

THEORY AND REALITY FOR CONTAMINANT REMOVAL CURVES

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PLOTS OF REMOVAL EFFICIENCY FOR PULPERS, PRESSURE SCREENS, CLEANERS, WASHERS, KNEADERS, DISPERSERS, FLOAT CELLS, AND PRESSURES VS. PARTICLE SIZE GIVE A TRUE PICTURE OF WHAT TO EXPECT WHEN USING TODAY'S EQUIPMENT.

McCool and Silveri developed an excellent tool to select equipment for the removal of contaminants of a specific size range.¹ Their undefined x-axis chart has ingrained itself into daily aspects of the paper business. It showed why and how one should use a given piece of equipment in a system. Equipment manufacturers used the tool to sell more equipment. Paper manufacturers used it as a reason to buy more equipment. It was a sales tool—not an accurate measure of what yesterday's equipment could remove. It was definitely not an indicator of what today's more modern equipment can remove.

This presentation will add fact to the sales tool by showing actual efficiencies for particle size variation and the removal rate for those particles using various pieces of equipment. The paper will further expand the equipment groupings to include equipment that did not exist earlier. There will also be a more realistic composite particle size removal chart with real removal rates and documented particle sizes.

Work by Kuhn *et al.* presented size removal ranges for some equipment.² They did not show removal rates. Although others have shown actual particle size removals for various equipment, no one has compiled a complete system with all components present. This paper will show what range of sizes today's pulpers, coarse screens, fine screens, forward cleaners, reverse cleaners, neutral buoyancy cleaners, washers, flotation cells, presses, kneaders, and dispersers can remove. After this, the paper shows a system efficiency curve for two types of systems—a high end design and a conventional design.

PULPERS

Removal by pulpers depends on two factors only—actual pulp dispersion and size of the extraction plate. The pulper is a crude barrier screen. It does not remove all particles of a specific size if they are flexible, extrudable, or predominantly one dimensional. A 50-mm-long sliver of wood can fit through an extraction plate with 6-mm perforations if it is only 4-mm wide.

Recycling pulpers today have extraction plates with holes as small as 3-mm diameter. Although extraction plates having holes of 6-, 9-, and 18-mm diameters are more common, the small diameter plates do find use in some recycle processes. Pulpers with such plate sizes may be substituted for coarse pressure screens.

Figure 1 shows a typical plot for removal of recycled fiber using perforated plates of 3-mm and 6-mm diameters.

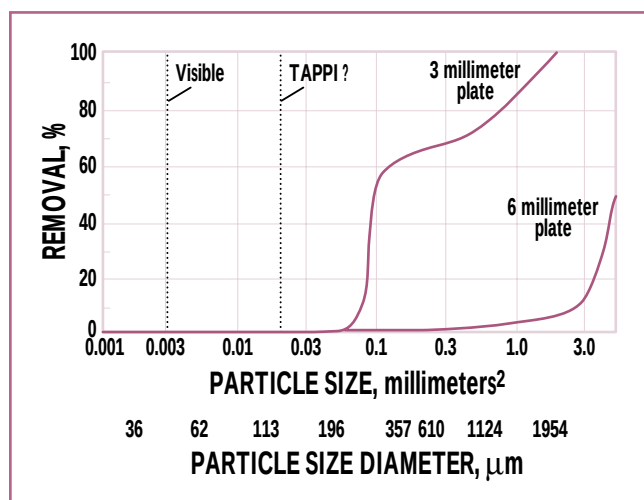
COARSE SCREENS

The coarse screens in recycling systems today are not the scalping devices of yesterday. They used 2.4-mm diameter perforations, and they were the first position where most contaminant removal occurred. A typical coarse screen today may have 1.6-mm perforations. If a coarse screen follows a pulper with perforations of 6-mm or 3-mm, one can easily reduce screen plate perforation size to 1-mm diameter. This increases the already large amount of removal at this position.

