Fibrous Contaminant Identification by Light Microscopy

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ABSTRACT

A contaminant is anything you do not want in your process or product. In this report, we describe an identification method for fibrous contaminants that arise primarily from wood and bark in the pulping process. Such contaminants can usually be satisfactorily identified simply by using light microscopy, rather than any other form of microscopy. A general approach to contaminant identification is described, and some of the more common fibrous contaminants are discussed and illustrated.

RÉSUMÉ

Un contaminant est tout ce que vous ne voulez pas retrouver dans votre procédé ou votre produit. Dans le présent rapport, nous décrivons une méthode d’identifier les contaminants fibreux qui proviennent principalement du bois et de l’écorce lors de la mise en pâte. On peut habituellement les identifier simplement à l’aide de la microscopie optique, plutôt que par toute autre forme de microscopie. Nous décrivons une méthode générale d’identification des contaminants, et certains des contaminants fibreux les plus courants sont illustrés et font l’objet de discussion.

KEYWORDS

IMPURITIES, IDENTIFICATION, PRODUCTION CONTROL, QUALITY, PARTICLES, TESTING, BARK, SIEVE CELLS, SHIVES, STRINGINESS, NODULES, BROKE, FIBERS, MICROSCOPY.
INTRODUCTION

Product quality demands are constantly increasing; customers want improved quality and uniformity. At the same time, sheet basis weights have been decreasing; there is progressively less room for non-uniformities to “hide”. As a result, contaminants in pulp and paper are receiving increasing attention.

Simply put, a contaminant is anything you don’t want in your process or product. There are two categories of contaminants: firstly, foreign materials – what we would naturally think of as contaminants; secondly, materials that are inherent to the process but occur in a form that is detrimental to product quality. These broad categorizations may seem obvious but are important because in many cases the materials that cause problems are not foreign to the process.

You will note that the phrase “fibrous contaminant” is prominent in this report. There are myriad contaminants (plastics, metal, scales/deposits, slime, lint) and numerous analytical tools and techniques for their identification; some of these have been well described in other reports [1–10]. This report deals primarily with pulp and paper contaminants that arise from wood and bark. These can usually be satisfactorily identified using light microscopy. This document is intended to be an aid to fibrous contaminant identification at the mill level.

FIBROUS CONTAMINANT IDENTIFICATION

There can never be a definitive paper on fibrous contaminants – there are simply too many varieties. As stated previously, there are some that originate directly from wood and bark, some that arise in pulping and papermaking and still others that arise in finishing and converting. These contaminants do not occur in isolation; there are synergistic effects. A fibrous contaminant can be a secondary effect of other problems such as chemical imbalances, deposits, improperly finished surfaces, or process changes. To further confound the issue, as manufacturing processes evolve and raw materials change, new contaminants can arise. Therefore, it is not feasible to describe all the types of fibrous contaminants that may occur. It is possible, however, to describe many of the most commonly encountered fibrous contaminants and, more importantly, a sound general approach to contaminant identification.

A GENERAL APPROACH TO FIBROUS CONTAMINANT IDENTIFICATION

Contaminant identification is one of the most useful applications of microscopy in pulp and paper. Even when a contaminant cannot be conclusively identified, microscopical examination can narrow the range of possibilities and help determine the appropriate next step(s) in the analysis of the contaminant. In other words, even when you cannot tell what a contaminant is, you can often tell what it is not.

The most useful tools in fibrous contaminant identification are the stereomicroscope and compound light microscope. More sophisticated tools can be used when necessary and available but most fibrous contaminant identification can be accomplished with a light microscope. These are relatively inexpensive analytical instruments and easy to implement at a mill.
A simplified flowchart of a systematic approach to contaminant identification is shown in Figure 1.

GET COMPLETE HISTORY

↕

light box

↕

stereomicroscope

↕

SEM & x-ray ↔ compound light microscope ↔ FTIR & other

Figure 1. Flowchart of a general approach to identifying contaminants.

