LIFE CYCLE ANALYSIS AND ENVIRONMENTAL IMPACT

ChE 4273

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LIFE CYCLE ANALYSIS

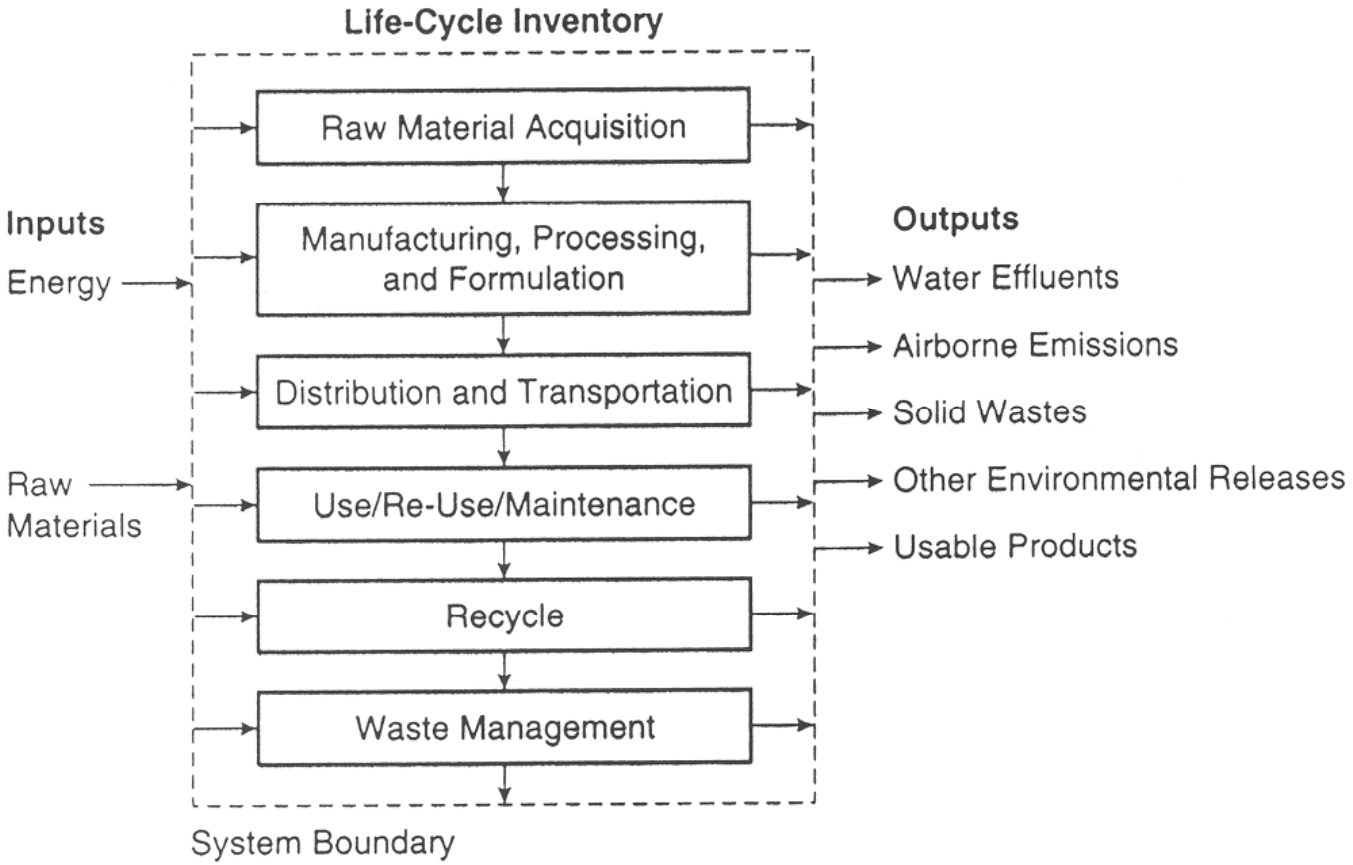
The inventory corresponding to all the activities associated with a particular product is calculated.

-Raw Materials used.
-Energy requirements of ALL steps
-Emmisions/Effluents produced in ALL steps
-Waste of ALL steps and the whereabouts of these waste.

-STEPS considered are:

Raw Material Acquisition
Manufacturing
Transportation
Recycle/Reuse
Wastes/Final disposal of used product

LIFE CYCLE ANALYSIS



INVENTORIES

EXAMPLE : ETHYLENE

Raw Materials: Oil/Gas
Energy needed: Coal/Oil/Electricity
Products: Polyethylene (mostly)
Wastes: From production of Ethylene and Polyethylene
Final Product Disposal: Landfills, Atmosphere

INVENTORIES

Life-Cycle Inventory Data for the Production of 1 kg of Ethylene (Boustead, 1993).

Category	Input or Output	Unit Average
Energy content fuels, MJ	Coal	0.94
	Oil	1.8
	Gas	6.1
	Hydroelectric	0.12
	Nuclear	0.32
	Other	<0.01
	Total	9.2
Feedstock, MJ	Coal	<0.01
	Oil	31
	Gas	29
	Total	60
Total Fuel + Feedstock		69
Raw Materials, mg	Iron ore	200
	Limestone	100
	Water	1,900,000
	Bauxite	300
	Sodium chloride	5,400
	Clay	20
	Ferromanganese	<1
Air emissions, mg	Dust	1,000
	Carbon monoxide	600
	Carbon dioxide	530,000
	Sulfur oxides	4,000
	Nitrogen oxides	6,000
	Hydrogen sulfide	10
	Hydrogen chloride	20
	Hydrocarbons	7,000
	Other organics	1
	Metals	1
Water emissions, mg	Chemical oxygen demand	200
	Biological oxygen demand	40
	Acid, as H+	60
	Metals	300
	Chloride ions	50
	Dissolved organics	20
	Suspended solids	200
	Oil	200
	Phenol	1
	Dissolved solids	500
	Other nitrogen	10
Solid waste, mg	Industrial waste	1,400
	Mineral waste	8,000
	Slags and ash	3,000
	Nontoxic chemicals	400
	Toxic chemicals	1

ENVIRONMENTAL IMPACT

Categories for which Indices are calculated:

Environmental Impact Index Categories for Process Flowsheet Evaluation.

Abiotic Indexes	*Health-Related Indexes*	*Ecotoxicity Indexes*
Global warming	Inhalation toxicity	Fish Aquatic Toxicity
Stratospheric ozone depletion	Ingestion toxicity	
Acid deposition	Inhalation carcinogenicity	
Smog formation	Ingestion carcinogenicity	

ENVIRONMENTAL IMPACT

Dimensionless Risk Index= $\frac{[EP * IIP]_i}{[EP * IIP]_{ref}}$

Where

EP= Exposure Potential
IIP= Inherent Impact Potential

ENVIRONMENTAL IMPACT OF A CATEGORY

$$I = \sum_i \textit{Dimensionless Risk Index}_i \times m_i$$

Kg/hr of chemical *i*

ENVIRONMENTAL IMPACT

Global Warming Potential : Cumulative infrared energy capture for the release of 1 Kg of a greenhouse gas relative to that of CO_2

$$GWP_i = \frac{\int_0^n a_i C_i dt}{\int_0^n a_{CO_2} C_{CO_2} dt}$$

where

a_i : radiative forcing of gas i (Wm^{-2}) (a function of conc.)
C_i : Concentration (ppm)
n : number of years (ie. 120 years for CO2, etc)

$$I_{GW} = \sum_i (GWP_i \times m_i)$$

Kg/hr of chemical *i*

ENVIRONMENTAL IMPACT

Ozone Depletion Potential: Predicted time and height integrated change in atmospheric ozone

$$ODP_i = \frac{\delta[O_3]_i}{\delta[O_3]_{CFC-11}}$$

where

$\delta[O_3]_i$: predicted change (from tables)

$$I_{OD} = \sum_i (ODP_i \times m_i)$$

Kg/hr of chemical *i*

ENVIRONMENTAL IMPACT

Acid Rain Potential: Ability to generate Hydrogen ions in water..

$$ARP_i = \frac{\eta_i}{\eta_{SO_2}}$$

where

η : moles of H^+ per mol of substance emmited

$$I_{AR} = \sum_i (ARP_i \times m_i)$$

Kg/hr of chemical *i*

ENVIRONMENTAL IMPACT

Smog Formation Potential: related to the change in moles of ozone formation due to the emission of one mol of a substance called incremental reactivity. Based on the following cycle

$$\left.\begin{aligned} NO_2 + h\upsilon &\rightarrow O + NO \\ O + O_2 + M &\rightarrow O_3 + M \\ O_3 + NO &\rightarrow NO_2 + O_2 \end{aligned}\right\}$$

which regulates the ozone level, function of the photolysis rate and the ratio of N oxides.

VOC form radicals that convert NO to NO2 changing the ratio of oxides.

$$\left.\begin{aligned} VOC + \bullet OH &\rightarrow \bullet RO_2 + other \\ \bullet RO_2 + NO &\rightarrow NO_2 + radicals \\ radicals &\rightarrow \bullet OH + other \end{aligned}\right\}$$

$$SFP_i = \frac{MIR_i}{MIR_{ROG}}$$

MIR_{ROG} Average value for reactive organic gases

$$I_{SF} = \sum_i (SFP_i \times m_i)$$

TOXICITY

Non Carcinogenic Toxicity: Ingestion and inhalation (related to concentrations and referred to toluene)

Carcinogenic Toxicity: Ingestion and inhalation (related to concentrations and referred to benzene)

A similar method of indices and risk indices is used.