# Recycling nonwovens

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## ABSTRACT

*The recycling of nonwoven materials is difficult due to several factors. Single resin systems have more potential for use in making products. Typical markets for nonwoven materials based on their characteristics are identified. Recycling of nonwovens by chemical and thermal decomposition processes is being developed by numerous companies. Early trials with thermal decomposition indicate that this process also applies to nonwoven materials. Based on our recycling experiences, guidelines for successful recycling programs are discussed. Environmental management standards being pursued in Europe could become a de facto requirement for doing business there.*

THE RECYCLING OF NONWOVENS continues to be a challenging task. At 3M, we annually sell about 18,100 metric tons of plastics and films to recyclers, but only a limited amount is nonwoven material.

A wide variety of products are made from materials that we sell for recycling. Only two items are made from nonwoven materials—the coffin pillows and toilet bowl scrubbers. See **Table I**.

Many potential consumer products can be made from singular plastic waste streams. High-density polyethylene (HDPE) can be used in drainage tubing, shrubbery pots, and plastic lumber. Polystyrene (PS) is used in videocassettes, food service trays, office equipment, and accessories. Polyvinyl chloride (PVC) has many potential applications as does polypropylene (PP) *(1)*. See **Table II**. Economics, processing equipment/conditions, and product usage determine the resin system used.

### Nonwovens recycling

Why are nonwovens difficult to recycle? First, they are often composed of comingled fibers of several resin families. Consequently, reprocessing them degrades the resins, and characteristics that made them materials of choice are no longer present. Second, the binders and surfactants used in the original product are often contaminants to further processing. Latex, for example, creates a fine dust when it shatters during mechanical processing. Without a collection system and baghouse, the dust level is prohibitive. Nonwovens are often light and fluffy, so without a compaction system, transportation costs exceed the value of setting up a recycling program.

### Markets for nonwoven scrap

The characteristics of nonwoven materials suggest that they could fit into markets for insulation, sound deadening, sorbents, and plastic lumber. Potential applications are horse blankets, furniture moving pads, garage door insulation, and furniture stuffing. Sound-deadening materials in autos and trucks, where bulky, inexpensive materials are used, could be an outlet for recycled nonwovens. Certain types of resin system materials could fit into the sorbents field. Finally, there is the area of void filling and cushioning. Recently, we received packages with ribbon scrap that served this purpose.

Many times, the use of scrap depends on the imagination of dealers, brokers, and entrepreneurs. The greatest value for 3M has been to reintroduce scrap into the manufacturing process to reduce our raw material needs and product costs. In a number of our manufacturing processes, we cut circles out of square material and internally generate scrap.

A good understanding of materials, binders, equipment, processing conditions, and the overall fabrication process has resulted in significant waste reduction programs. An example is the elimination of solvents in a process by changing fiber systems; this resulted in significant waste reduction.

### Recycling technologies

Nonwovens can be recycled by three technologies: mechanical and chemical processes, and thermal decomposition. The mechanical approach is most widely used. Often involving separating and opening the fibers, it is the lowest-cost approach. It is most cost effective when (a) it is done in conjunction with a process and (b) it does not involve compaction for shipment and transporting. Adding steps to a recycling process is not a value-added procedure.

***Chemical processes.*** Chemical processes that are used for some resin systems can also apply to nonwoven materials. The processes are hydrolysis, glycolysis, alcoholysis, and methanolysis *(2)*. A summary of these processes and the companies or universities that are developing them is shown in **Table III**.

Glycolysis is a process that partially breaks down polyester (PET) into monomers for reuse. It can use existing facilities, with some modifications, at several companies. The process is more economical than hydrolysis or methanolysis but results in depressed melt points and color.

Major investments are currently being made to provide the chemical breakdown of PET to monomers for reuse on a commercial scale via the methanolysis process. Other compa-

**KEYWORDS**
*Chemical degradation, chemical reactions, degradation, end use, fabric, nonwovens, processes, pyrolysis, recycling, specifications, standards, technology.*

| | |
|---|---|
| Coffin pillows | Banana tree mulch |
| Toilet bowl scrubbers | Flower pots |
| Upholstery filling | Garden hose |
| Sleeping bag insulation | Lawn edging |
| Trash bags | Truck mud flaps |
| Tape dispensers | Paper towels |
| Computer chip carrier trays | Halloween safety arm bands |

***I. Products made from material that is recycled by 3M***

| HDPE | PS | PVC | PP |
|---|---|---|---|
| Drainage tubing | Videocassettes | Nonfood containers | Disposable diapers |
| Shrubbery pots | Food service trays | Sewer pipes | Outdoor furniture |
| Nonfood bottles | Flower pots | Irrigation, drainage pipe | Large molded containers |
| Plastic lumber | Office equipment | Flower pots | Footwear components |
| Trash cans | Roofing and wallboard | Outdoor furniture | Heavy sheet |
| Automotive mud flaps | Table tops | Truck bed liners | Ink bottles |
| Kitchen drainboards | Waste containers | Parking lot curbs | |
| Beverage bottle crates | Landscape timber | Speed bumps | |
| Pallets | Wood-substituted products | | |
| Locker room benches | | | |
| Vanities | | | |
| Shower curtains | | | |
| Restroom partitions | | | |

***II. Potential applications for postconsumer recycled resin. Source: SRI International.***

nies, both here and overseas, are also pursuing this approach.

