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Pollution Prevention Options In Wood Furniture Manufacturing

A Bibliographic Report

POLLUTION PREVENTION OPTIONS IN WOOD FURNITURE MANUFACTURING

A BIBLIOGRAPHIC REPORT

FEBRUARY 1992

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SECTION I: INTRODUCTION

Overview

The United States Environmental Protection Agency (EPA) developed this bibliographic report to assist wood furniture manufacturers in developing cost-effective pollution prevention practices to reduce or eliminate their releases of the 17 chemicals targeted for reductions in EPA's 33/50 Program. In addition, EPA developed this report to educate its own staff and State personnel on pollution prevention opportunities in these industries. EPA hopes this report also will assist the public, engineering and business students, and other interested persons in learning about pollution prevention.

The 33/50 Program is EPA's voluntary pollution prevention initiative to reduce national pollution releases and off-site transfers of 17 toxic chemicals by 33 per cent by the end of 1992 and by 50 per cent by the end of 1995. The Agency is inviting companies to participate in this voluntary program by examining their own industrial processes to identify and implement cost-effective pollution prevention practices for these chemicals. The Program aims, through voluntary pollution prevention activities, to reduce releases and off-site transfers of a targeted set of 17 chemicals from a national total of 1.4 billion pounds in 1988 to 700 million pounds by 1995, a 50% overall reduction.

While EPA is seeking to reduce aggregate national environmental releases of the 17 chemicals by 50 per cent by 1995, individual companies are encouraged to develop their own reduction goals to contribute to this national effort. EPA also encourages companies to reduce releases of other TRI chemicals and to extend these reductions to their facilities outside the United States. EPA will periodically recognize those companies that have committed to reduce their releases and transfers of the targeted chemicals, and publicly recognize the pollution prevention successes these companies subsequently achieve.

POLLUTION PREVENTION CAN:

- ***Reduce a company's costs and legal liabilities associated with waste treatment and disposal;***
- ***Reduce production costs by conserving raw materials, water, and energy; and***
- ***Protect the environment and public health.***

THE 17 CHEMICALS TARGETED FOR REDUCTIONS IN THE 33/50 PROGRAM:

Benzene	Methyl Ethyl Ketone
Cadmium and Compounds	Methyl Isobutyl Ketone
Carbon Tetrachloride	Nickel and Compounds
Chloroform	Tetrachloroethylene
Chromium and Compounds	Toluene
Cyanide and Compounds	1,1,1-Trichloroethane
Lead and Compounds	Trichloroethylene
Mercury and Compounds	Xylenes
Methylene Chloride	

These chemicals were selected from the Toxics Release Inventory (TRI). The TRI is a computerized data base containing public information on the annual releases and transfers of approximately 300 toxic chemicals reported by U.S. manufacturing facilities to EPA and the States. Since 1987 federal law has required facilities to report the amount of both routine and accidental releases of the 300 listed chemicals to the air, water and soil, and the amount contained in wastes transferred off-site. As required by the Pollution Prevention Act of 1990, TRI industrial report requirements will be expanded, beginning in calendar year 1991, to include information on pollution prevention.

What is Pollution Prevention?

Pollution prevention (sometimes referred to as source reduction) is the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. Pollution prevention includes practices that reduce the use of hazardous materials, energy, water or other resources, and practices that protect natural resources through conservation or more efficient use.

Pollution prevention should be considered the first step in a hierarchy of options for reducing the generation of pollution. The next step in the hierarchy is responsible recycling of any wastes that cannot be reduced or eliminated at the source. Wastes that cannot be recycled should be treated in accordance with environmental standards. Finally, any wastes that remain after treatment should be disposed of safely.

EPA is promoting pollution prevention because it is often the most cost-effective option to reduce pollution and the environmental and health risks associated with pollution. Pollution prevention is often cost effective because it may reduce raw material losses, reduce reliance on expensive "end-of-pipe" treatment technologies and disposal practices, conserve energy, water, chemicals, and other inputs, and reduce the potential liability associated with waste generation. Pollution prevention is environmentally desirable for these very same reasons: pollution itself is reduced at the source while resources are conserved.

Perhaps the best way to understand pollution prevention is to consider a few examples of some possible types of pollution prevention

techniques and processes. Some general examples of pollution prevention techniques are described below:

- Production Planning and Sequencing -- plan and sequence production so that only necessary operations are performed and that no operation is needlessly "undone" by a following operation. One example is to sort out "reject" parts prior to painting. A second example is to reduce the frequency of cleaning equipment by painting all products of the same color at the same time. A third example is to schedule batch processing in a manner that allows the wastes or residues from one batch to be used as an input for the subsequent batch (e.g., to schedule paint formulation from lighter shades to darker) so that equipment need not be cleaned between batches.

- Process or equipment modification -- change the process, parameters or equipment used in that process, to reduce the amount of waste generated. For example, you can change to a paint application technique that is more efficient than spray painting.

