ChemMatters April 1993 Page 12

Old News, New Paper

By John K. Borchardt

Why bother recycling paper? A ton of 100% recycled paper saves

- 17 trees
- enough energy to power an average home for six months
- 7000 gallons of water
- 60 pounds of air-polluting gases
- 27 cubic feet of landfill space
- as much as $100 in waste disposal costs

There are several steps in recycling paper, and we'll trace the process by following an old newspaper as it is recycled.

The first steps in recycling

Recycling waste paper begins with collecting the paper. Many households take old newspapers to recycling centers; others have curbside pickup. The paper must be sorted by the collector or paper broker because different types of old paper are made into different types of paper products. For example, old newspaper is used in the production of new newspaper as well as paperboard for cereal boxes.

Deinking

At the paper mill the sorted paper undergoes the first stage of deinking in a process called pulping. The paper is placed in a large tank (pulper), where it is violently mixed with hot water (40-70 °C) and a caustic chemical such as sodium hydroxide (pH 8.5-10.5). As the mixture is agitated, the paper breaks apart into individual fibers and the ink is separated and dispersed. The resulting "pulp" is a slurry of wood fibers and suspended ink, which looks like gray oatmeal.

To get rid of the gray appearance, the ink must be removed from the rest of the slurry. Newspaper ink is primarily carbon black suspended

in mineral oil (see the article "Ink," *Chem Matters* February 1993) and, like most oils, is not compatible with water. Surface active agents, called surfactants for short, help remove the ink. The surfactant traps the ink particles in watersoluble micelles that can be washed away (see box, Surfactants).

Sticks and stones

At this point the pulp is still a crude mixture that contains assorted junk such as paper clips, staples, and dirt, as well as sticks and stones picked up during paper collection. The pulp is passed through a coarse screen to remove the large objects, then goes to a cyclone separator. The cyclone spins the pulp to separate particles that are denser than the surrounding liquid. Next comes the fine screen, which removes smaller particles.

The ink particles pass through the screens and must be removed by flotation and washing. The pulp is transferred to a flotation tank, where a bubble-enhancing surfactant is added and air is blown into the bottom of the tank. Streams of fine bubbles rise through the tank, and the large ink particles (40-micrometer diameter or more) attach to the bubbles and are trapped in the foam at the top of the tank.

The smaller ink particles (2-20 micrometers) are now largely concentrated in micelles. The pulp is trapped on a screen and rinsed with water to remove these particles.

Bleaching

Newsprint contains a certain amount of lignin, a major component of wood. The caustic chemicals in the pulper form carbon-carbon double bonds (C=C), which give the lignin a yellow color. Some mills add bleach to the pulper, but the pulp must also be bleached after the ink is removed.

The ink-free pulp flows through a tall, heated tower in which hydrogen peroxide or sodium hydrosulfite is added. The oxidative bleaching of hydrogen peroxide breaks the molecule at the C=C bond; the sodium hydrosulfite reduces the C=C bonds to single bonds, C-C. Either way, the yellow is eliminated. (Sunlight can also create these double bonds, which is why a sheet of newspaper left on your lawn for a day or two turns yellow.)

Converting pulp to paper

Now the clean, white deinked pulp is ready to be made into new newspaper, called newsprint. The pulp is diluted until it is 99.7% water by weight and goes to the paper machine—the same kind that was used to make the original newsprint. The heart of the paper machine is a

horizontal moving screen—something like a moving sidewalk—that travels at speeds up to 95 km per hour (about 60 miles per hour). The dilute pulp flows onto the screen and, as it moves forward, most of the water drains through. The moving sheet is dried by pressing it against felt rollers, followed by steam-heated rollers. Finally, the paper is wound into large rolls and is ready for shipment back to the newspaper pressroom.

Chemical additives are used to strengthen some grades of paper.

SIDE BARS

Surfactants

Surfactants are compounds that help oily chemicals mix with water. They are the key ingredient in laundry detergents, which must remove oily sweat and greasy stains from clothes. Surfactants have dual personalities; the molecules contain a water-hating portion called a hydrophobe and a water-loving portion called a hydrophile (the colored portions below).

The hydrophile of dodecylbenzene sulfonate, commonly used in laundry detergents, is the water-attracting electric charge on the end of the molecule. (Because this is a negative charge, it is called an anionic surfactant.) The second molecule above is a non-ionic surfactant used in deinking paper. Its hydrophile contains polar covalent bonds that attract water. Non-ionic surfactants are preferred for deinking because they produce less machine-clogging foam and are less expensive.

When present in proper concentration, the surfactant molecules clump together in micelles, microscopic spheres with the hydrophile pointing outward, in the water. The hydrophobes are on the inside, which minimizes their contact with water and creates an oil-friendly environment. Ink, which consists mostly of oily ingredients, readily enters the micelle and is thereby separated from the cellulose fibers. It is possible to process 1000 kilograms of old newspapers with less than five kilograms of surfactant.

These include modified starches and various synthetic polymers such as phenolics, polyamines, and polyacrylamides. Tissue products such as napkins are often made from recycled paper, and they require different additives that maintain paper strength when the paper is wet. Additives called sizing agents are used to make some types of paper resist penetration by liquids.

Recycling mills produce a second product besides paper—sludge. Sludge is a thick mixture of water, ink, small cellulose fibers, and assorted paper contaminants. This sludge must be disposed of by using

methods that are both environmentally acceptable and economical. Some mills dispose of it in a properly designed landfill; others incinerate the sludge (this reduces its volume by 70% and provides the mill with heat), then send the ash to a landfill.

Cycling ahead

Paper takes up more room in our landfills than any other waste. New government regulations are under consideration that will lead to more paper recycling, and this will prompt the paper industry to build more recycling mills. New technology must be developed to produce more effective, environmentally acceptable deinking chemicals, as well as inks and adhesives that are easier to remove. This is a challenging time for the chemists, chemical engineers, paper engineers, and mechanical engineers who work in paper recycling.

CAPTIONS

Recycled paper enlarged 450 times by a scanning electron microscope. This paper sample contains 70% recycled fibers: 20% pre-consumer waste (scrap from paper plants), and 50% deinked post-consumer waste. Contrary to common belief, the fibers in recycled paper are not shorter or weaker than those in virgin paper because, after deinking, any broken fibers are filtered from the pulp. The filler that is visible between the fibers is largely calcium carbonate.

BIOGRAPHY

John K. Borchardt works in the field of paper recycling at the Shell Development Company in Houston, TX.