EPA/600/A-93/112

"EPA's Life Cycle Methodology: Guidelines for Use in Development of Packaging"

Mary Ann Curran
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
Pollution Prevention Research Branch
Cincinnati, Ohio 45268
513/569-7837

Approaches to reducing environmental effects of products and processes have moved steadily upstream over the years from end-of-pipe controls to source reduction and recycling of hazardous waste, and more recently, toward multimedia pollution prevention. Life Cycle Assessment (LCA) continues the trend of expanding our view and approach to environmental protection. LCA takes a holistic approach by analyzing all the cradle-to-grave environmental releases and impacts associated with a product, process or activity.

HISTORY OF LCA'S

Although LCA has become a popular buzz word during the last 2 years, LCA's have been used by industry for over twenty years. The development of the LCA concept is generally attributed to Harry Teasley of Coca-Cola. In 1969, under Teasley's direction, a life cycle study of different beverage containers was conducted by the Midwest Research Institute.[1] In 1974, the EPA conducted a similar study to compare the life cycles of different beverage containers.[2] After completion of this study, EPA did not pursue LCA any further. Today, with pollution prevention and green product design as driving interests, LCA is finding rediscovered interest within both public and private sectors. This new found interest extends to Europe and other countries where LCA is typically referred to as "ecobalance."

PACKAGING LCA'S

An informal review of the open literature found 29 references to product life cycle studies, 17 of which are related to packaging materials or packaging systems. Beverage containers (cans, bottles and cartons) are the focus of ten of these studies. These packaging-related studies are provided in the bibliography at the end of the paper. (Contacts for getting copies of the reports are provided when known.)

SETAC WORKSHOPS

In August 1990, the Society of Environmental Toxicology and Chemistry (SETAC) organized a one-week workshop in Vermont to begin to address the need to develop a technical framework for conducting LCA's. EPA was one of several sponsors of this workshop. The workshop was attended 54 people who had expertise in conducting LCA's or in areas that are included in LCA's. The participants included representatives from government, industry, academia, consulting firms and environmental organizations.

The goal of the workshop was to determine the current state-of-the-art for LCA's and to identify research needs that would lead to improving the methodology. Improving and standardizing the methodology will hopefully encourage and facilitate a wider use of LCA's and ensure more meaningful results. The most significant output of the workshop was the consensus by the participants that an LCA can be divided into 3 components:

1) an inventory of the inputs and outputs associated with the full life cycle,

2) the translation of these inputs and outputs into environmental impacts, and

3) the identification of opportunities for lessening either the inventory inputs and outputs or the resultant impact on the environment.

A complete LCA would include conducting all three components.[3]

