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"LIFE CYCLE ANALYSIS: ITS PLACE IN WASTE MANAGEMENT"

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Introduction

For the last thirty years in the United States, waste generation rates have risen each year. With the use and disposal of consumer products representing 80% of the municipal solid waste (MSW) stream, it would seem logical for decision makers to target consumer product wastes as an area of concern and opportunity to reduce waste generation rates. Solid waste management decision makers have recognized Integrated Solid Waste Management (ISWM) as a concept combining several techniques to manage distinct elements of the waste stream and encourages an ISWM plan to assist the decision maker in taking a systems approach to the problem. The components of the waste management "hierarchy" - source reduction, recycling, treatment and disposal, all complement each other as the decision maker prepares a strategic plan. Unfortunately, decision makers are making costly decisions about waste streams with only limited information. Consumers demand information about products before comparing features and values, and making choices, and producers have a good knowledge of what is happening within the firm to produce consumer products, yet MSW decision makers look only at the waste stream and select where it is to go in the "hierarchy." MSW decision makers do not have the data necessary to make an informed choice. This paper describes a systems concept known as life cycle analysis, and its place in waste management. Much of the input for this presentation is a result of an invitation by the International Solid Waste Association (ISWA) to submit an article for the ISWA Yearbook on LCA and MSW management, along with twenty-six years experience working with EPA's Solid Waste Program and Pollution Prevention Research Program.

Product systems should be for the entire life of the product including disposal. ISWM should include the entire system to determine the real environmental impacts. Without considering the entire system, a decision to increase recycling as part of the ISWM plan may appear to be a long-term solution, only to discover after capital expenditures that certain recyclables in a waste stream may be eliminated through source reduction. With producers looking at consumer products in a broader view, it would be prudent for MSW decision makers to follow the trends that will change the waste stream and adjust their strategic plan accordingly. One trend is volume-based fees on MSW which provide the generators with incentive to reduce waste at the source or through increased recycling efforts. Another trend is that of producers and consumers becoming more informed about source reduction which will bring about changes in the waste stream. The emergence of regulations that makes it more difficult to site a treatment or disposal facility or indicates bans on certain wastes such as yard waste is a trend that will affect the waste stream. Waste management decision makers need dynamic tools to manage a changing population's waste stream. Bold new initiatives are being implemented to reduce waste and bold new thinking is needed to look beyond the immediate environmental impact to all environmental impacts.

When the waste management hierarchy is fully understood by waste management decision makers, there seems to be agreement that reducing waste is one of the correct objectives. Reducing waste at the source requires analyzing the waste stream and making appropriate adjustments such as a process change, material change and/or operational change. There is a management gap between these adjustments to reduce waste by the producer and consumer and the actual management of the generated wastes by the waste management professional. The LCA concept supports the producer, consumer, and waste management professional in taking a systems approach in determining and understanding the waste stream. With the use of LCA the product (which is a combination of resources) can be analyzed to determine how changes to these resources can favorably improve the product to have the least negative impact on the environment. Waste management has been an evolutionary rather than revolutionary process in the United States which has found a niche within the existing social-economic-political structures. There are a number of difficult environmentally related issues when considering product differentiation and product development, and what appeals to the consumer in the marketplace. In brief, product development and product differentiation will enhance consumer satisfaction over time (evolutionary), and consumers who are informed and act rationally will seek quality products at low prices. Eventually the economics of the allocation of resources through products will provide the consumer with what is wanted and what is good for the environment. With a price system as a means for allocating resources within our framework of American capitalism, we will have some difficulty with the operation and efficiency of incorporating environmental issues with resource issues. This difficulty will expand as we work together on global environmental problems and economics will be the driving force and language of environmental issues for the third millennium.