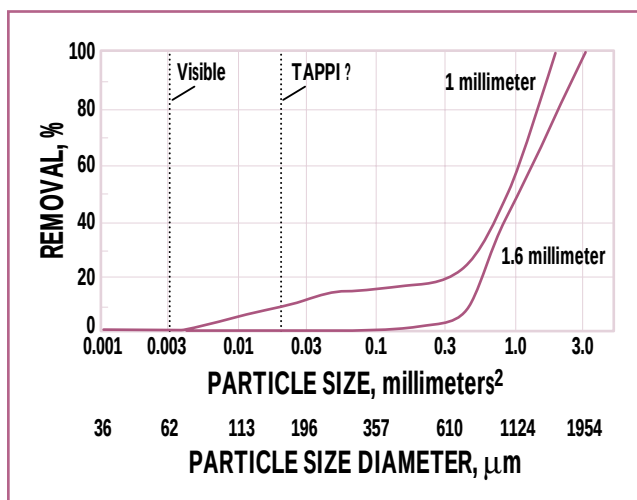
Figure 2 shows a typical plot of contaminant removal by size for both perforation plates of 1-mm and 1.6-mm diameters.

¹ McCool, M. A. and Silveri, L., *TAPPI 1987 Pulping Conference Proceedings*, Book 1, TAPPI PRESS, Atlanta, p. 33.

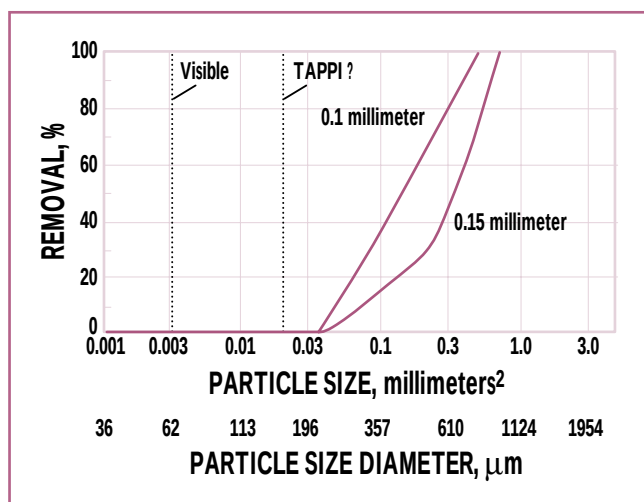
² Kuhn, D., Mahony, L., and Puhar, E. M., *TAPPI 1996 Recycling Symposium Proceedings*, TAPPI PRESS, Atlanta, p. 333.



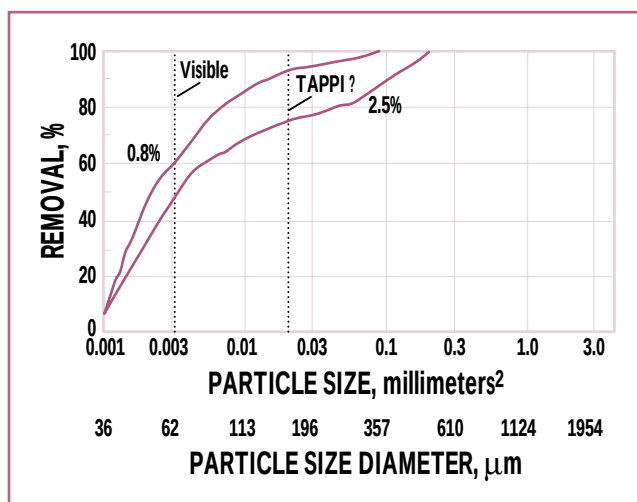
1. Removal by pulpers



2. Removal by coarse screen



3. Removal by fine screen



4. Removal by forward cleaner for sand

FINE SCREENS

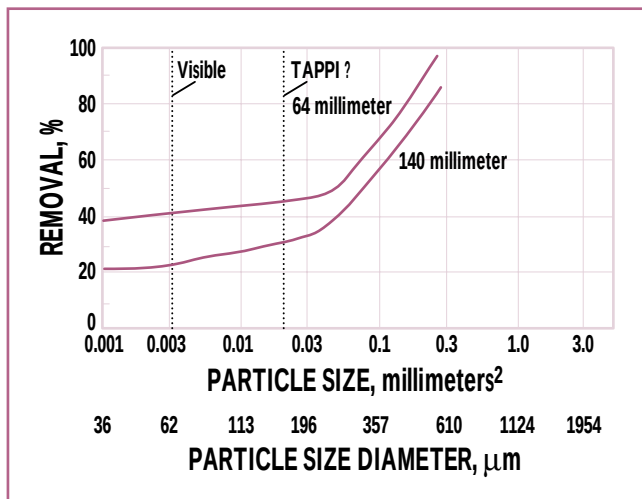
The term fine screens refers to pressure screens placed after coarse screens. These screens usually have contoured slotted plates. The slot width depends largely on the screen plate size used in the previous coarse position. A large slotted plate of 0.2–0.25-mm usually follows a large coarse screen perforation. There must then be a third screen—the micro screen. If the coarse screen can successfully use a small perforated plate with 1.0-mm-diameter openings or 0.2-mm slots, the fine screen can have 0.1-mm slots—the domain of the micro screen. This type of system eliminates the third screening stage.

The curves in **Fig. 3** show the removal with fine screens fitted with both 0.1-mm and 0.15-mm-wide slots.

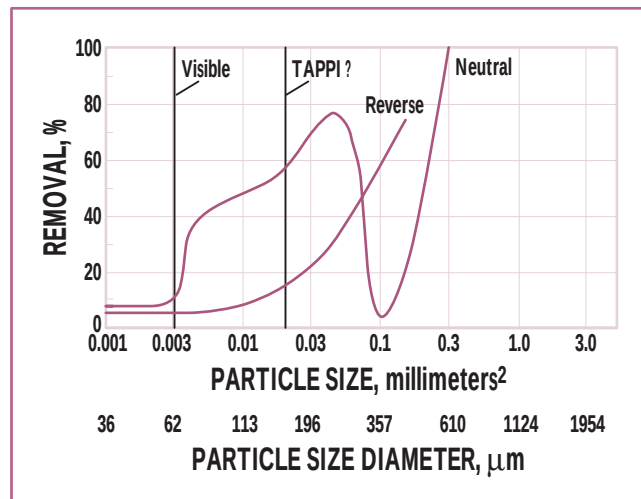
CLEANERS

There are many cleaners now that were not available even five years ago. Let us examine the removal for two types of forward cleaners—a reverse (lightweight) removal cleaner and a neutral density cleaner.

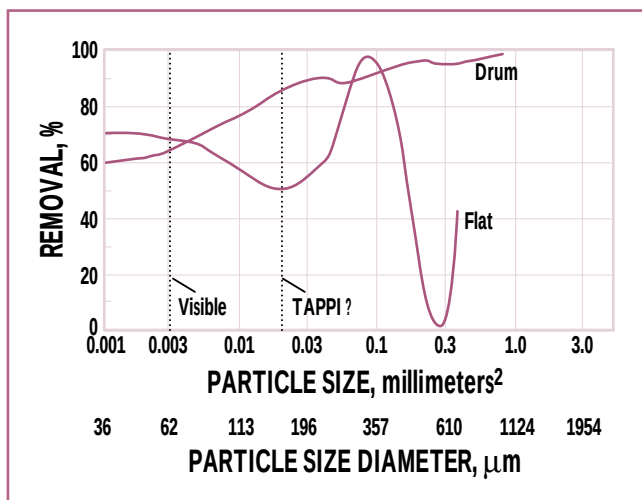
Note that particle size removal becomes considerably more accurate with progression through a system. Extraneous flakes and oversize particles that mask small particles are gone. Very large particles are less predominant. It therefore is possible to expand the particle size scale for plots after the screen positions. In addition, more contaminant removal means small amounts remain. Now particle size removal is more erratic because an accept sample may have one particle in a size group while there was none noted for the feed.



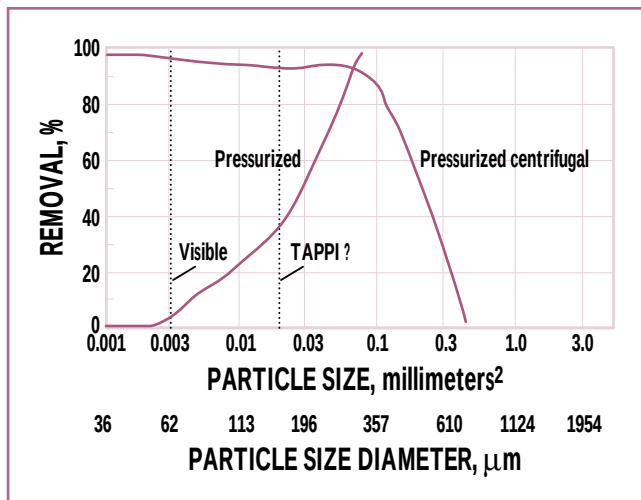
5. Removal by forward cleaners



6. Removal by reverse, neutral buoyancy cleaners



7. Removal by washers



8. Removal by flotation cells

High consistency sand removal cleaners

This new class of cleaners has evolved from a need to protect the fine and micro screens from excessive or accelerated wear by abrasive sand and other gritty material. It is a forward cleaner but one that operates at a higher consistency than normally expected. The capabilities of the fine screen to handle elevated inlet consistencies dictate the consistency of operation. If that screen can process 2.5% inlet consistency, then that is the process consistency of the sand cleaner. When that screen can process only 1.5% inlet consistency, the cleaner's job is simpler—it needs to operate at that lower consistency.

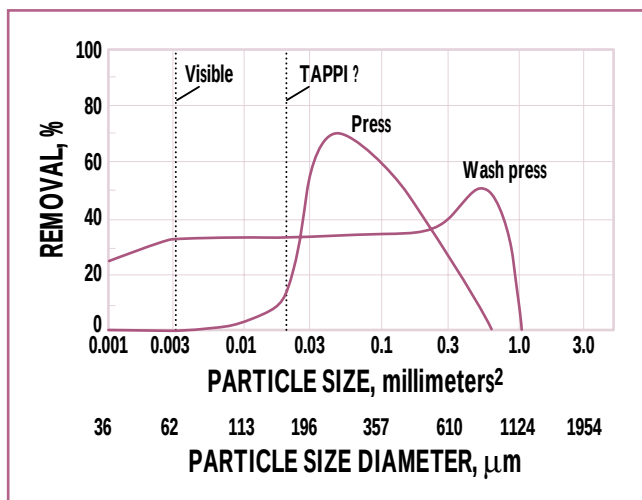
A note of caution is appropriate. What constitutes good removal effect here may not relate to the particle

size removal. It is possible that high abrasion materials may not fall into the large size classifications but into some intermediate range.

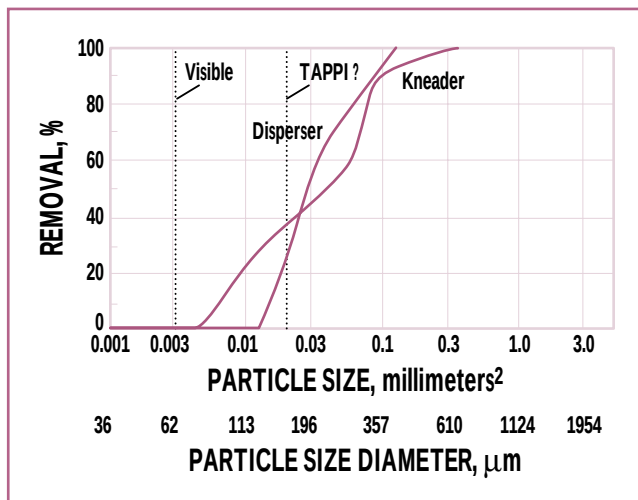
Figure 4 shows the sand cleaner particle size removal rates at operating consistencies of 0.8% and 2.5%. This plot shows one cleaner at two consistencies. It is probable that a second, less effective cleaner would work in a system at the lower consistency for reasons other than efficiency.

Recycle system forward cleaner

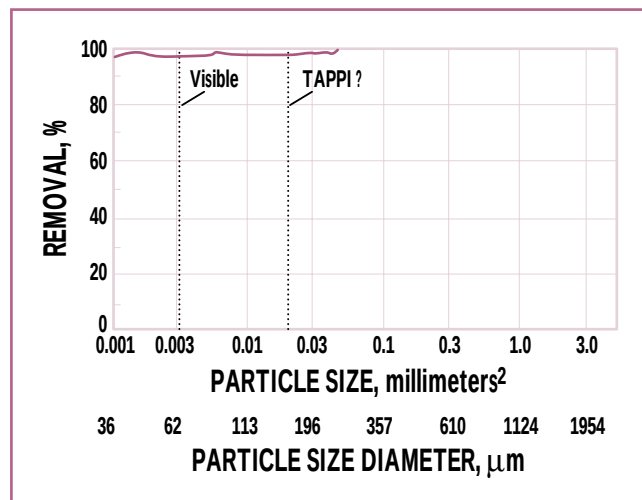
After fine screening, it is safe to use a forward cleaner without fear of constant plugging. There is a large cleaner choice for this position. The unit could have a large, small, or intermediate diameter. The main purpose of the forward cleaner is to remove heavyweight contaminants.



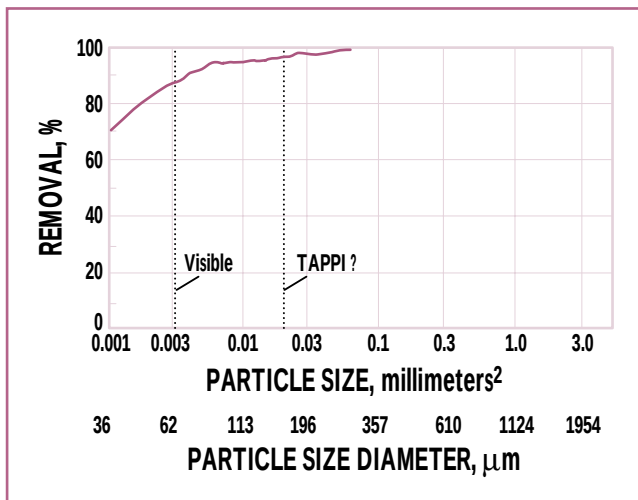
9. Removal by screw presses



10. Removal by kneader and disperser



11. Top end system composite



12. Conventional system composite

To do this well, it must operate at a low inlet consistency of 0.8% or less. As consistency increases, the particle size removal will decrease unless the geometry of the cleaner decreases or the pressure drop across the cleaner increases.

The curves in **Fig. 5** are for cleaners operating at their designed consistency and pressure drop ranges. The figure shows a small, 64-mm-diameter fine cleaner and a larger, 140-mm-diameter cleaner.

Reverse, neutral buoyancy cleaners

The cleaners that follow forward cleaners remove contaminants not removed by screens or forward cleaners. They do not remove heavyweight contaminants. The contaminants remaining at this point are lightweight or have neutral buoyancy. Special classes of cleaners are

necessary to remove these contaminants. Each class attacks a different contaminant component that is not as size restrictive as the ink contaminants. These plastic, sticky, wax, and hot melt contaminants may have a full range of particle sizes. They may be attached to large but thin flakes of paper or individual fibers. They may curl or form a tube so a much larger contaminant can pass through the screen systems. Their shape may be sufficiently irregular to pass through a forward cleaner system.

Larger contaminants than one might suspect can therefore exist this far into the system. More erratic particle size removal is more likely than with other equipment. It is possible to remove large, intermediate, or small contaminants effectively depending on the type of

contaminant present. For instance, neutral buoyancy stickies form intermediate and large sized contaminants. Plastic contaminants may be large.

Figure 6 shows the removal rates for two cleaner types that remove lightweight contaminants.

Washers and flotation cells

A note about system philosophy may be necessary here. Some people swear by flotation. Others prefer washing alone. Certain people combine both techniques. Considering the original McCool-Silveri curve, both are essential to complete contaminant removal. Flotation devices often have a precursor. This is a device that prepares the pulp contaminants for flotation by reducing contaminant particle size. The device does not physically remove contaminants. It reduces the overall size so the contaminants fall from consideration as troublesome, visible components. Although they may precede the equipment used in this stage, this paper addresses such devices later. Note that washing may precede flotation or vice versa.

The data of **Fig. 7** shows particulate removal for two aggressive types of washers. They are not standard chemical or gravity/vacuum drum washers. The increased removal of large particles indicates there are obviously other actions taking place with one washer. This type of washer causes attrition of more brittle ink particles. It therefore appears to have a broader range of removal.

The flotation devices available vary from open, high residence time vats to pressurized, flow-through types. The two devices in **Fig. 8** are closed, pressurized devices of differing designs. They illustrate the variability of removal inherent with flotation.

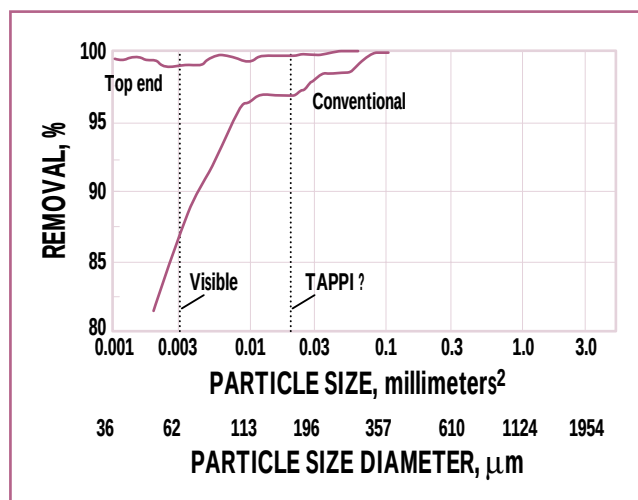
SCREW PRESS

There is often a high consistency thickening stage following washing in a recycled system. This prepares the pulp for bleaching. Consistencies of 30–35% are normal. Other systems also require a high consistency, but the reason is not for bleaching. It is to prepare the pulp for flotation by kneading or dispersion. Screw press thickening does accomplish some washing, and there can be some brittle ink attrition. This is especially true if the previously used washer is not the attrition type. The screw press is a mechanism people do not often consider for removal.

Figure 9 shows removal rates for two different screw presses. One press has a mechanical back pressure device. The other does not.

KNEADER AND DISPERSER

As noted above, the last equipment in the primary process loop does not really remove contaminants. It reduces contaminant size so that some contaminants then fall into the subvisible or color range. This equip-



13. System comparison

ment is part of a modern recycled fiber system and warrants inclusion here. One should carefully select the equipment location within the system to prevent an accumulation of colloidal or microsize contaminants within a tight water loop. It also is necessary to prevent the breakdown of large contaminants into a smaller size that is harder rather than easier to remove. Stickies are the major contaminants in this category.

Figure 10 shows removal following all other equipment previously mentioned except flotation. Flotation would normally follow the attrition step in a recycle system of modern design.

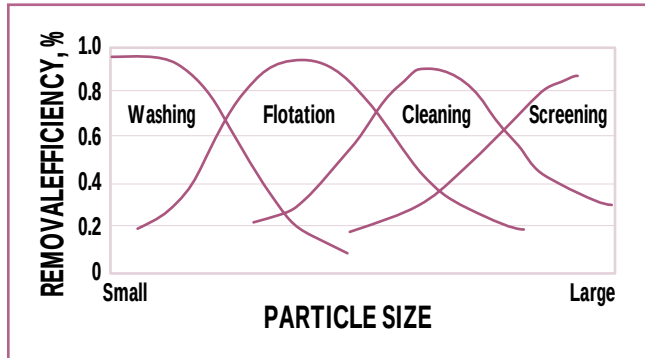
PUTTING EVERYTHING TOGETHER

Taking each low end plot and combining them onto one graph and doing the same with each high end plot onto a different graph provides new particle size distribution removal charts that are factual representations of equipment capabilities today. **Figure 11** shows the top end composite plot, and **Fig. 12** is the conventional system composite. Combining the two charts gives **Fig. 13** showing the spread that a conventional system can remove when processing recycled fibers today.

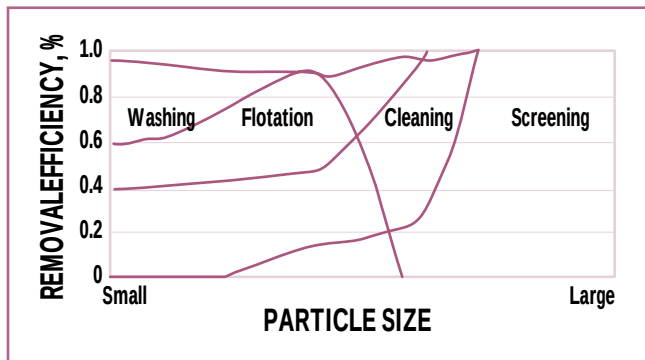
Figure 14 depicts the old way of looking at particle size removal. The cumulative plot of equipment average removals for the conventional and top end systems in **Fig. 15** gives a picture of contaminant removals generated by today's systems. Note that this equipment does not necessarily represent a complete system. Duplication of washing, thickening, cleaning, bleaching, or dispersion may occur in a complete system. It is not surprising that the difference between the two is not too great for large contaminants. The difference is greater approaching the 0.02 mm² and smaller size ranges.

Perhaps least surprising is that the removals for each

RECYCLING



14. Particle size removal for various units



15. Particle size removal with the new model

piece of equipment do not have the exact definitions previously thought. The overlapping of curves is not as clear as previously presented.

The designer of systems today obviously has more choices than ever before to match equipment synergies to obtain the best performance for his needs. It is still quite evident that any one, two, or three pieces of equipment will not generate contaminant free pulp. This paper has shown that the selection of equipment for contaminant removal is more complex than originally suggested.

Were the old days better when one could simply select the desired equipment from a simple chart that had no x-axis? Admittedly the process was easier, but information available today makes selection more scientific. **TJ**

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