Environmental Life Cycle Assessment

For the U.S. Environmental Protection Agency

Asphalt Overlay & GSB-88 Sealer Binder

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A Case Study Performed for the

U.S. Environmental Protection Agency

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Abstract

The U.S. EPA has developed guidance for the use of Life Cycle Assessment (LCA) for environmentally preferable purchasing. To support the guidance development, pilot studies were performed, one of which is described here. The study was performed in only four months, using simplified impact assessment methodologies. It showed that one product was environmentally preferable. This pilot demonstrated that LCA's are feasible for the purpose of purchasing decisions.

Introduction

One of the important applications of Life Cycle Assessment is the procurement of environmentally preferable products. In theory, a full life cycle assessment will permit the purchaser to identify which products are preferable, and use that information to improve his or her own environmental performance. In practice, however, life cycle assessments can be very time consuming and costly, and the lack of a consistent format for performing them creates barriers to direct comparisons of products.

The U.S. Federal Government is under executive order to procure environmentally preferable products (Executive orders 12873 and 13101), and the U.S. EPA has an office (the office of the environmental executive) devoted to providing guidance on how to determine environmental preferability. EPA guidance does not require the use of LCA, but it does suggest that the assessment of multiple attributes and a life cycle approach would strengthen the quality of the decisions being made (64 FR 45809; http://www.epa.gov/opptintr/epp).

In support of the Environmentally Preferable Purchasing initiative, the Systems Analysis Branch of the EPA performed a study aimed at developing guidance for performing LCA's for purchasing. The requirements for the study were that any guidance would be:

- Easy to use
- Yield results in a timely manner
- Meet the needs of procurement officials and vendors
- Conform, as much as possible, to the requirements of DIS 14042 for comparative assertions

The outcome of the project was an initial formulation for a Framework for Responsible Decision-making (FRED), which would include both financial and LCA-based environmental assessments. As a first step, only the environmental assessment portion of FRED was elaborated in this document. The guidance limits the assumptions and number and types of analyses in order to simplify the LCA process.

The ISO DIS 14042 requires that the list of impact categories and category indicators be comprehensive. Based on expert opinion among the project group, the following impact categories were chosen:

- Global warming
- Stratospheric ozone depletion
- Acidification
- Eutrophication
- Photochemical smog
- Human Health (divided into carcinogenic and non-carcinogenic)
- Ecological Health
- Resource Depletion (divided into several sub-categories)

Several other types of impact categories were evaluated for consideration, for example, habitat loss or groundwater nitrification. However, it was not possible to identify generally accepted models for calculating indicators for these impact categories, and they were therefore excluded from the study. ISO 14042 requires that all impact categories be supported by natural science based models, thus supporting this decision. One of the weaknesses of the LCIA (Life Cycle Impact Assessment) methodology is that known impacts for which models have not been derived are automatically excluded from consideration.

Several different indicators and models were evaluated for these impact categories, and three pilot projects undertaken to test the feasibility of doing LCA's for the purpose of environmentally preferable purchasing. Two of these projects, (comparing insulation for housing, and comparing three different types of motor oil) were based on data previously gathered by NIST (National Institute of Standards and Technology) and available in a database representing U.S. industry averages. The third pilot was based on a comparison of two types of road treatment designed to prolong the life of asphalt roads. This last pilot was performed using data collected for this study from both industry sources and from a particular small vendor, Asphalt Systems Incorporated (ASI, Salt Lake City, UT). Gathering data from a small vendor over a short time frame was thought to be a good test of whether it would be possible to practically apply LCA methodology to purchasing decisions without unduly burdening small businesses. The road treatment pilot project is the subject of this paper.

The two road maintenance products evaluated represented two methods of maintaining roads: applying a thin layer (1.5 inches thick) of asphalt cement and applying a water based asphalt emulsion (GSB 88) containing a natural mineral product, gilsonite. Both of these products are applied to asphalt roads before significant deterioration has occurred (three to five years into the life of the road), and neither adds structural strength to the road. Each extends the life of the road considerably. The table below compares the characteristics of the two products.

