OVERVIEW OF LIFE CYCLE ASSESSMENT OF TREATED TIMBER PRODUCTS

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Summary

The Life Cycle Assessment (LCA) is a tool that can be used in an attempt to evaluate the environmental and health impacts associated with the manufacture, use and ultimate disposal of the product. The assessment requires an accurate inventory of energy and raw materials inputs and an inventory of outputs including water effluents, air emissions, solid waste, other releases and usable products. Some outputs may be recycled. The rest are subject to waste management. Sufficient data must be available on preservative treated wood products in order to enable a "cradle to grave" mass-balanced inventory and environmental and human health impact analysis of the type described in this paper. There are not presently available sufficient data on air emissions and environmental fate to complete an all-embracing LCA of treated wood products. However, any attempted analysis of the environmental impact of treated wood products should also consider the other options--do without the product or consider the environmental impact of the alternatives. Decision makers should make no assumptions based on perceived environmental effects of alternate materials. An LCA comparison should be made between competing materials based on the best available data.

1. Introduction

Life Cycle Assessment (LCA) is also known by other names such as Life Cycle Analysis, Eco-Profiling and Resource and Environmental Profile Analysis. It is a new and rapidly evolving form of systems analysis that is beginning to be used by industry and governments to evaluate the total, or "cradle to grave" environmental impact of a product, an operation or an entire industry. Most Life Cycle Assessments consider the energy and raw materials used to manufacture or produce a product and the wastes released to the environment. A comprehensive assessment considers the environmental impact of producing the raw materials and energy that are needed to produce the product and the environmental impact of the wastes produced from the raw material production as well as the wastes produced from the manufacture or production of the product. The assessment includes a study of the environmental fate of the wastes, such as byproducts of biodegradation and combustion and/or the benefits of recycling and the use of alternate raw materials. Thus, the term "cradle to grave" has been coined.

This overview of LCA will serve only as a introduction to the subject. The methodology of accomplishing an LCA has been extensively reviewed (Assies, 1991; Erlandsson *et. al.*, 1992; Smith *et. al.*, 1993; and Udo de Haes, 1992). The LCA of treated wood poles has been discussed (Erlandsson *et. al.*, 1992). An LCA on wood harvesting was presented (Lubkert, 1991) which described the various energy requirements, exhaust gases, effluent waters and bark and other wood wastes. The problems associated with the disposal or recycling of treated wood waste were discussed (Voss and Willeitner, 1993), and some answers with respect to extraction of the arsenic and metals from treated wood waste (Honda *et .al.*, 1991; Stephan *et. al.*, 1993) and combustion of the heavy metal treated wood waste (Cornfield *et. al.* 1993; Pasek and McIntyre, 1993) have been published. The reader is referred to these papers for a more in-depth discussion of these subjects.

2. The Holistic Approach

As legislative controls and consumers' sympathies over environmental issues become more sophisticated, industry is recognizing the need to evaluate the mass-balance and fate of toxic chemicals used in operations and released to the environment. However, the environmental impact of a product, an operation or an industry includes much more than accounting for the chemicals used in processing. Consider, for example, the gasses of combustion that are released to the atmosphere each year by the burning of grain or sugar cane fields or clearcut forest land prior to site preparation and replanting. Consider the toxic gasses such as PAHs and greenhouse gasses released to the environment by the kilning of cement rock and limestone for the production of Portland cement, or the production of immense quantities of mining wastes such as gangues or arsenopyrite from leaching operations used in the production of gold, copper, cobalt, silver, antimony and other metals. These wastes may include selenium, arsenic, cyanide and heavy metals such as lead. Consider the wastes produced and space required for strip mining for coal, required for the generation of energy used in production of steel and aluminum.

> The Society for Environmental Toxicology and Chemistry defined LCA as, "an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and material uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements. The assessment includes the entire life-cycle of the product, process or activity, encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling and final disposal."

This definition describes an holistic approach to environmental management. This approach is based on comprehensive inventorying and evaluation of various cumulative environmental impacts. The scope of an LCA determines what issues are taken into account. The variety of issues ranges from energy analysis to human health, ecological stability, resource use, habitat modification, noise pollution or social and economic factors such as the loss of jobs and resultant effect on small communities. Some LCAs concentrate on only the negative environmental or health effects of an operation or a product. Others include social or economic issues such as a consideration of benefits as well as risks, similar to an environmental impact statement. These benefits might include an analysis of the positive outputs of a product or operation such as avoiding the use of alternate materials that would require greater energy, produce greenhouse gasses or increased air pollution.

The more comprehensive LCAs require a considerable accumulation of data, expert panel assessments, quantitative methods in which computer models are used to manipulate quantitative information on releases, rates, interrelationships of variables under different assumptions of production or changes in the underlying parameters affecting inputs and outputs.