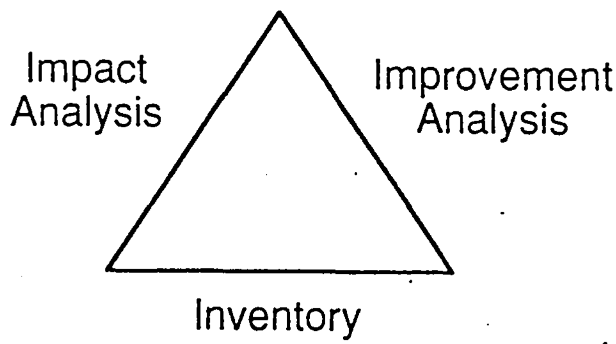
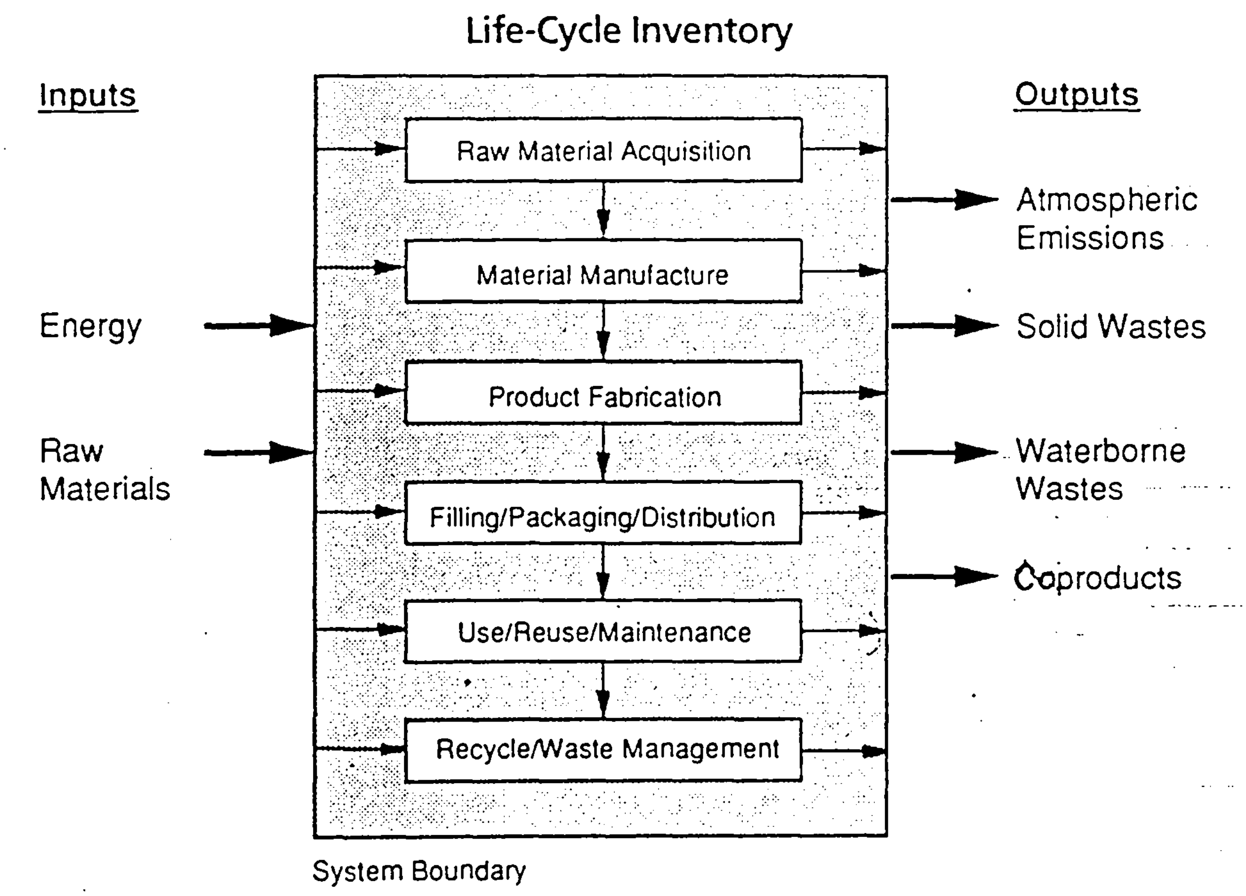


FIGURE 1.

SETAC hosted an additional two life cycle workshops. One was an impact analysis workshop which was held in Sandestin, Florida, in February 1992 and the other was a data quality workshop which was held in Wintergreen, VA, in October 1992. SETAC will be producing proceedings form these workshops, also. For information, call the SETAC Foundation at 904/469-9777.

METHODOLOGY

Life cycle refers to the cradle-to-grave stages associated with the production, use and disposal of any product. Figure 2 depicts all of the steps that must be accounted for in a complete life cycle assessment, although transportation is shown here as a separate stage, it should be accounted for in each of the other stages as transportation occurs. The goal of a life cycle inventory is to create a mass balance which accounts for all the inputs and outputs to the overall system. It emphasizes that changes made within the system may result in transferring pollutant between media or it may create upstream or downstream effects.