Table 1 Description of the Products

	Asphalt Cement	GSB 88
Application	Spray of tack coat, followed by application, and steam rolling	One step spray application, and sand application
Composition	Asphalt mixed with aggregate	Asphalt, gilsonite, detergents and emulsifiers plus water diluent
Temperature of application	165□F or above	Ambient
Delay before traffic	1-2 hours	1 hour
Frequency of application	7-9 years	3-5 years

There are several other specialized methods for maintaining asphalt cement roadways, but these tend to be based on trade secret chemical compositions, and were not included in this study.

Methodology

System Function and Functional Unit and Audience

The function provided by the alternative products is the maintenance of good quality roads (five on a scale of ten, where 10 is the as built condition). The functional unit is twenty years of one lane mile. The inventory includes two application of the thin layer of asphalt cement, and five applications of the GSB 88.

The primary audience for this assessment was federal procurement officers. Secondary audiences included vendors, other officials and practitioners.

System Boundaries

The system studied included all unit processes except those used for the production of hydrochloric acid. This material comprised less that one percent of the total mass of the products, and it was expected from the composition of the materials that the acid would be neutralized in use, thus posing no significant environmental threat.

All inputs and outputs were accounted for as long as they comprised at least:
1. One percent of the mass
2. One percent of the energy, or
3. One percent of the expected toxicity scores

Primary data was not available for the asphalt production, but was gathered from published sources (EPA, American Petroleum Institute). Information on the production of the GSB 88 and the tack coat was obtained from the manufacturer, as was information on the application of the GSB 88, the tack coat and the thin layer of asphalt cement. The flow charts below identify the systems under study.

Information about the emissions and resource use associated with transportation and from the use of electricity was derived from the LCAdvantage database (Battelle, 1998). Electricity was assumed to be from the average U.S. Grid.

Figure 1

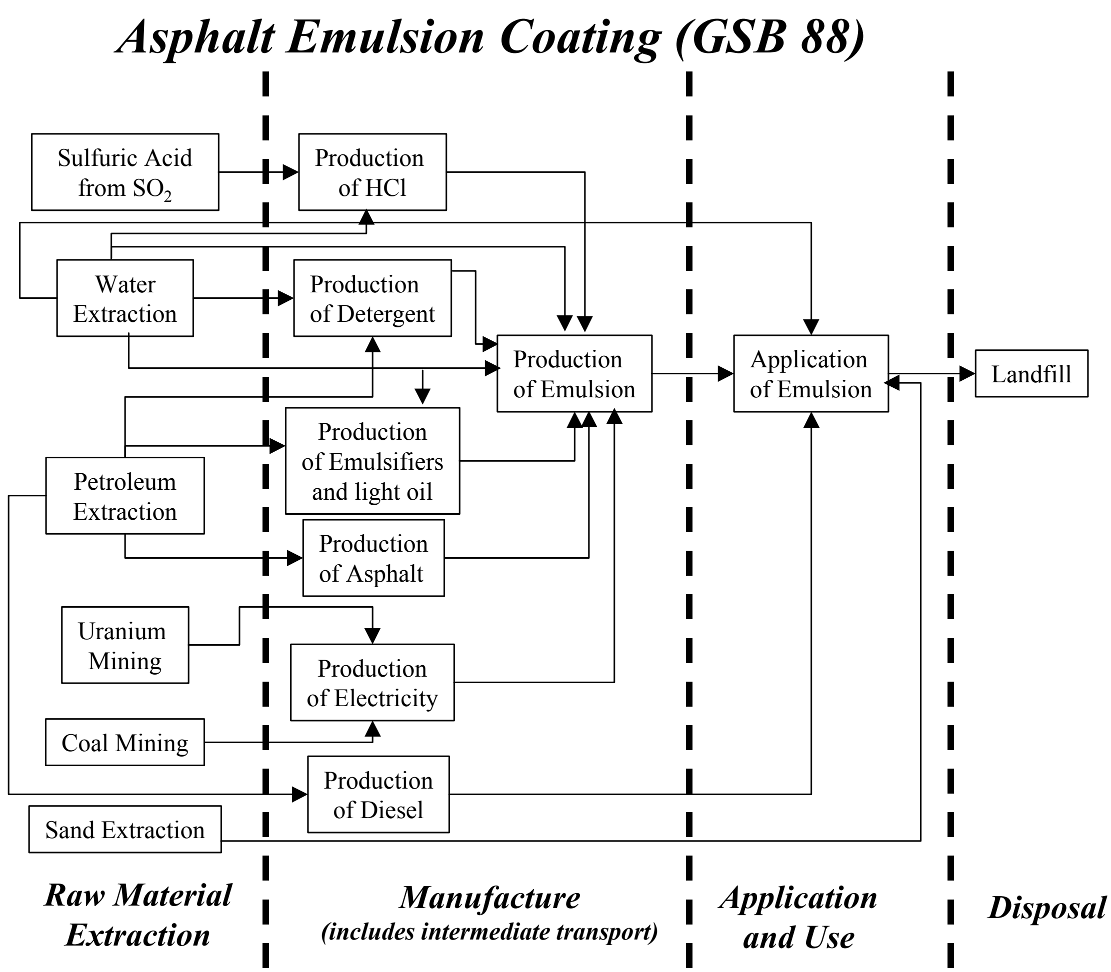
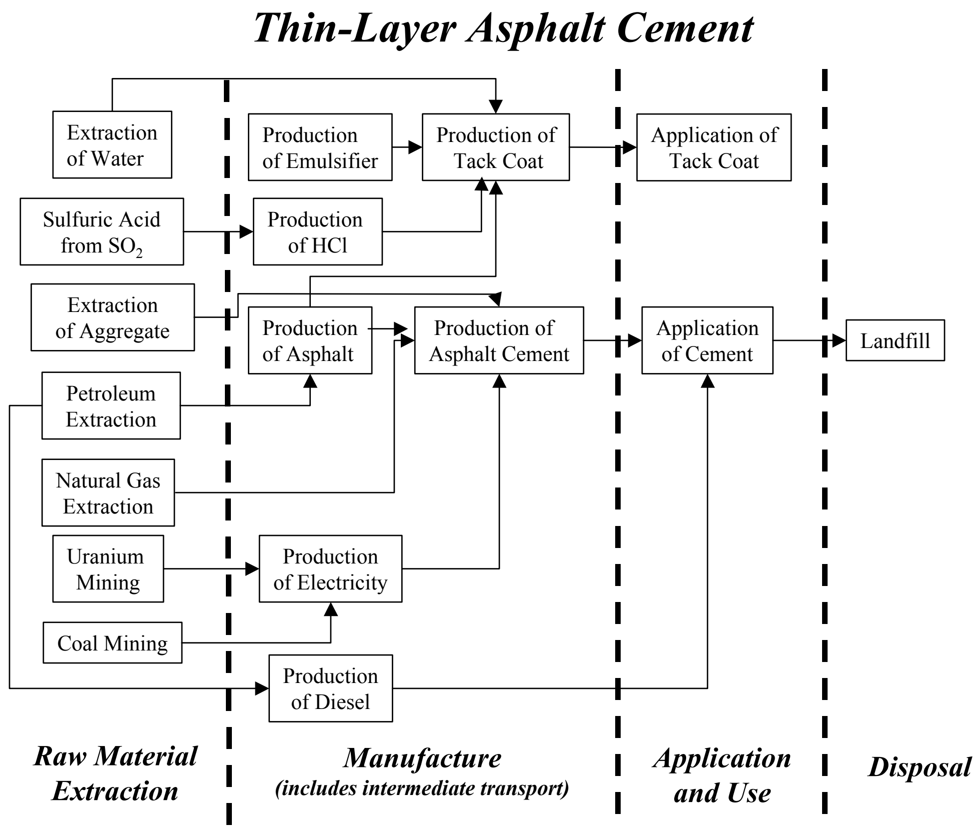


Figure 2



Category Indicators and Models

Global Indicators

The global warming indicator was based on the 100-year horizon for radiative forcing (IPCC, 1996) and expressed in units of CO_2 equivalents. Stratospheric ozone depletion was based on the Montreal protocols, evaluated at infinite time horizon in units of CFC-11 equivalents (Hauschild and Wenzel, 1998).