The advantages of the methanolysis process are (a) it produces reusable raw materials, such as dimethyl terephthalate (DMT) and glycol, and (b) by-products from the process, such as methanol, have value. The disadvantages of the process include high capital cost, high energy usage, the requirement of large production volumes, and emissions *(3)*.

The amount of contamination is important. Most approaches can only handle contamination in the 3–5% range and remain economical.

Dissolution, developed at Rensselaer Polytechnic Institute, is another chemical process for recycling plastics. Its advantages are that it can separate comingled waste and that contaminants can be easily filtered. However, it is a relatively expensive process that uses solvents, which create additional concerns.

***Thermal decomposition.*** The thermal decomposition processes are monomer recovery, refinery recycling, hydrogenation, electrokinetics, gasification, molten metal bath, and advanced pyrolysis.

Over the past two years, 3M has investigated the pyrolysis method. This process produces oil or gas, depending on the feedstock, additives, and operating conditions.

We have identified 11 developers that are working with this technology and have visited eight of the locations. Our interest has primarily been with PET, but we have also tested pilot quantities of nonwovens at two locations.

A typical nonwoven material tested was 39% PET, 37% polypropylene, 16% carbon, 4% rayon, and 4% acrylic. This comingled mixture was tested to examine the feasibility of converting various products by a thermal depolymerization process with a fluidized bed of silica sand. The yield of the process, which was far from optimized, was 35% hydrocarbon liquid, 23% gas, and 42% ash *(4)*. A major concern is what form the nonwoven material must take to achieve a consistent feed.

While advanced pyrolysis is capable of processing comingled plastic materials, the economics of this process must be closely studied. These variables include capital costs, energy costs, production volumes, contaminant levels, experienced yields (hydrocarbon liquid or reusable raw materials), and concerns about emissions and environmental residue over the long term.

| Process | Developer | Commercial feedstock[b] | Status[c] | Targeted comments |
|---|---|---|---|---|
| Chemical processes | | | | |
| Hydrolysis | General Motors | 4 | E | Twin-screw extruder converts polyurethanes to polyols |
| Glycolysis | Goodyear | 1 | C | Partial breakdown of PET to monomers for reuse |
| | Mobay | 4 | E | Polyol is produced for reuse at 10–20% replacement of virgin content |
| Alcoholysis | Oxid[d] (Houston) | 2 | C | Reduces PET into polyols for polyisocyanurate foam |
| | Institute of Tech. (Aachen, Germany) | 7 | E | Automotive seats glycolized into high-viscosity polyols for use in rigid PUR foams |
| Methanolysis | DuPont | 2 | C | Full PET breakdown to monomer for reuse |
| | Eastman | 1 | C | Full PET breakdown to monomer for reuse |
| | Hoechst Celanese | 1, 2 | C | Full PET breakdown to monomer for reuse |
| | Synergistics Ind. (St. Remi, PQ, Can.) | 2 | D | Degrades PET in conventional esterification unit into plasticizer for PVC |
| Thermal decomposition | | | | |
| Monomer recovery | Battelle Labs | 3 | D | Dedicated process unit breaks plastic down to monomer for closed-loop reuse |
| | National Resource Energy Laboratories (Golden, CO) | 3 | D | Dedicated process; depolymerizes plastic waste to recover monomers |
| | Tokyo Institute of Technology | 5 | E | Fluidized bed of silica sand yields 80% combustible methane and ethylene gases |
| Refinery recycling | Amoco Chemicals | 3 | D | Refinery coking; conversion of plastic waste to hydrocarbons |

*Table III continued on next page*

***III. Key tertiary recycling processes[a]***

| | | | | |
|---|---|---|---|---|
| | Chevron Chemical, Mobil Chemical | 3 | D | Refinery coking; conversion of plastic waste to hydrocarbons |
| | Fuji Recycle[e] | 5 | C | Dedicated process unit and catalyst yield gasoline, kerosene, and gas oil |
| Hydrogenation | UK-Wesseling (Cologne, Germany) | 3 | D | High-pressure coking of plastics into hydrocarbons |
| Electrokinetic gasification | Mid-Ohio Tech. (Toledo, OH) | 2 | D | Electric arcs activate free radicals, separate polymer into industrial gas fractions |
| Molten metal bath | Molten Metal Technologies (Cambridge, MA) | 8 | C | Polymer waste injected into metal solvent bath yields gases, chemicals, alloys |
| Advanced pyrolysis | Advanced Pyrolysis (Hamburg University) | 9 | D | Fluidized-bed pyrolysis process yields a high-quality oil |
| | American Plastics Council, Conrad Industries | 5 | E | Pyrolysis process yields high-quality oil |
| | Wayne Technologies (Victor, NY) | 9 | D | Three-stage condensation takes plastics stream to oil, gases, and char |
| | SMC Automotive Alliance/SPI (Washington, DC) | 10 | D | Sheet-molding compound waste is pyrolized into pyrogas, oil, and char |

