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Project Summary

Sources and Factors Affecting Indoor Emissions from Engineered Wood Products: Summary and Evaluation of Current Literature

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Reconstituted engineered wood components (e.g., particleboard and medium-density fiberboard) are common to several types of consumer wood products (e.g., residential and ready-to-assemble furniture and kitchen cabinets). The selection of resins used to bind the components, coatings, and laminates applied to the components to produce the final products affects emissions of formaldehyde and other volatile organic compounds from the products to the indoor environment. Research Triangle Institute is collaborating with the Indoor Environment Management Branch of the U.S. Environmental Protection Agency's Air Pollution Prevention and Control Division in a project entitled, "The Application of Pollution Prevention Techniques to Reduce Indoor Air Emissions from Composite Wood Products." The research objectives are to characterize indoor air emissions from engineered wood products and to identify and evaluate pollution prevention approaches for reducing indoor air emissions from these products.

The research has a five-phase approach: (1) evaluate existing data and testing methodologies; (2) convene research planning meetings; (3) select high-priority emissions sources; (4) evaluate high-priority emissions sources; and (5) develop and demonstrate pollution prevention approaches for reducing indoor air emissions from high-priority sources. The report summarizes information from the first two phases of research. Information presented here will be used to select reconstituted wood components with various finishing and resin systems for initial emissions screening.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

Several recent U.S. Environmental Protection Agency (EPA) studies have identified indoor air quality (IAQ) as one of the most important environmental risks to the Nation's health. People spend approximately 90% of their time indoors in environments such as residences, public buildings, and offices where concentrations of many pollutants are frequently higher than outdoor urban air. Some indoor activities can lead to indoor air pollutant levels up to 1,000 times higher than outdoor levels.

EPA's Air Pollution Prevention and Control Division (APPCD) is responsible for much of EPA's indoor air engineering research and seeks to integrate IAQ and pollution prevention (source reduction) into a strategic approach to indoor source management. The research objective of APPCD's Indoor Environment Management Branch is to employ accepted pollution prevention techniques (e.g., process modification and product reformulation) to reduce indoor air contamination through the development of "low-emitting materi-

als" (LEMs). A LEM is designed to emit fewer pollutants when used in the same manner as another material in the same indoor environment.

In the past, approaches for improving IAQ have generally focused on mitigation techniques, (e.g., increased or improved ventilation and air cleaning) rather than source reduction. Although these traditional mitigation approaches can result in improved IAQ, they do not prevent pollution; furthermore, the pollution is simply transferred to another medium. Depending on the source of indoor air pollution, another approach is to focus on source management, ensuring that pollutants never enter the indoor environment. In the Pollution Prevention Act of 1990, Congress declared that pollution should be prevented or reduced at the source whenever feasible. Sources may be reduced by modifying equipment, processes, and procedures; reformulating or redesigning products; substituting raw materials; and improving use procedures. In multimedia pollution prevention, all environmental media are considered while avoiding transfer of risks or pollution from one medium to another.

EPA Research on Engineered Wood Products

The Research Triangle Institute (RTI) is collaborating with APPCD in a cooperative agreement entitled, "The Application of Pollution Prevention Techniques to Reduce Indoor Air Emissions from Composite Wood Products." The objectives of this research are first to characterize indoor air emissions from engineered wood products and then to identify and evaluate pollution prevention approaches (e.g., developing LEMs) for indoor use. This research includes five phases: (1) evaluate existing data and testing methodologies; (2) convene a research planning meeting; (3) select high-priority emissions sources; (4) evaluate high-priority emissions sources; and (5) develop and demonstrate pollution prevention approaches for reducing indoor air emissions from selected high-priority sources.

The report summarizes information collected in the first two phases of the project. Information presented here, along with information from outside technical advisors, will be used to select products for further research. The technical advisors include representatives of trade associations, industry, state government, academia, and technical assistance providers. Extensive source characterization will be carried out on the selected products. Pollution prevention approaches will be identified and applied. These improved products will be evaluated through quantitative emissions measurements to decide the technical and economic feasibility, total pollution prevention potential, and IAQ benefits of the pollution prevention approaches.