Regional Indicators

The Eutrophication indicator was based on the Redfield Ratio, (Redfield, 1942), which states that the ratio of carbon to nitrogen to phosphorus in aquatic biomass is 106:16:1, on an atom basis. The indicator was expressed in phosphate equivalents.

The acidification indicator was based on the stoichiometric conversion of acid forming gases and acids to hydrogen ion equivalents, and was expressed in units of SO_2 equivalents. (Hauschild and Wenzel, 1998).

The photochemical smog indicator was based on the maximum incremental reactivity of volatile organic compounds, as calculated by Carter (1998). This approach gives worst-case estimates of the potential ozone produced, and is expressed in ozone mass equivalents.

Local Indicators

The Human Health indicator was derived using the University of California Berkeley/Environmental Defense Fund Scorecard. This human toxicity model produces two scores: one based on carcinogenic risk (in benzene equivalents) and one based on non-carcinogenic risks (in toluene equivalents).

The Ecological Health Indicator is based on a model developed by the Research Triangle Institute (RTI) for the U.S. EPA. (EPA, 1995). It is a scoring model based on the toxicity, and persistence of toxic substances. The indicator is expressed as a unitless number, with higher numbers indicating higher risk than lower numbers.

Resource Depletion

The Resources indicator was based on the model presented by Soil and Water and by Scientific Certifications Systems (ISO TC207 SC3, N66). This model integrates use, recycling, and resource stocks and flows. For this study, resources were divided into fossil fuel (per British Petroleum, 1998) and other mineral resources (per USGS, 1998). Analysis is based on the 50 year time horizon.

In addition to these two sub-indicators, land use, solid waste generation and water use were reported as further indicators of resource depletion.

Results

The summary inventory for the two products is shown below. Inventory data was collected over a three month time frame. The data indicate that on a mass basis alone, the GSB 88 performs better than the asphalt cement.

Table 2
Summary Inventory

System Description Raw Materials	Asphalt Cement Thin Layer (2applic) lb/lane mile/20yr	Asphalt Emulsion GSB 88 (5 applic) lb/lane mile/20yr
Asphalt	122,621	47,790
Aggregate	2,181,960	0
Diesel (application)	3,063	15
Diesel to prep	884	0

System Description Raw Materials	Asphalt Cement Thin Layer (2applic) lb/lane mile/20yr	Asphalt Emulsion GSB 88 (5 applic) lb/lane mile/20yr
hotmix		
Sand	0	17,600
Gilsonite	0	21,500
HCl	32	24
Water	4,779	173,317
NP-40 (Detergent)	0	285
Surfactant	156	29
Light Cycle Oil	0	585
Land use (road, m2)	5888	5888
Land use (mfg, m2)	<10	2

The figure below summarizes the results for the impact assessment portion of the study. All indicator results are shown with one significant figure only.

Table 3
Summary Impact Assessment

	LCIA Totals	
Indicator	**GSB 88**	**Asphalt Cement**
Global Warming (kg CO_2 equiv.)	20,000	40,000
Ozone Depletion (kg CFC-11 equiv.)	0	0
Acidification (kg SO_2 equiv.)	100	300
Eutrophication (kg PO_4 equiv.)	0.007	0.02
Photochemical Smog (kg O_3 equiv.)	40	80
Human Toxicity		
Cancer (kg benzene equiv.)	0.08	0.2
NonCancer (kg toluene equiv.)	2	5
Ecotoxicity (dimensionless)	1000	2000
Resource Depletion		
Fossil (tons oil equivalent)	40,000	90,000
Mineral (equiv tons)	0	0
Precious metals (equiv tons)	0	0
Other Indicators:		
Land Use (ha)	0.6	0.6
Water Use (m^3)	80	2
Solid Waste (ton)	30	800

As can be seen, the GSB 88 performed as well as or better than the asphalt cement in all categories except water usage. All the water usage in these two products derives from the water contained in the GSB 88 itself. No wastewater is generated. The land use indicates the area of one lane mile of road; land use during manufacture was less than one percent of the land use during the use phase of these products. Based on these considerations, the GSB 88 can be considered to be environmentally preferable to the asphalt cement for this application. Data from the impact assessment phase of the study mirrored the data from the inventory phase of the study. This might not be the case where more sophisticated impact assessment models were used, see discussion below.

The data were also analyzed by life cycle stage. Such an analysis is useful for identifying the sources of environmental impacts and potential areas for improvement. The results are shown below. For this study, transportation was modeled based on information gathered from primary sources, and the application was assumed to occur in northern Florida, where currently the U.S. Department of Defense is using the GSB 88. As it happens, this scenario represents a worst-case transportation impact for the emulsion. The results for several of the indicators appear to be due to the impacts of transportation. From the point of view of the purchaser, this indicates that efforts to reduce transport distance or to choose environmentally preferable transport methods (e.g. barge transport over truck) can ameliorate the impacts of the product.

Table 4
Impact Assessment Percentage by Life Cycle Stage: GSB 88

	Emulsion - by LC Stage				
Indicator	**Raw Materials**	**Manufacturing**	**Transport**	**Use**	**Disposal**
GWP	12	34	54	0	0
ODP	0	0	0	0	0
Acidification	15	17	69	0	0
Eutrophication	0	91	9	0	0
Photochemical Smog	20	7	73	0	0
Human Health					
Cancer	13	78	10	0	0
NonCancer	10	81	9	0	0
Eco Health	21	14	63	2	0
Resource Depletion					
Fossil	85	6	9	0	0
Mineral	0	0	0	0	0
Precious	0	0	0	0	0
Other Indicators:					
Land Use	0	0		100	0
Water Use	0	28	0	72	0
Solid Waste	0	0	0	0	100

Table 5
Impact Assessment Percentage by Life Cycle Stage: Asphalt Cement

	Cement - by LC Stage				
Indicator	**Raw Materials**	**Manufacturing**	**Transport**	**Use**	**Disposal**
GWP	9	76	14	1	0
ODP	0	0	0	0	0
Acidification	13	66	19	2	0
Eutrophication	0	98	2	0	0
Photochemical Smog	20	20	59	0	0
Human Health					
Cancer	12	85	3	0	0
Non-Cancer	9	88	2	0	0
Eco Health	25	47	22	8	0
Resource Depletion					
Fossil	82	16	2	0	0
Mineral	0	0	0	0	0
Precious	0	0	0	0	0
Other Indicators:					
Land Use	0	0	0	100	0
Water Use	0	100	0	0	0
Solid Waste	0	0	0	0	100

Interpretation and Quality Assessment

The validity of this assessment depends on the quality of the data collected and on the appropriateness of the analysis. As is the case for most LCA's the data were a combination of primary and secondary data sources, as shown below

Table 6
Data Sources and Types

Data	Type	Source
Asphalt	Industry Average	Industry Association
Aggregate	Primary	Manufacturer
Diesel (application)	Primary; surrogate	Applier
Diesel to prep asphalt	Industry Average	Published Data
Sand	Primary	Manufacturer
Gilsonite	Primary	Manufacturer
HCl	Primary	Manufacturer

Water	Primary	Manufacturer
NP-40 (Detergent)	Primary	Manufacturer
Surfactant	Industry Average	Published Data
Light Cycle Oil	Primary	Manufacturer
Land use	Calculated	This Study
Land use	Mixed	Manufacturer, Engr. Estimate

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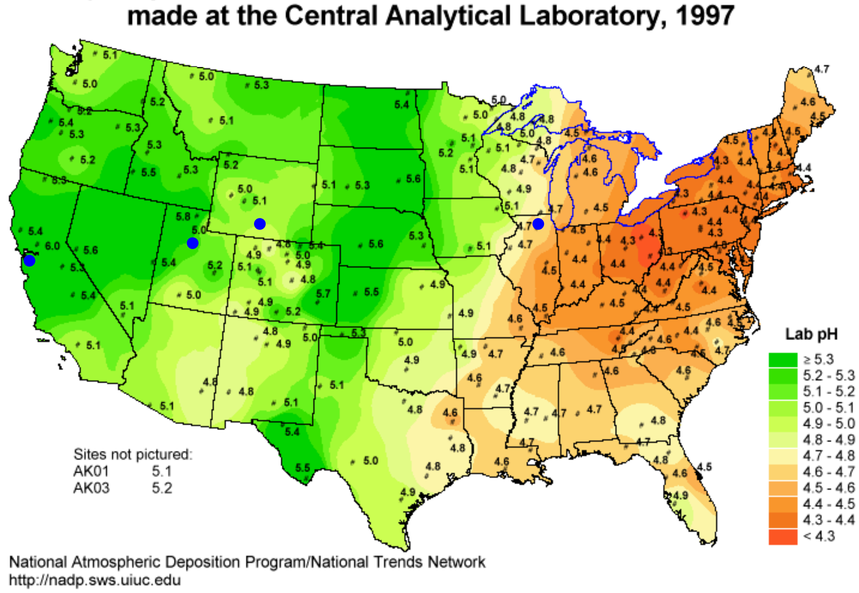
Since the majority of the data collection consisted of primary data from the manufacturers, it is likely that this source of data is as good as possible. However, one can make a legitimate argument that the impact assessment phase of the study did not conform to the requirements for environmental relevance laid out in ISO 14042.

Specifically, neither the regional nor the local impact indicators took into account the regional and local environmental conditions. Instead, they relied on analyses focused early in the environmental mechanism. For example, acidification was evaluated as acid equivalents, without regard for the sensitivity of the receiving environments. In this case, the GSB 88 was manufactured in Utah, where acid precipitation is not currently a problem. With one exception, its components were also manufactured where acid precipitation does not currently pose a significant environmental threat, as shown in the map below (blue dots show manufacturing locations).

Figure 3

Hydrogen ion concentration as pH from measurements made at the Central Analytical Laboratory, 1997



This site-specific information could have been incorporated into the model for the acidification indicator. Similarly, information about the environmental status of the local environments is available for impact categories such as photochemical smog, eutrophication and human and ecological health.

However, performing this type of assessment is limited by the quality of the inventory and environmental data available. Current inventory data bases do not identify the locations associated with particular emissions and resource uses. This limits site-specific impact assessment to data gathered from primary sources.

Although the situation is changing, the information about the environmental state of particular locations is generally patchy, especially when the locations are in less developed parts of the globe. Today, manufacturing is a global business, where components of a product may be manufactured in a dozen different countries, and used and disposed of in dozens more. In order to calculate an indicator that is equivalent for all its sub-indicators it is essential that comparable environmental data exist at all locations where the articles are manufactured used and disposed. For the moment, such an assessment is limited to operations performed in developed nations.

The FRED guidance is valuable for helping purchasing agents make choices between different products, because it identifies a comprehensive and consistent list of impact categories that can be used for all purchases. FRED also leaves room for the development of more environmentally relevant indicators for these impact categories. Following this guidance, even small companies can collect and perform LCA's at a low cost and without excessive time commitment. This LCA study was performed in only four months.

Conclusions

While there is still an opportunity to improve the impact assessment phase of LCA's in general and those used for purchasing decisions in particular, this pilot project demonstrated that LCA's are feasible for environmentally preferable purchasing, even when the company is small and time and money are short.

The FRED choice of environmental impact categories helps manage the number and types of data that need to be collected, thus streamlining the LCA process for procurement.

Partly because there was an overall superior environmental performance by GSB 88, the U.S. Department of Defense currently plans to purchase significant amounts of the product. Should the purchase be completed, this would further support the use of the LCA approach to Environmentally Preferable Purchasing.

There are other aspects of products that influence the purchase decision, including cost and convenience. As it happens, the GSB 88 product outperforms asphalt cement in those two areas as well. Its overall lifecycle cost is superior (Kindler, 1997) and application methods are less complicated. For other products, this is not so, and in many cases, cost vastly outweighs environmental performance as a decision parameter. The FRED methodology's planned next step is to integrate costing techniques with the environmental assessment.

Acknowledgements

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