Defining system boundaries

FIGURE 2.

LCA is a useful tool for identifying such tradeoffs, however, current applications of LCA have not been performed in consistent or easily understood ways. This inconsistency has caused increased criticism of LCA. The EPA recognized the need to develop an LCA framework which could be used to provide consistent use across the board. Also, additional research is needed to enhance the understanding about the steps in the performance of an LCA and its appropriate usage. Research activities of the EPA's Pollution Prevention Research Branch in Cincinnati, Ohio, are leading toward the development of an acceptable method for conducting LCA's. This research has resulted in the development of a guidance manual for conducting life cycle inventories. The manual is intended to be a practical guide to conducting and interpreting the life cycle inventory.

A ten-step approach to performing a comprehensive inventory is presented in the manual along with the general issues to be addressed.

1) Define the Purpose
2) Define the System Boundaries
3) Devise a Checklist
4) Gather Data
5) Develop Stand-Alone Data
6) Construct a Model
7) Present the Results
8) Conduct a Peer Review
9) Interpret the Results
10) Communicate the Results

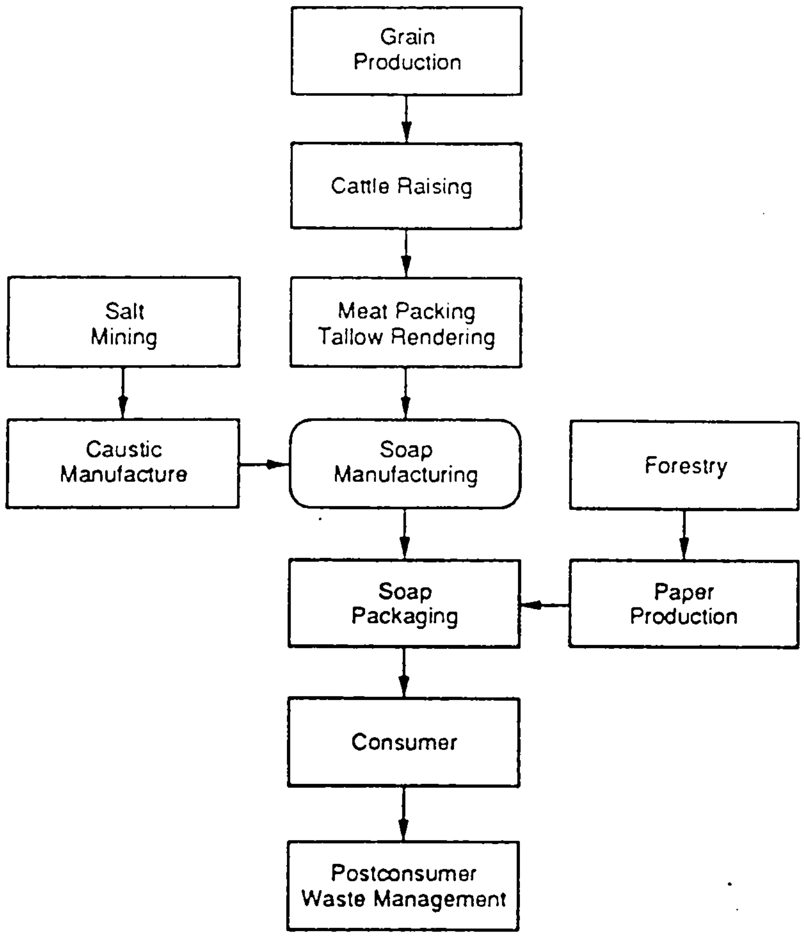
Define the Purpose

The inventory process begins with a conceptual phase to define both the purpose for performing the inventory and the scope of the analysis. The decision to perform an inventory is usually based on one of several possible objectives regarding a process, product, or activity. These objectives include the need to establish baseline information, to identify opportunities where reduction in resource use and emissions might be achieved, to compare alternatives, or to help guide the development of new designs. A clear definition of the purpose will help ensure that the results will be useful.