The first step is to take a complete history of the problem. When did the problem occur? What were the process conditions? Was it a one-time problem or is it on-going? Is it periodic and if so are there records of the timing of the problem? Was there anything else unusual going on at the time the problem occurred? Are the samples provided representative of the problem? After getting as complete a history as possible, one can begin to examine the sample. Note that as the investigation proceeds, new questions may arise and so one may need to keep going back for more information.

One should start with the lowest magnification observation available and then proceed to higher resolution techniques as appropriate. Therefore, one starts with examination by the naked eye. Samples for identification are often in the form of a pulp or paper sheet with contaminant material embedded in it. The sample should first be examined “as is” and as much information gathered as possible before disturbing the sample in any way. A light box is useful for examining such samples. The stereomicroscope can then be used to examine the sample in reflected and/or transmitted light as appropriate.

As the investigation continues it will likely be necessary to isolate the contaminant from the material it is contained in and, subsequently, to dissect the contaminant. At all stages, one should try to preserve the integrity of the sample as much as possible so as not to limit the possibilities for subsequent analyses. This is particularly important if there are only a small number of examples of the contaminant available for examination.

In all cases, one should avoid jumping to conclusions, and instead examine the material thoroughly with all appropriate methods before making an informed judgment as to the identity of a contaminant. Logic and common sense are important especially when only a small amount of material is available for examination. As physicist Sam Treiman stated in the so-called Treiman’s Theorem:

“Impossible things usually don’t happen.” [11]

In the next section the necessary tools for contaminant identification are listed and a more detailed description of the process is given.
CONTAMINANT IDENTIFICATION – DETAILED PROCEDURES

Tools

- Stereomicroscope with reflected and transmitted light accessories
- Compound light microscope
- Clear (glass or plastic) Petri dishes – various sizes
- Squeeze bottle with pure water
- Dropper bottle with pure water
- Fine tipped forceps (2 pair)
- Dissecting needle
- Glass slides (recommend having both 25×75mm & 50×75mm sizes available)
- Coverslips (to match slides)
- Flat plates: one black; one white (each large enough to hold largest slides or Petri dish)
- Glass or plastic screw top vials
- Labels and permanent marker

Isolating contaminants from a sheet of pulp or paper

Contaminant samples are often in the form of inclusions in a sheet of pulp or paper and visible as “spots” of some kind: coloured, shiny, transparent, etc. [12]. The particles may be at the surface of the sheet or buried within the sheet structure. There is no way to conclusively determine the cause of a spot in the sheet simply by its size and shape. Consider the relatively frequently encountered case of translucent spots in finished paper (see Figure 2). A number of different contaminants can all result in such spots, all having a similar appearance; hence, the need for isolation and identification of these spots.

Ensure that all samples are properly labeled before beginning so that you can keep track of them.

Once you have learned as much as you can with the sample intact then you can attempt to isolate the particle. This is usually best done while observing the sample under the stereomicroscope. Make sure the surrounding work spaces and your instruments are clean so that you do not contaminate your sample.

Particles at the surface of a sheet may be simply removed using fine forceps and placed in water in a Petri dish (labeled!) for subsequent observation. Look to see if there is an identifiable pattern as to which side of the sheet the contaminants are found on.

If the particle is embedded within the sheet structure then analysis becomes more complicated. If it is not already circled, it is a good idea to circle the inclusion with pencil so that the area that needs to be dissected is clearly marked. A set of perpendicular lines can also be used for the same purpose (see Figure 3). Transmitted light is usually best for this situation. Under the stereomicroscope, a drop of water is added to the sheet in the area of the inclusion. The sheet structure is carefully peeled back layer by layer until an inclusion is uncovered. The inclusion is removed with forceps and placed in a Petri dish as before. If no obvious inclusion is found, then collect all the material from the circled area and place it in water in a clean petri dish. Gently disperse the material in the dish with your dissecting needle. Often a recognizable particle or agglomerate will be seen. This can be isolated with forceps as before. If the sheet is difficult to disperse, the material can be placed in a blender or disintegrator to see if an identifiable agglomerate or particle can be distinguished from the “regular” sheet. Isolating contaminants from a sheet takes patience and practice.
Figure 2. A spot in light-weight coated paper. Top: the spot is seen as a dark shiny area in reflected light. Bottom: the spot is seen as translucent when viewed in transmitted light.
Figure 3. A sample of spots in paper. The spots were circled with a pen on the sample as received. The pencil marks were added to help in locating the particles during subsequent dissection.