The components of a Life Cycle Assessment that were mentioned in the definition include:

Inventory
Impact Analysis
Improvement Analysis

3. Life Cycle Inventory

The complete and accurate identification and quantification of the inputs and outputs is the most important aspect of the LCA, because exaggerated estimates and assumptions can lead to grossly inaccurate economic, health and environmental impact analyses. The types of data required may include:

A) Raw materials acquisition and energy inventory including fuels, water, minerals extraction, infrastructure, roads and buildings

B) Manufacturing, processing and formulation inventory including feed stocks on-site storage and handling, receipt through final product packaging and distribution. This inventory includes inputs and outputs. It includes the conversion of gaseous wastes to liquids or solid wastes (or byproducts for sale). For example, a large smelter in Canada converted polluting sulfur dioxide from the stack to ammonium sulfate fertilizer and made a profitable byproduct for sale. Another Canadian smelter converted a waste arsenical flue dust to copper arsenate for sale to CCA wood preservative producers.

C) Distribution and transportation inventory includes energy, air emissions and noise.

D) Use, re-use and maintenance. The inventory ends when the product is discarded for recycling or disposal.

E) Recycling. The recycling can be classified as pre-consumer recycled materials (drums, strapping, chips and bark) and post-consumer recycled materials, which are materials that have been separated from solid waste. An example of the latter is utility poles that are recycled as bumper logs for parking lots or as a fuel for firing electric power plants.

F) Waste management includes wastes to air, water or land disposal.

The Life Cycle Inventory global or holistic approach is to include all raw materials taken from the environment as inputs, and the outputs are either useful products or wastes. Mass balances are calculated within and between all subsystems and a sensitivity analysis should be performed and all assumptions justified. Figure 1, taken from Smith *et. al.*, (1993) illustrates the components of the Life Cycle Inventory.

4. The Life Cycle Impact Analysis

The Life Cycle Impact Analysis is a technical, quantitative and/or qualitative process to classify and evaluate the effects of the inventory components. These effects range from energy consumption, human and ecological health to noise, resource use and social and economic aspects. There is no accepted standard on which issues should be covered, So this outline adds some positive outputs to an otherwise medium-oriented or effect-oriented approach. Table 1 lists some effects to consider, most of them generally considered adverse to health and the environment. Table 2 lists some effects, related to treated wood and forest products, that are positive outputs from the use of wood instead of steel or concrete for building materials, railroad ties, highway sound barriers, guard rail posts and utility poles. The adverse health and environmental effects of treated wood in an LCA should be compared to the adverse health and environmental effects of using alternate materials.

It is illustrative to consider the comparison of energy requirements to manufacture wood products versus concrete, steel and aluminum and to consider the greenhouse gasses released from the production of concrete. Concrete is made from Portland cement. Cement rock used to make Portland cement contains 33 to 37% carbon dioxide as carbonate, and the lime used in cement comes from limestone, which contains 40 to 44% CO_2. The roasting of these materials in about 180 US cement kilns to produce about 77 million tons of Portland cement per year each operating day releases about 263,000 tons of CO_2. In addition, the kilns burn over 8 million tons of coal and other solid fuels including old tires and hazardous waste, releasing methane, CO_2 and other various gases to the environment. These facts should be considered in an impact analysis of alternative materials.

The energy requirements for extraction, manufacturing and transportation of a ton of concrete block is three times greater than a ton of lumber, seventeen times greater for steel and seventy times greater for aluminum than for wood. Carbon emissions from energy use in manufacturing 100 square feet of interior framing are 2.5 times greater when steel framing is used than when wood framing is used. Many examples can be calculated, using facts and figures such as the following:

1. Reinforced concrete requires 8.3 times as much energy as wood per unit of tensile strength.
2. Reinforced concrete requires 8 to 14 times as much energy as wood per unit of modulus of rigidity.
3. Reinforced concrete requires 6 times as much energy as wood per unit of fatigue strength.
4. Any plastic requires over 10 times more energy than concrete per unit of fatigue strength, or from 40 to 150 times more energy than wood per unit of fatigue strength.

Emissions should be considered on the basis of their:

1. Harmful effects on man, animals, plants or ecosystems (such as the aquatic food chain) or other targets such as stratospheric ozone or global atmosphere.
2. Persistence in the environment.
3. Mobility or dispersion tendency (fugacity).
4. Accumulation in sediments or fatty tissue of fish, birds and man.
5. Synergism with other substances or transformation products.

The evaluation of these hazards and risks may involve a point system that scores the various considerations and the cost of remediation of the impact.

5. Life Cycle Improvement Analysis

The Life Cycle Improvement analysis may include recommendations for substituting alternative chemicals as wood preservatives, modifying forestry practices, reducing environmental releases by process changes (such as closed steaming or kiln drying of poles) or retrofitting waste management systems to more effectively control emissions (such as cooling creosote-treated ties by use of a cold water bath before opening cylinder door).

An LCA should not always consider only the perceived negative environmental effects. By definition, any preference or comparison of chemicals, products or activities includes some sort of arbitrary judgment as to what is a preferred environment or preferred state of nature. Undisturbed nature is not benign. It is not in perfect harmony or in a delicate state of balance. It often is violent. Consider the lightning-caused wildfires that destroyed the forests of Yellowstone National Park. Change and turmoil, disorder and chaotic activity are the rule rather than constancy and balance. This is the Second Law of Thermodynamics which rules throughout the universe and man can not change it.

Disturbance by man often improves the environment. In the U.S. net annual growth of timber has increased 62% since 1952, and growth per acre has increased 71%. Standing timber volume per acre in U.S. forests is 30% greater than in 1952. Total annual forest growth exceeds harvest by 37%.

These practical benefits were achieved by the controlled use of forest practices including clearcutting, burning and planting. Today's kinder, gentler forestry includes a return to thinning and creating diversity in the forests. These changes are recommended where there is a concern for wildlife habitat and food chain. These are examples of Life Cycle Improvements from the raw material side and they are associated with a certain cost. For example, wildlife trees left standing are candidates for blowovers unless they are very large with huge root systems, and thinning is a more expensive form of harvesting than clearcutting.

Therefore, product, process or activity improvement can be directed towards mitigating negative impacts on health and the environment, but the costs of any improvements should be thoroughly evaluated. There is usually a rule of diminishing returns as the price increases, so decision makers should cautiously evaluate the costs of eradicating miniscule releases of environmentally noxious agents versus the benefits of doing so. The LCA of a product, process or activity should be put in perspective with health and environmental impact of the alternate decisions and the risks associated with living in concert with nature.

References

Assies, J. 1991. State of the art. in *Life Cycle Assessment, Proceedings of the SETAC-Europe Workshop on LCA*, Leiden, The Netherlands, 2-3 December, 1991.

Cornfield, J.A., S. Vollam and P. Fardell. 1993. Recycling and disposal of timber treated with waterborne copper based preservatives. *Inter. Res. Group on Wood Preserv.* Document No: IRG/WP/50008. 19 pp.

Erlandsson, M., K. Odeen and M-L Edlund. 1992. Environmental consequences of various materials in utility poles - a life cycle analysis. *Inter. Res. Group on Wood Prreserv.* Document No: IRG/WP/3726. 14 pp.

Honda, A., Y. Kanjo, A. Kimoto, K. Koshii and S. Kashiwazaki. 1991. Recovery of copper, chromium and arsenic compounds from the waste preservative-treated wood. *Inter. Res. Group on Wood Preserv.* Document No: IRG/WP/3651. 8 pp.

Lubkert, B. 1991. IDEA i an international database for ecoprofile analysis. A tool for decision - makers. IIASA, Laxenburg, Austria.

Pasek, E.A., and C. McIntyre. 1993. Treatment and recycle of CCA hazardous waste. *Inter. Res. Group on Wood Preserv.* Document No: IRG/WP/50007. 20 pp.

Smith, S.R., R.J. Murphy and D.J. Dickinson. 1993. A methodology for the life-cycle assessment of treated timber products. *Inter. Res. Group on Wood Preserv.* in Document No: IRG/WP/50001. 18 pp.

Stephan, I., H.H. Nimz and R.D. Peek. 1993. Detoxification of salt impregnated wood by organic acids in a pulping process. 1993. *Inter. Res. Group on Wood Preserv.* Document No: IRG/WP/50012. 11 pp.

Udo de Haes, H.A. 1992. Progress report on LCA. Paper presented at the LCA Symposium in Potsdam, Germany, 25-26 June, 1992.

Voss, A., and H. Willeitner, 1993. Possibility and problems of characterizing treated wood after service with regard to disposal. *Inter. Res. Group on Wood Preserv.* Document No: IRG/WP/50006. 6 pp.

Table 1. EFFECTS TO CONSIDER

Inputs:

- Scarce, renewable resources
- Non-renewable resources

Negative Outputs:

- Global warming
- Ozone Depletion
- Human Toxicity
- Environmental toxicity
- Acidification
- Eutrophication
- Photo-oxidant formation
- Space requirements
- Nuisance (smell, noise)
- Occupational safety
- Effects of waste heat on water

Table 2. POSITIVE OUTPUTS (treated wood and other forest products)

Increased employment
Lower annual cost
Increased oxygen output
Decreased carbon dioxide output
Increased carbon storage
Decreased air pollution
Lower energy requirements
Increased habitat diversity

Figure 1. Life Cycle Inventory