.

Ongoing measurements of plastic levels will establish trends for a particular mill. One can assess how improvements in the aforementioned defense strategies (e.g., the

1. Inspection for plastic using the light box technique



2. Schematic of Paprispec© System

installation of a new screening system) have reduced plastic levels. Correlations of plastic levels with other events, such as a change in chip supplier or a mill shutdown (when large amounts of plastic packaging material accompany new equipment into the mill) may indicate sources of plastic. Also, intermill comparisons can be made to establish preferred sources of pulp (for paper mills buying pulp) or to identify any commonalities among mills which have very low levels of plastic.

Analysis of the detected specks may indicate their origin. The specks may then be eliminated at their source. Fourier-transform infrared (FTIR) spectroscopy, for example, can give a very specific description of the plastic type and is useful for this purpose *(5)*.

CURRENT TECHNIQUES FOR MONITORING PLASTIC IN PULP

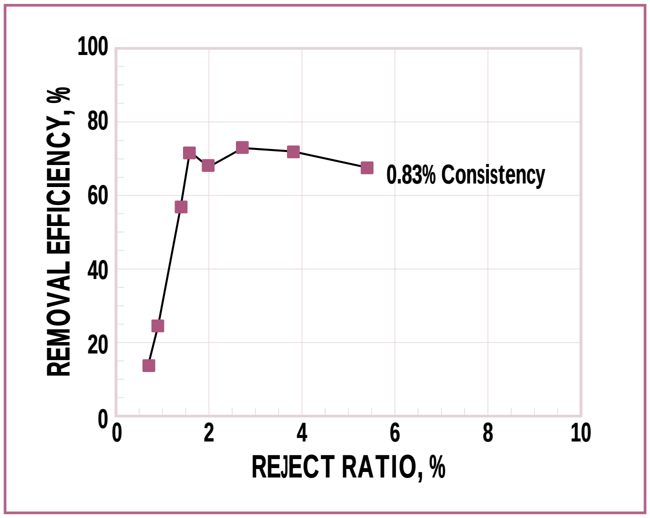
While detection is an important part of defending against plastic contamination, the current techniques have some severe limitations. The light box technique is the most common method of detecting plastic specks for producers of market pulp. With this method, a grader will take a single sheet of pulp (about 0.8 m by 0.8 m) and place it on a light box so that it is illuminated by both transmitted and reflected light. The pulp may be wetted to make it more translucent. The grader manually inspects the sheet for common contaminants like dirt specks and shives and makes a count of each, as shown in **Fig. 1**. The grader will also remove the specks from the pulp sheet and attempt to determine if they are plastic by some combination of tests, i.e., crushing a speck to assess friability; probing it with a hot needle to test the melting point; conducting sink/float tests; or examining the speck under a microscope.

There are several problems with light box inspection. First, many plastic specks are clear or white and are difficult to see against the white pulp sheet. Second, the test is somewhat subjective, and plastic counts can vary from one grader to another. Third, the technique is slow and labor intensive. Finally, and perhaps most seriously, the statistics of inspecting for trace contaminants like plastic indicate that very large sample sizes are required, much larger than are practical with the light box approach. For common contaminants like shives, several pulp sheets may provide an accurate measurement. Plastic contaminants, however, are objectionable at trace concentrations, in the order of several specks per 100 kg of pulp. According to statistical analysis, several thousand pulp sheets would be required for a single measurement of plastic concentration. This number compares poorly with inspection routines which may only see 10 pulp sheets inspected per hour.

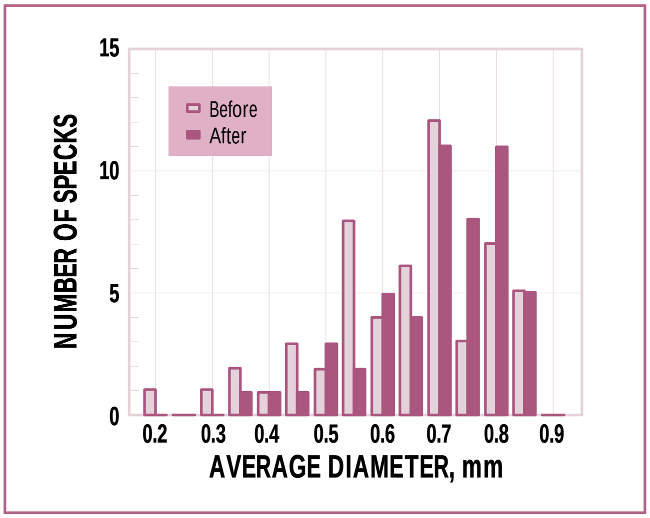
The lab screen method is also used for measuring levels of plastic contamination. In this approach, a sample of the pulp slurry is tapped at some convenient location in the process and brought to the mill lab. The suspension is then passed through a laboratory screen with 0.10- or 0.15-mm wide slots, and the oversized contaminants are examined to determine which are plastic. This method will enable many of the clear and white plastic specks to be detected. However, it is even more time-consuming than the light box technique, and the sample sizes are substantially smaller.