Note that inclusions can be very small indeed. Some may be hard and difficult to hold with forceps; the particles may tend to shoot out from the forceps’ grip. Others may be soft and stick to the forceps or needle. By observing the transfer of particles under the stereomicroscope, one can ensure that the particles end up in the right place. The flat plates mentioned in the list of tools are useful as bases for holding Petri dishes or slides containing small particles; the particles may be dark or light and will be easier to find against a contrasting background.

Once the particles are isolated in a Petri dish, try to ensure that any fibres that belong to the sheet from which the particle was isolated, rather than to the particle itself, are removed so that they do not confound subsequent analyses. This may be difficult, or sometimes impossible, to accomplish.

An example is shown in Figure 4. After isolating one of the Figure 3 spot particles from the sheet, the material appeared to consist of pulp fibres. Careful examination and through-and-through focusing revealed some unusual-looking twisted cells at the edges of the particle. Further dissection separated the layer of fibre that was obscuring the particle – in this case, a softwood sclereid cluster.
Figure 4. Top: Particle isolated from a translucent spot in the sample shown in figure 3. A network structure of pulp fibres is visible in the particle as initially isolated. Bottom: the same particle after further dissection. The thin layer of surface paper structure has been removed, revealing the actual contaminant, a softwood sclereid cluster in this case.

When appropriate to the investigation, a sample can be taken from the “normal” or “non-spot” area of the sheet for comparative analysis [12].

**Observation with the stereomicroscope**

Isolated material can be viewed in transmitted or reflected light or both depending on the accessories of the stereomicroscope in use. It is extremely useful to have transmitted light capability for the stereomicroscope.
The identity of a particle may appear obvious at this stage and thus it would seem unnecessary to examine the particle at higher magnification. However, examination at higher magnification is useful and recommended, particularly in the learning stages of contaminant identification. With experience, an analyst may become confident in identifying many contaminants using only stereomicroscopy. Depending on the purpose of the analysis, this may indeed be sufficient. If this approach is being taken, it is good practice to take a few examples of the particles and examine them at higher magnification. This will confirm the identifications and may also reveal additional important details.

**Observation with the compound microscope**

Material must be mounted on a slide for observation with the compound microscope. Isolated particles can be placed in a drop or two of water on a glass slide. A coverslip is added and the slide can be viewed in transmitted light at a wide range of magnifications. Thick particles may be difficult to observe clearly. If this is the case the coverslip can be removed, the particle isolated (on a different slide if necessary), carefully dissected, and then remounted for observation.

If the identification is still uncertain then various other microscopy techniques can be employed. For example, the dissected material can be allowed to dry on the slide and various stains employed to enhance contrast, or to differentiate chemical pulp from mechanical pulp among other things. PAPTAC standard B.3P describes a number of useful fibre stains and their applications. Polarized light can be very useful in examining fibrous contaminants. It is not within the scope of this report to describe all the microscopical techniques that can be applied to contaminants. Nevertheless one should be aware that there are many techniques available.

Avoid the use of a permanent mounting medium for an unidentified particle because it makes it difficult to recover the particle for further analysis if it is necessary. After a particle is identified, one can then make a permanent slide to keep as a reference if desired. It should be kept in mind that the appearance of a fibrous contaminant in a permanent medium will be somewhat different than that of the same particle mounted in water. This is due to the difference in the refractive index of water (1.33) and that of typical permanent media (usually ~1.5). The refractive index of fibre wall material is around 1.52; when mounted in a medium of similar refractive index, fibres become more transparent.