- Raw material substitution or elimination -- replace existing raw materials with other materials that produce less waste, or a non-toxic waste. Some examples include substituting water based coatings and adhesives for solvent based coatings and adhesives.

- Loss prevention and housekeeping -- perform preventive maintenance and manage equipment and materials so as to minimize opportunities for leaks, spills, evaporative losses and other releases of potentially toxic chemicals. For example, clean spray guns in a manner that does not damage leather packings and subsequently causes the guns to leak; or place drip pans under leaking machinery to allow recovery of the leaking fluid.

- Waste segregation and separation -- avoid mixing different types of wastes, and mixing hazardous wastes with non-hazardous wastes. This technique makes the recovery of hazardous wastes easier by minimizing the number of different hazardous constituents in any given waste stream. Also, it prevents the contamination of non-hazardous wastes. For example, segregate solvents by solvent type.

- Closed-loop Recycling - use or reuse of a waste as an ingredient or feedstock in the production process on-site. Recycling in which a waste is recovered and reused in the production process on-site as an input is a form of pollution prevention. One example is using a small on-site still to recover and re-use degreasing solvents.

- Training and Supervision -- provide employees with the information and the incentive to minimize waste generation in their daily duties. For example, this might include ensuring that employees practice proper and efficient use of tools and supplies, and that they are aware of, understand, and support the company's pollution prevention goals.

Information on Pollution Prevention

One good source of information on pollution prevention is EPA's Pollution Prevention Information Clearinghouse ("PPIC"). PPIC contains technical, policy, programmatic, legislative, and financial information on pollution prevention efforts in the United States and abroad. The PPIC may be reached by personal computer modem ("PIES"), telephone hotline or mail. Associated with the PPIC is the PIES, or Pollution Prevention Information Exchange System, a free 24-hour computer bulletin board consisting of message centers, technical data bases, issue-specific "mini-exchanges", and a calendar of pollution prevention events. The

PIES allows a user to access the full range of information in the PPIC. For information on how to use the PPIC/PIES call (703) 821-4800. To logon to the PIES system using a modem and a PC call (703) 506-1025 (set your communication software at 8 bits and no parity). Many of the documents referenced in this report are available through the PPIC/PIES.

While the PPIC provides a centralized information source, you may wish to seek the guidance or help of pollution prevention experts. Some organizations that you may wish to contact include:

Trade Associations - often trade associations can provide you with pollution prevention assistance directly, or they can refer you to someone who can.

State Waste Management Agencies -- These agencies often have staff people who are knowledgeable about pollution prevention and are willing to provide assistance. Many states now have pollution prevention programs which may be able to offer information and sometimes technical assistance on pollution prevention.

Regional Environmental Protection Agency Offices -- There are ten Regional Offices of the U.S. Environmental Protection Agency. The easiest way to find out which Regional Office is responsible for your area is to call the toll free RCRA/Superfund Hotline (see below) and ask for the telephone number or address of the Regional Office responsible for your area.

EPA Office of Research and Development Pollution Prevention Research Branch, at (513) 569-7215 can also provide technical and engineering pollution prevention information.

Environmental Protection Agency -- Within U.S. EPA Headquarters you may conveniently contact any of the following information sources:

EPA Waste Minimization Branch, at (703) 308-8402, can provide you with technical waste minimization information;

Pollution Prevention Division, at (202) 260-3557, can assist you in understanding pollution prevention and provide a great deal of pollution prevention information; and the

RCRA/Superfund Hotline, at (800) 424-9346 (or (202) 260-3000), can answer your pollution prevention questions, help you access information in PIES, and assist you in searching for and obtaining documents.

A comprehensive, national listing of pollution prevention resources, documents, courses, and programs, including names and phone numbers, is contained in an annual EPA publication. Copies of this document -- *Pollution Prevention Resources and Training Opportunities* in 1992 -- may be obtained by calling the PPIC/PIES support number at (703) 821-4800.

Purpose of this Report

This report is intended to help wood furniture manufacturing companies develop pollution prevention practices to reduce their releases of the 17 chemicals targeted for reductions in the 33/50 Program, as well as other pollutants and wastes generated. In addition, this report is intended to assist EPA staff, state environmental agencies, and other interested persons in learning about pollution prevention opportunities. The remainder of this report provides:

- An overview of the various wood furniture manufacturing processes and the wastes they produce;
- A quick reference to pollution prevention options applicable to many of these processes, including summaries of economic benefits; and

- A bibliography of references that describe additional information on potentially useful pollution prevention options, procedures, techniques, as well as waste recycling options.

Limits of this Report

This report provides an overview of the pollution prevention and recycling alternatives that may be available in this industry. This report is only a starting point to assist the user in his or her preliminary research and development of pollution prevention options. Of course, each company remains responsible for identifying, evaluating and implementing pollution prevention practices that are appropriate for its particular situation. By compiling and distributing this report EPA is not recommending the use of any particular processes, raw materials, products, or techniques in any particular industrial setting. Compliance with environmental, occupational and safety and health laws, as well as all applicable federal, state, and local laws and regulations is the responsibility of each individual business and is not the focus of this document.