HISTORICAL DEVELOPMENT OF THE PAPRISPEC© SYSTEM

There have been a number of efforts to develop a measurement system for plastic contaminants, one of which led to the patented Paprispec© System *(6)*. In 1987, Northwood Pulp and Timber Ltd. and



3. Containment removal efficiency as a function of the reject ratio for the reverse cleaner



4. Comparison of speck size distribution before and after a 24 h residence in the mini-screen

Paprican developed a plan to install a reverse-type centrifugal cleaner (where the pulp sample was tapped from the process stream) and to sample the reject flow from the cleaner. This type of centrifugal cleaner concentrates plastic and other lightweight contaminants in its reject stream, while heavy debris, shives and most of the pulp exit through the accept stream. When the reject ratio (i.e., the reject flow divided by the feed flow) is small, the reject flow has a concentration of plastic specks 10–100 times that in the feed flow. The effective sample size is increased by this amount. However, the rejects still contain some residual pulp and must go on to a time-consuming laboratory screening treatment. The method was not convenient enough for routine use at Northwood and was discontinued.

The Northwood approach, did however, come to the attention of Robitaille and Peeling *(7)*. They built a plastic monitoring system that also used a cleaner to concentrate plastic specks from a sampled pulp stream, but in their approach the plastic-rich reject stream went to a flotation tank. The underflow from the flotation tank returned to the process, while the lightweight plastic specks accumulated on the surface of the tank. The sample stream could thus be drawn from the process stream continuously. The sample size (i.e., the quantity of pulp fed to the cleaner during a daily inspection period) increased to the equivalent of more than 1000 pulp sheets. To assess the level of plastic contamination, the floating specks would be skimmed from the surface of the flotation tank and counted. The number of specks would then be divided by the total mass of pulp fed to the cleaner to obtain a measurement of plastic concentration.

The system developed by Robitaille and Peeling has been used for the last seven years at St. Anne-Nackawic Pulp Co. Ltd. Since that time, several Weyerhaeuser pulp mills have built their own versions of this system *(8)* and used them to monitor plastic levels. However, while Robitaille and Peeling's system was quite superior to the light box and lab screen methods, its limitations prevented more widespread use. Foam, steam and pulp accumulated on the surface of the flotation tank in certain applications and interfered with speck collection, making the procedure time consuming and somewhat subjective. More seriously, calculations of the buoyant and drag forces on a plastic speck revealed that small flotation tanks would not reliably capture the smaller diameter specks. The required diameter of the tank would be too great for convenient mill use.

The next step in development occurred in 1991 when Fletcher Challenge Canada Ltd. and Paprican designed and built a unit for monitoring plastic concentration that used a modified flat screen in place of the flotation cell. This avoided the aforementioned problems with the flotation cell. In this new configuration, the screen was modified so that it could be directly coupled to the reject outlet of the centrifugal cleaner. Thus plastic specks would be concentrated by the cleaner and passed to the screen, where they would accumulate. When a speck count was made (typically once per day or once per shift), the screen plate containing the specks was removed and replaced with a clean screen plate. The detection system could resume operation while a manual count of the specks was made.

5. Paprispec© prototype used in mill installation

The cleaner-flat screen system was an improvement over the cleaner- flotation tank approach, and several mill installations followed. It also had some serious operating problems, however. In some mills, significant amounts of pulp and bleached shives would accumulate with the plastic specks and obscure them. A chemical treatment was needed to dissolve the fibrous material so that the plastic specks could be counted. This additional step increased the time required to make a speck count to about 30 min.

An additional problem with the flat screen was the possibility of a screen overflow. Overflows were typically ascribed to upsets in the mill system that affected the feed pressure or feed consistency to the cleaner. This, in turn, caused higher consistency pulp to go through the reject outlet of the cleaner and to the screen. Overflows did not occur often, but when they did, the specks were lost, and no measurement could be made. Further development was clearly required.

PAPRISPEC© SYSTEM

Paprispec© is the plastic monitoring system that grew from the work described above. A schematic of the system is given in **Fig. 2**. The path through the system begins with a sampling line that draws a continuous stream of pulp from the process. The sampling point is typically on the accept line from the mill's pulp cleaning system, where the consistency is low and the flow is downstream of the mill's stock preparation equipment. Typical flow rates and consistencies are 180 l/min and 0.8%, yielding a sampling rate of about 2000 kg o.d. of pulp per day.