The colour of the material being examined may be significant. It may, for example, indicate the degree of delignification or the presence of wood resin. Black particles may be displaying their natural colour or the result of heating or charring. A highly coloured particle may require thorough dissection to make the material thin enough for transmitted light observation. Sometimes particles that look black to the eye can be seen to have a different colour under the microscope. Colour information should be recorded along with the other observations in the course of normal note-taking during the investigation.
SOME COMMON FIBROUS CONTAMINANTS

In the following section, some of the more common fibrous contaminants are considered in detail. They include:

Contaminants originating from bark:
- Sclereids
- Phellem
- Sieve cells

Contaminants originating from wood, wood fibre or their processing:
- Shives
- Knife Knits
- Strings /Nits/Ropes
- Broke/Recycled/Nodules

Other fibrous contaminants:
- Synthetic and natural fibres.

Correct identification of contaminants requires familiarity with their characteristics and appearance. This report is intended to be a reference guide for this purpose. However, acquiring a thorough knowledge of wood and fibre morphology is the best preparation for this kind of work.

On the following pages, the various types of contaminants, their origin, appearance and differentiation are discussed. Illustrations of the contaminants are provided. Bear in mind that the examples shown in each case are exactly that: examples. There can be considerable variation in appearance within a class of contaminants. The general characteristics that define each class are the most important, not the exact appearance or size of the contaminants in the images shown in this report. The examples shown are primarily in the context of softwood kraft pulp. The appearance will vary depending on the species and the particular process or product.

While a few examples are included, a comprehensive treatment of non-wood fibres, synthetic fibres and natural fibres is not in the scope of this report. These kinds of fibres are usually easily distinguished from wood pulp fibres and are less frequently encountered. Learning to distinguish these types of materials is useful and there are other excellent references for this purpose [13,14].

Basic information on the types of quality problems caused by the various contaminants is provided, along with suggestions to ameliorate these problems in some cases. However, these sections are by no means exhaustive or authoritative.
Terminology is also a challenge in dealing with contaminants. Individual mills often have their own specific terminology to describe various contaminants. Where possible, a list of synonyms for the contaminant described is included.

One of the most commonly encountered and frequently confusing terms is “fibre bundle”. By definition, the term fibre bundle can be considered equivalent to shive. However, in terms of its everyday application, it is commonly used to describe any agglomerate of material that appears to be fibrous in nature. It is always a good idea to ask for clarification if someone uses the term fibre bundle. It is worth noting that examples of most of the contaminants listed in the following section have, at one time or another, been received by the author for identification labeled as “fibre bundles”.

**Non-fibrous contaminants**

In doing contaminant identification work, one will frequently encounter contaminant material that is clearly not fibrous, such as dirt, ash, pitch, scale, metal, rust, plastic etc. Unless it can be identified microscopically, such material will require chemical analysis. In some cases spot tests may be useful [15].
SCLEREIDS

Synonyms: “Stone cells”[16]; also sometimes incorrectly called and/or spelled “scleroids” or “sclerids”.

Definition and origin:
Sclereids are clusters of thick-walled cells from bark. In many species, they occur in the inner bark as well as the outer. When bark is not completely removed, sclereids can enter the process.

Characteristics / Differentiation:
Sclereids are clusters of thick-walled, multi-lamellar, often variable-shaped cells that occur in the bark of trees [17,18]. They range in size from microscopic to a few millimetres in length or width. The clusters are often somewhat flat with an oval or round shape. In softwoods particularly, the cells are often heavily branched, twisted and intertwined. Like wood fibres, sclereids are lignocellulosic cells; they can range in appearance from very dark in their native state in outer bark, to white in the case of bleached pulps. Sometimes resin can be found in sclereid cell lumens, imparting a brown or orange colour to the cells.

Examples of sclereids are shown in Figure 5. Note that it is not always possible to tell if sclereids are from hardwood or softwood; significant variation and overlap in appearance exist.

Problems caused:
The most common problem caused by sclereids is translucent spots in paper (“fisheyes”, “shiners”, “windows”). These dense clusters create a localized area of high density which becomes completely compacted during finishing or calendering resulting in a local loss of opacity. Sclereids can cause scratches in blade-coated paper among other problems.

Implications / Remedies:
Sclereids can cause serious product quality problems; in general, the higher the grade of paper and the lower the basis weight the worse the potential problems.