Define the System Boundaries

Once the purpose has been determined and the intended use is known, the system should be defined. "System" is defined generally as a collection of operations that together perform some defined function. Great care should be taken in defining the system to be analyzed and in explaining how the boundaries were drawn. Clearly set boundaries help ensure valid interpretation of the results and directly affect the outcome of the study. Two studies on the same product will have different outcomes if the boundaries are different.

The manual uses a theoretical bar soap as an example system. Even something as seemingly simple as a bar of soap becomes very complicated when all of the related life cycle stages are included. Figure 3 is a simplification of the steps that are involved in a bar soap life cycle.



Example system flow diagram for bar soap production

FIGURE 3.

Devise a Checklist

The inventory checklist is a tool that covers most decision areas in the performance of an inventory. A checklist guides data collection and validation It also leads to model building. Analysts need to develop a tailored checklist for a specific application so that all the important stages and categories of information are included.

Conduct a Peer Review

The need for peer review stems from concerns in four areas: 1) questioning the overall results, 2) lack of understanding regarding methodology or scope, 3) desire to verify data, and 4) communication of results. Peer review should be established and implemented early in any study. While an exact peer review process is yet undetermined, the process should address the four areas of concern.

Gather Data

Each subsystem requires inputs of materials and energy, requires transportation of products, and has outputs of products, co-products, solid waste, atmospheric emissions and waterborne wastes. Data is gathered for the amounts and kinds of material inputs and the types and quantities of energy usage. The environmental releases to air, water and land should be quantified by type of pollutant. Possible sources for data include facility-specific and averaged industrial data, government reports, reports in the open literature, product specifications, and laboratory test data.

Develop Stand-Alone Data

Stand-alone data must be developed for each subsystem to fit the subsystems into a single system. There are two goals to achieve this step: 1) present data for each subsystem consistently by reporting the same product output from each subsystem and 2) develop the data in terms of the life cycle of only the product being examined. A standard unit of output must be determined for each subsystem, for example, 1,000 tons of harvested trees or 1,000 tons of packaged product. The units for the subsystems do not have to be the same as that of the final product. Once the data are reported at a consistent level, the environmental releases to be attributed to each subsystem are calculated, usually on a weight basis.

Construct a Model

The next stage is model construction which incorporates the data into a computer spreadsheet or other accounting technique. The results from the model give the total picture of energy and resource use and environmental releases from the overall system. The overall system flow diagram is important because it numerically defines the relationships of the individual subsystems to each other in the production of the final product. It is important that each subsystem be incorporated in the model with its related components and that each be linked together in such a way that inadvertent omissions and double-counting do not occur.

Present the Results

When reporting the final results, it is important to thoroughly describe the methodology used in the analysis. The report should explicitly define the system and its boundaries. All assumptions that were made in performing the inventory should be clearly explained. The results can be presented most comprehensively in tabular form. Graphical presentation of information helps to augment tabular data and can aid in interpretation. The presentation format of data should be consistent with the purpose of the study and should not arbitrarily simplify the information solely for the sake of presenting it.

Interpret the Results

How the results will be interpreted depends on the purpose for which the analysis was performed. Careful interpretation is required to avoid making any unsupported statements.

Communicate the Results

In reporting life cycle inventory results, a timely, continuous approach is recommended. The steps to a continuous communication process include 1) identifying the intended audience or audiences early in the study, 2) determining the message to be communicated, and 3) selecting the methods that can most effectively be used to communicate with each audience. Throughout the development and application of the life cycle inventory method, the knowledge gap between analysts and audiences will close.