Literature Summary

The literature summarized in the report includes applicable material types, indoor air emissions, and pollution prevention opportunities.

Material Types

This cooperative research focuses on indoor air emissions from engineered wood products (e.g., furniture, cabinets, and building materials). Raw materials used to construct these products include wood, glues, organic-based finishes and coatings, and a variety of paper and plastic laminates. Resins and wood used to manufacture engineered wood products and their finishing materials are sources of organic emissions. The most commonly used resins in the U.S. are phenol-formaldehyde, urea-formaldehyde, and methylene-diphenyl diisocyanate (MDI). The different chemistries of these resins result in different emissions characteristics. Types of finishing materials used on engineered wood materials include laminates, edge-bands, adhesives for attaching laminates and edge-bands, conversion varnish coatings, paints, stains, fire retardants, and preservatives. Some of these materials are sources of organic emissions; others, such as laminates or veneers, may help reduce emissions. Evaluating and understanding the indoor air emissions associated with each of these raw materials are critical to the development and evaluation of pollution prevention opportunities such as low-emitting or low-impact materials.

Indoor Air Emissions

In 1984, the U.S. Department of Housing and Urban Development (HUD) established formaldehyde product standards for all plywood and particleboard materials bonded with a resin system or coated with surface finish containing formaldehyde when installed in manufactured homes.* Many plywood and particleboard manufacturers changed their products to comply. Several studies evaluated various sources of indoor air emissions and how the emissions rates are affected by various parameters. One study concluded that new building materials produced high emissions levels, but with effective ventilation these emissions could be reduced; the maximum concentration of formaldehyde reached 0.122 mg/m^3 in the new office building investigated for the study. Another indoor analysis suggested that building materials may be the main source of organic compounds in the indoor environment: the total average concentration for the most frequently identified compounds in this study was 72.96 μg/m^3, and the average arithmetic mean emissions rate for all the identified compounds was 9.5 mg/m^2 • h. Two other studies presented predicted emissions rates and emissions rate ranges, respectively, for several engineered wood products.

Still other studies analyzed samples of various engineered wood products. A National Particleboard Association two-part preliminary study analyzed emissions from finished and unfinished engineered wood products [for most of the finished samples of southern yellow pine (SYP) substrates, the total volatile organic compound concentrations, ranging from 156 μg/m^3 at 24 hours to 2,520 μg/m^3 at 120 hours, were lower than for unfinished SYP substrates, ranging from 2,880 μg/m^3 at 24 hours to 918 μg/m^3 at 120 hours]. Besides measuring organic emissions for water-damaged chipboard, which had a mean formaldehyde concentration of about 0.0475 mg/m^3, one study evaluated microbiological growth from water-damaged chipboard samples, which revealed significant growth of fungi following water damage (the results of these analyses are presented in the full report). Although not discussed in the full report, EPA performed earlier research on a variety of consumer products and building materials that presented emissions rate data and discussed the effect of temperature and air exchange on the emissions rate.

Reported information concerning organic and formaldehyde emissions rates and concentrations depended on the design and objectives of each study. Emissions data for each individual study were collected using different analytical test methods. Because methods used to collect emissions data were study-dependent and researchers presented emissions data differently, comparative conclusions could not be drawn between the studies presented in this report.

* The HUD safety standards for certified plywood and particleboard used in manufactured home construction require that formaldehyde emissions not exceed 0.2 ppm (0.246 mg/m^3) from plywood and 0.3 ppm (0.369 mg/m^3) from particleboard, as measured by the specified air chamber test, Large-Scale Test Method FTM 2-1983. Individual engineered wood products are tested in accordance with the following loading ratios: plywood—0.29 ft^2/ft^3 (0.369 m^2/m^3), and particleboard—0.13 ft^2/ft^3 (0.43 m^2/m^3). Using the operating conditions specified in FTM 2-1983 and the formaldehyde emissions rate equation, formaldehyde emissions rates are 0.13 mg/m^2 • h (2.66 x 10^{-8} lb/ft^2 • h) for plywood and 0.43 mg/m^2 • h (8.81 x 10^{-8} lb/ft^2 • h) for particleboard.

