

Use of OSHA Data in an LCI Approach to Develop Health & Safety Indicators for Selected Packaging Materials

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Background

- Variety of programs and initiatives available or being developed to assess the sustainability or preferability of different packaging materials
- Criteria include total energy, renewable/non-renewable energy, solid waste, global warming, resource depletion, etc.
- Assessing toxicity/safety presents extra challenges

Current Options for Assessing Health Issues Associated with Materials

- Toxicological studies
- Life cycle impact assessment

Limitations: Toxicology Studies

- Focus on health issues associated with end-product materials
- Do not consider the cumulative harmful effects of the “upstream” sequence of processes required to produce the material

Limitations: LCIA

- LCIA evaluates potential impacts on human health and the environment for aggregated emissions released over a product's life cycle
- Life cycle data do not track concentrations, exposure, time frame, etc.
- The total quantity of a given emission might represent a single highly concentrated release with direct human exposure, or multiple low-level releases occurring at many locations over different periods of time
- Health impacts of a cumulative quantity of a substance can be very different depending on release/exposure scenarios

Safety Issues

- Toxicology and LCIA focus on exposures to substances that may have harmful impacts on **health**
- An additional health and safety consideration is **injuries** associated with direct physical harm, e.g., from working with dangerous equipment, heavy lifting, repetitive motion injuries, etc.

Study Objective and Proposed Approach

- Objective: Develop a reasonably simple method of assessing “cradle-to-production” health and safety for various packaging materials
- Proposed approach: Combine LCA modeling with OSHA data on recordable injuries and incidents

Rationale

- OSHA data provide an actual indication of the exposures and hazards of individual industry sectors, including both **illnesses** from exposures and **injuries** from other workplace hazards
- LCA models include the entire sequence of unit processes required to produce a material
- Applying OSHA sector data to corresponding unit processes in a life cycle model would result in a cumulative “life cycle” health and safety indicator that reflects actual hazards associated with the full sequence of processes involved in producing a material

Scope of Trial Project

- Several common packaging materials were selected for analysis, including paperboard, aluminum, and several plastic resins.
- Analysis covered steps from raw material extraction through production of material ready for conversion
- Analysis focused on the industry sectors associated with raw material extraction and subsequent material processing steps.

Exclusions

- Injuries/illnesses for the following elements of each material system were excluded from the analysis:
 - Production and delivery of process energy (for example, production of electricity, natural gas, diesel fuel, etc.)
 - Production of capital equipment used in each industry sector
 - Production of ancillary materials or material inputs that account for less than one percent of the total weight of product output

Steps Involved

- Compile complete list of unit processes used in the LCI models for the selected packaging materials.
- Determine number of OSHA cases of injury/illness associated with each unit process.
- Link injury/illness data for each unit process to the corresponding weighting factor in the LCI packaging material models.
- Add the individual unit process weighted data to arrive at total cases of injury/illness per ton of each packaging material

LCA Material Models

- Resins: ACC Plastics Division resin data in the U.S. LCI database
- Aluminum, paperboard: Franklin Associates' internal database

OSHA Data

- According to Code of Federal Regulations Standard 29 section 1904.7 an injury or illness is considered to be recordable
“...if it results in any of the following: death, days away from work, restricted work or transfer to another job, medical treatment beyond first aid, or loss of consciousness. You must also consider a case to meet the general recording criteria if it involves a significant injury or illness diagnosed by a physician or other licensed health care professional, even if it does not result in death, days away from work, restricted work or job transfer, medical treatment beyond first aid, or loss of consciousness.”
- For each material, two indicators were developed: one based on **total recordable incidents**, and one based on **incidents with days away from work**.

Challenges

- OSHA data are reported by NAICS (North American Industry Classification System) code
- OSHA data not always available at level of detail corresponding to individual unit processes in life cycle model
- Example: NAICS codes 325188 (Organic chemicals other than alkalies & chlorine) and 325199 (Inorganic chemicals other than cyclic crudes & intermediates) cover hundreds if not thousands of different materials.
- Thus, some allocation was required.

LCI Unit Process	Closest NAICS category with published OSHA data	Description	2005 OSHA cases (thou) (1)	
			Total recordable	Cases with days away from work
Corn growing & harvesting	1111	Oilseed and grain (2)	17	6.1
Logging	1133	Logging	3.8	1.7
Crude oil extraction	211111	Crude petroleum & nat gas extraction	2.5	1
Natural gas production & processing				
Coal mining	21211	Coal mining	4.6	2.9
Bauxite mining	212299	All other metal ore mining	0.1	<50 cases
Limestone mining	212312	Crushed & broken limestone mining & quarryin	1.3	0.5
Salt	212393	Other chemical & fertilizer mineral mining	0.1	0.1
Corn starch	311221	Wet corn milling	0.4	0.1
Paperboard mills	32213	Paperboard mill	1.1	0.4
Petroleum refining	32411	Petroleum refineries	1	0.5
Petroleum coke	32419	Other petroleum & coal products	1	0.7
Benzene	32511	Petrochemical manufacturing	0.3	0.1
Ethylbenzene/styrene				
Mixed xylenes				
Paraxylene				
Ethylene				
Propylene				
Pyrolysis gas				
Ethylene dichloride/vinyl chloride monomer				
Oxygen	32512	Industrial gas mfg	0.5	0.2
Chlorine	325181	Alkalies & chlorine mfg	0.2	0.1
Sodium hydroxide				
Sodium chlorate	325188	All other basic inorganic chem mfg	0.8	0.2
Methanol	325199	All other basic organic chem mfg	0.9	0.2
Acetic acid				
Ethylene glycol				
Ethylene oxide				
GPPS resin	325211	Plastic matl & resin mfg	1.5	0.3
HDPE resin				
PET resin				
PP resin				
PVC resin				
Lime	32741	Lime mfg (2)	0.2	(3)
Metallurgical coke	331111	Iron & steel mills	5.3	1.4
Alumina production	331311	Alumina refining (2)	0.3	(3)
Virgin aluminum	331312	Primary aluminum prodn	0.7	0.2

(1) Bureau of Labor Statistics, <http://www.bls.gov/iif/oshwc/osh/os/ostb1621.pdf>. Table 2. Numbers of nonfatal occupational injuries and illnesses by industry and case types, 2005.

(2) Calculated by difference (total for higher-level NAICS category minus incidents for other subcategories). For example, injuries for NAICS 1111 were calculated as incidents for NAICS 111 - incidents for categories 1112, 1113, 1114, and 1119.

(3) Attempting to calculate by difference as described in (2) resulted in negative values due to use of rounded numbers, so incidents with days away from work were modeled as 0.

Allocation Options

- Allocate based on the specific product's share of the **physical quantity of output** for that code
- Allocate based on the specific product's share of the total **value of shipments** for that code

Implicit Assumptions

- Allocation by weight % inherently assumes that cases of illness and injury are similar **per ton of output** for all materials within the NAICS code.
- Allocation by \$ value implies that injuries and illnesses are similar **per dollar value of output** for all materials within the NAICS code.
- Without additional detailed analysis of OSHA incidents within each NAICS code, the accuracy of either of these inherent assumptions cannot be confirmed or disproved.

Allocation by Weight

- Within a given NAICS code, allocation of OSHA incidents on a weight basis is reasonable if category consists largely or entirely of products that are similar in nature and that are produced by similar types of processes.
- However, this assumption may **not** be accurate if some products within the category cause disproportionately high numbers of associated injury/illness. This could be the case, for example, if a few products within that code are highly toxic or flammable, or involve the use of dangerous equipment.

Allocation by Value

- Some NAICS codes cover so many products that it is not feasible to determine a total production tonnage for the code (i.e., by identifying production tonnages for all the individual products covered within the code and summing them).
- In this case, can use data on total value of shipments to allocate OSHA incidents per \$ of output, then multiply by selling price of individual product in \$/ton to estimate OSHA incidents/ton of specific materials.
- However, there are several problems with this allocation approach...

Allocation by Value (continued)

- Total dollar value for each product within the code is based on the total quantity of the product produced and the selling price per unit of product.
- Some products produced in high tonnages will have lower dollar value per ton, while some products produced in low tonnages will have higher dollar value per ton.

Allocation by Value (continued)

- Total annual value of shipments reflects price volatility over the course of an entire year, which can be substantial. However, conversion from OSHA incidents/\$ to OSHA incidents/ton made using a single value for \$/ton.
- Thus, allocation based on weight of output was the preferred allocation method and was used where sufficient data were available

Data Sources Used for Allocation Calculations

To maximize transparency and credibility, publicly available data sources were utilized to the extent possible, particularly annual data series such as

- Annual Survey of Manufactures;
- Energy Information Administration reports on petroleum, natural gas, and coal;
- US Geological Survey Mineral Commodity Summaries, etc.

Because the most recent available OSHA data were for 2005, allocations to specific products were performed using 2005 production and price data wherever possible.

Allocation of OSHA Incidents by Mass

LCI Unit Process	NAICS category	Description	Total recordable cases (thou)	Total 2005 production (short tons)	Cases per ton
Corn growing & harvesting	1111	Oilseed and grain	17.0	466,866,000 (1)	3.6E-05
Logging	1133	Logging	3.8	532,008,075 (2)	7.1E-06
Crude oil extraction	211111	Crude petroleum & nat gas extraction	2.5	795,936,728 (3)	3.1E-06
Natural gas production & processing					
Coal mining	21211	Coal mining	4.6	1,131,498,000 (3)	4.1E-06
Limestone mining	212312	Crushed & broken limestone mining & quarrying	1.3	1,301,300,000 (4)	1.0E-06
Salt	212393	Other chemical & fertilizer mineral mining	0.1	90,860,000	1.1E-06
Paperboard mills	32213	Paperboard mill	1.1	49,372,000 (5)	2.2E-05
Petroleum refining	32411	Petroleum refineries	1.0	801,806,433 (3)	1.2E-06
Chlorine	325181	Alkalies & chlorine mfg	0.2	20,721,000 (6)	9.7E-06
Sodium hydroxide					
GPPS	325211	Plastic matl & resin mfg	1.5	49,173,500 (6)	3.1E-05
HDPE					
PET					
PP					
PVC					
Lime	32741	Lime mfg	0.2	22,000,000 (4)	9.1E-06
Alumina production	331311	Alumina refining	0.3	5,267,163 (7)	5.7E-05
Virgin aluminum	331312	Primary aluminum prodn	0.7	2,729,100 (4)	2.6E-04

(1) Bureau of the Census, Statistical Abstracts

(2) Forest Products Laboratory

(3) Energy Information Administration

(4) US Geological Survey

(5) American Forest & Paper Association

(6) Data provided by American Chemistry Council

(7) No domestic alumina production; total wt of alumina refined based on lb alumina/lb primary aluminum (from LCI model)

Allocation of OSHA Incidents by \$ Value of Shipments and \$/Ton of Material

LCI Unit Process	NAICS category	Description	Total recordable cases (thou)	Total 2005 Value of Shipments (thou \$) (1)	Cases per \$ output	\$/ton for product of interest	Source, age of price data (2)	Cases per ton
Benzene	32511	Petrochemical manufacturing	0.3	44,444,853	6.7E-09	\$ 807	CMR Feb 06	5.4E-06
Ethylbenzene/styrene						\$ 1,020	CMR Feb 06	6.9E-06
Mixed xylenes						\$ 800	CMR Feb 06	5.4E-06
Paraxylene						\$ 900	CMR Feb 06	6.1E-06
Ethylene						\$ 1,070	CMR Feb 06	7.2E-06
Propylene						\$ 830	CMR Feb 06	5.6E-06

(1) U.S. Census Bureau. **Annual Survey of Manufactures, Value of Product Shipments: 2005**. Table 1. Value of Shipments for Product Classes: 2005 and Earlier Years. <http://www.census.gov/prod/2006pubs/am0531gs1.pdf>

(2) CMR = Chemical Market Reporter

LCI Unit Process	OSHA cases per ton	Cases allocated by weight or \$		
Corn growing & harvesting	3.6E-05	Weight		
Logging	7.1E-06	Weight		
Crude oil extraction	3.1E-06	Weight		
Natural gas production & processing	3.1E-06	Weight		
Coal mining	4.1E-06	Weight		
Bauxite mining	4.4E-06	\$		
Limestone mining	1.0E-06	Weight		
Salt	1.1E-06	Weight		
Corn starch	1.5E-05	\$		
Paperboard mills	2.2E-05	Weight		
Petroleum refining	1.2E-06	Weight		
Petroleum coke	2.4E-06	\$		
Benzene	5.4E-06	\$		
Ethylbenzene/styrene	6.9E-06	\$		
Mixed xylenes	5.4E-06	\$		
Paraxylene	6.1E-06	\$		
Ethylene	7.2E-06	\$		
Propylene	4.3E-06	Wt, \$ (1)		
Pyrolysis gas	3.2E-06	\$		
EDC/VCM	2.7E-06	\$		
Oxygen	5.1E-06	\$		
Chlorine	9.7E-06	Weight		
Sodium hydroxide	9.7E-06	Weight		
Sodium chlorate	2.2E-05	\$		
Methanol	1.2E-05	\$		
Acetic acid	1.4E-05	\$		
Ethylene glycol	1.3E-05	\$		
Ethylene oxide	1.2E-05	\$		
GPPS	3.1E-05	Weight	3.8E-05	\$
HDPE	3.1E-05	Weight	3.4E-05	\$
PET	3.1E-05	Weight	3.0E-05	\$
PP	3.1E-05	Weight	3.0E-05	\$
PVC	3.1E-05	Weight	2.5E-05	\$
Lime	9.1E-06	Weight		
Metallurgical coke	4.2E-06	\$		
Alumina production	5.7E-05	Weight		
Virgin aluminum	2.6E-04	Weight		

(1) Based on refinery output data from EIA and total chemical production data provided by ACC, in 2005 31% of propylene was produced at refineries, and 69% was produced at petrochemical facilities. Thus, the cases per ton for propylene reflect a production-weighted average of the cases/ton for petroleum refineries (from Table 2) and the cases/ton for propylene produced at petrochemical facilities (from Table 4).

	Wtd OSHA cases per ton of pkg material	% of total	OSHA total cases per 10,000 tons of pkg material		Wtd OSHA cases per ton of pkg material	% of total	OSHA total cases per 10,000 tons of pkg material
HDPE Resin				PET Resin			
Crude oil extraction	8.7E-07	2%		Crude oil extraction	1.9E-06	4%	
Petroleum refining	3.3E-07	1%		Petroleum refining	7.2E-07	1%	
Natural gas extraction & processing	2.9E-06	7%		Natural gas extraction & processing	7.2E-07	1%	
Olefins (Ethylene) production	7.2E-06	17%		Olefins (Ethylene) production	1.4E-06	3%	
HDPE	3.1E-05	73%		Oxygen	1.1E-06	2%	
TOTAL	4.2E-05	100%	0.4	Ethylene Oxide	3.0E-06	6%	
PVC Resin				Ethylene Glycol	4.2E-06	8%	
Crude oil extraction	4.0E-07	1%		Methanol	6.5E-07	1%	
Petroleum refining	1.5E-07	0%		CO/Acetic Acid	5.1E-07	1%	
Natural gas extraction & processing	1.3E-06	3%		Mixed xylenes	2.8E-06	6%	
Olefins (Ethylene) production	3.3E-06	7%		Paraxylene	3.2E-06	6%	
Salt mining	5.2E-07	1%		PET (includes PET, PTA, DMT, TPA)	3.1E-05	60%	
Chlorine	5.2E-06	12%		TOTAL	5.1E-05	100%	0.5
Oxygen	7.4E-07	2%		Aluminum - Virgin Ingot			
EDC/VCM	2.7E-06	6%		Salt mining	1.4E-07	0%	
PVC	3.1E-05	68%		Sodium hydroxide manufacture	1.4E-06	0%	
TOTAL	4.5E-05	100%	0.4	Limestone mining	1.7E-07	0%	
GPPS Resin				Lime production	8.0E-07	0%	
Crude oil extraction	2.3E-06	5%		Bauxite mining	2.2E-05	6%	
Petroleum refining	8.9E-07	2%		Alumina production	1.1E-04	28%	
Natural gas extraction & processing	1.6E-06	3%		Coal mining	6.4E-07	0%	
Olefins (pygas)	8.3E-07	2%		Metallurgical coke production	6.1E-07	0%	
Olefins (Ethylene) production	2.1E-06	4%		Crude oil production	1.2E-06	0%	
Benzene production	4.3E-06	9%		Petroleum coke production	9.1E-07	0%	
Ethylbenzene/Styrene production	6.9E-06	14%		Aluminum smelting	2.6E-04	65%	
GPPS resin manufacture	3.1E-05	62%		TOTAL	3.9E-04	100%	3.9
TOTAL	4.9E-05	100%	0.5	Bleached Kraft Paperboard			
PP Resin				Roundwood harvesting	3.4E-05	42%	
Crude oil extraction	1.2E-06	3%		Wood residues	2.0E-05	25%	
Petroleum refining	4.5E-07	1%		Limestone mining	6.7E-08	0%	
Natural gas extraction & processing	2.7E-06	7%		Lime production	3.2E-07	0%	
Olefins (Propylene) production	4.2E-06	11%		Salt mining	8.9E-08	0%	
PP	3.1E-05	78%		Sodium hydroxide production	5.8E-07	1%	
TOTAL	3.9E-05	100%	0.4	Sodium chlorate production	1.1E-06	1%	
				Oxygen	7.8E-08	0%	
				Corn growing and harvesting	1.2E-06	1%	
				Corn starch	4.5E-07	1%	
				Kraft Bleached Paperboard Manufacture	2.2E-05	28%	
				TOTAL	8.0E-05	100%	0.8

	OSHA total cases per 10,000 tons of pkg material	OSHA days away from work cases per 10,000 tons of pkg material
HDPE Resin	0.4	0.1
PVC Resin	0.4	0.1
GPPS Resin	0.5	0.1
PP Resin	0.4	0.1
PET Resin	0.5	0.1
Aluminum - Virgin Ingot	3.9	0.9
Bleached Kraft Paperboard	0.8	0.3

Results and Observations (1)

- Largest contributions to the aggregated cradle-to-production safety factor are generally for unit processes with highest weighting factors. Thus, the data quality is most critical for these steps.
- Unit processes with the highest weighting factors are generally the process steps closest to final material production or raw material extraction steps (particularly raw materials such as ores or wood that have large subsequent processing losses)

Results and Observations (2)

- Unit processes with the largest OSHA score contributions tend to be the ones requiring the least allocation assumptions, e.g., logging (1133), paperboard mills (32213), virgin aluminum production (331312).
- Although allocation was required for resin production (325211, the dominant contributor to scores for plastic) sufficient resin-specific data were available to use both the allocation by weight approach and the allocation by dollar value approach. The results are very similar for the two approaches, suggesting that allocation can be done with reasonable accuracy for resins.

Reliability of Conclusions

- The key factor in the reliability of the results of this analysis is the reliability of the OSHA data itself, which serves as the underlying basis for the entire analysis.

OSHA Underreporting

- Recent articles indicate that there may be significant underreporting of OSHA incidents. Reasons include the following:
 - Intentional underrecording (e.g., to meet corporate goals or to compare favorably with competitors)
 - Unintentional underrecording (because employers or record-keepers do not understand the recording and reporting system)
 - Inaccurate recording (employers do not place a high priority on recordkeeping and do not supervise recordkeepers properly)

OSHA Exemptions

- Some establishments and industries exempt from OSHA reporting based on number of employees or type of industry
- Exemption for size (10 or less employees) excludes some establishments that may have significant injury rates. For example, many small farms have 10 or fewer workers. Agricultural injury rates are relatively high compared to many other industry sectors. Workers on small farms would be expected to have injury rates similar to workers on larger farms.

Potential Magnitude of Underreporting and Exclusions

- Studies cited in *Journal of Occupational and Environmental Medicine*
 - University of California-Davis study estimated that up to 69 percent of workplace injuries and illnesses may be missed
 - Michigan State University study found that BLS statistics missed approximately two-thirds of Michigan nonfatal workplace injuries and illnesses in a three-year period (75% of missed incidents due to underreporting)
- Actual incidents likely to be higher than reported numbers used as the basis for this study
- Effect of underreporting on **comparative** cumulative results for packaging materials is likely to be small

Conclusions

- There are many limitations and assumptions involved in allocating OSHA data to specific unit processes so that they can be used in LCI model frameworks to calculate a cradle-to-material total for the production of packaging materials.
- LCI OSHA results are probably not sufficiently accurate to make fine distinctions between materials, but some of the differences in results are large enough to suggest that they are meaningful.
- Development of reliable health and safety ratings using OSHA data would be facilitated if OSHA data for material sectors were available at a greater level of detail.