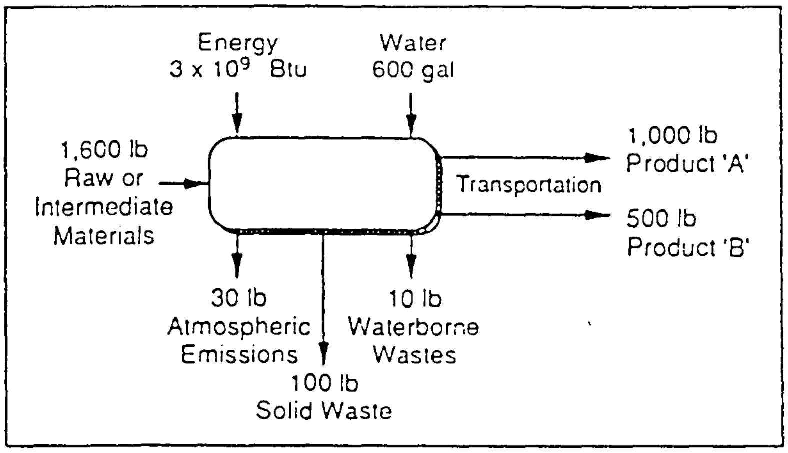
DECISION POINTS

Within the life cycle "community," there is general agreement on major elements that should be included in a life cycle inventory. However, decision points occur in the process of accounting for energy and environmental releases which lead to apparent differences in methods. For example, co-product allocation is one of these decision points. As seen in Figure 2, a typical process results in multiple products. In this example, our process makes 100 lb of product A and 500 lb of Product B. One simple way of allocating the environmental releases from the process among the products is using weight basis. Therefore, two-thirds of the releases would be attributed to A and one-third to Product B. However, weight basis is not the only possibility. Allocation could also be done by market share as well as other ways.

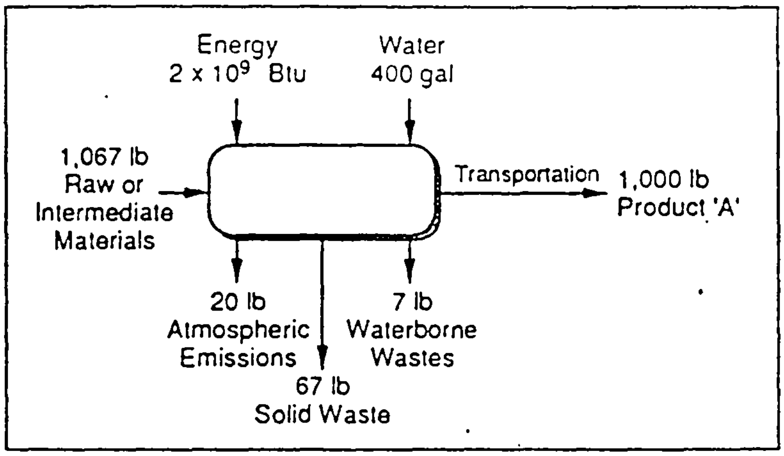
LIFE CYCLE DESIGN

LCA provides valuable information, but it does not provide a complete picture alone when determining the soundness of a product or process design. For a manufacturer to make an informed decision regarding the best use of resources to improve a product line, additional information is needed. This includes total cost assessment which brings external costs (for example, liability costs) into the calculations of production costs. It is important

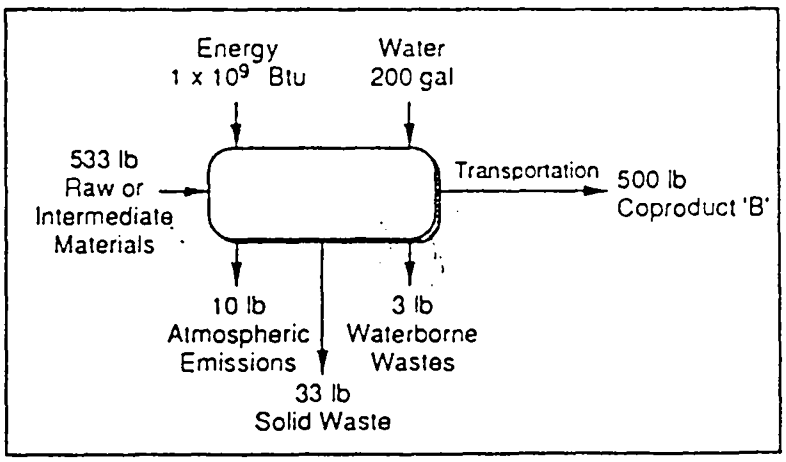
Actual process flow diagram for the production of Products 'A' and 'B'