The sample stream goes to the reverse cleaner, which concentrates the plastic specks in its reject stream. Meanwhile most of the flow (and most of the pulp) goes out of the accept line of the cleaner and returns to the process stream. The reject flow from the cleaner then passes to a custom-designed mini-screen, where the plastic specks are isolated. The reject flow from the cleaner has a consistency less than 0.1% and a flow rate of 5 to 10 l/min. The removal efficiency for plastic specks in the cleaner is assumed to be 70%, which is reasonable for the values of pulp temperature, feed pressure and flow and reject ratio used in this application.

The mini-screen is a key development that distinguishes Paprispec© from the preceding plastic detection systems. Like process-scale pressure screens, the mini-screen has a cylindrical screen plate with small, 0.15 mm-wide slots. Within the screen plate is a rotor that backflushes the screen slots and clears them of any accumulated fibers. The mini-screen is pressurized to avoid any of the overflow problems encountered with the cleaner-flat screen detection system.

The mini-screen operates in one of three modes. In the collection mode, the pulp in the feed flow to the mini-screen, passes through the screen plate and returns to the process stream. Plastic specks are retained by the screen plate until the system is purged and the specks are collected for counting. This is followed by the flush mode, where the flow to the mini-screen is stopped, and a water flow enters the screen to flush any residual fiber to the screen's accept line. When this is complete, the accept line is closed and the plastic specks are purged from the screen and directed to a collection cup (purge mode). The system can then resume normal operation in the collection mode.

The other key development in Paprispec© is a programmable control system that controls the changes between operating modes, and the switching of the control valves and screen motor. Paprispec© will typically operate in collection mode for 8–24 h. Then, at a pre-programmed time, the system switches into flush mode for a few minutes. This is followed by the purge mode, which lasts for about 2 min, and then the system returns to collection mode.

SUPPORTING EXPERIMENTATION

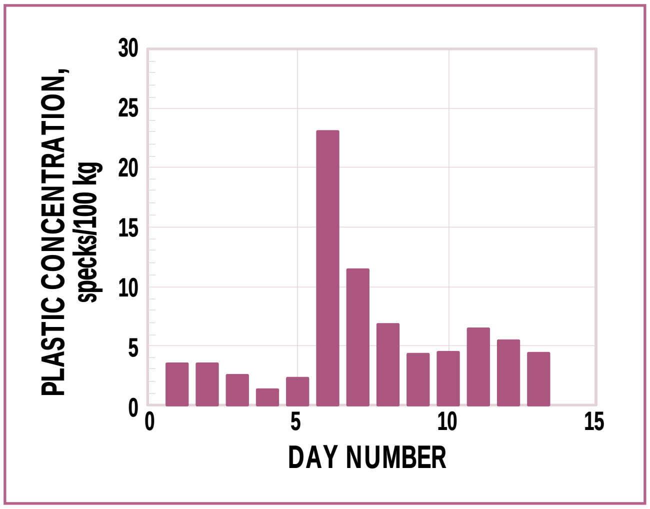
The operation of the Paprispec© System depends on several key assumptions, and each was evaluated in controlled pilot plant tests. The first assumption was that the centrifugal cleaner will remove plastic specks from the pulp suspension at an efficiency of 70% and that these specks will be retained by the mini-screen. To test this, the Paprispec© System was operated under normal conditions, with a feed flow of 0.8% consistency bleached kraft pulp. A premeasured dose of 0.5 mm-diameter polyethylene specks was then injected into the feed flow of the cleaner. After several minutes, the system was switched from collection mode to flush mode to purge mode, and the amount of specks collected was compared to the amount injected into the system. This quantity is termed the *contaminant removal efficiency*, and it is shown in **Fig. 3** as a function of the reject ratio. One sees that contaminant removal efficiency is in the range of 65 to 75% for reject ratios above 2%, which is the minimum reject ratio at which the reverse cleaner should be operated.

A high degree of survivability was required for the plastic specks retained in the mini-screen. In the extreme case, the Paprispec© System would be operated on a 24-h cycle, and a plastic speck would be caught at the start of the collection mode. This speck would be required to remain in the mini-screen for that period of time and to remain undamaged. To test this requirement, a collection of 55 polyethylene specks were measured for size using an image analysis system. They were then placed directly inside the mini-screen, and the unit was run in the pilot plant for a 24-h period. The specks were collected after the usual flush/purge cycles, and 52 of the 55 specks were recovered (95% recovery). **Fig. 4** shows that there was no appreciable comminution or shift in the size distribution of the specks.