Integrated Solid Waste Management and Life Cycle Analysis

When looking at a product's cradle-to-grave life, ISWM comes near the end of the cycle when the decision maker is determining which of several alternative waste management techniques to manage and dispose of specific components of the waste stream. At this point it is difficult to take advantage of source reduction, the most preferred technique in the hierarchy, because a waste already exists. The waste management decision maker is more likely to consider recycling, composting, energy recovery, and landfilling because of a missed opportunity to consider source reduction. The waste management decision maker can encourage source reduction and can even provide incentives for source reduction, but the producer and consumer controls the potential waste stream. The waste management decision maker can be an effective member of a product systems team that tracks the product from its inception to disposal.

When it comes to MSW, current thinking tends to be focussed strictly on the waste rather than on the consumer product. To offset the landfill capacity crisis (as in parts of the US), MSW professionals generally think that the solution is to divert material going to the landfill. If a product that is being manufactured cannot easily be recycled, re-design is encouraged to make it recyclable. What is missing is thinking about the secondary impacts that these changes have on the product system as a whole. This thinking is "Life Cycle Analysis (LCA)." In Europe, the term "ecobalance" is used more frequently. LCA consists of looking at a product, production process, packaging, or activity from its inception to its completion. The basic stages included in a life cycle are raw materials acquisition, manufacturing, use/reuse/maintenance, and recycle/waste management.

LCA addresses the realization that solving one problem almost always creates others. For example, a manufacturer may substitute a toxic, chlorinated solvent with an aqueous cleaner. However, the effects of the production and disposal of the new cleaner must be taken into account as well as the fact that more aqueous cleaner may be required than the original solvent to do the same job in some cases. The tradeoff here is increased quantities for decreased toxicity.

A complete LCA can be viewed as consisting of three complementary components:

> Inventory Analysis - identification and quantification of energy and resource use and waste emissions;
>
> Impact Analysis - the assessment of the consequences that identified wastes have on the environment; and
>
> Improvement Analysis - the evaluation and implementation of opportunities to effect environmental improvement.

A properly conducted life cycle inventory analysis will account for total energy and resource requirements, atmospheric emissions, waterborne effluents, and solid wastes for a specific system. The system boundary is drawn around parts or all of the life cycle stages and then the LCA technique is applied within the constraints of the system boundary. This system flow diagram for the life cycle stages is illustrated in Figure 1. To date, there has been little documentation which addresses a systems approach for evaluating environmental impact. To begin filling this systems approach gap, the EPA recently completed a guidance manual which provides impartial guidelines for conducting the inventory analysis component of an LCA. While inventory analysis is a fairly straightforward, basic engineering approach to quantifying environmental releases, the approach to translating the potential, broad impacts to human and ecological health and welfare is much more difficult. The US EPA continues to study the impact analysis component within the LCA research program. The improvement analysis component requires research which builds upon what is being learned through applying inventory and impact analysis. Currently there is limited RD&D activity for this component.

It is argued that a modern company that produces any consumer product can only claim to be a good steward of the earth if it practices LCA. One example of ISWM and LCA working together is the encouragement of improved, environmentally conscious packaging. Today, about one-third of all MSW by weight is product packaging. Better packaging design can reduce the quantity of wastes generated and make a tremendous impact on the quantity and characteristics of the MSW stream. Packaging for the MSW decision maker is usually seen first with waste collection, however it would be to the consumer's advantage to have the MSW professional be part of the producer's design team. LCA is the approach that producers can use to consider the total impact on the environment. The producer listens to the consumer with the use of marketing surveys, toll-free numbers, and demand for the product. The producer will also listen to the consumer regarding environmental concerns, particularly when it will increase the consumer's costs. With the trend for stricter and more expensive MSW management, it would be wise for the producer to seek the advice of the MSW decision maker to serve the consumer better. This partnership with the producer, consumer, government and waste professional truly reflects ISWM and encourages the acceptance of LCA principles.

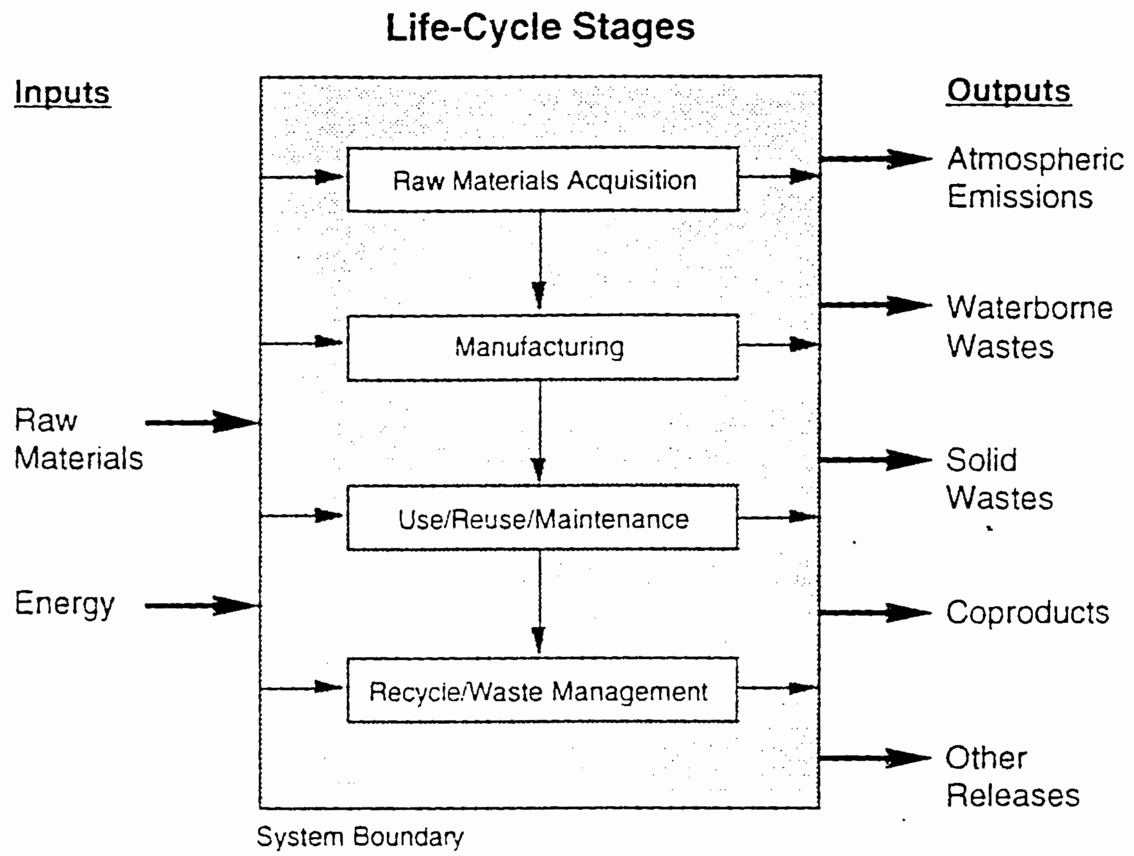

Figure 1
Defining system boundaries

Figure 1. Life Cycle Stages

Interpretation and Application of LCA Principles

There appears to be a lack of clarity in interpreting the actual environmental impacts that has lead to confusion when presenting the results of a life cycle study to the public. LCA results can enlighten consumers and manufacturers when faced with the choice between different products which serve a similar function. One well known, and highly debated, example is reusable, cloth diapers versus disposable diapers. The solid waste professional would, no doubt, opt for the use of reusable cloth diapers reducing the impact on the MSW system, however the local government environmental authority must consider other environmental impacts regarding water and energy.

A life cycle study conducted by Franklin Assoc. Ltd. in 1990 compares the two diaper systems. The report, which provides only inventory data and does not attempt impact analysis, gives results for water use, environmental emissions (atmospheric, waterborne, and solids), and energy use. For example, the data include industrial and postconsumer solid waste generation (volume) of the total solid waste of individual diaper systems among single use diapers, commercial laundering of cloth diapers, and home laundering of cloth diapers. Most of the solid waste from the single use diaper system is in the form of postconsumer waste, while the solid waste for the cloth diaper is primarily in the form of industrial waste. The single largest category of solid waste for both the commercial and home systems is wastewater treatment sludges. The data show that the single use diaper system produces about two times the volume of total solid waste produced by the composite cloth diaper. For total waterborne wastes, the reusable, composite cloth diaper produces over seven times as much wastes as the single use diaper system when the weights of all contaminated water are summed.

While the debate will continue over how data like these are generated, what assumptions are used, how the boundaries are drawn, etc., the point of the illustration is that difficult decisions may have to be made about resulting tradeoffs. In the diaper example, increased water and energy use and the resulting environmental emissions are the tradeoffs for decreased solid waste generation. This may also hold true for life cycle data collected on a single product where improvements are identified within the system. Tradeoffs may be found between the original product or process and the modified version which incorporates pollution prevention.

Because it can be costly to gather the quantitative and qualitative data needed to conduct an LCA, EPA's Risk Reduction Engineering Laboratory is developing methodologies and technical criteria which will result in less costly screening tools for evaluating or identifying pollution prevention alternatives. There may always be interpretation issues and controversy surrounding the use of LCA due to the need for judgements by the decision maker. This does not mean that the LCA concept should not be used due to an inability to collect all the available data or to assure complete confidence in the results. The LCA concept is a sound approach to gather and interpret data, and invoke sound judgement to make a decision. The more LCA is perfected for waste management issues, the more precise tool it will become.

Summary and Conclusions

Consumers, producers, government and waste professionals are the decision makers around the world who must work together to reduce the generation of MSW at the local level. The products produced in South America or Asia may have resources from Africa and Australia, and be consumed in North America or Europe. Generally, the product is disposed near the point of consumption. In this global economy, there is no assurance that the product produced in a country will be consumed in that same country. Life Cycle Analysis (LCA) is a tool to evaluate the environmental consequences of a product or activity holistically, across its entire life. For decision makers to choose environmentally sound products and for producers to encourage the practice of pollution prevention through the design, manufacture, use and disposal of their products, LCA can identify and evaluate opportunities to reduce environmental impacts. ISWM with LCA is a combination that requires the waste professional to cooperate with the producer and consumer in determining the best options for waste management at the local level. At the local level, elected officials face a myriad of politically unpopular decisions about MSW. LCA will provide the information to discuss tradeoffs and build cooperation among decision makers throughout the life of every product from "cradle to grave."

A combined LCA and ISWM systems approach to managing solid waste may seem theoretical and unrealistic, particularly to local jurisdictions where local elected officials are attempting to site a facility or increase collection/disposal rates. LCA is a powerful tool to assess the total waste stream and determine tradeoffs, and it will take patience and agreement from waste generating producers and consumers who have not traditionally considered environmental impacts. Like children, we stand on one foot and then on the other, waiting impatiently for technological solutions, so eager for the arrival that we miss the approach. Waste management decision makers must view themselves as a crucial part of the overall solution working with others up and down the life cycle stages which lead to the MSW stream.

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16. ABSTRACT

When the waste management hierarchy is fully understood by waste management decision makers, there seems to be agreement that reducing waste is one of the correct objectives. Reducing waste at the source required analyzing the waste stream and making appropriate adjustments such as a process change, material change and/or operational change. There is a management gap between these adjustments to reduce waste by the producer and consumer and the actual management of the generated wastes by the waste management professional. The LCA concept supports the producer, consumer, and waste management professional in taking a systems approach in determining and understanding the waste stream. With the use of LCA the product (which is a combination of resources) can be analyzed to determine how changes to these resources can favorably improve the product to have the least negative impact on the environment. The purpose of the paper is to discuss how LCA can be the tool to assist waste management decision makers.

17. KEY WORDS AND DOCUMENT ANALYSIS

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