Pollution Prevention Opportunities

Pollutants are managed most effectively at their source. The major approaches are chemical substitution, process changes, and product redesign. Strategies vary depending on whether emissions are the result of offgassing from construction or finished materials (e.g., organics in wood products) or product operation or use. When offgassing is the major emissions source, low-emitting materials may be substituted. When product use or operation is the major source of emissions, knowledge of the relevant process is essential in developing emissions controls or redesigning the product to reduce emissions. In either case, chemical substitution may be warranted if a product or equipment is found to emit chemicals shown to cause serious human health or environmental effects. Several possible approaches for developing low-emitting materials are wood alternatives, alternative resins and scavengers, and laminate or veneer use. These pollution prevention and source management approaches are discussed briefly.

Alternatives to Wood Feedstock

The primary reason for including agricultural fiber sources (wood alternatives) in this report is to identify their potential to reduce indoor emissions from the use of engineered wood products. However, data on the indoor air emissions from engineered agricultural products were not found; therefore, emissions tests of these products are required.

A potential alternative for wood used to manufacture engineered wood products is agricultural fiber. Agricultural fiber comes from two main sources: agricultural crops grown for fiber (e.g., kenaf) and residues of crops grown for other purposes (e.g., wheat, cotton). Agricultural fibers are used in many countries to manufacture composite panel products, such as insulation board, particleboard, medium-density fiberboard, and hardboard. A global literature search conducted at the U.S. Department of Agriculture, found 1,039 citations on the use of agricultural fibers for manufacturing composite panels. Many of these applications are used in developing countries where there is not enough wood to cover the needs for fuelwood, industrial wood, sawn wood, and wood-based engineered panels.

In the U.S., engineered panels are manufactured primarily from wood. However, agricultural fibers are available that have the potential to be used in engineered panels; sources of these fibers include bagasse, cereal straw, corn stalks and cobs, cotton stalks, kenaf, rice husks, rice straw, and sunflower hulls and stalks. Recently, a plant was built in North Dakota that manufactures particleboard from wheat straw and MDI resins.

Alternative Resins and Scavengers

Several resin and additive approaches exist for reducing formaldehyde board emissions from urea-formaldehyde bonded products, such as particleboard and medium-density fiberboard. Included are low molar ratio urea-formaldehyde resins, the use of formaldehyde scavengers with urea-formaldehyde resins, melamine-fortified urea-formaldehyde resins, phenol-formaldehyde resins, and MDI resins. While these alternative resins and additives result in products with significantly lower formaldehyde emissions, only low molar ratio urea-formaldehyde resins and formaldehyde scavengers have made a significant penetration in the particleboard and medium-density fiberboard industries.

Urea-formaldehyde resins are the most commonly used adhesives for engineered wood manufacture in the U.S.; second in volume are phenol-formaldehyde resins. MDI resins are the third most commonly used type in the U.S. Originally, the formaldehyde-to-urea molar ratio for the urea-formaldehyde resin was 2.0. This molar ratio corresponded to the number of chemically reactive groups present in the reagents. In the early 1980s, most urea-formaldehyde resins marketed as wood adhesive resins contained a molar ratio of 1.8 although proof was available that lowering the overall molar ratio further reduced the potential for postmanufacture formaldehyde release. Nonetheless, progress has been made in formulating low-molar ratio resins.

A wide range of molar ratio resins is used in urea-formaldehyde bonded products. For particleboard, when a single resin is used throughout the board, the formaldehyde-to-urea molar ratio can fall within the range set by the face/core systems; medium-density fiberboard products use resins with formaldehyde-to-urea molar ratios higher than particleboard resins; hardwood plywood products use the highest formaldehyde-to-urea molar ratios. The nature of the product and process dictates which formaldehyde-to-urea molar ratio to use. The molar ratio directly influences the ultimate strength the resin will produce in the board; i.e., certain products require higher molar ratio resins to attain an adequate level of bond strength.

Often, formaldehyde emissions cannot be sufficiently lowered with resin use alone. To avoid incurring significant losses in productivity or board quality, many North American plants use scavengers with urea-formaldehyde resins to reduce formaldehyde emissions. (Consequently, although not exclusive, another potentially beneficial impact for plants is reduced formaldehyde exposure for workers.) These scavengers fall into two categories: scavengers that are incorporated before pressing the panel and scavengers that are incorporated after pressing. The basic premise of the two approaches is essentially the same: both approaches allow the use of resins with a higher molar ratio and all their attendant benefits while achieving acceptable emissions by scavenging the excess formaldehyde. The molar ratio directly impacts the ultimate strength the resin will produce in the board; i.e., certain products require higher molar ratio resins to attain an adequate level of bond strength. Urea scavengers have been used widely for many years. This method is very effective in reducing formaldehyde emissions with minimal impact on other resin performance characteristics. It has been used extensively where the use of lower molar ratio resins resulted in significant losses of resin efficiency (bond strength) or productivity.

Most plants incorporate scavengers before pressing the panel. The most prevalent type of prepressing scavenger is chemical urea. Another type of prepressing scavenger is a scavenging wax emulsion in which the scavenging chemicals are added to the normal wax emulsion. (The wax, a mixture of petroleum hydrocarbons, is typically added as an emulsion to retard the absorption of water by the board. Wax emulsions are dispersions of very small wax particles in water.) This approach eliminates the need for a separate metering and storage system for the scavenger but does not provide flexibility in scavenger level for different products or conditions. A relatively new prepressing scavenger method is combination blending, commonly called combi-blending. Combination blending is the process by which two liquid urea-formaldehyde resins are used in combination to reduce formaldehyde emissions without a loss in board properties or in production efficiency.

One advantage of combination blending over urea scavenger is that, unlike simple urea, the scavenger resin has adhesive properties and contributes to bonding. Consequently, it can be used to replace part of the regular resin rather than being an add-on. This can mean significant savings in total additive cost. Typically, the scavenger resin is combined

with the normal resin just before application to the wood, although good results have also been achieved using separate application of the two components. This technology lends itself to batch mixing or mixing in storage. Long-term contact of the two components results in a mixture that behaves similarly to a low molar ratio resin.

Postpressing treatments are much less common than prepressing treatments but can be very effective. The most well known of these is to gas the panels with anhydrous ammonia. Other techniques that have been tried include the application of liquid ammonia or ammonia salt solutions to the board surface before stacking. All three methods use the reactivity of ammonia to formaldehyde forming a relatively stable compound.

Source Management Approaches

Overlays on engineered wood products include veneers, laminates, vinyl films, decorative foils, high-pressure laminates, and paper-based overlays. Although designed for other purposes, such as aesthetics, these can serve as effective barriers to emissions. For emissions to occur, the compound must be present at the surface and in contact with ambient air. These overlays can also protect the resins from drastic changes in relative humidity and temperature, reducing the potential for hydrolytic attack. However, note that additional resins may be used as adhesives to attach these covers to the wood products. Both urea- and phenol-formaldehyde resins have been used for this purpose and, as a result, increase the amount of resin present as a potential source. Other adhesives used for attaching laminates and veneers include water-based contact cement, epoxy, and polyvinyl acetate.

A final report covering the research conducted under this cooperative agreement between EPA and RTI will be issued upon completion of the research in 1996. Additional information on indoor air emissions from engineered wood products is available from studies presented in the full report, which also presents additional information on resin chemistry. An evaluation of the health and environmental effects was beyond the scope of work for this project.

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***Elizabeth S. Howard** is the EPA Project Officer (see below).*
The complete report, entitled "Sources and Factors Affecting Indoor Emissions from Engineered Wood Products," (Order No. PB96-183876; Cost: $25.00, subject to change) will be available only from
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