A third requirement of the Paprispec© System was that there would be no fiber buildup within the screen unit. Any significant accumulation of fibers would interfere with counting the specks and dictate that an additional treatment would be required to isolate the specks. To test for fiber accumulation, the Paprispec© System was run for a 24-h period in the pilot plant with a typical feed pulp and under typical operating conditions. The amount of fiber purged with the plastic specks was oven-dried and weighed. In repeated tests, it was determined to be less than 0.1 g o.d. At this level, the pulp did not obscure the plastic specks in any way.

PAPRISPEC© MILL TRIALS

Following the successful pilot plant tests described above, Paprispec© was tested at three different pulp mills, each producing bleached kraft market pulp. A photograph of a Paprispec© prototype that was used in one of these installations is shown in **Fig. 5**. The principal finding of these trials was that, in each case, Paprispec© could be used to provide day-to-day reports on the level of plastic contamination in the pulp. Data from one trial are given in **Fig. 6**, and they show that plastic levels were generally less than 5 specks/100 kg of pulp o.d. There was, however, an outbreak of plastic on Days 6 and 7, when the levels exceeded 10 specks/100 kg.



6. Daily measurements of plastic levels from a mill trial

There is continuing discussion about what the maximum permissible level of plastic should be. Maximum levels of 2.5 specks/100 kg and 5 specks/100 kg have been cited by different mills (roughly equivalent to 3 and 6 parts per billion, respectively). However, it has been difficult to set meaningful limits for plastic concentration without a practical measurement technique. Now that Paprispec© is available, correlations can be established between plastic levels and the problems that plastic specks cause. Manual grading of the pulp (using the light box technique) was also done during the Paprispec© trials, but only the occasional plastic speck was found. Paprispec© has detected plastic specks at every mill where it has been tested—every day. This indicates that there is a background level of plastic contamination that is always present, in addition to the plastic outbreaks where the speck levels increase to values of more than 20 specks/100 kg.

The Paprispec© System operated with a high degree of reliability throughout these tests—with one exception. In the first trial, underdesign of the screen plate caused it to fail from mechanical fatigue. Once this problem was remedied, the unit operated well. There were no significant accumulations of fiber within the screen. The time for making a measurement of plastic specks was reduced from 30 min (using the flat screen method) to 30 s.

An important benefit of the Paprispec© approach is that specks can be retained for study and archiving. One can classify the specks by their color, shape and chemical makeup and match them to possible sources of plastic. The vast majority of the specks found during mill trials have been clear or white. This underlines one of the chief difficulties in assessing plastic levels through manual inspection and the light box technique. FTIR analysis of the specks has shown that most specks were polyethylene or polypropylene. More surprisingly, specks of polyamide were also identified in

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Cleaners, detection, impurities, inspection, instruments, measurement, monitoring, plastics, pulps, quality control, screens.

various mill trials. A close match was made with the oil-based defoamers used in these mills. It was speculated that the defoamer had agglomerated and been hardened in the pulp dryer to form small specks that were potentially as harmful as common plastic specks.

IMPLICATIONS OF CONTAMINANT MEASUREMENTS

A determination that the background level of plastic specks is about 3 specks/100 kg means that a pulp mill shipping 1000 metric tons/day of pulp to a coated paper producer will also be shipping 30,000 specks/day to that mill. During unsatisfactory mill operation, streaks and breaks might occur at the frequency of 10 per day, which implies that 99.97% of the specks did not cause a problem. One must conclude that the role of plastic contaminants in paper machine upsets is strongly statistical. For a speck to cause a streak or break, it must present itself in a very particular way to the coating blade—perhaps in combination with some transient condition on the paper machine. This contrasts with past attitudes toward plastic contamination, where the discovery of a single speck could justify the rejection of an entire pulp shipment.

The statistical nature of the problem also implies that the likelihood of particular specks causing a problem is a function of their size, shape, and other physical factors. Rather than a simple speck count, a weighted count should be developed which reflects that certain specks are more likely to cause problems than others. To determine the weighting factors, one would need to use the Paprispec© System to correlate machine upsets with the concentration and type of specks in the furnish.

The most important implication of this work is that Paprispec© provides a convenient and meaningful way to assess levels of plastic contamination. Producers of bleached kraft pulp and recycled pulps now have a way to monitor the quality of their product, to assess the impact of any process changes and to investigate the sources of plastic. Makers of photographic paper, coated papers and other high-value, plastic-sensitive grades have a tool to assess the cleanliness of the pulp they buy, as well as their internal sources of contamination. **TJ**

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