The presence of sclereids indicates incomplete debarking. Sclereid problems tend to be seasonal (difficulty debarking frozen wood). Many species contain sclereids in the inner bark and this may be present in significant amounts even when all the outer bark is removed [18].

A precise measurement method for sclereid content in kraft pulp has been developed recently at Paprican [19].

Cleaners and in some instances barrier screening have been effective in removing sclereids. Contact Paprican for the latest information in regard to sclereid removal.
Figure 5. Transmitted light micrographs of sclereid clusters of various types, shapes and sizes. a) to c) are softwood sclereid clusters. b) shows a partially bleached softwood sclereid cluster. d) to f) are hardwood sclereid clusters.
PHELLEM CELLS

Synonyms: “Stone cells” [18], Cork [17].

Definition and origin:
Phellem cells are thick-walled bark cells that occur in clusters.

Characteristics / Differentiation:
Phellem cells are clusters of radially flattened, polygonal (typically hexagonal) cells from outer bark [17]. They are similar to sclereids in many ways but are distinct in appearance. In some instances the cell margins have an undulate, serrated or “gear-tooth” appearance. Phellem can be thin or thick-walled. Examples of phellem are shown in Figure 6.

Problems caused:
Essentially they can cause the same problems as sclereids: translucent spots in paper (“fisheyes”, “shiners”, “windows”); coater scratches; etc.

Implications / Remedies:
Phellem indicates the presence of outer bark in the raw material.
Figure 6. Clusters of phellem cells: a) and b) transmitted light micrographs of clusters of phellem cells found in a bleached kraft pulp; c) transmitted light micrograph of a cluster of phellem cells from a mechanical pulp; d) scanning electron micrograph of part of a cluster of phellem cells showing detail of the interlocking “gear-tooth” appearance of the cell margins.
SIEVE CELLS

Definition and origin:
Sieve cells are thin-walled inner bark cells in softwoods [17].

Characteristics / Differentiation:
Sieve cells can occur as single cells or, more commonly, as a shive-like group of cells; indeed, they may be mistaken for bleached kraft shives. The cells are thin-walled and flexible. Under reflected light they may have a shiny, shimmery appearance. Viewed in transmitted light in the compound microscope, they have a textured appearance and, at the edges of a group of cells or in individual cells, they sometimes have a “scalloped” appearance. Sieve cells have a slippery feel as well, although one would rarely encounter them in quantities and concentrations sufficient to pick up and handle.

Illustrations of sieve cells are found in Figure 7.

Problems caused:
Sieve cells are not commonly cited as the source of product quality complaints, nevertheless they are thought to bond poorly and if in sufficient quantity on the surface of a sheet would affect print quality. It has been suggested that they can contribute to coater scratches.

Implications / Remedies:
Like sclereids, sieve cells indicate incomplete debarking. If sieve cells are observed, one might anticipate that sclereids may also be present.
Figure 7. Sieve cells. a) Reflected light micrograph of a group of sieve cells (top) next to a shive (bottom); both were found in a softwood kraft pulp. b) &c) Transmitted light micrographs of groups of sieve cells. Note the textured appearance of the cells. d) Higher magnification transmitted light micrograph of sieve cells. e) Scanning electron micrograph showing the surface of a few contiguous sieve cells; the circular areas with the fine web-like structures are called sieve areas and give rise to the textured appearance of the cells in transmitted light. f) Closeup of a sieve area.
SHIVES

Synonyms: Fibre bundles; chop [20,21]; sliver [16].

Definition and origin:
Shives are incompletely pulped wood structure. Whether pulped chemically or mechanically, they are the product of incomplete defibration. They occur for various reasons: incomplete penetration of cooking liquor, over-thick chips, inadequate cooking time or cooking liquor, presence of resin or other material that “protects” wood from pulping, or inadequate refining [21]. This word is sometimes pronounced “shivs”.

Characteristics / Differentiation:
Shives display organized wood structure. Typically they are long rectangular particles and at higher magnification one can see that they are composed of orderly rows of fibres and rays at right angles to the long axis of the fibres. Shives may also be oval or football shaped, particularly for hardwoods. Sometimes shives are encountered that consist solely of ray tissue; this usually only occurs with hardwoods containing broad rays. Shives arising from knots or branchwood [22] may be distinguished in some cases based on the presence of reaction wood and the size and shape of the fibres. Examples of shives are shown in Figure 8.

Problems caused:
• Web breaks [23]
• Uneven micro-formation
• Bumps
• Translucent spots in paper (“fisheyes”, “shiners”, “windows”)

Implications / Remedies:
See definition and origin. Raw material or cooking must be modified to avoid problems. Barrier screening to remove shives and/or treatment (refining, more cooking, bleaching [24], etc.) are employed in some mills.
Figure 8. Shives. a) to c) transmitted light micrographs of a softwood kraft shive shown at increasing magnification. In c) the cross-field pitting is clearly visible, enabling, along with sample origin information, identification of the shive as spruce. d) A shive in a newsprint sheet that was the initiation point for a web break. e) The same shive isolated from the paper sample. The morphology indicated that it was a mechanical pulp shive; a staining test confirmed it.
KNIFE KNITS

Synonyms: Knife-edge nits, nits, knits.

Definition and origin:
Knife knits are pieces of the cut edge(s) of market pulp sheets that will not disperse because the edge has been fused together during cutting. Knife knits are generally thought to be associated with dull knives on the cutter/layboy although the set-up and operation of the knives or process conditions such as sheet moisture content may be just as significant [12].

Characteristics / Differentiation:
The distinct cut edge on one side and freely dispersed fibre on the opposite side are characteristic of knife knits [12]. A similar-looking defect originating from the cut edge of a paper sheet is also possible. By analyzing the types of fibres in the contaminant, it may be possible to distinguish such a particle from a knife knit originating from a pulp sheet. Examples of knife knits are shown in Figure 9.

Problems caused:
Uneven micro-formation; bumps; translucent spots in paper (“fisheyes”, “shiners”, “windows”); web breaks; can act as seed material for the formation of larger agglomerates of fibre.

Implications / Remedies:
Check knives and/or operating parameters of cutter/layboy.
Figure 9. Softwood kraft knife knits: a) viewed in reflected light; b) viewed in transmitted light; c) scanning electron micrograph.
PULP STRINGS

Synonyms: Strings, Nits, Knits [16], Ropes [25].

**Definition and origin:**
“Normal” pulp fibres that have become wrapped around and entangled with one another. They can form in various ways but typically form in places where there are circular or spiraling (vortex) or shear flow conditions [26]. Anything that can trap fibres in places where these flow conditions may exist can lead to stringing [21,26–29]. For example, internal surface defects such as metal burrs or poorly fitting joints can act as points for initiation of stringing [27–29].

**Characteristics / Differentiation:**
There is a distinct twisted pattern in these agglomerates. They tend to resemble tiny woven ropes. Strings can range in size from small and short (a few mm) to relatively thick and very long (>1m). Some people use the term rope to refer to very large strings. To help determine the cause of the stringing, the string should be dissected and particular attention paid to the fibres at the core of the string. Often there is only long fibre present here but sometimes obvious problematic material like shives, synthetic fibres or excessively long fibres (such as some non-woods) have been encountered. In general, any long fibrous material is ideal seed material for string formation. However, strings often form with no such seed material other than “regular” pulp fibres. The longer the fibres in the furnish, the greater the potential for string formation [25]. Once a string starts to form and build it can catch anything that is in the furnish, even short fibres. Illustrations of pulp strings are shown in Figure 10.

**Problems caused:**
- Translucent spots in paper (“fisheyes”, “shiners”, “windows”). Like any fibrous agglomerate they create a localized area of high density which becomes completely compacted during finishing or calendering resulting in a local loss of opacity.
- Web breaks [26].

**Implications / Remedies:**
Once formed, strings may not break down readily. While screens may be able to remove strings, efforts must be directed at prevention of their formation [26–28]. Ensuring that all surfaces are smoothly finished [27–29], that excessively long fibre is avoided [25], that the consistency is low enough to prevent excessive flocculation, and that vortex flow is minimized [25] are all applicable.
Figure 10. Pulp strings: a) and b) pulp strings viewed in transmitted light; b) shows the typical twisted, intertwined structure of a string; c) and d) strings viewed in the scanning electron microscope; the twisted structure characteristic of strings can be seen clearly.
BROKE / RECYCLED / NODULES

Synonyms: Broke chips [20]; flakes [21]; paper specks [16].

Definition and origin:
These are all pieces of previously formed sheet structure, whether pulp sheet or paper sheet, that have been introduced to the furnish from either internal or external sources. They are essentially undispersed pieces of an already formed fibre network. Broke is material that is internally repulped and sent back into the process. Recycled generally refers to material that came from an external source, i.e. post-consumer fibre. The term Nodules usually refers to undispersed material from market pulp sheets [30–32].

Characteristics / Differentiation:
When such particles are contained in pulp or paper sheets, they can be very difficult to isolate from the surrounding sheet during dissection. Careful isolation of “spots” as described in the text is critical. Such particles can be quite small and the source difficult to ascertain. These particles are characterized by a sheet-like structure as found in any paper, as well as an absence of any other obvious contaminant. These pieces should be further dissected and attempts made to identify fibres by species and/or process. This may distinguish them from rest of the furnish in some cases but in many instances there may be no way to tell the actual source of the material. Any fillers or coatings associated with such an agglomerate may also help identify the source. Illustrations of a contaminant in the “recycled” category are found in Figure 11, and a brief case history is found below.

Problems caused:
• Translucent spots in paper (“fisheyes”, “shiners”, “windows”)
• Web breaks
• Can act as seed material for larger agglomerates of fibre.

Implications / Remedies:
Inadequate repulpin g. Unplanned or unusual fibre inputs. Recycled or broke from wet strength papers. Nodules are caused by “over-drying” or over-pressing of pulp sheets, particularly at the surface of the sheet. These received considerable attention when flash-drying was introduced in the 1960s [30–32].

Case Study
In the case illustrated in Figure 11, a bleached softwood kraft pulp mill was experiencing an intermittent but on-going serious problem with large spots appearing in the finished pulp sheets. Inspection on a light box would reveal these large spots. Samples were received for analysis. Careful dissection enabled isolation of the material causing the spots. They displayed a definite sheet structure and further dissection and analysis revealed that they contained softwood fibres of a type not used in the mill and also a substantial amount of hardwood fibre including species not locally available. The mill ran only softwood in their furnish and this was confirmed by analysis of a “non-spot” portion of the pulp sheet. This suggested an unusual fibre input somewhere in the mill. Comparisons against paper materials in use at the mill produced a match between the spots and the blotter paper in use in the mill’s testing lab. It was discovered that the bins for the used blotters were periodically being emptied into the repulper. Mill personnel had not expected any problems since the blotters were ostensibly made of 100% bleached chemical pulp fibre. However, the blotters were not dispersing and were causing spots in the sheet. The problem had thus occurred intermittently over the course of many months.
Figure 11. a) A dark spot in a market pulp sheet; the spot was circled in quality control testing. b) The material isolated from the spot had its own sheet structure. Further analysis revealed a different species composition in the spot compared to the pulp sheet enabling the source of the contaminant to be determined (see text on previous page for details).
OTHER FIBRES: NON-WOOD; SYNTHETIC; NATURAL

As mentioned previously, it is not in the scope of this report to deal with all the types of fibrous material that may be found in pulp and paper besides wood fibre. The origin, nature and differentiation of these types of fibres is thoroughly treated elsewhere [13,14]. Below (Figure 12) are a few examples of the many types of such fibres that may be encountered. As in wood fibres, there can be wide ranges of variability in appearance.

Figure 12. Examples of synthetic and natural fibres: top – a dull nylon; middle – a rayon; bottom – a natural “fibre” – hair.
CONCLUSION

A systematic approach to contaminant identification and some of the more common fibrous contaminants have been described. By adopting a systematic approach to contaminant identification, knowledge and experience can be accumulated. Contaminant identification is one of the most useful applications of microscopy in a mill. The first step in dealing with a problem is to define it properly; contaminant identification is an important part of this process.

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