Flow diagrams showing the normalized resources and environmental releases for each coproduct



Coproduct Allocation for Product 'A'



Coproduct Allocation for Product 'B'

FIGURE 4.
Example coproduct allocation based on relative weight

that the same boundaries be used for both the inventory study and the total cost assessment for continuity. Must also consider product efficacy to be sure that product changes do not affect the quality and effectiveness of the final product. Similarly, marketing studies must be conducted to ensure that new or modified products still meet consumers' needs. And, of course there are legal and environmental considerations which must be met. These five components together, when conducted concurrently, provide a sound basis for decision-making.

THE FUTURE OF LCA

EPA will continue its research efforts to develop LCA as a useful tool for industry to use in evaluating and improving products and processes. We will continue to investigate possible approaches to carrying out the impact analysis component, however, this appears to be a much longer-term research area. A more immediate need is to identify the major methodological differences recognized by leading LCA practitioners and begin dialogue between them which will lead to a consensus approach.

Continued research is also needed in the area of "streamlining" since the LCA process can be very time consuming requiring thousands of data points. Streamlining will possibly occur as more assessments are conducted and "blocks" of data become available for future studies. For example, information on the production of a standard cardboard carton of specified dimensions may be plugged into any system where such a carton is used.

A second approach to streamlining may exist in a type of "life cycle review" where environmental consequences are identified where they occur in any of the life cycle stages. The occurrences of these releases or impacts can be identified and accounted for through available literature, industry-specific data or through the use of an expert panel. While this approach appears to be have merit, especially in product design activities, an exact procedure for performing a life cycle review which yields verifiable results is yet to be developed.

References:

1. "'Life Cycle Analysis' Methodology, Policy Impact Studied," COPPE Quarterly, Volume 5, Number 1, Spring 1991.

2. EPA, "Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives," prepared by MRI, EPA/530/SW-91c, 1974.

3. Society of Environmental Toxicology and Chemistry, "A Technical Framework for Life Cycle Assessments," December 1991.

Bibliography of Packaging-Related LCA Studies:

EPA, "Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives," prepared by MRI, EPA/530/SW-91c, 1974. (National Technical Information Service, Springfield, VA, 22161, 703/487-4650)

"Resource and Environmental Profile Analysis of Plastics and Competitive Materials," prepared for the Society of the Plastic Industries by MRI, Kansas City, Missouri, 1974.

Hunt, R.G. & W.E. Franklin, "Resource and Environmental Profile Analysis of Beer Containers," Chemtech, August, 1975. (Franklin Associates, 4121 West 83rd St., Prairie Village, KS, 913/649-2225)

EPA, "Resource and Environmental Profile Analysis of Five Milk Container Systems," prepared by MRI, 1978.

Franklin Associates, Comparative Energy and Environmental Impacts of 21 PET and 11 Refillable Glass Bottles Used for Soft Drink Delivery Systems in Germany, Prairie Village, Kansas, 1985. (Franklin, above)

Franklin Associates, "Comparative Energy and Environmental Impacts for Softdrink Delivery Systems, Prairie Village, Kansas, 1989. (Franklin, above)

Lundholm, M.P. and G. Sundstrom, "Tetra Brik Asceptic Environmental Profile," printed in Sweden by AB Faelths Tryckeri, Varnamo, 1986 and 1989.

