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10. RESEARCH ON COMBUSTION OF WOOD CONTAINING NON WOOD MATERIALS

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10.1. Summary

Residue wood and sludge from the primary and secondary manufacture and disposal of wood products, such as wood pallets, wood rail ties, and demolition wood, represent a tremendous alternative energy source.

However, environmental regulators are concerned about the environmental impact of combustion of such residue because the residue may contain adhesives, resins, plastics, preservatives, and paints.

This report first describes nonwood components in wood residue and sludge and then describes research in the United States related to the combustion of wood residue. The research studies are aimed at providing environmental regulators and project developers with the information necessary for informed decisions on the use of wood residue for fuel.

The use of residue for fuel represents a potential solution to two major problems: The need for alternative energy production and the need for alternative waste disposal.

10.2. Sources of Wood Residue Fuel

The major sources of wood residue are the primary and secondary forest products industries, used wood pallets and containers, and demolition wood. The primary forest products industries process logs and chips to produce lumber, plywood composition board, and pulp and paper. The manufacturing residues contain adhesives (in the wood products) and fillers and dyes (in the paper).

The secondary forest products industries process lumber, plywood, and composition boards to produce furniture, cabinets, windows, doors, millwork, prefabricated buildings, mobile homes, and many other types of products.

The residues from manufacturing these products can contain many different organic and mineral materials. Used pallets and containers are usually free of materials that are difficult to burn. Demolition wood, however, can include paints containing heavy metals, wood preservatives, and fire retardants.

10.2.1 Forest Products Industry Residue

Table 1 lists nonwood components present in wood products manufactured by primary and secondary wood products industries.

In primary forest products industries, the phenol formaldehyde resin found in exterior plywood is usually catalyzed with sodium hydroxide. Extenders are based on wood or agricultural products. The urea formaldehyde resin in interior plywood is usually catalyzed with an acid such as hydrochloric acid or aluminum chloride.

Table 1: Nonwood components of forest industry residue

| Forest products industry | Product | Nonwood residue |
|--------------------------|---|---|
| Primary | Exterior plywood | Phenol formaldehyde resin, extenders |
| | Interior plywood | Urea formaldehyde resin |
| | Composition board | |
| | Wet-process hardboard | Phenol formaldehyde resin, wax, tempering oil (e.g., linseed oil), alum, sulfuric acid |
| | Dry-process hardboard | Phenol formaldehyde resin, wax |
| | Particleboard | Urea formaldehyde resin, wax |
| | Flakeboard | Phenol formaldehyde resin, wax |
| Secondary | Pulp and paper | Sludges: dyes, inks Dyes and inks: heavy metals |
| | Furniture, cabinets, windows, doors, millwork, prefab buildings | Adhesives, plastic overlays, resins, pigments, urethanes, oils, inorganic materials, clay fillers, dyes, inks |

^aResins contains sodium catalysts and organic fillers.

Isocyanate resins are gradually replacing phenolic resins.

The adhesives found in the residue from secondary forest products industries are similar to those found in residue from primary industries. Overlays are mostly melamine resins and pigments. Finishes contain urethanes, condensed oils, and alkyd and latex resins. The drying agents contain cobalt, manganese, and zinc. Pigments contain many different inorganic elements such as lead, titanium, zinc, iron, and cadmium. Paper may contain clay fillers, wet-strength resins, dyes, and inks.

10.2.2. Used Wood Pallets and Containers

The surface of pallets and containers may contain some nonwood materials, but very little of these materials penetrates the wood because it is difficult

to impregnate wood with appreciable amounts of chemicals. Fasteners can be magnetically removed during crushing and grinding of pallets and containers.

10.2.3. Demolition Wood

Because demolition wood comes from many sources, it contains many different nonwood components. The wood is usually mixed with wallboard, cement, roofing, insulation, metal, plastics, and dirt. Manual and automatic processing can separate the wood from most contaminants; painted wood can be removed from the demolition residue.

Demolition wood is often treated with preservatives or fire retardants. Preservatives that increase the resistance of the wood to decay, insects, and marine borers include creosote, pentachlorophenol, copper-8-quinolate, copper naphthenate, and borate and salt compounds made with copper, chromium, arsenic, and zinc.

Wood structural materials are treated with chemicals to increase resistance to fire. Chemicals used for fire retardants include borates, phosphates, ammonium sulfate, and resins (melamine, urea, and dicyanodiamide).

10.3. Research on Wood Residue Fuel

Research in progress includes studies on (a) wood residue characterization, (b) behavior of mineral matter during wood combustion, and (c) combustion of wood residue using a small-scale combustor.

10.3.1. Wood Residue Characterization

A **wood** characterization study, entitled “Wood Products in the Waste Stream: Characterization and Emission Testing Protocol Development”, is aimed at identifying possible elements of the wood waste resource that

could have an adverse impact on the environment should these elements be combusted in a conventional wood energy system.

The study is sponsored by several agencies in the United States and Canada through the New York State Energy Research and Development Authority. The goal is to identify environmental control strategies that allow for the combustion of wood residues for energy production in an environmentally acceptable manner.

Phase I will characterize the potential environmental consequences of combusting wood residues. Phase H will test the air and ash emissions from industrial facilities that are burning wood residue fuels.

In Phase I, the types of wood residue available in both industrial and municipal waste streams in several U.S. states and one Canadian province will be identified along with current uses or disposal methods. For each type of residue, the moisture content and amounts of nonwood materials, such as adhesives, paints, plastics, and preservatives, will be estimated. Representative samples of the wood residue will be chemically analyzed for certain heavy metal, organic, and mineral contents of the ash. The chemical composition data will be used to evaluate the air emissions and wood ash characteristics from the combustion of wood residue.

Combustion systems used for burning wood residue will be studied in reference to size, type of combustor, operating conditions, environmental controls, and ash disposal practices. Information on the known emission characteristics of the system will also be obtained. Pollution control equipment will be evaluated for capability of reducing emissions and controlling ash composition to within environmentally acceptable limits. Components of the wood residue that are of environmental concern will be identified.

Phase 1 will also identify the environmental regulations that govern the collection, disposal, and combustion of wood residues in the areas under

study. Methods used to prepare wood residue for use as fuel will be described.

In Phase II, composition of the combustion gas, fly ash, and bottom ash will be measured at facilities that are burning certain wood residues to determine the fate of the nonwood components.

10.3.2. Behavior of Mineral Matter During Wood Combustion

A project is being conducted on the physical and chemical behavior of mineral matter in wood and bark at high temperatures in oxidizing and reducing conditions. The project is sponsored by the U.S. National Science Foundation at the University of Wisconsin-Madison and Forest Products Laboratory, Madison, Wisconsin. The objective is to better understand the process of ash formation and deposition in combustors and gasifiers. At this time, the study is focused on only the ash associated with clean wood, but the information gained will be applicable to other mineral matter in wood residue.

Efforts have focused on various thermal and chemical analyses of wood ash to identify the physical and chemical changes that accompany mineral matter transformations in wood. The thermal analyses include thermogravimetry (TGA) and differential thermal analysis (DTA). The chemical analyses include electron spectroscopy for chemical analysis (ESCA), inductively coupled plasma emission spectroscopy (ICPES), and x-ray diffraction analysis (XRD).

The TGA and DTA results indicated the presence of endothermic processes at temperatures over 700°C accompanied by a mass loss that ranged from 23% for poplar ash to 48% for pine ash. In the case of pine and aspen ash, mass loss occurred in two or more distinct steps, indicating the presence of two or more distinct transformation temperature regions. The ICPES results of low temperature (600° C) ash indicated that the primary elemental constituents of the ash are calcium, magnesium, and potassium. The amount

of calcium ranged from about 35% in oak ash to about 25% in poplar ash and that of potassium ranged from about 17% in pine ash to about 8% in poplar and oak ash. The amount of magnesium ranged from about 4% in aspen ash to about 8% in poplar ash. The XRD results indicated that calcium is present predominantly as a carbonate, potassium as a carbonate and as sulfate, and magnesium as an oxide.

The mass loss observed during TGA was primarily the result of decomposition of calcium carbonate in the first step and dissociation of potassium carbonate and subsequent vaporization of potassium oxide. The first step in mass loss is evident in all the TGA results, and subsequent steps are visible only in aspen and pine ash, which contain relatively more potassium.

As a result of dissociation, at temperatures over 1300° C the ash is depleted in potassium and becomes richer in calcium and magnesium. The XRD results of the ash at high temperatures indicated presence of predominantly oxides of calcium and magnesium and small amounts of potassium sulfate.

Wood ash formation is observed when wood is heated on a hot stage of an optical microscope. At hot stage temperatures of less than 400° C, the combustion is slow and undisturbed by air movements. Formation of individual ash fibers can be seen and has been recorded with a video camera. Color transformations range from grey or brownish-white, depending upon species, at low temperatures to brown-black at 1300°C; at 1000°C, the transition color is blue-green for most species.

This research will continue to investigate the transformation of the mineral matter to ash. The changes in ash composition with increasing temperature will be observed in various species to determine how the original composition affects these changes. During low temperature ashing, the volatiles are being condensed on a cooled platinum surface and analyzed for mineral content. Both potassium and phosphorus have been found. Mineral nodules in the ash are also being observed with an electron microscope. This research will also be performed on bark and later under reducing conditions for both wood and bark.

10.3.3. Small-scale Combustor Tests

A small-scale combustor with a 0.1-m square bed will be used to burn certain wood residues containing nonwood materials at the University of Wisconsin-Madison in a study sponsored by the Forest Products Laboratory. Combustion conditions of temperature, oxygen, turbulence, and time will be controlled. Gas chromatography (GC) and GC-mass spectrometry will be used to measure oxygen, carbon monoxide, carbon dioxide, nitrous oxide, light hydrocarbon composition, and complex organic compounds. This study was started in June 1991.

10.4. Papermill Sludge

The disposal of sludge from the production of pulp and paper is an increasingly difficult problem. Sludge is normally disposed of by landfilling, burning, or landspreading. The demand for recycled paper is expected to double by the year 2001, and the industry is moving quickly to increase their capacity for deinked paper. To find sites for new mills, there is a need for more knowledge about the rate of production and characteristics of papermill sludge. Information on the chemical content of sludge is needed to select the combustion equipment for burning the sludge.

During the production of pulp and paper, from 18 to >113 kg of combined sludge is produced per ton of pulp plus paper produced (1,2). Typically, mills that manufacture mechanical pulp produce the least sludge and mills that use recycled paper produce the most sludge. To increase the rate of recycling and to meet the demand for more recycled paper, new deinking papermills will be constructed. To reduce transportation costs, the new mills will be located in urban areas where landfill costs are high and alternative disposal methods are desirable. Information is needed on the production rate and physical and chemical characteristics of the sludge to facilitate obtaining the permits required to construct the mills and to suggest alternative disposal methods.

The study is planned in three phases. The aim of the first phase is to obtain information about operating deinking mills in North America. Of primary interest is the production rates of sludge produced from various feedstocks and current disposal methods. The aim of the second phase is to determine the physical and chemical characteristics of the sludge from most or all the deinking mills. In the third phase, sludge chemistry will be correlated with paper feedstock and inks to determine the source of the chemicals in the sludge.

Samples of sludge obtained from the mills will be analyzed for heavy metals and total mineral, nitrogen, ash, and carbon content. Mineral content includes phosphorus, potassium, calcium, magnesium, sulfur, zinc, manganese, boron, copper, iron, sodium, and aluminum. Heavy metals include arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, zinc, and titanium.

The chemical content of the sludge will be compared with that of the feedstock to learn the origin of the chemicals in the sludge. In particular, we will try to learn how the chemical content of the inks influences the chemical content of the sludge.

The origin of the sludge samples will be kept confidential, and we expect that the mills will contribute to the cost of the chemical analysis.

References

McGovern, J.N., J.G. Berbee, J.G. Boekheim, and A.J. Baker. Characteristics of combined effluent treatment sludges from several types of pulp and paper mills. *Tappi* 66(3):115-118, 1983.

Hoekstra, Pat L Paper recycling creates its own set of environmental problems. *American Papermaker* 54(4):30-33, 1991.