# Properties of Wood Waste Stored for Energy Production

*Isaac Slaven, Eva Haviarova, and Daniel Cassens*
*Department of Forestry and Natural Resources*
*Purdue University*

EXPERT REVIEWED


## Introduction

Storage of wood biomass is not a new concern, but our current focus on using wood for renewable energy has brought it back to researchers' attention. Since much of the past research done on pile storage relates to paper pulp chips, most of it dates to the 1960s and 1970s. Fiber shortages during that period caused increased interest in higher pulp yields (Zoch, Springer, & Hajny 1976). Further interest in the use of whole trees came about from the energy crisis of the late 1970s. Recent efforts by the government to create a U.S. energy portfolio rich in renewable resources have renewed this interest (Foust, et al., 2007; Perlack, et al., 2005).

Many barriers stand in the way of the use of wood biomass for energy. This publication focuses on problems and control of the rate of degradation and decomposition of wood biomass in storage.

## Factors in Chip Storage

The bulkiness (low bulk density) of wood chips dictates that to be economical, pulp and paper production requires large volumes of the raw material. In fact, the volumes are so large that much of the chip storage is outside. It was found in early research that outside chip storage (OCS) and handling cost less than inside or covered storage when the chips are destined for pulp production (Bergman 1973). When chips are to be used for fuel, drying prior to storage and covered storage are the most economical (Springer 1979).

Exactly how chips deteriorate in wood-chip piles is not completely understood (Koch 1985). Observed changes in the chips and chip piles are dry matter weight loss, temperature changes, moisture content, heat of combustion, and pH. Buggeln (1999) states that none of the variables in chip deterioration act independently. Understanding conditions that lead to deterioration can help us better predict how a pile with specific particle properties will act.

Weight loss refers to the loss of dry matter. In much of the research, this is measured as a loss of specific gravity. This can happen through three main methods of natural deterioration in wood: fungi, bacteria, and insects (Koch 1985). Included in fungi are stains, molds, and fungal rots such as brown rot, white rot, and soft rot. The fungal rots have little effect on the volume of wood, but begin to reduce the specific gravity of the wood as much as 2%–4% within two months (Lindgren & Eslyn 1961).

Loss of weight is an important consideration for chips stored for fuel. Research shows that higher heating values of chips in storage are associated with weight loss (White & DeLuca 1978) and that the net heating values decrease (White, Curtis, Sarles, & Green 1983). Even though the higher heating value (HHV) may in some cases increase, the total usable heat of the pile diminishes as the chips gain moisture and the chip dry material loses weight.

Dry material weight loss has been attributed to fungal infestation (Bergman 1973), bacterial infestation (Feist, Springer, & Hajny 1973), and chemical reactions such as oxidation and hydrolysis (Bergman 1974). Hydrolysis reactions of holocellulose (the combination of cellulose and hemicellulose), break the polymeric chains into fermentable sugars (Dinus, Payne, Sewell, Chiang, & Tuskan 2001). In fact, the use of fungi as a pretreatment for cellulosic ethanol has been discussed (Duff & Murray 1996). Fungal activity is also responsible for the fermentation of the fractionated holocellulose. However, when this happens in the presence of aerobic bacteria and oxygen, they can change the ethanol into acetic acid, or vinegar (Cleenwerck & DeVos 2008).

Piles going through these reactions are more susceptible to spontaneous combustion. In one case, the "strong odor of acetic acid" was reported near a pile that, a few weeks later, spontaneously ignited (Cole 1972). Chips in OCS that have undergone significant thermal degradation contain ethanol extracts in excess of 10 times the normal amounts (Bergman 1974). When these chips get hotter than 100°C and are exposed to ample amounts of oxygen, they may spontaneously ignite.

One other consideration for fuel chips in OCS is pH. Koch (1985) states that the combustion of acidic and alkaline fuels can corrode combustion equipment and ductwork. The degradation of wood chips through hydrolysis, fermentation, and oxidation that results in the production of acetic acid lowers the average pH of the moisture in the wood chips. In a chip and bark pile during six months of storage, the initial pH dropped from near-neutral to neutral (5 to 7) to an average of 4 (White & DeLuca 1978).

The rates of deterioration of hardwood vary considerably. One frequently cited study indicates that the total dry material loss in clean, bark-free, green wood chips was approximately 3% over 180 days (Zoch, et al., 1976). However, under similar conditions with whole tree chips, dry material loss was nearly 19% in 180 days.

## Effect of Particle Size on the Pile

Particles that have been most heavily researched are chips—the particles that come from a chipper. These chips generally fall in the range of 0.25 to 0.5 inches in thickness by 1.0 to 2.0 inches in width and length. Historically, specifications of the pulp and paper industry have developed limits on the size of particles accepted.

Because the improved use of wood wastes from primary and secondary industry is essential to meet national bioenergy goals (Perlack, et al., 2005), a wider range of wood waste material must be considered. These would include whole tree chips, logging residue, sawdust, sanderdust, shavings, or material cut-offs. Each of these has a different geometry and allows different amounts of airflow during pile storage.

For example, rectangular cut-off pieces have a greater amount of space between piled pieces than does sawdust. When there is more space between the particles, then there is more opportunity for air to move between the particles. The increase in airflow through a pile will reduce the moisture and the viability of fungi and bacteria. Finer particle sizes increase the adsorption of water and increase susceptibility to fungal attack (Lehtikangas 2000).

Although the shape of a wood biomass pile is of little consequence, the size of the pile is important. One recent document outlines pile height considerations for wood that is dried below its fiber saturation point, or 20%–28% dry-basis moisture content (Federal Woody Biomass Working Group 2010). In some cases in the South, pile heights are generally limited to 25 feet. In western states, pile height is typically limited to 50 feet. No explanation was provided for this difference.

## Prevention of Chip Deterioration and Pile Fire

The spontaneous combustion of piles of chips and sawdust can be caused by a multitude of factors. The complexity of the interrelation among these factors makes it difficult to predict; however, one mathematical model accounts for more than 30 factors (Ferraro, Lohrer, Schmidt, Noll, & Marlow 2009). Taken individually, the contributing factors can be better controlled. However, in a practical setting, it is difficult to isolate one without affecting others. Table 1 summarizes practices to control some of these factors.

Smith and Hatton (1971) stated that the best method for wood chip storage and usage is a first in—first out inventory management policy. In addition to that, they note that the rate of dry material loss decreases with time after the initial heating-up peak has been reached. It has been observed that dry matter loss can be up to 4% in the first two months (Lindgrin & Eslyn 1961), but Smith and Hatton observed that 1% per month is the longer-term average rate in undisturbed piles.

Chipped fuel wood, or hogged fuel, usually contains the bark and leaves of the tree. The inclusion of bark and leaves exacerbates deterioration. An ideal scenario would be dried chips with no bark or leaves and no exposure to precipitation, since the wood degrades at a much slower rate under these conditions (Zoch, et al., 1976). Springer (1979) suggests that drying chips eliminates the hazard of spontaneous ignition.

**Table 1.** *Variables that can be controlled to help prevent pile fires.*

| Variable | Apparent effect(s) | Mitigation |
|---|---|---|
| Moisture | High moisture allows fungal and bacterial activity that leads to temperature increases. | Use pre-drying, regular pile turning, first-in/first-out inventory practices, and indoor pile storage allowing air movement. |
| Oxygen | Aerobic bacteria increase their activity.<br>Oxygen is a critical ingredient for spontaneous combustion. | Regularly include oxygen through pile disturbance before heat raises temperature to near-combustion levels. |
| Particle size | Smaller particles gain water faster and dry slower due to the inhibited flow of unsaturated air. | Maintain largest particle size possible as long as possible; prevent exposure to weather. Use methods to separate fines, such as screening. |
| Bark and leaf inclusion | Bark and leaves provide a higher concentration of nutrients for fungal and bacterial activity. | Separate bark and leaves prior to size reduction. Pile rotation. First-in/First-out inventory practice. |
| Compaction | Reduced space between particles inhibits air circulation, thereby improving conditions for fungal and bacterial activity (though a perceived benefit is the reduction of rapid, initial heating that oxygen exacerbates). | Use improved materials handling and inventory management systems that do not require vehicles to travel on piles. |
| Storage time | Expect dry material loss, HHV reduction, increased risk of spontaneous combustion. | Improve forecasting and inventory management practices. |

Chip piles with bark inclusion deteriorate at a more rapid rate (Bergman 1974; Springer 1979). An inventory with high moisture and bark inclusion should be rotated frequently (Koch 1985; Springer 1979), however, frequent rotation is costly in both time and resource utilization.

## Other Considerations for Chip Storage

Compaction has been shown to decrease the rate of pulp chip deterioration due to fungal activity (Bois, Flick, & Gilmer 1962). It should be noted that pulp chips do not contain a significant amount of bark, and that chip pile fires require adequate amounts of oxygen to begin and persist. Another study indicated that compacted chips from logging residues cause the average temperature of a compacted chip pile to be 15°C less than a non-compacted pile (Nurmi 1999).

It has also been observed, however, that compaction can inhibit vertical airflow in the pile, which can then lead to increased pile temperatures (Buggeln & Rynk 2002). The pile temperatures increase because heat cannot be released as quickly as it is produced. This heat can lead to spontaneous combustion of the pile (Beever 1982; DeHaan 1996).

The biological degradation of wood chips emits significant amounts of carbon dioxide and methane (Wihersaari 2005; Zoch, et al., 1976). Both methane and carbon dioxide are greenhouse gases generally regarded as having a negative impact on the Earth's climate. In addition to the material yield perspective, rapid use of wood materials, as opposed to long-term storage, is better for the environment (Wihersaari 2005).

## Summary

The use of wood for energy can be a sustainable practice. Preferably, wood residues stored outside and destined for sustainable energy production should have adequate airflow and should be protected from the rain and snow; however, the costs of protection may be prohibitive. In a world of increasing energy demands, proper management and rapid inventory turnover can help make wood a part of a renewable and sustainable energy portfolio.

## References

Beever, P. F. (1982) Characteristics of spontaneous fires. *Journal of Occupational Accidents*, 3, 299-305.

Bergman, Ö. (1973). Wood substance loss in some chip Storage experiments. In *IUFRO Symposium* (pp. XVII-1 – XVII-28). Stockholm: Institutionen för Virkesäla, Skogshögskolan.

Bergman, Ö. (1974). *Thermal degradation and spontaneous ignition in outdoor chip storage*, (Research Notes Nr R 91). Stockholm, Sweden: Institutionen för Virkesäla, Skogshögskolan.

Bois, P. J., Flick, R. A., & Gilmer, W. D. (1962). A study of outside storage of hardwood pulp chips in the Southeast. *Tappi*, 45(8), 609-618.

Buggeln, R. (1999). Outside storage of wood chips. *Biocycle*, 40(6), 32-34.

Buggeln, R. & Rynk, R. (2002) Self-heating in yard trimmings: Conditions leading to spontaneous combustion. *Combustion Science and Utilization*, 162-182.

Cleenwerck, I. & De Vos, P. (2008). Polyphasic taxonomy of acetic acid bacteria: an overview of the currently applied methodology. *International Journal of Food Microbiology*, 125(1), 2-14.

Cole, A. H. (1972). Chip pile fire. *Pulp and Paper Magazine of Canada*, 73, 137-140.

DeHaan, J. D. (1996). Spontaneous ignition part I: What really happens. *Fire and Arson Investigator*, March, 13-17.

Dinus, R. J., Payne, P., Sewell, M. M., Chiang, V. L., & Tuskan, G. A. (2001). Genetic modification of short rotation popular wood: properties for ethanol fuel and fiber production. *Critical Reviews in Plant Science*, 20(1), 51-69.

Duff, S. J. B. & Murray, W. D. (1996). Bioconversion of forest products industry waste cellulosics to fuel ethanol: a review. *Bioresource Technology*, 55, 1-33.

Federal Woody Biomass Utilization Working Group. (2010). *Woody Biomass Feedstock Yard Business Development Guide: A resource and business guide to developing a woody biomass collection yard*. Retrieved July 27, 2010 from http://www.forestsandrangelands.gov/Woody_Biomass/documents/feedstock_yard_guide.pdf.

Feist, W. C., Springer, E. L., & Hajny, G. J. (1973). Spontaneous heating in piled wood chips – contribution of bacteria. *Tappi*, 56(4), 148-151.

Ferraro, F., Lohrer, C., Schmidt, B. M., Noll, M., & Malow, M. (2009). A mathematical model to predict the heating-up of large-scale wood piles. *Journal of Loss Prevention in the Process Industries*, 22, 439-448.

Foust, T. D. Wooley, R., Sheehan, J., Wallace, K., Ibsen, D., Dayton, D, et al. (2007). *A National Laboratory Market and Technology Assessment of the 30 × 30 Scenario*, (NREL/TP-510-40942).

Koch, P. (1985). *Utilization of hardwoods growing on southern pine sites* (USDA Forest Service Agriculture Handbook Number 605).

Lehtikangas, P. (2000). Storage effects on pelletised sawdust, logging residues, and bark. *Biomass and Bioenergy*, 19, 286-293.

Lindgren, R. M. & Eslyn, W. E. (1961). Biological deterioration of pulpwood and pulp chips during storage. *Tappi*, 44(6), 419-429.

Nurmi, J. (1999). The storage of logging residue for fuel. *Biomass and Bioenergy*, 17, 41-47.

Perlack, R.D., Erbach, D.C., Wright, L.L., Turhollow, A.F., & Graham, R.L. (2005). *Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply*. Tennessee: Oak Ridge National Laboratories. (NTIS No. PB2005-108232).

Springer, E. L. (1979) *Should whole-tree chips for fuel be dried before storage?* (USDA Forest Service Research Note FPL-0241).

Smith, R. S. & Hatton, J. V. (1971). Economic feasibility of chemical protection for outside chip storage. *Tappi*, 54(10), 1638-1640.

White, M.S., Curtis, M. L., Sarles, R. L., & Green, D. W. (1983). Effects of outside storage on the energy potential of hardwood particulate fuels: Part II higher and net heating values. *Forest Products Journal*, 33(11/12) 61-65.

White, M. S. & DeLuca, P. A. (1978). Bulk storage effects on the fuel potential of sawmill residue. *Forest Products Journal*, 28(11), 24-29.

Wihersaari, M. (2005). Evaluation of greenhouse gas emission risks from storage of wood reside. *Biomass and Bioenergy*, 28, 444-453.

Zoch, L. L., Jr., Springer, E. L., & Hajny, G. J. (1976). *Storage of aspen whole-tree chips under laboratory conditions*. (USDA Forest Service Research Paper FPL 288).

Visit www.ces.purdue.edu/bioenergy for free, downloadable copies of all of the publications in the Purdue Extension BioEnergy series.

PURDUE AGRICULTURE

Produced by Agricultural Communication New 01/11