Franklin Associates, "Resource and Environmental Profile Analysis of Foam Polystyrene and Bleached Paperboard Containers," Prairie Village, Kansas, June 1990. (Franklin, above)

O.C.L. Mekel and G. Huppes, "Environmental Effects of Different Packaging Systems for Fresh Milk," September 1990. (CML, Leiden University, P.O. Box 9518, 2300 RA Leiden, The Netherlands, (0) 71 277461)

Martin B. Hocking, "Paper versus Polystyrene: A Complex Choice," Science, Vol. 251, February 1, 1991.

Vinyl Product Lifecycle Assessment," prepared for the Vinyl Institute, September 17, 1991. (Chem Systems, 303 South Broadway, Tarrytown, NY, 10591-5487, 914/631-2828)

The Tellus Institute, "Impacts of Production and Disposal of Packaging Materials - Methods and Case Studies," prepared for the Council of State Governments, November 1991. (Tellus Institute, 89 Broad Street, Boston, MA, 02110, 617/426-5844).

Lundholm, M.P. and Sundstrom, G., "Resource and Environmental Impact of Two Packaging Systems for Milk, Tetra Brik Cartons, and Refillable Glass Bottle."

Deloitte and Touche, "Tetra Pak Inc.: Summary Report Energy and Environmental Impact Profiles in Canada of Tetra Brik Aseptic Carton and Glass Bottle

Packaging Systems," 1991.

D.G. Koch and C.C. Kuta, "Assessing Environmental Tradeoffs: Procter & Gamble's Approach to Life Cycle Analysis," in Inside Environment, December 1991. (P&G Ivorydale Technical Center, 5299 Spring Grove Ave, Cincinnati, OH, 45217, 513/627-5584)

"Reusable versus Disposable: A Comparison of the Environmental Impact of Polystyrene, Paper/Cardboard and Porcelain Crockery," TAUW Infra Consult B.V., May 1992. (Commissioned by the Ministry of Housing, P.O. Box 450, 2260 MB Leidenschendam, The Netherlands, 70-317 4174)

Anne-Marie Tillman, H. Baumann, E. Eriksson, and T. Rydberg, Packaging and the Environment: "Life Cycle Analyses of Selected Packaging Materials; Quantification of Environmental Loadings," September 1991. (Chalmers Industrieteknik, S-412 88 Gothenburg, Sweden, +46 31 72 40 20)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before complet

1. REPORT NO. EPA/600/A-93/112	2.	3.
4. TITLE AND SUBTITLE EPA's Life Cycle Methodology: Gudelines for Use in Development of Packaging		5. REPORT DATE 11/9/92 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Mary Ann Curran		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS US EPA Risk Reduction Engineering Laboratory 26 W. Martin Luther King Drive Cincinnati, OH 45268		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Risk Reduction Engineering Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268		13. TYPE OF REPORT AND PERIOD COVERED conference paper 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

PACK EXPO '92, Chicago, IL, 11/9/92

16. ABSTRACT

Approaches to reducing environmental effects of products and processes have moved steadily upstream over the years from end-of-pipe controls to source reduction and recycling of hazardous waste, and more recently, toward multimedia pollution prevention. Life Cycle Assessment (LCA) continues the trend of expanding our view and approach to environmental protection. LCA takes a holistic approach by analyzing all the cradle-to-grave environmental releases and impacts associated with a product, process or activity.

An informal review of the open literature found 29 references to product life cycle studies, 17 of which are related to packaging materials or packaging systems. Beverage containers (cans, bottles and cartons) are the focus of ten of these studies. These packaging-related studies are provided in the bibiography at the end of the paper. The paper includes discussion of the history of LCA's, SETAC's involvement in LCA, EPA's guidance on life cycle inventory methodology, life cycle design, and the future of LCA.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
life cycle assessment life cycle analysis LCA cradle-toOgrave ecobalance		

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 12
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE