Annual Patents Review  
January — December 2004

Roland Gleisner, Karen Scallon, Michael Fleischmann, Julie Blankenburg, and Marguerite Sykes

KEYWORDS


INTRODUCTION

This review summarizes patents related to paper recycling that first appeared in patent databases during the 2004. Two on-line databases, Claims/U.S. Patents Abstracts and Derwent World Patents Index, were searched for this review. This feature is intended to inform readers about recent developments in equipment design, chemicals, and process technologies for recycling paper and alternative products derived from post-consumer paper. Only brief summaries of individual inventions are included in this review. Because many of the patents are not readily available in English, much of the information was extracted from abstracts that were translated to English. For more complete information, readers will need to access the full text of a specific patent. Three excellent on-line sources for further review are located at http://www.uspto.gov, http://ep.espacenet.com, and http://www.mayallj.freeseve.co.uk.

As an indication of the amount of patent activity in the papermaking field, the 104 patents reviewed here were selected from 255 patent abstracts obtained in an initial search. Patents in this review were selected on the basis of their specific applicability to the paper recycling industry compared with papermaking in general.

EQUIPMENT

Several patent documents published in 2004 are directly concerned with mechanical improvements to the pulper. One such patent application is for a pulper design using high pressure, hot water jets [1]. The water jets are arranged around the tank cone near the pulper rotor and eject flow tangentially in the opposite direction of the rotor rotation. Jets also can be placed in the vertical walls of the pulper. The inventors claim that the dual action of the jets and rotor will significantly reduce the time to process recovered papers.

Another recent application describes an improved horizontal drum pulper design [2]. In this invention, a semicircular stationary tube is coaxially mounted inside the horizontal drum. A channel is formed between the drum wall and the tube. There is a slight deviation between the axis of the drum and the tube so that the channel becomes narrower at the outlet end of the pulper. Compression of the pulp in this channel creates low-shear fiberization, minimizing contaminant size reduction. Also, the channel forces the pulp to ride to the top of the drum before falling off the drum wall. A helical paddle can be mounted to the drum to assist with the transport of the pulp and contaminants through the pulper.

Another patented pulping system uses a horizontal drum-type pulper along with a pressure screen [3]. The system is intended for the recovery of fibers from laminated reclaimed papers such as milk cartons and juice boxes. The horizontal pulper contains a full length rotor with blades extending from the shaft arranged to form a screw. The stationary pulper wall has circumferential rings attached along its length. The paper is compressed between the moving rotor blades and the stationary rings, which turns the wastepaper into fiber. Material is moved through the pulper by the screw action of the blades on the rotor. At the outlet, the pulp is diluted and directly supplied to a rotating foil pressure screen. An auxiliary pump is not required to transfer the pulp since the pulper has a higher elevation than the screen; the supply pressure to the screen is determined by the height differential between the two pieces of equipment. Large contaminants are intermittently discharged from the screen while lighter contaminants are concentrated in the central vortex created by the rotating foil and continuously removed.

Authors are associated with the USDA Forest Service, Forest Products Laboratory, Madison, WI 53705.
In a U.S. patent application, Selin describes a pulper for producing paper pulp from recovered paper containing undesired scrap particles [4]. The pulper efficiently prevents disintegration of relatively large scrap particles and minimizes the loss of fibers. The bottom and vertical walls of the pulper join to form a circular peripheral reject chute. The chute is situated under the rotor for collecting rejects. The reject chute extends helically in the direction of the rotor and slopes downward. The circumferential chute wall has a cylindrical shape and extends vertically to form the reject chute. A valve is adapted to discharge rejects in batches from the reject chute.

Two recent patent publications are concerned with the pulping rotors themselves. In the first, assigned to Kadant Lamort, a new rotor allegedly increases pulping efficiency of recovered papers [5]. The rotor has multiple blades extending from the core of the rotor. The bases of the blades have a low profile foil shape. A concave profile is blended to the base and extends upward from the outer tip of the blade base towards the rotor core. This upper profile is used on all the blades except that it is truncated a short distance from the rotor core on alternate blades. In the second patent assigned Voith Paper Patent GMBH, the pulper rotor has paddles attached to the rotor’s underside [6]. The paddles sweep across the extraction sieve to prevent plugging by large contaminants, permitting acceptable fibers to pass through the sieve and providing the first step of contaminant separation.

A final disclosure in the pulper category is a German patent application on an extraction sieve in a recovered paper pulper [7]. The inventors have designed plasma-coated, bars to attach to the extraction sieve. This invention is particularly intended for contaminant-containing recovered papers. The bar surfaces are plasma coated to a depth of 500 microns with one of many potential materials, including nitrites, carbides, and oxicarbonnitrides of group IVb, Vb, and VIb elements. The bars are radially mounted to the sieve to protect it from wear.

There also have been numerous disclosures for equipment other than pulpers. One of these, by Gauss, is for an improved cleaner with a tangential contaminant outlet [8]. The cleaner is a symmetrical cylinder with a tangential inlet and a central accept outlet at the top. The unique feature is the contaminant outlet at the bottom of the cleaner. The outlet tube is tangentially located relative to the radius of the cleaner body and also with its axis at an angle to the cleaner body. The location is claimed to enhance the centrifugal separation forces on the heavy contaminants.

Haffner was issued a patent for a design that combines the functions of filtering, decontaminating, and thickening recycled pulp into a single apparatus [9]. It also provides the complementary function of clarifying the filtrates. The apparatus rotates all its internal components at a high speed. Pulp is introduced through the center of the apparatus and accelerated by paddles to the angular speed of the apparatus. The pulp is forced across a flat circular screen surface by centrifugal force where the fibers are separated from the greater part of the water. The thickened pulp is evacuated through extraction nozzles at the outer periphery of the apparatus. Contaminants with specific gravities lower than one become concentrated near the center of the rotating screen and are drawn off by a centrally located pipe. The water passing through the screen is further clarified by the centrifugal action of the apparatus. Since such high gravity forces are generated in the apparatus, small differences in density can be used for separation. More complete embodiments of the apparatus include the functions of fractionating, deinking, and purifying the pulp with slots or boles. The inventor also applied for patent protection on a related fiber screening apparatus that uses a rotating conical screen [10]. The screen element is driven on an axis through the cone apex. Pulp is pumped into the concave side of the screen and is accelerated in a radial direction. Acceptable fiber passes through the screen while rejects are pushed up the cone walls to the periphery by centrifugal force and ejected from the housing. Because of centrifugal force, a foil type rotor is not needed for clearing the screen, thus lowering the cost of the apparatus. The unit also can thicken the pulp.

Another equipment invention covers a device for recovering paper production waste [11]. The device is designed for the continuous production of paper webs, in particular tissue paper. The invention uses a small re-pulping device in concert with a Yankee drier for the recovery and recycling of processing waste from the drier itself. The device may be situated below the Yankee drier or at other locations in the paper production line where waste, scrap, and paper trimmings are generated. The collected material is recycled automatically, without the need for storing and transporting them from the working zone. The device consists of a container for collecting the material and at least one pressurized water nozzle to intercept the material falling into the container. The water jet breaks up the structure of the scrap paper material and separates the paper into individual fibers. A pump transfers the resulting slurry so that it may be reintroduced into the production cycle.

Voith Paper Patent GMBH has been assigned a patented welding process that can extend the drum life of paper recycling centrifuge [12]. The powder-welded hard coating is an alloy of carbon and chrome or niobium and forms the lining of the drum. Weld beads of the coating are applied to the drum material before forming the drum and run in the axial direction of the drum.

A more durable belt has been developed by Spence and Riding for use on a double nip thickening (DNT) washer.
The belt has a cast-in-place polymer edge guide that penetrates through the fabric. The edge guide tapers from the outside edge towards the thickness of the belt, reducing flexing stress concentrations. This also alleviates abrasion of the belt where the edge guide rides in the DNT washer drum groove. Since no heat is used in applying the edge guide, damage to the belt fabric is prevented during manufacturing. The combined design improvements prevent belt delamination, thus assuring a longer belt life.

A final equipment patent, issued to Visscher and Austin, is for a paper sorting screen [14]. Disc screens have a problem effectively separating office paper (OP) by size since much of the OP may have similar shapes. Therefore, the screen was developed to effectively classify this material. It contains multiple shafts aligned along a frame and configured to rotate in a direction causing paper products to move along a separation screen. The shafts are configured with a shape and spacing so that substantially rigid pieces of the paper products move along the screen while non-rigid pieces of the paper products slide down between adjacent shafts. In one embodiment, the screen includes at least one vacuum shaft that has a first set of air input holes configured to suck in air to retain the non-rigid paper products. A second set of air output holes are configured to blow out air to dislodge the paper products retained by the input boles.

**CHEMICALS AND PROCESS TECHNOLOGIES**

**Fiber Recovery Processes**

Many of the recent patent publications are concerned with more effectively removing contaminants and maintaining or improving yield while using currently available recycling process equipment. The inventive features can include additional or alternative arrangements of unit operations, improved control strategies of the operations, or more effective use of traditional or novel chemicals.

A patent application by Awadel-Karim discusses pulping techniques for recovered paper using a dipolar aprotic protophylic solvent [15]. The process is reported to increase yield while providing high quality fibers. The solvent interacts with the hydrogen bonds, resulting in easier fiber separation and greater exposure of cellulose fiber. This allows easier separation of contaminants and reduces post-pulping processing. Since alkaline treatments are not used at the pulping stage, most of the hemi-cellulases are retained with the fibers. Because the fibers are more flexible and less prone to breakage, increased yield can result. The application also claims techniques for controlling fiber quality by adjusting pulping parameters such as solvent concentration, stock consistency, temperature, time, and energy. These parameters are adjusted on the basis of a multitude of downstream fiber properties.

Selin has applied for a patent for a method and system for producing a suspension of high quality recycled fibers with improved cleanliness, strength, and dewatering ability [16]. In the outlined process, fiber suspension is produced from reclaimed paper by first filling a pulper with a batch of the paper. The pulper is operated to partly defibrate the batch of paper without disintegrating coarse impurities. The partly defibrated batch of paper is separated into a coarse reject fraction and an initial fiber suspension containing some paper fragments and fine impurities. The initial fiber suspension is pumped through a rotary screen apparatus, provided with a tubular fine screen and a pulper-type impeller that rotates coaxial with the tubular screen to defibrate the paper fragments remaining in the initial fiber suspension.

Using a somewhat related idea, Chung has disclosed a method to efficiently separate long and short fibers during the repulping of old corrugated containers (OCC) [17]. In the process, the short fibers from the easily pulped corrugated medium are extracted from the pulper first. After additional pulping, long fibers from the relatively difficult-to-pulp linerboard are removed. By continuously monitoring the consistency of the water in the pulper, the point at which all the corrugated medium has been fiberized can be determined and the short fibers subsequently extracted. Additional water is then added to the remaining linerboard portion for additional fiberization. A central controller manages the process using set points derived from initial tests (See also PPR, 12 (3), 21-25, May 2003).

Several of the reviewed disclosures apply to the use of flotation for contaminant removal. In the first of these, Baetz et al. have patented a multi-stage flotation process for improving fiber recovery and separation of rejects [18]. The reject rate from the first stage of flotation is set at 3-5% less than the maximum. The fiber accepts are then thickened and processed in a dispersion unit. This is followed by a second flotation stage where the reject rate is increased to compensate for the lower rejection rate of the first stage. The complete process is directed by a controller. It is also possible to send the rejects from each stage to a respective secondary flotation unit for additional fiber recovery.

With the goal of optimizing deinking conditions, Gab1 et al. have invented a control strategy for flotation systems [19]. The arrangement has two sub-systems for controlling both the liquid level and foam level in a flotation cell. A downstream instrument measures the quality of the accept fiber and compares the value to the set point value. A control signal is transmitted to the two subcontrollers to adjust either or both the liquid and foam levels as needed. By controlling the quality within the set point band, the pulp will not be either over- or undertreated, and fiber loss will be kept to a minimum. The quality measure can be based on such properties as brightness, dirt count, or stickies.
Suess and Grimmer have disclosed an invention for the flotation deinking of recycled pulp that removes the hydrophilic and water soluble inks without a washing step [20]. The pulp slurry is initially processed in a flotation cell at alkaline conditions with an anionic surfactant. Following this stage, carbon dioxide is injected into the pulp, thus forming carbonic acid and reducing the pH to the 5–7 range. The acidified pulp is again processed in a second flotation cell with a cationic or non-ionic surfactant to remove the hydrophilic and water-soluble inks. By eliminating the washing step between flotation stages, the yield is increased since filler and fiber are not lost. Prior acidic flotation methods have used strong acids such as sulfuric acid to adjust the pH. By using carbonic acid in the second flotation step, filler is not dissolved and yield is increased. Further, salts in the water streams are not increased. Additionally, the rejects from the first and second stages of flotation can be combined for simultaneous fiber recovery and treatment.

Another process for reclaiming paper fibers from mixed recovered papers includes using different surfactants at the separate flotation stages [21]. The disclosure by Ono and Osato describes the sequential operations of pulping, screening, flotation, kneading, bleaching and flotation. A different surfactant is added before each flotation step since the ink particles and contaminants have different sizes and properties at each stage. By using a more specific surfactant at each point, brightness and yield are improved as demonstrated by examples in the disclosure.

Last, Kagawa et al. have devised an effective deinking process for ash-containing recovered papers [22]. Through the combination of two different deinking chemicals and a water filtration unit, brighter pulps can ultimately be derived. A high-alcohol deinking chemical is used at the pulper while a fatty acid deinking chemical is employed during flotation. The clean dilution water provided by the water filtration unit is also one of the factors in achieving brighter pulps according to the inventors. The first steps are pulping with a first deinking chemical, diluting the pulp to 2–4% consistency and washing. Next the pulp is screened and bleached. Finally, the second deinking chemical is added to the pulp, which is then processed in a dispersion and flotation unit. The recovered waters from all thickening processes are treated in the filtration unit. Comparative examples between the new and prior methods are given.

Three of the process disclosures deal with mitigating the effects of stickies by the application of minerals to the fiber slurry [23]. In the first, assigned to Oji Paper Company, a pulping process is described that uses talc to both pacify and increase the specific gravity of adhesive particles generated from magazine-containing reclaimed papers. The talc has a water absorption coefficient of less than 0.4 ml/0.5 g, as tested by Surin equipment. The talc particle diameter is ideally 10-19 microns and is applied at 0.5–2% based on oven-dry fiber weight. The talc is added before a surfactant if a surfactant is used during pulping. Zinc oxide can also be added during pulping. The fiberized slurry is processed using traditional operations such as cleaning, screening, flotation, and bleaching. The cleaner removes a large percentage of the adhesive particles that are bound to the talc particles; any remaining adhesive is pacified by the talc.

In a somewhat related patent publication assigned to Akzo Nobel NV, a cationic clay is used to reduce the negative effects caused by pitch and stickies [24]. Preferably the clay is a magnesium-aluminum having a stacking 3R2 molecular arrangement. The clay can be added to the pulp slurry at numerous points in the system at a dose of 0.5-2%. The 3R2 clay when used in combination with other additives such as retention and drainage aids, improves their effectiveness since the pitch and stickies are tied up. Examples of tests conducted to compare the pitch and stickie adsorption of the 3R2 clay against the 3R1 clay, and talc are given. The tests show improved adsorption with the 3R2 clay.

Finally, the application for an invention by Lasmarias et al. describes a method for removing contaminants from a slurry of recycled paper [25]. The method is comprised of adding a cationized mineral to the paper fiber slurry to form complexes between the cationized mineral and the contaminants such as waxes, pressure sensitive adhesives, or hot melts. These complexes are then separated from the paper fibers by size, density, or a combination of both. The repulping should occur before the cationized mineral is added to the slurry. The fiber slurry can be treated to remove coarse contaminants by any conventional process such as screening or sieving prior to the addition of the cationized mineral.

The next four patent publications are concerned with handling the minerals present in the recovered papers. The first publication provides techniques for the recovery of fiber and fillers from flotation rejects. The method, by Adachi and Fujioka, increases yield by retaining the filler materials while still maintaining brightness [26]. The rejects from a first flotation stage are thickened and then kneaded. This is followed by a second flotation step on the kneaded rejects. Accepts from the second flotation stage, both fiber and filler, are combined with the accepts from the first flotation step. One additional advantage of the process is that bleaching is not required on the fiber recovered from the 1” flotation reject stream.

Onoki et al. have developed a flotation deinking method that retains a large percentage of the tiller with the recovered fiber, thereby increasing the recycling yield and reducing costs related to sludge disposal [27]. The process uses an appropriately selected surfactant so that the bubble surface
tension decreases over time. As the surface tension decays, the froth is no longer able to hold the heavier filler particles and releases the filler hack into the flotation cell slurry. Details of the dynamic and static surface tension of the surfactant required for achieving high brightness and filler retention are given in the patent.

Another invention relates to a process for recycling cleaner rejects and to their re-use in paper making [28]. The proposed recycling process reuses the cleaner rejects containing fibers, coating pigments, or fillers or both after they are milled to the appropriate grain size suitable for raw materials for the paper stock or coating slurry. The invention provides an environmentally friendly concept for using cleaner rejects by enabling them to be recycled as completely as possible.

Finally, Suzuki and Yoshida have taken a different approach; their goal is to remove as much mineral material as possible from the recycled fiber. The disclosed method uses a dispersant during the pulping or kneading of recycled fiber to significantly reduce the ash content after washing [29]. The method is especially geared toward recovered papers containing 15–35% ash, such as old magazines. The dispersant is used at 0.5–5%, based on fiber weight. Various dispersants can be used including polyacrylates, polycarboxylates, dialkyl sulfosuccinates, or sulfonic group-modified polyvinyl alcohol. In trials on a recovered paper with 19% ash, the control pulps still contained 14% ash, whereas the dispersant-treated samples contained 4% ash.

Two recent patents describe methods for recovering fiber from water-resistant papers. In the first, Togo and Miyaguchi have disclosed a new process for recovering fiber from wet-strength papers [30]. A halogenated hydantoin (imidazole derivative) compound is added at the pulper along with traditional pulping chemicals. The compound is applied at 1%-10% of the fiber weight and reacts with the wet-strength enhancers to help liberate the fibers. The hydantoin compound is not as corrosive as previously disclosed compounds. Further, it can be used with mixtures of recovered papers so that separate fiberization of the wet-strength paper is not required. The organic compound can be one of several variations of the general structure disclosed in the patent.

In a second disclosure, details for recovering high quality kraft fibers from laminated papers through proper pulping and screening steps are given [31]. The plastic laminated papers are pulped below 70°C at a consistency of greater than 15%. After 60 min, the pulp is extracted through a sieve plate with 5–15 mm holes. The pulp is then screened with 0.5–3 mm holes, followed by a centrifugal cleaner to remove any heavy contaminants. A final screening is conducted with 0.05–0.3 mm slits. These screening accepts are then processed in a lightweight cleaner. The pulp can then undergo additional operations such as refining and flotation. The resulting pulp can be used alone or in blends with other pulps for papermaking. Examples of paper made from the pulp show little or no plastic carryover as well as good strength.

Daio Paper Corp is the assignee on five patent publications pertaining to the recycling of unsorted recovered papers. All disclosures pertain to processes for producing high quality recycled pulp from unsorted recovered papers that include magazine and books commingled with large quantities of hot melts and plastics. A common distinction in these disclosures is that the new methods can generate a quality pulp from a variable reclaimed paper supply, whereas previous methods required a more uniform source. In the first patented process, the material is pulped and the pulp is transferred to an auxiliary disintegrator [32]. Here the pulp is broken up further and the pulp is subsequently discharged through a sieve with 2.2 mm holes. Next, the pulp is screened in two steps with 1.4 mm holes and 0.15 mm slots. Typical unit operations can follow the screening. The second patent describes controlling the contaminant level and yield of screening accepts by means of an on-line contaminant sensor [33]. The on-line sensor monitors particlesizesinether the reject or accept line of a 0.12-mm screen. Since the contaminant level of unsorted recovered paper is variable, the screening reject rate must also be varied to maintain a controlled level of contaminants while maintaining yield. The third process also uses on-line monitoring of fiber accepts from a screening operation [34]. In this case, the screen with 0.05–0.12 mm slots is used as a fiber fractionator on the flotation accepts. The sensor controls the screen reject rate between 10% and 50% on the basis of the fiber-length set point. The fiber accepts from fractionation are used for printing papers whereas the rejects can be used for newsprint or magazine. The fourth disclosed process excludes alkali treatment during the initial stages of recycling to prevent hot melts and other foreign material from going into solution [35]. The unsorted reclaimed paper is pulped, screened, floated, kneaded, and bleached. The pulp is subsequently passed through a flotation stage to remove the remaining ink loosened in the bleaching step. The final disclosure suggests pulping the recovered paper at 46°C –60°C for 10 to 30 min to promote the separation of ink [36]. After fiberization, the temperature of the pulp is lowered to less than 40°C during the subsequent contaminant removal steps. Below this temperature, any hot melt adhesives will solidify and agglomerate for easy removal.

Dockal-Baur and Selder have developed an arrangement of flotation, fractionation, and dispersion operations with lower energy and equipment costs for producing deinked fiber [37]. The pulp slurry is first processed in a flotation cell. Accepts are subsequently separated into fine and coarse fiber fractions. The coarse fibers are re-screened to remove
additional contaminants and the accept fibers are processed in a dispersion unit and recombined with the initial fine fiber accepts. The mixture is then passed through a flotation cell; cleaned fibers are processed by traditional methods as needed.

A cost-effective method for producing stickie-free recycled fiber has been assigned to Voith Paper Patent GMBH [38]. The fiberized stock is processed by an initial screening stage followed by a fine screening stage. The fine screening stage uses two cascaded screens. Accepts from the first fine screen are sent for further processing; rejects are fed to the second fine screen that blends its accepts with the accepts from the first screen. The rejects from the second fine screen are subsequently fractionated into long and short fiber components. The long fiber fraction is passed through a beating stage while the short fiber fraction is screened an additional time. These cleaned short fibers are then blended with the beaten long fibers and the resulting mixture obtains further cleaning in a flotation cell. Flotation accepts are blended with the rejects from the first fine screen for processing in the second fine screen.

Employing hydrogen peroxide combined with ozone, Kizara has developed a deinking strategy that produces clean fibers while lowering the chemical oxygen demand in the process wastewaters [39]. The process can be used for newsprint, magazine, and office papers, and it eliminates the typical alkali soak. After fiberization, the fiber is mixed with 1-3% hydrogen peroxide and sodium silicate with a resulting pH of 6-8 and mixed with 0.5-2% ozone under high shear. This mixture is allowed to react for 1–60 min at a temperature 70°C. This pulp can then receive a washing or flotation treatment. The ozone is claimed to help exfoliate the ink, possibly by oxidative degradation at the ink–fiber interface.

Hautala has applied for a patent on a recycling process that recovers a larger and higher quality portion of fiber than conventional processes [40]. Waste that contains fibers and combustible material is slushed in a continuous-operation high-consistency pulper to suspend the fibers contained in the waste. The fiber suspension is discharged from the pulper continuously through a screen plate. Unfiberized material is discharged by means of a mechanical transfer device. The fiber suspension is sorted and cleaned for use as raw material in paper or board. Unfiberized material and rejects are separated from the fiber suspension in the sorting and cleaning stages and used as fuel in energy production or used as raw material.

Recycled Papers

Daio Paper Corp is the assignee on numerous patents concerned with papers containing old magazines (OMG) and methods for producing them. In all cases, typical recycling unit operations are used in addition to some unique steps or features. Many comparative examples using the processes are given in the patent publications. The first two of these publications regard producing high bulk publication papers using a bulking agent. The papers contain at least 70% OMG and use a specified bulking agent at the rate of 1–15 kg/ton [41], [42]. The resulting papers have a density of 0.35–0.8 g/cc after a calendaring process and a roughness of less than 10 microns.

The next two patents discuss using OMG combined with kraft pulp to produce office papers with high brightness and low dirt counts. One method uses at least 5% OMG and has dirt counts less than 20 mm²/m² and a roughness less than 2.8 microns [43]. A dispersion unit is used in the process just prior to a hydrogen peroxide bleaching step. Bleaching is followed by a second flotation stage. Finally, the pulp is adjusted to a cation level of 0.03–0.10 meq/L with a coagulant prior to blending with the Kraft pulp. The other method uses at least 10% OMG and has a final whiteness greater than 73% (JIS-P8123) [44]. Ideally, a deinking agent is added at numerous addition points at the multiple stages of flotation. Also, the pH of the papermaking is adjusted to prevent scaling from the calcium carbonate carried with the OMG.

Another patent assigned to Daio Paper Corp explains methods for producing coated papers containing at least 10% OMG [45]. The OMG pulp is adjusted to a cation level of 0.03–0.10 meq/L with a coagulant before blending with the base pulp. Lightweight wrapping papers containing at least 10% OMG are addressed in yet another patent [46]. The papers have tensile strengths of 12 kN/m with tear strengths of 15 N.m/g. The process includes using a screen with a slit or hole diameter of less than 0.12 mm. An on-line impurity sensor monitors screening accepts and the reject rate is adjusted accordingly. The OMG can also be used as a portion of the base stock for a removable or “pseudo” adhesive paper [47]. The details of the adhesive coating are given in the patent. The OMG-containing base paper is said to have good printability with limited linting.

Four additional patents assigned to Daio Paper Corp are related to newsprint containing greater than 5% OMG. The first describes an operational step of using a screen with 0.12 mm slits to fractionate and clean the OMG pulp [48]. This fraction is blended with the base pulp, producing papers with tensile strengths of 2.4 kN/m. The second publication relates to OMG-containing newsprint having brightness values greater than 53.5% based on JIS-P 8123 [49]. The method includes separate additions of a deinking agent during the multiple stages of flotation. The next patented process uses an auxiliary disintegrator during the initial pulping of OMG [50]. The resulting OMG-containing newsprint has a Bekk smoothness of less than 39 seconds using JIS-P 81 19. Last, a process is described for producing OMG-containing newsprint with friction forces less than
Packaging. The recovered fibers are bleached and then describe packaging papers produced from various ratios of deinking in multiple stages of flotation.

Two Russian patents assigned to Kartontara Stock Co. describe packaging papers produced from various ratios of high yield chemi-thermomechanical pulp (CTMP) and secondary fiber. The first patent relates to corrugating medium having a light coating applied in the glue press [52]. The second patent describes a linerboard consisting of an upper layer of 100% recovered paper, with middle and lower layers composed of mixtures of CTMP and recovered paper [53]. Either or both of the upper and lower layers can receive a coating. Both patents suggest the papers can be economically produced while having improved rigidity and strength. Examples of containers using the papers are also given.

A process has been developed to recycle fibers from recovered laminated liquid packaging papers, such as juice or milk cartons, back into their original use [54]. The recovered fibers are sandwiched between layers of virgin pulp, which are then coated for reuse as liquid food-grade packaging. The recovered fibers are bleached and then sterilized by use of photocatalysts and ultraviolet rays or reactive oxygen species.

A recent Japanese patent discusses methods for producing a water- and oil-proof paper that is inexpensive and easily recycled [55]. The paper is produced by the T-die co-extrusion melting laminating method that applies a 10–25 micron coating. A blend of polyolefin and tackifier is first applied to the paper to form an adhesive layer. The components are proportioned to balance coating toughness, coverage, and adhesion against releasability during recycling. A second coating, consisting of a polyolefin and a wax, is applied over the adhesive layer coating to provide additional water and oil resistance. Results of bench-top disintegration studies show that the coated paper should be easily recycled while providing the necessary water and oil resistance.

Additives

Braig et al. have developed an improved papermaking retention aid that is a polymethyleneamine with repeating aminomethylene units [56]. The retention aid has a very high cationic charge density when compared to a polyethyleneimine. The polymer is derived from imidazole or its derivatives by hydrolysis. The new aid is especially effective at retaining tine particles, such as fillers, and at fixing stickies.

Asakura et al. have designed a chemical agent for increasing the bulk of recycled fibers with the added benefit of increased oil absorption [57]. The hulk promoter has an 8–24 carbon alkyl group, an ethylene or propylene group, and a butylene group. Proper proportions of these groups are described to provide optimal effectiveness for hulk, oil absorption, system cleanliness, and cost. During stock preparation, the hulking agent is applied at 0.03%-8% on the basis of fiber weight and is said to be compatible with other additives. Bench top trials show an approximate 10% increase in bulk and a 20% increase in oil absorption.

Stickie and pitch deposition can be minimized through the use of a newly disclosed water-soluble polymer [58]. The branched high molecular weight polymer provides the dual function of fixation and anionic trash reduction when added to pulp. The polymer is produced by using a suitable radical initiator to post-crosslink monomers of diallyldimethyl ammonium chloride (DADMAC). The resulting compound has shorter crosslinking bridges than those that are crosslinked with a polyolefinic crosslinker. The molecular weight of the new compound is preferably greater than 850,000 grams per mole. The new DADMAC polymers show improved performance when compared with commercially available compounds.

A recently disclosed deposit inhibitor can act against deposits from biological organisms. stickies, and pitch [59]. The multi-faceted protection ultimately leads to a simpler and less costly treatment program. The inhibitor uses 0.1%-10% tenside in an organic hydrophobic solvent along with a stabilized halogen such as bromine or chlorine. The additive does not form an emulsion but rather small droplets. This allows the additive to deposit on wires, felts and piping rather than staying water borne. This has the effect of better protecting the equipment surfaces while reducing foaming. The inhibitor is used at 10-1000 ppm depending on the fiber consistency in the particular application. Various trials conducted at papermaking installations showed improvement in the control of deposits through the use of the inhibitor.

A new fungicide works synergistically when combined with a biocide according to a recent patent application by Ashworth et al. [60]. The fungicide is a potassium salt of N'-hydroxy-N-cyclohexyl diazenium oxide. The fungicide is unique since no toxic heavy metals are used, and it is stable in a high pH environment. The combined biocide–fungicide has multiple potential applications including the pulp and paper industry.

Enzymes

Enzyme preparations continue to be explored for improved deinking of used papers. The patents and patent applications reviewed here include novel enzymes, enzymes that modify fiber surfaces to improve pulp drainage, enzymes that improve brightness or target specific paper inks or printing, and even include an assay technique to predict
the effectiveness of a specific enzyme/surfactant preparation.

A recently published patent application describes a cellulase preparation comprising nonionic surfactants combined with endoglucanases derived from zygomycetes [61]. This patent also includes the method of treating reclaimed paper with a cellulase preparation in concert with a deinking agent. The additional benefit of improved pulp drainage can be accomplished by another application of this cellulase preparation.

Another patent application covers deinking of starch containing recovered papers by the inclusion of a starch-degrading enzyme and a pectate lyase [62]. This invention covers both the enzyme preparations and the point at which they are added during the deinking sequence.

Perhaps the most comprehensive newly issued patent for enzymatic deinking covers removal of non-contact printed wastepaper using an enzyme mixture characterized by a high ratio of beta-glucosidase activity to filter paper units (FPU) activity [63]. This assay technique for screening enzyme preparations for potential deinking agents on the basis of the ratio of beta-glucosidase activity to FPU activity eliminates the need for pulping trials. Preparations developed using this method modify fiber surfaces and reduce ink particle size and shape to facilitate removal.

Genes encoding novel cellulases and a gene encoding a protein that facilitates the action of these cellulases and enzyme preparations containing such proteins are described in another patent application [64]. The native hosts and culture medium of these hosts for novel cellulases are disclosed. The inventors claim these proteins are useful in both the textile and pulp and paper industries.

A neutral pH range (between 4.0 and 8.5) is used for pulping reclaimed paper in the presence of lipase, and a fatty acid ester is central to this patent application for effective deinking [65]. Ink particles are dislodged and subsequently removed from the reclaimed fiber.

A recent Japanese patent covers a novel endoglucanase protein comprising a fully defined sequence of 266 amino acids in which one or more amino acids are substituted, deleted, added, or inserted [66]. This protein is useful for processing cellulose fibers including deinking paper, improving pulp drainage, and decreasing fiber stiffness. The patent covers sequencing, host cells, culture, and extraction.

A bacterial laccase used for chemical treatment of phenolic compounds or aromatic amines, especially dyes, is claimed in this patent [67]. This laccase and a biocatalyst with immobilized bacterial spores can be used either for oxidative decolorization of waste liquor or dye synthesis by oxidative coupling. A special advantage of bacterial laccases is their alkaline pH optima and tolerance of high temperatures, which makes them compatible with conditions used in the pulp and paper industry.

The method of preparing a water-based biological enzyme deinking agent for newsprint is described in this patent by Dong [68]. A cellulase and hemicellulase are combined with a surfactant, containing potassium oleate or alkyl benzene sulphonate or polyether, which acts as a carrier for the deinking agent intermediate A. Next, an alkaline lipase acting on a triglyceride ester bond and surfactant combine to make deinking intermediate B. Finally, intermediates A and B are combined in a ratio ranging from 3:7–7:3 to form product C, the novel deinking agent.

A novel cellulase derived from cellulase NCES is resistant to surfactants and useful for removing color from cellulose fibers and for deinking post-consumer paper [69]. A fully defined sequence of 205 amino acids is covered in this patent. The amino acid residues 162–166 are substituted by different amino acid sequences to form the novel cellulase. The advantages of this invention are that the cellulase is not deactivated by surfactants and that pulp drainage is improved.

The final patent covering enzyme use in recycling recovered paper combines bleaching and cellulase treatment to produce ink-free pulp [70]. The pulp is first bleached with peroxo acid containing peroxy acid at pH 7–9, followed by processing with cellulase. This sequential treatment reduces the amount of wastewater generated during deinking and improves ink removal. Fiber strength is maintained even though no alkali is added in the processing.

**Deinking Chemicals**

Numerous newly issued patents were issued for deinking chemicals, primarily surfactants [71]. Kemira Chemical, Inc. is the assignee of a deinking method and novel surfactants. The non-ionic surfactants used for deinking recovered paper primarily include C16 to C18 aliphatic alcohol alkoxylates to produce paper having excellent brightness. Because these surfactants prevent redeposition of ink particles, the deinked pulp has a low effective residual ink concentration. Pulp deinked by this method requires a low amount of sizing when compared with traditional surfactants. The surfactant composition can be varied to adapt to specific deinking needs. Low foaming wastewater and minimized deposition on papermaking equipment are additional benefits claimed.

A deinking agent primarily for ONP and OMG is the subject of another invention [72]. This agent contains up to 10% of acetylene alcohol or an alkylene oxide adduct of acetylene
alcohol. When added to the pulper, this compound effectively removes ink from reclaimed paper.

A world patent has been issued for producing a deinking agent that includes an alkali metal silicate especially useful in removing water-soluble red printing inks from reclaimed paper [73]. The novelty lies in the copolymerisate based on acrylic acid, maleic acid or their ester, nitrite, or amide derivatives being either neutralized or saponified. The process is less expensive than previous processes, ensures better dispersion of dissolved contaminants and inks, and inhibits the re-adsorption onto the recycled fibers.

The Lion Corporation is the assignee of a flocculant for ink during the flotation stage [74]. The flocculant displays hydrophobicity, excellent adsorption of ink, and cohesive power sufficient to aggregate ink for subsequent removal.

Specially formulated non-ionic surfactants have the capability to peel inks from thermosensitive recording paper and pressure-sensitive paper as well as from magazines, newsprint, and computer papers [75]. This Japanese patent claims these surfactants produce a deinked pulp with high whiteness while preventing the discoloration of fibers.

Another patent claiming the ability to peel inks is described as an alkylene oxide deinking agent [76]. The advantage of this agent is its excellent ink collection feature and anti-foaming property that preserves pulp yield.

Recycled mixed papers appropriate for printing by an inkjet printer using aqueous ink can be produced by this newly patented method [77]. After the paper is fiberized, a surfactant-based ink removal agent and a sizing agent are added to the pulp slurry. When pulp deinked using this method is made into printing paper, the resulting paper has excellent printing properties, including inkjet printing.

A world patent has been awarded for a deinking additive containing an organo-modified siloxane [78]. The additive is introduced to fiberized wastepaper during flotation, resulting in excellent ink removal and a pulp of high brightness. This additive has the additional benefit of clarifying the process water.

A papermaking chemical composed of a polyamine polyalkoxylate, made by adding an alkylene oxide to the amino group in a polyamine compound, has proven to be useful for the manufacture of various coated papers and the white layer of corrugated boxboard [79]. The unique advantage of this agent is enabling the use of recycled fibers, improving paper machine speed, and preventing deposits on the paper making equipment during manufacture.

An eco-friendly biodegradable deinking agent has been granted a world patent [80]. This compound contains an aliphatic hydrocarbon group, an oxyethylene group, an oxypropylene group, or an oxybutylene group. Use of this deinking agent claims to produce a clean, white recycled fiber from newspaper and magazines.

**Bleaching**

Two recent patent publications assigned to Kemira OYJ address the hydrogen peroxide bleaching of all types of pulps, without the addition of alkaline silicate stabilizers. In both cases, the intent is to mitigate the negative effects of the silicate carryover such as scaling or interfering with wet-end chemistry. In the first application, poly-alpha-hydroxyacrylic acid (PHAA) and a polycarboxylate polymer are used together as a hydrogen peroxide stabilizer [81]. The two chemicals are mixed with the pulp prior to the application of an alkaline peroxide bleaching solution. The polycarboxylate polymer binds the alkaline earth metal ions, allowing the more expensive PHAA to perform its function at lower doses. Trials with a de-inked pulp indicate the compounds work as effectively as alkaline silicate. The second disclosure deals with the generation of a stable aqueous composition from the above-mentioned chemicals and its application during bleaching [82].

Bleaching with hydrogen peroxide is also the topic of another recent patent application by Pan [83]. The invention uses an organic solvent in a conventional peroxide bleaching solution to improve yield and brightness. The desired outcome of the process is to retain hemi-cellulases while partially delignifying the pulp. Ethanol is the preferred solvent as it will dissolve lignin but will not dissolve hemicellulose. The ethanol substitutes for up to 50% of the water in the bleaching solution. Based on the equivalent brightness of a mechanical pulp, the new method increased fiber yield 3% and consumed 50% less hydrogen peroxide compared with conventional methods.

**Test Methods**

Detecting and measuring dissolved and colloidal contaminants in papermaking waters can be accomplished by means of a recent Finnish invention [84]. The method is especially useful for determining stickies occurring in paper recycling processes. The turbidity of a water sample is measured both before and after a pH adjustment and the resulting difference can be correlated to the dissolved and colloidal contaminant levels. An acid is used to lower the system pH to the 3 to 5 range. The turbidity monitor can he either on-line or a bench top instrument. After determining the pH difference in readings, an efficient dose of coagulant or other chemical can be added to treat the water.
A method and an apparatus for testing the quality of reclaimed paper containing brown cardboard or colored plastic fragments has been developed by Bedard et al. [85]. The method employs an image analysis technique to provide quality indication data useful for establishing appropriate processing parameters. Polychromatic light is directed onto wastepaper on a conveyor where a camera generates color image pixel data representing color components of the inspected area. The image data is processed by comparison with a table containing color classification data related to one or more contaminants. A match is a high probability that the contaminant is present. The classification color data are originally derived using a Bayesian statistical distribution on imaged contaminants. With this function, multiple contaminants types can be discerned. Once the quantity of total contaminants is determined, an indication of the quality of the reclaimable paper can be determined.

Chou et al. have recently disclosed methods for both determining the amount of groundwood in recovered papers and techniques to efficiently recover the groundwood for use in absorbent paper products [86], [87]. The first disclosure relates to a rapid process for determining the groundwood percentage in recovered paper, whereas the second disclosure pertains to using the groundwood determination to choose the appropriate deinking and bleaching processes on the fiber. The groundwood determination process comprises preparing an absorbent sheet from the secondary fiber and characterizing the initial color of the absorbent sheet by spectrophotometry. The sheet is then treated with a phloroglucinol stain and the color is again characterized. Comparison of the pre- and post-treatment color of the sheet is shown to be an indication of the amount of untreated groundwood. This new method for determining groundwood content differentiates between bleached and unbleached groundwood, whereas previous methods did not. Also, the new method is at least twice as fast as the previous methods. The color characterization comprises determining CIE, L*, a*, b* and brightness values and their corresponding delta values. Once these delta values are determined, appropriate uses for the fiber can be selected. Further, as suggested in the second disclosure, the delta value can be used to aid the selection of a bleaching-deinking strategy or to enable optimization of fiber blending for particular products.

Wastewater Treatment

A recently disclosed strain of bacteria used for biological treatment of pulp and paper mill wastewaters shows improved reduction in the total dissolved solids (TDS) [88]. The bacteria strain has an accession number of MTCC 5098. By using methods presented in the application, the TDS can be reduced by 10% in 24 hours, as demonstrated by reported examples. Methods are also described for culturing and preparing the bacteria for application to the wastewater. Ichikawa and Mori have developed a beneficial use for screening rejects in the dewatering of sludge from biologically treated wastewaters [89]. Because of the large organism content, these particular sludges can be difficult to dewater. In this process, sludge is mixed with the fiber-containing rejects and a coagulant. The coagulant is a macromolecule of anionic and cationic polymers described fully in the patent. The added fiber makes up 10% to 20% of the solids in the sludge while the coagulant is added at 50-300 ppm. The combination of fiber and coagulant improve the pressing solids of the sludge.

Hymo Corporation is the assignee in three recent patents pertaining to papermaking and wastewater treatment coagulants. The first is a disclosure related to the dewatering of excess sludge generated by biological wastewater treatment using a cationic or cationic-anionic organic macromolecule bridging gel [90]. The patent sets forth methods for developing a coagulant composed of either co-polymerized acrylic cationic monomers and non-ionic monomers or acrylic cationic monomers and anionic monomers. The resulting 5–15 million molecular weight polymers can he water-in-oil emulsions, pastes, or powders depending on the polymerization technique used. A wide selection of compounds can be used for polymerization, as fully described in the patent. Examples comparing the treatment of sludge with the new coagulants versus slaked-lime show improved dewatering with the new coagulants. In a related patent, a surfactant with a high hydrophilic-lyphophilic balance (HLB) is used during the dilution of high molecular weight water-in-oil emulsion polymers used for wastewater treatment [91]. The surfactant has an HLB balance of 10–20. The surfactant is blended with the high molecular weight polymer and dilution water in an in-line mixer or pump. The surfactant improves the dispersion of the polymer and prevents the formation of condensable particles. The last patent reveals techniques for producing water-soluble dispersions for use in paper making or water treatment [92]. The dispersions are blends of water soluble polymers and amidine molecules less than 100 microns in size. The resulting polymers can he developed to have any combination of ionic charge desired. The high molecular weight amidine molecules are de-polymerized in the presence of the hydrogen peroxide to produce molecular weights of 5,000–10,000. These amidine molecules are then reacted with the water-soluble components using a polymerization initiator such as an azo system. The claimed benefit to these techniques is that polymerization can he done without salts, thus opening the process to a wider range of monomers.

Sanyo Chemical Industries Ltd. has also developed a new coagulant for use in the treatment of wastewaters [93]. The flocs resulting from the use of the polymers are said to be stable and easily dewatered. The polymer consists of a water soluble unsaturated monomer having one double bond and a crosslinking unsaturated monomer having two or more.

A method and an apparatus for testing the quality of reclaimed paper containing brown cardboard or colored plastic fragments has been developed by Bedard et al. [85]. The method employs an image analysis technique to provide quality indication data useful for establishing appropriate processing parameters. Polychromatic light is directed onto wastepaper on a conveyor where a camera generates color image pixel data representing color components of the inspected area. The image data is processed by comparison with a table containing color classification data related to one or more contaminants. A match is a high probability that the contaminant is present. The classification color data are originally derived using a Bayesian statistical distribution on imaged contaminants. With this function, multiple contaminants types can be discerned. Once the quantity of total contaminants is determined, an indication of the quality of the reclaimable paper can be determined.

Chou et al. have recently disclosed methods for both determining the amount of groundwood in recovered papers and techniques to efficiently recover the groundwood for use in absorbent paper products [86], [87]. The first disclosure relates to a rapid process for determining the groundwood percentage in recovered paper, whereas the second disclosure pertains to using the groundwood determination to choose the appropriate deinking and bleaching processes on the fiber. The groundwood determination process comprises preparing an absorbent sheet from the secondary fiber and characterizing the initial color of the absorbent sheet by spectrophotometry. The sheet is then treated with a phloroglucinol stain and the color is again characterized. Comparison of the pre- and post-treatment color of the sheet is shown to be an indication of the amount of untreated groundwood. This new method for determining groundwood content differentiates between bleached and unbleached groundwood, whereas previous methods did not. Also, the new method is at least twice as fast as the previous methods. The color characterization comprises determining CIE, L*, a*, b* and brightness values and their corresponding delta values. Once these delta values are determined, appropriate uses for the fiber can be selected. Further, as suggested in the second disclosure, the delta value can be used to aid the selection of a bleaching-deinking strategy or to enable optimization of fiber blending for particular products.

Wastewater Treatment

A recently disclosed strain of bacteria used for biological treatment of pulp and paper mill wastewaters shows improved reduction in the total dissolved solids (TDS) [88]. The bacteria strain has an accession number of MTCC 5098. By using methods presented in the application, the TDS can be reduced by 10% in 24 hours, as demonstrated by reported examples. Methods are also described for culturing and preparing the bacteria for application to the wastewater. Ichikawa and Mori have developed a beneficial use for screening rejects in the dewatering of sludge from biologically treated wastewaters [89]. Because of the large organism content, these particular sludges can be difficult to dewater. In this process, sludge is mixed with the fiber-containing rejects and a coagulant. The coagulant is a macromolecule of anionic and cationic polymers described fully in the patent. The added fiber makes up 10% to 20% of the solids in the sludge while the coagulant is added at 50-300 ppm. The combination of fiber and coagulant improve the pressing solids of the sludge.

Hymo Corporation is the assignee in three recent patents pertaining to papermaking and wastewater treatment coagulants. The first is a disclosure related to the dewatering of excess sludge generated by biological wastewater treatment using a cationic or cationic-anionic organic macromolecule bridging gel [90]. The patent sets forth methods for developing a coagulant composed of either co-polymerized acrylic cationic monomers and non-ionic monomers or acrylic cationic monomers and anionic monomers. The resulting 5–15 million molecular weight polymers can he water-in-oil emulsions, pastes, or powders depending on the polymerization technique used. A wide selection of compounds can be used for polymerization, as fully described in the patent. Examples comparing the treatment of sludge with the new coagulants versus slaked-lime show improved dewatering with the new coagulants. In a related patent, a surfactant with a high hydrophilic-lyphophilic balance (HLB) is used during the dilution of high molecular weight water-in-oil emulsion polymers used for wastewater treatment [91]. The surfactant has an HLB balance of 10–20. The surfactant is blended with the high molecular weight polymer and dilution water in an in-line mixer or pump. The surfactant improves the dispersion of the polymer and prevents the formation of condensable particles. The last patent reveals techniques for producing water-soluble dispersions for use in paper making or water treatment [92]. The dispersions are blends of water soluble polymers and amidine molecules less than 100 microns in size. The resulting polymers can he developed to have any combination of ionic charge desired. The high molecular weight amidine molecules are de-polymerized in the presence of the hydrogen peroxide to produce molecular weights of 5,000–10,000. These amidine molecules are then reacted with the water-soluble components using a polymerization initiator such as an azo system. The claimed benefit to these techniques is that polymerization can he done without salts, thus opening the process to a wider range of monomers.

Sanyo Chemical Industries Ltd. has also developed a new coagulant for use in the treatment of wastewaters [93]. The flocs resulting from the use of the polymers are said to be stable and easily dewatered. The polymer consists of a water soluble unsaturated monomer having one double bond and a crosslinking unsaturated monomer having two or more.
unsaturated vinyl or allyl groups. Extensive details of possible chemical combinations and polymerization methods are given in the disclosure, along with a claim that the coagulant can be used in papermaking.

Still another Japanese patent describes an aggregation agent for paper manufacture and wastewater treatment [94]. It is a cross-linkable ionic water-soluble polymer obtained by polymerizing monomer mixtures having vinyl groups. One application is for clarifying process water and aggregating yield is increased and the favorable cohesive power of the cross-linkable ionic water-soluble polymer obtained by unsaturated vinyl or allyl groups. Extensive details of are given in the disclosure, along with a claim that the possible chemical combinations and polymerization methods cannot react to form the hard and unusable Ca

In cases where dewatered sludge is incinerated, the remaining ash still needs disposal. To alleviate this problem, Hiyoshi et al. have developed an incineration process that ultimately produces valuable zeolites, along with recoverable calcium carbonate, talc, and titanium dioxide [95]. The ideal temperature for sludge incineration is between 500°C and 600°C. At this temperature the cellulose is oxidized, the kaolin is converted to metakaolin, the calcium carbonate has limited conversion to calcium oxide, and the talc and titanium dioxide are unchanged. With limited calcium oxide, the metakaolin cannot react to form the hard and unusable CaAl2SiO7. The resulting inorganic ash is then treated with a 3 N sodium hydroxide solution at 80°C to 120°C, which converts the metakaolin to zeolites. The zeolites can be separated from the waste sodium hydroxide and other remaining minerals, all of which can be re-used.

Recovery of the inorganic components from deinking sludge can be accomplished by the methods proposed by Dahlblom et al. [96]. The temperature and pressure of the sludge is raised above the supercritical point of water after which oxygen is injected. The organic components of the sludge are oxidized, leaving behind the re-useable inorganics such as fillers and pigments. Prior to supercritical oxidation in a high-pressure reactor, the sludge is adjusted to 15-40% organics and 15-30% solids so that it has pumpable viscosity. The temperature during oxidation is maintained below 600°C to prevent degradation of the inorganic solids. The heat generated during the oxidation step is recovered for the beating process. After oxidation of the organic constituents, the discharged inorganic solids slurry and gases are separated. Depending on the resulting properties, the filler may be used directly in papermaking or may receive additional cleaning steps.

One last waste water treatment patent discloses methods for treating fluorescent brightening agents [97]. Any of numerous claimed redox mediators can be applied to the water at doses of 0.01 mmol/L to 100 mmol/L and at a pH of 2–12. A lacasse can also be used with the redox mediator to synergistically decompose the brightener.

**ALTERNATIVE PRODUCTS**

**Alternative Uses of Recovered Paper**

Biodegradable thermoplastics can be produced from cellulose contained in papermaking wastewaters according to methods described by Tsutomu [98]. The process includes a step for removing the collector flocculent through a water or hydrochloric acid washing. The recovered cellulose is next treated with benzyl chloride in a sodium hydroxide and tetramethylammonium iodide solution for 2 hours at 40°C and 5 hours at 100°C. Finally, the solution is mixed with diethylether, filtered, and dried. The process attaches benzyl groups to the cellulose creating the thermoplastic with melting points in the 200°C range. The process is deemed to be more economic than disposing of the fiber through landfilling or incineration.

A related biodegradable thermoplastic resin process has been patented by Nakas et al. [99]. The technique is microbial-based and uses xylan extracted from pulp production processes (and possibly recovered papers) along with levulinic acid to generate polyhydroxyalkanoates with properties similar to petroleum-based polyesters. By controlling the amount and timing of the levulinic acid addition, varying properties can be generated.

Toyama et al. have recently disclosed a process for producing hydrogen and methane from waste organic solids, including wastepaper [100]. The solids are ground and mixed with a wastewater stream. The slurry is heated under pressure in 3 different stages. The first stage is used to solubilize the organic content. The second stage employs any of numerous metallic catalysts to perform a methanation reaction that generates the majority of the recoverable methane and hydrogen gases. Oxygen is injected in the third stage to finish decomposing any remaining organic components.

A patent has been issued to Hang for the invention of a manufacturing method and application of a multi-purpose agricultural paper [101]. The agricultural paper encompasses non-polluting, biodegrading, and strong light-blocking abilities so that it can be used as a carrier of antagonistic microorganisms for being applied in plant cultivating. The paper can also be used as a functional basic material to control weeds, control pests, sow seeds, grow seedlings, supply fertilizer, save fertilizer, save manpower, and cultivate special plant species. The method of manufacturing the multi-purpose paper consists of producing a cleaned secondary fiber, adding at least one functional additive into the clean paper pulp, and forming paper with an uneven surface structure.
Miscellaneous

An interesting alternative paper product for use as cushioning or insulating material has been proposed in a Japanese patent [102]. The paper is formed with microcapsules of foaming agents encapsulated in polymer. Upon heating, the polymer releases the foaming agent and forms air pockets in the paper web, creating the cushioning and insulating properties. The resulting paper is said to be smooth and recyclable.

Ricoh Company LTD has recently developed an improved method for in-office recycling of printed and copied office papers [103]. The system uses a low melting temperature resin acting as an interface between the paper and the toner. The used copied papers are subsequently processed in a mechanical toner-removal machine for the recovery of reusable paper. Preferably, a specially designed copier applies the resin to the paper just prior to the application and fusing of the toner. The resin can also be blended with the toner and applied to the paper simultaneously. The melting temperature of the hydrophilic resin layer is selected to be lower than the toner fixing temperature used in the copier. The resin, which can be selected from numerous organic chemicals disclosed in the patent, is said to hydrogen-bond with the paper surface and to have limited penetration into the paper. During toner removal, the paper is heated above the melting temperature of the resin layer, but below the toner fixing temperature, thus fluidizing it and allowing the attached toner particles to be easily brushed off the paper. A related disclosure describes improvements to previously patented thermal reversible copy paper [104]. The special paper has a thermal reversible coating that is printed with a heated stylus; the printing is removed by reheating the sheet. An additional polymer layer, having a water contact angle between 75 and 100 degrees, is applied over the thermal reversible layer. This additional layer is where typical users might make notes with pens and pencils in an office setting. During the sheet regeneration phase in a separate machine, the top surface of the paper is brushed with an erasure belt to remove the handwritten ink while the sheet is heated to erase the thermal reversible printing.

PATENTS CITED


63. Yang, J., Eriksson, K., Ma, J., Pierce, M. Composition for enzymatic deinking of waste paper. Assigned to University


78. Nellessen, B. Method of deinking. Assigned to Dow Coming. Publication number AU 2003254593 (February 16, 2004).


86. Chou, H., Thomas, H., Palm, A., Witkowski, T., Clasing, R., Keen, S., DiPietro, D. Process for facilitating the use of high lignin containing waste paper in the