The information contained in this report is intended to be a fairly comprehensive bibliography of the documented information on pollution prevention and recycling practices for the wood furniture industry. However, the collection, organization and dissemination of pollution prevention information is a relatively new undertaking, as well as an ongoing and evolutionary process. In addition, there are limits to any bibliography, including this bibliography. Thus, this bibliography may not contain every relevant article on pollution prevention and recycling for wood manufacturers. EPA encourages all users who discover, in the literature or in the field, pollution prevention options that are not cited in this report to share this information with EPA. Please submit any corrections, updates, or comments on this report to:

Pollution Prevention Information Clearinghouse
Science Applications International Corporation
7600-B Leesburg Pike
Falls Church, VA 22043

or

Special Projects Office (TS-792A)
Office of Pollution Prevention and Toxics
U.S. EPA
401 M Street, S.W.
Washington, D.C. 20460

SECTION II:
OVERVIEW OF FURNITURE MANUFACTURING

Introduction to Furniture Manufacturing Industries

The furniture industry encompasses manufacturers of both metal and wood furniture. This report focuses on the wood furniture manufacturing portion of this industry. Pollution prevention techniques for metal furniture manufacturing are contained in the companion report *Pollution Prevention Options In Metal Fabricated Products Industries: A Bibliographic Report.* Within the wood furniture manufacturing sector, three industries were identified as responsible for the majority of environmental releases of one or more of the 33/50 Program target chemicals: Wood Household Furniture -- Except Upholstered; Wood Household Furniture -- Upholstered; and Wood Office Furniture. Table 1 lists the types of products produced by each of these industries (1). These industries typically include processes that shape, assemble and finish wood into different types of furniture.

Table 1. Wood Furniture Manufacturing Industries

SIC 2511 Wood Household Furniture, Except Upholstered This group includes establishments that manufacture wood household furniture commonly found in dwellings such as: • Beds • Stools • Chests • Bookcases • Tables • Headboards • Chairs • Desks
SIC 2512 Wood Household Furniture, Upholstered This group includes establishments that manufacture upholstered furniture on wooden frames such as: • Chairs • Couches • Sofas • Recliners • Rockers
SIC 2521 Wood Office Furniture This group includes establishments that manufacture office furniture such as: • Benches • Cabinets • Chairs • Bookcases • Desks • Filing Cabinets • Tables • Partitions

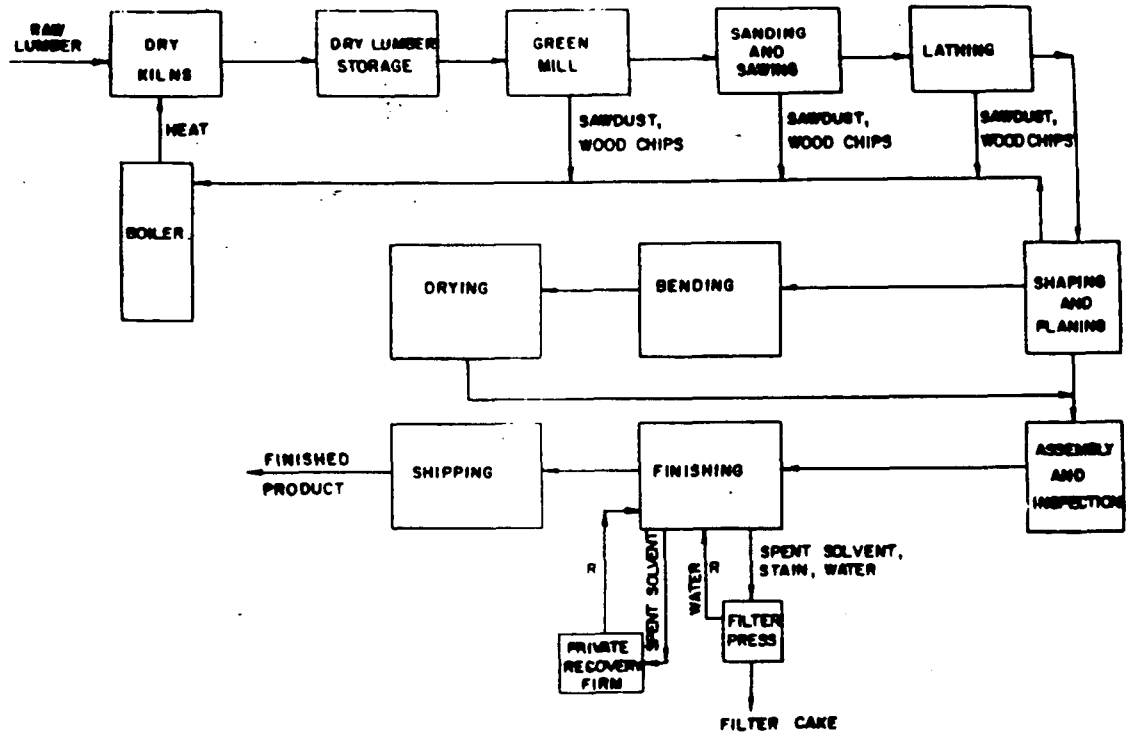
Wastes of Concern

The wood furniture industry was selected for this 33/50 Program report because of the large volume of solvent releases reported by this industry in the Toxic Release Inventory (TRI). A wide range of solvents are reported as used in the furniture industry, including alcohols, ketones, esters, glycols, glycol ethers, aliphatics, aromatics, amines, and chlorinated solvents (2,3). The major 33/50 Program solvents released from this industry are methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylenes. The overwhelming majority of environmental releases of solvents from this industry are via atmospheric emissions. Appendix A summarizes reported releases of target chemicals from the wood furniture manufacturing industry. Trace amounts of cadmium, chromium, mercury and lead are also reported as released in wood furniture manufacturing process wastewater (4).

Furniture Manufacturing Processes

The four general processes of any wood furniture manufacturing operation are raw stock shaping, parts assembly, finishing or coatings application, and unit packaging. Figure 1 is an example of an operation diagram for a wood furniture manufacturing facility (5). Raw stock shaping and unit packaging operations do not use or generate wastes containing any of the 17 chemicals of concern. Wastes from shaping operations are predominantly wood (e.g., dust and shavings) which are typically burned in the boiler as a fuel supplement. Unit packaging wastes are nonhazardous solid wastes such as paper, plastic, cardboard, and wooden pallets. Finishing operations, and to a lesser extent gluing during parts assembly, are the major sources of solvent wastes and releases. Finishing involves coating, drying, and sanding the furniture in a series of repeated steps until

Figure 1. Process Flow Diagram: Franklin Furniture, Greeneville Tennessee



the desired final appearance is achieved. Table 2 lists typical furniture operations using materials which may generate hazardous wastes. Solvents are used in the stains, paints, and finishes as well as in inks used in the printing of simulated wood grain onto plywood and particle board. Solvents used in finishing operations are typically a complex blend of different types of solvents. Solvents are also used to strip earlier coatings from pieces prior to recoating. Further solvents are used in cleanup operations (i.e., removing overspray from spray booths and rinsing solvent-based finishes from spray lines and equipment between color changes).

Table 2. Typical Operations Using Materials Which May Generate Hazardous Wastes

Typical Process/Operation	Typical Materials Used	Typical Material Ingredients	General Types of Wastes Generated
Wood cleaning and wax removal	petroleum distillates, white spirits	petroleum distillates mineral spirits	ignitable wastes, spent solvents, volatile emissions
Refinishing/Stripping	paint removers, varnish removers, enamel removers, shellac removers, paint solvents, turpentine	acetone, toluene, petroleum distillates, methanol, methylene chloride, alcohols, ketones, oxygenated solvents	ignitable wastes, ignitable paint wastes, solvent still bottoms, volatile emissions
Staining	stains	mineral spirits, alcohol pigments	ignitable wastes, spent solvents, solvent still bottoms, volatile emissions
Painting	enamels, lacquers, epoxy, alkyds, acrylics	toluene, pigments, titanium dioxide, epoxyester resins, aromatic hydrocarbons, glycol ether, halogenated hydrocarbons, vinylacetate acrylic	ignitable paint wastes, ignitable wastes, solvent still bottoms, paint wastes containing heavy metals, volatile emissions
Finishing	varnish, shellac, polyurethane, lacquers with residues	denatured alcohols, resins, shellac, petroleum distillates, toluene, diisocyanate	ignitable wastes, spent solvents, solvent still bottoms, volatile emissions
Cleaning brushes, spray gun and spray equipment, and overspray from spray booths	paint thinners, enamel reducers, varnish removers, shellac removers, white spirits	acetone, toluene, petroleum distillates, methanol, methylene chloride, isopropanol, mineral spirits, alcohols	ignitable paint wastes, ignitable wastes, spent solvents, solvent still bottoms, volatile emissions
Gluing, cleaning adhesive application equipment	Adhesives	methyl isobutyl ketone, methyl ethyl ketone, xylene, toluene, 1,1,1,tricholorethane	volatile emissions

Source: Tennessee Hazardous Waste Minimization Program.

Gluing operations are another source of atmospheric solvent releases. The amount of adhesives used in wood furniture manufacturing varies depending on the type of product. Adhesive use may not be a significant source of solvent releases from a facility that has minimal gluing operations. However, solvent releases due to adhesive use from a facility manufacturing products with vaneer may be significant. Commonly used solvents in adhesive formulations include methyl isobutyl ketone, methyl ethyl ketone, xylene, toluene, and 1,1,1, trichloroethane (6). Solvents are also used to clean adhesive application equipment such as spray guns.

General Source Reduction and Recycling Techniques

Finishing operations are the largest source of environmental release of solvents and hence the focus of most source reduction and recycling efforts. The most common management of solvents is recycling or disposal. Many facilities incinerate spent solvents or burn them for fuel since the solvents are typically non-halogenated and have high BTU values (2). Table 3 provides examples of source reduction and recycling options for finishing and gluing operations. Recycling solvents from adhesives operations may not be practicable at facilities which use small quantities of adhesives.

Table 3. Examples of Source Reduction and Recycling Options for Finishing and Gluing Operations

Types of Techniques	Description	Examples of Costs and Savings and Other Information*
Source Reduction		
Training and Supervision	Train spray gun operators in proper spray techniques to minimize coating waste generation.	Annual cost savings: $50,000 to $70,000. Finishing material required reduced 8-10%. [Reference #4.]
Production Planning and Sequencing	Flush equipment first with dirty solvent before final cleaning with virgin solvent.	Waste savings/reduction: 98%; from 25,000 gallons of paint cleanup solvents to 400 gallons. Company uses cleanup solvents in formulation of subsequent batches. [Reference #8, p. 14]
	Use virgin solvents for final equipment cleaning, then as paint thinner.	Reduced solvent requirements. [Reference #4, p. 15]
	Schedule coatings so as to minimize color changes or paint with lighter colors before darker colors to minimize the number of equipment cleanouts.	
	Consolidate solvent cleaning operations to reduce losses through centralized cleaning and standardized solvent usage.	
	Standardize cleanup solvent use to help identify solvent use, consumption, and release patterns.	

Table 3. Examples of Source Reduction and Recycling Options for Finishing and Gluing Operations (continued)

Types of Techniques	Description	Examples of Costs and Savings and Other Information*
Production planning and sequencing (continued)	Preinspect parts to prevent painting of obvious rejects.	
	Reuse cleaning solvents for the same resin system by first allowing solids to settle out of solution.	
	Use pressurized air mixed with a mist of solvent to clean equipment.	
Process or Equipment Modifications	Implement alternatives to compressed air spray gun systems including: • Airless and air assisted airless	Material consumption reduced 15%. Annual cost savings: $55,000. Waste volume from spray booth cleanup reduced 50%. Payback period: 1 year. [Reference #4, p. 14]
	• Electrostatic spray systems	Annual cost savings: $150,000. Payback period: 2 years. Waste savings/reduction: 25% reduction in wiping stain compared to conventional spray units. [Reference #4, p. 18, #25]
	• Flat line finishing	Annual savings: 20-30% savings in total coating costs. Payback period: 2 years. Waste savings/reduction: 25% VOC reduction. [Reference #4, p. 17]
	• High-volume low-pressure (HVLP)	Reference #1, #23, #24, #25
	• Vacuum systems	Reference #11
	• Heaters in conjunction with compressed air or airless systems	Reference #1
	Investigate use of substitutions to solvent-based adhesives: • Water-based adhesives • Radiation curable adhesives • electron beam curing ultraviolet curing • 100% liquid reactive adhesives • High solids adhesives	These are newly emerging technologies. [Reference #20]

Table 3. Examples of Source Reduction and Recycling Options for Finishing and Gluing Operations (continued)

Types of Techniques	Description	Examples of Costs and Savings and Other Information*
Raw Material Substitutions	Investigate substitution to solvent-based coatings such as: a) Water-based inks b) Water-based coatings c) High-solids coatings d) CO_2-based coatings e) Vernoia oil-based coatings	a) Annual cost savings: $75,000 in raw material savings, $37,000 in disposal costs. [Ref. #4, p. 15] b) References #3 & #19 c) Reference #19 d) Reference #14 e) A newly emerging technology. [Ref. #15, p. 12]
	Replace water-based paint booth filters with dry filters. Dry filters will double paint booth life and allow more efficient treatment of wastewater.	Annual cost savings: $1,500. Waste Savings\Reductions: 3,000 gallons/year. [Reference #9]
Waste Segregation and Separation	Segregate cleaning solvents to facilitate recycling.	References #1 & #6
	Segregate non-hazardous paint solids from hazardous paint solvents and thinner.	
	Segregate solvent waste streams and keep free from water contamination.	
Inventory	Establish inventory procedures to minimize degradation of stock (e.g., rust forming on inside of open cans) and amount of unusable coating if a product goes out of production, changes.	Accumulation of unusable materials prevented, disposal costs for "wastes" avoided, direct cost savings for new coating materials. [Reference #4]
Recycling and Reuse		
Solvent Recycling	Capture solvent emissions from gluing for reuse. Methods include use of activated carbon or condensers, membrane system, Brayton cycle heat pump, polymer absorption.	Membrane system, Brayton cycle heat pump, polymer absorption are emerging technologies and have not yet been proven. [Reference #20]
	Recycle spent solvents with recovery units including: • small on-site solvent recovery stills to recycle spent lacquer thinner.	Annual cost savings: $5,700. Payback period: 1 year. [Reference #4]
	• small in-house stills to recycle methylene chloride.	Payback period: 2 years. Incentive was to avoid RCRA liability related to disposal. [Reference #4]
	• in-house stills to recycle xylene.	Payback period: 13 months. [Reference #4]

Table 3. Examples of Source Reduction and Recycling Options for Finishing and Gluing Operations (continued)

Types of Techniques	Description	Examples of Costs and Savings and Other Information*
Recycling and reuse (continued)	• batch distillation units to recover xylene from paint equipment cleanup.	Payback period: 13 months. Annual savings: $5,000. [Reference #8, p. 18]
	• recovery system for solvents contained in air emissions.	Annual savings: $1,000. [Reference #8, p. 10]
	• batch distillation units to recover isopropyl acetate generated during equipment cleanup.	Payback period: 2 years. [Reference #8, p. 17]
	• small solvent recovery stills to recover spent paint thinner from spray gun cleanups and excess paint batches.	Capital investment: $6,000 for a 15 gallons capacity still. Annual savings: $3,600 in new thinner savings; $5,400 in disposal savings. Payback period: less than 1 year. Waste Savings/reduction: 75% (745 gallons of thinner recovered from 1,003 gallons). Product/Waste throughput information: 1,500 gallons of spent thinner processed per year. [Reference #8, p. 6]
	• a methyl ethyl ketone solvent recovery system to recover and reuse waste solvents.	Annual savings: $43,000/year; MEK recovery rate: 20 gallons/day, reflecting a 90% reduction in waste. [Reference #9, p. 7]
	Arrange an agreement with other small companies to jointly recycle cleaning wastes.	Reference #1 & #6
	Develop cooperative recycling with other facilities in area to make distillation economically viable for all participants.	Reference #1 & #6
	Recover and reuse cleanup solvents for cleaning operations or with a compatible coating operation.	
	Modify spray booth to allow recovery and reuse of overspray solids.	
	If possible, return extended shelf life items to the manufacturer rather than disposal; if manufactures won't take the items they may be sold or donated as a raw material.	

Table 3. Examples of Source Reduction and Recycling Options for Finishing and Gluing Operations (continued)

Types of Techniques	Description	Examples of Costs and Savings and Other Information*
Loss Prevention and Housekeeping	To prevent spray gun leakage, submerge only the front end (or fluid control) of the gun into the cleaning solvent.	
	Improve housekeeping practices to reduce spillage of cleaning solvents.	
	Perform routine maintenance to prevent equipment from breaking down.	
	Fix leaks and routinely monitor for leaking equipment.	
	Investigate using Statistical Process Control to improve product quality.	Reference #26

* Reference numbers refer to documents listed in Tables 4 and 5.

Note: The cost, savings, and waste reduction information in Table 3 is based on case studies and reflects the successes of wood furniture manufacturing facilities. However, specific applications are variable and thus this information should only be used as an indicator of how a particular pollution prevention option may perform at a particular facility. These case studies are found in EPA's PPIC/PIES.

SECTION III
POLLUTION PREVENTION DOCUMENTS

Compendiums and Guides

Table 4 contains a listing of some key guides and compendiums on waste minimization, pollution prevention and recycling that may be of particular interest or use for wooden furniture manufacturing. In many instances, these documents may provide a firm with important information as it begins to explore pollution prevention options for its operations. Copies of documents with EPA document numbers may be obtained from EPA or the Pollution Prevention Information Clearinghouse (PPIC). Copies of documents with PIES catalogue numbers may be obtained through PPIC.

Table 4. Recommended Compendiums and Guides

Title	Date	Author & Reference	Abstract
1. Managing and Recycling Solvents in the Furniture Industry	May 1988	North Carolina Pollution Prevention Pays Program, Raleigh, N.C. (PIES #034-018-A-000)	Topics covered include factors involved in change; proper spray techniques; a description and list of the advantages and disadvantages of coating methods, water-based and high solids coatings; good housekeeping procedures; North Carolina regulations governing waste solvents; waste management options and recycling options. Document includes case studies of successful source reduction and recycling technologies implemented by furniture manufacturing facilities. Appendices list coating suppliers, equipment suppliers, waste management and waste exchange information sources.
2. Alternative Approaches to Waste Reduction in Materials Coating Processes	1987	Gardner, Lisa, C., and Huisingh Donald, Hazardous Waste & Hazardous Materials, Vol 4, No. 2, pp 177-191 (PIES #534-001-A-000)	Describes the constraints and considerations to be considered before changing to an alternative coating. Discusses advantages and disadvantages of water-based coatings, high solids coatings, electron beam curing, and ultraviolet (UV) curing systems as well as recent developments in these technologies.

Table 4. Recommended Compendiums and Guides (continued)

Title	Date	Author & Reference	Abstract
3. Reducing Emissions From the Wood Furniture Industry With Waterborne Coatings	1980	USEPA, Industrial Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH EPA/600/2/80/160	Document provides an in-depth report on the factors and impediments to switching from a solvent-based coating to a water-based or lower-solvent coating. This report discusses findings from a cooperative project between EPA and the wood furniture manufacturing industry to identify, test, and evaluate lower hydrocarbon finishes for wood furniture as well as quantify the VOC reductions.
4. Case Summaries of Waste Reduction by Industries in the Southeast	1989	North Carolina Pollution Prevention Program (PIES #112-003-A)	Compendium of case studies that describe source reduction and recycling techniques that have been used in the furniture manufacturing industry in southeastern states. Case studies provide technical and economic information on proven techniques and technologies.
5. Waste Minimization Opportunity Assessments Manual	1988	USEPA, Office of Research and Development EPA/625/7-88/003	Describes a procedure to identify waste reduction opportunities for industrial processes. While the manual is not specific to any particular industry, it is designed to provide a systematic assessment strategy to any industrial sector.

Additional Pollution Prevention Information

EPA has identified additional sources of information that discuss pollution prevention concepts, techniques and technologies as they apply to furniture manufacturing or coating operations in general. Many of these documents are contained in the PPIC repository. Documents may be available though the PPIC depending on copywrite status and the desires of the author and or publisher. The following table of references is divided by general topic area.

Table 5. Additional Pollution Prevention Resources

Title	Date	Author	Abstract
Solvent Usage and Recycling			
6. Guidelines for Waste Reduction and Recycling Solvents	1989	Oregon Department of Environmental Quality, Hazardous Waste Reduction Program of Oregon, Portland OR (PIES #038-009)	This document provides a detailed discussion of sources of solvent waste, source reduction methods, solvent recovery capture and reuse, the advantages and disadvantages of different types of recycling options, as well as factors to consider when deciding what recycling option to choose. This document is not specific to the furniture manufacturing industry but provides useful information on solvent recycling options.
7. "Solvent Distillation: In-House or Contract"	March 1990	Carney, Michael, Industrial Finishing, 3/90, pp 30-31 (PIES #528-028-A-000)	Briefly describes the advantages and disadvantages of on-site versus off-site solvent recycling.
8. Accomplishments of North Carolina Industries: Case Summaries	January 1989	Pollution Prevention Pays Program, North Carolina Department of Natural Resources and Community Development, Raleigh, N.C. (PIES #034-012-A-040)	Describes forty case studies of waste minimization techniques from different industries; includes economic data.
9. Hazardous Waste Reduction, Annual Report	1987	Boeing Corporation, (PIES #806-01)	Describes waste minimization efforts at Boeing Corporation facilities. Furniture manufactures may find the discussion on solvent recovery and reuse valuable.
10. Compendium on Low-And Non-Waste Technology	1981	United Nations Geneva Switzerland, p 32. (PIES #400-032)	This document contains over 100 different case studies on a wide range of industries. Each case study briefly describes the conventional technology, the new technology, and cost and or environmental savings from the new technology.
Equipment Modifications/Changes			
11. "How Rapid Rack Raised Transfer Efficiency"	October 1990	Industrial Finishing, October, 1990	Discusses, in detail, how a vacuum system coating operation works, its advantages and disadvantages, and lists a commercial vender contact. While the discussion focuses on a fabricated metal facility the article provides good background information on vacuum coating systems.
12. "Boost Overall Transfer Efficiency"	May 1990	Walberg, Arvid, C., Industrial Finishing, 5/90, pp 20-30 (PIES #528-027-A-000)	This article discusses the major transfer efficiency parameters in applying coatings with electrostatic spray systems.

Table 5. Additional Pollution Prevention Resources (continued)

Title	Date	Author	Abstract
13. "Understanding Electrostatic Finishing"	September 1990	Robinson, Frank, and Dennis Stephens, Industrial Finishing, 9/90, pp 34-37 (PIES #528-026-A-000)	A technical introduction to electrostatic finishing principals is presented. Describes the use and characteristics of rotary atomizers, air/airless spray, powder guns and liquid coating electrostatic systems.
Alternative Coatings/Technologies			
14. "New CO_2 Spray Finishing Technology!"	September 1989	Schrantz, J., Industrial Finishing, 9/89 (PIES #528-025-A-000)	Discusses the environmental\safety, economic, and performance factors of Unicarb, a CO_2-based coatings. The technology involves formulating a coating with only "coalescing" (retarder or tail) solvents; the CO_2 replaces the fast-evaporating "cutting" (dilutent) solvent. The CO_2-based coating reportedly reduces VOC emissions by 30% to 70% depending on the coating type.
15. "Paint Technology Can Boost L.A.'s Pursuit of Clean Air"	November 1990	Lents, James, M., American Paint & Coatings Journal Convention Daily, p17-18, November 2, 1990 (PIES #591-001-A-000)	Describes research underway to develop zero-VOC coatings and UV curable finishes. Numerous zero-VOC coatings using vernonia oil as a base are being tested. A high quality ultraviolet-curable base coat for furniture that successfully highlights wood grain has been developed. Research is reportedly underway to develop a high quality ultraviolet-curable topcoating for wood furniture.
16. An Evaluation of Control Technology For Spray Painting	1982	O'Brian, Dennis, M., and Hurley, Donald, E., American Industrial Hygiene Association Journal, 43(9):695-703, 1982	Presents a technical review of water-based, high-solid coatings; including the advantages and disadvantages of each coating type.
17. "Waterborne Paint Circulation"	July 1990	Bankert, Peter, J., Industrial Finishing, 7/90, pp 42-43 (PIES #528-024-A-000)	Discusses the circulation system characteristics critical to converting a solvent-borne coating circulation system to a waterborne coating circulating system.
18. "Exciting Infrared and UV Developments"	September 1990	Schrantz, J., Industrial Finishing, 9/90, pp 14-121 (PIES #528-023-A-000)	Discusses recent developments in infrared and ultraviolet curing equipment/finishes; lists commercial suppliers.
19. "Intense Resin R&D Bearing Fruit"	January 1991	Schrantz, Joe, and Baily, Jane, Industrial Finishing, 1/91, pp 20-24 (PIES #528-022-A-000)	Describes new commercially available waterborne, high-solid, and powder coating resins. The resins are not specifically for the wood furniture manufacturing industry.

Table 5. Additional Pollution Prevention Resources (continued)

Title	Date	Author	Abstract
20. Adhesives Manufacture: Source Reduction of Chlorinate Solvents	June 1990	Source Reduction Partnership, Metropolitan Water District of Southern California and Environmental Defense Fund. (PIES #609-004-A-000)	The document evaluates pollution prevention options: chemical substitution, process modification, product substitution, and solvent recovery and recycling. Discussion is not specific to furniture manufacturing.
21. Airless Spray Techniques	1982	Airless Spray Training Series. GRACO, Inc., Minneapolis, MN	This manual introduces the correct airless spraying techniques when operating a manual airless spray gun.
22. The Efficient Utilization of Materials in the Finishing Room	Undated	DeVilbiss Education Services 83A, DeVilbiss Company, Toledo, OH	This document discusses factors leading to efficient spray gun technique. It is designed for the spray gun operator.
23. "HVLP Spray Puts You Into Compliance"	March 1989	Marg, Ken, Metal Finishing Vol. 87, No. 3, pp. 21-23	Describes HVLP spray technology.
24. "HVLP Spray: Ten Questions Answered"	March 1990	Products Finishing, pp. 46-51	Answers ten questions on high volume, low pressure spray technology.
25. "Coatings for Compliance"	July 1990	Graves, B; Products Finishing, pp. 56-69	Describes advantages and disadvantages of different coating technologies.
26. "The Basics of SPC"	June 1991	Schneberger, G.L., Industrial Finishing, pp. 28-30	This article describes applying statistical process control techniques to a paint line.

SECTION IV
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APPENDIX A

Releases of the 17 Chemicals of Concern
by Wood Furniture Manufacturing Industries (in pounds)

SIC 2511	Wooden Household Furniture, Except Upholstered				
Chemical	**Air**	**Land & Injection**	**Water**	**Transfers**	**Total**
CH_2CL_2	62369	0	0	500	62869
Chromium	0	0	0	250	250
MEK	4360161	5221	0	237378	4602760
MIBK	1247698	0	0	18800	1266498
Toluene	12425089	15032	0	526415	12966536
Xylene	5208690	3386	0	200069	5412145
TCE	14413	0	0	750	15163
111 TCE	145038	0	0	0	145038

SIC 2512	Wooden Household Furniture, Upholstered				
Chemical	**Air**	**Land & Injection**	**Water**	**Transfers**	Total
CH_2CL_2	5160	0	0	16080	21240
Chromium	0	0	0	8000	8000
Cyanide	0	0	0	573	573
MEK	51398	0	0	1684	53082
MIBK	349209	0	0	500	349709
Toluene	878683	0	0	21240	899923
Xylene	480136	0	0	8522	488658
111 TCE	189126	0	0	2640	191766

Releases of the 17 Chemicals of Concern
by Wood Furniture Manufacturing Industries (in pounds) (continued)

SIC 2521	Wood Office Furniture				
Chemical	**Air**	**Land & Injection**	**Water**	**Transfers**	**Total**
CH_2CL_2	6700	0	0	3800	10500
Chromium	500	0	0	0	500
MEK	226672	24925	0	31880	283477
MIBK	202547	0	0	13283	215830
Toluene	667462	0	0	71838	739300
Xylene	471299	0	0	37762	509061
111 TCE	62153	0	0	1020	63173

Key:

CCL_4	Carbon Tetrachloride
$CH_2 Cl_2$	Dichloromethane
$CHCL_2$	Chloroform
MEK	Methy Ethyl Ketone
MBK	Methyl Isobutyl Ketone
TCE	Trichloroethylene
PCE	Tetrachloroethylene
111 TCE	1,1,1-Trichloroethane

Notes:

- Land category includes underground injection.
- Other Transfers include transfers to POTWs.
- Only primary SIC code field was used to avoid double counting.
- Transfers refers to quantity of the chemical sent to off-site disposal, treatment, or storage facilities.

Source: USEPA, Toxics Release Inventory Database, 1988.