[a] Sources: Modern Plastics, July 1991, and Walden Research Inc.
[b] Categories: 1=PET bottles; 2=mixed PET; 3=comingled thermoplastics; 4=polyurethane foams; 5=polyolefins; 6=auto shredder residue; 7=automotive seats (mixed polymers); 8="nuisance"plastics (medical waste, wire and cable, heavy metal-containing products); 9=plastics-rich municipal solid waste; 10=thermosets
[c] Categories: C=commercial; D=demonstration plant; E=experimental
[d] Company acquired the reprocessed polyol line (Chardol) made by Chardonol Chemical in a process similar to that which Oxid uses.
[e] Represented in the United States by Fagan Technology, Furlong, PA

## APPENDIX

### *ISRI guidelines*

- The paper stock section covers the basics that also apply to plastics. The success of any buyer-seller relationship is an atmosphere of "good faith."
- The purchase agreement covers a list of items including quantity, grades, packing, price units, transportation charge, shipping instructions, shipping period, terms, and method of invoicing.
- Practices that the seller must follow are listed. They cover selling material warranted to conform to grade definitions, preparation of materials for shipment, identification, loading, shipping notifications, invoicing, and prompt acknowledgment when shipments are rejected.
- The buyer must also follow accepted practices regarding unloading, settlement within days of unloading, and rejection of loads.
- Miscellaneous practices identify when ownership of shipments occurs, who pays demurrage charges, carrier selection, weight discrepancies, moisture content, replacement, and promptness of shipments.
- In the event of total disagreement between the buyer and seller, disputes will be settled by arbitration, and the loser pays for the arbitration.
- Common grade definitions are important, as is the agreement on the percent of contamination or prohibitive material and the percent of material in a form that is not suitable for consumption as the grade specified.

### *Successful recycling guidelines*

A strong corporate commitment to waste minimization, along with ever-stricter environmental regulations and the rising cost of waste disposal, has made recycling a priority.

The following guidelines can help facilities plan and execute successful recycling programs.

- **Commit to recycle.** A recycling program is a commitment to change. This means changing the way that a waste stream is evaluated. It also means assigning the recycling program responsibility to a person who is dedicated to making change happen and backing up that person with management support and resources.
- **Identify products/materials.** Determine exactly what kind of material is to be worked with, what is presently discarded, how much is being disposed of, and what are present disposal costs. Identify the type of finish, adhesive, and binder used. Documents such as material safety data sheets, waste stream profiles, and material specifications are good sources of information. At this point, try to determine the overall costs of the recycling program, including containers, handling, storage, and landfill cost avoidance to help decide if you should continue with program development. Historically, successful recycling programs have been achieved with materials that are reused in the same kind of application, e.g., steel to steel or glass to glass. Some products have trim directly recycled into the product. In others, scrap is reprocessed and used in other products.
- **Develop and evaluate outlets.** Start with local recycling companies. Even if they do not handle the material that you want to recycle, they can often direct you to someone who does. Local government waste coordinators can help. Use the experienced specialists in the Resource Recovery Department, if your company has one. Writing waste collection steps on a flow chart can help identify potential problem areas. Identify environmental concerns, the requirements for preparation and packaging, and whether the outlet has the ability to handle the waste stream. Start recycling slowly. If your company will be a frequent shipper, consider using a dispatch ticket system to reduce paperwork.
- **Negotiate terms with outlet.** A good example of terms is shown in an Institute of Scrap Recycling Industries circular *(5)*. See the appendix. It covers guidelines for nonferrous scrap, ferrous scrap, glass cullet, paper stock, and plastic scrap. It is a guide that assists its members in buying and selling materials.
- **Monitor performance of all the outlets for ongoing results.**
- **Maintain a balance with recycling programs.** Many programs cost more than they return, so balance the desire to be environmentally responsible with your program's economic bottom line.

## CONCLUSION

Will recycling maintain its momentum? For industry, the answer is most likely yes, especially if a company does business in Europe. An environmental management standard (BS 7750) published by the British Standards Institution address-es controlled and uncontrolled emissions of solid and other wastes. The International Standards Organization (ISO) in Geneva is developing standard ISO 14000, which also covers environmental management certification issues. Following the success of ISO 9000 standards, this new standard could become a de facto requirement for doing business in Europe and other regions. The general view is that ISO 14000 will apply to products, activities, and plant operations that impact nonwoven materials recycling. **TJ**

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*Received for review Nov. 2, 1994.*

*Accepted June 5, 1995.*

*Presented at the TAPPI 1995 Nonwovens Conference.*

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