



BREAKOUT SESSION 7

Green Chemistry: Foundation for Business Development

How to assess chemicals & materials for “greenness”

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Sustainable Research Group

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12:30 pm - 1:30 pm



Definition of Green Chemistry

Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and applications of chemical products.

Principles of Green Chemistry

1. Prevent waste
2. Design safer chemicals and products
3. Design less hazardous chemical syntheses
4. Use renewable feedstocks
5. Use catalysts, not stoichiometric reagents
6. Avoid chemical derivatives
7. Maximize atom economy
8. Use safer solvents and reaction conditions
9. Increase energy efficiency
10. Design chemicals and products to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents

12 PRINCIPLES OF GREEN CHEMISTRY

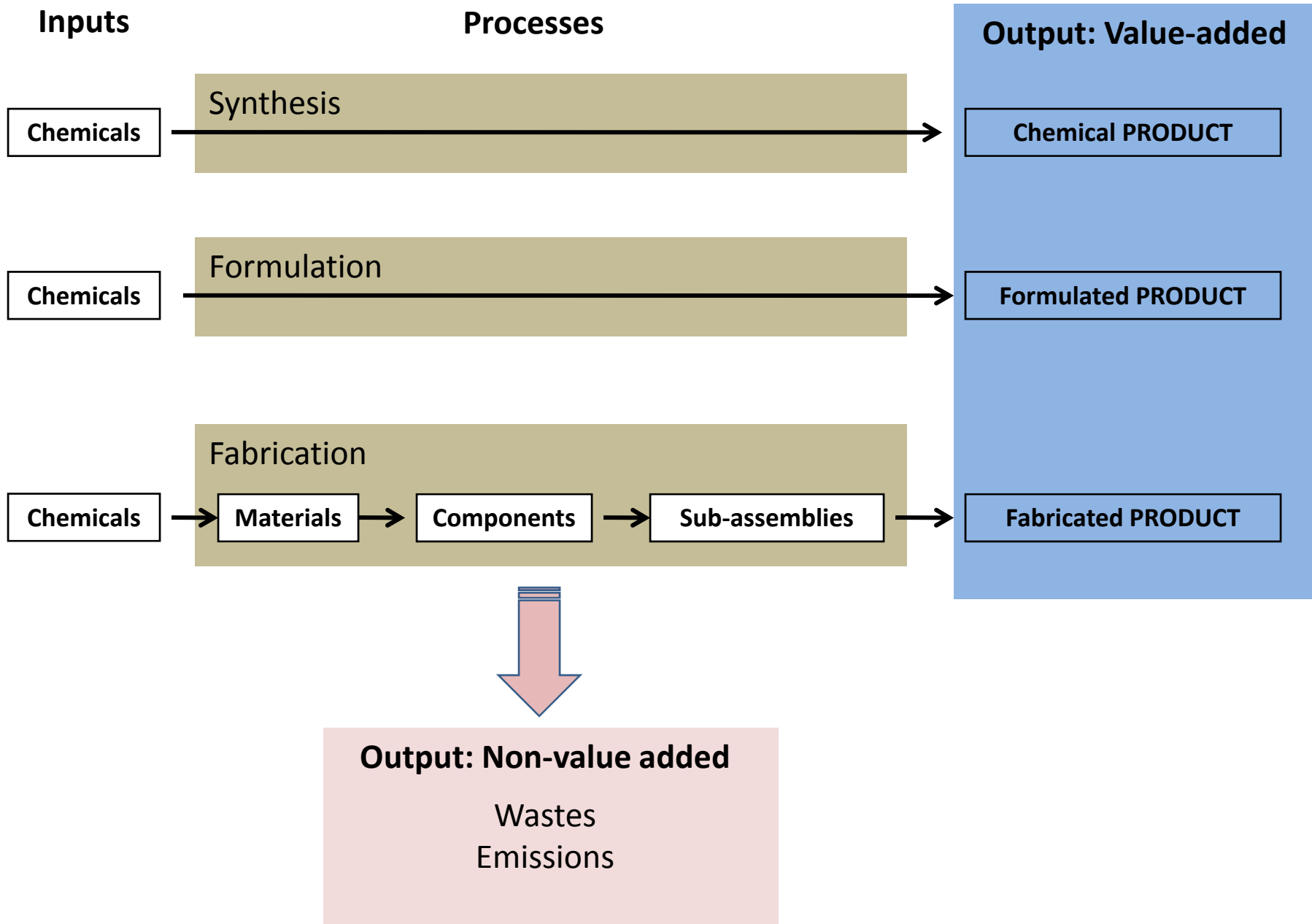
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|---|---|-----|--|
| | E | 1. | Prevent waste |
| | H | 2. | Design safer chemicals and products |
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| H | E | 4. | Use renewable feedstocks |
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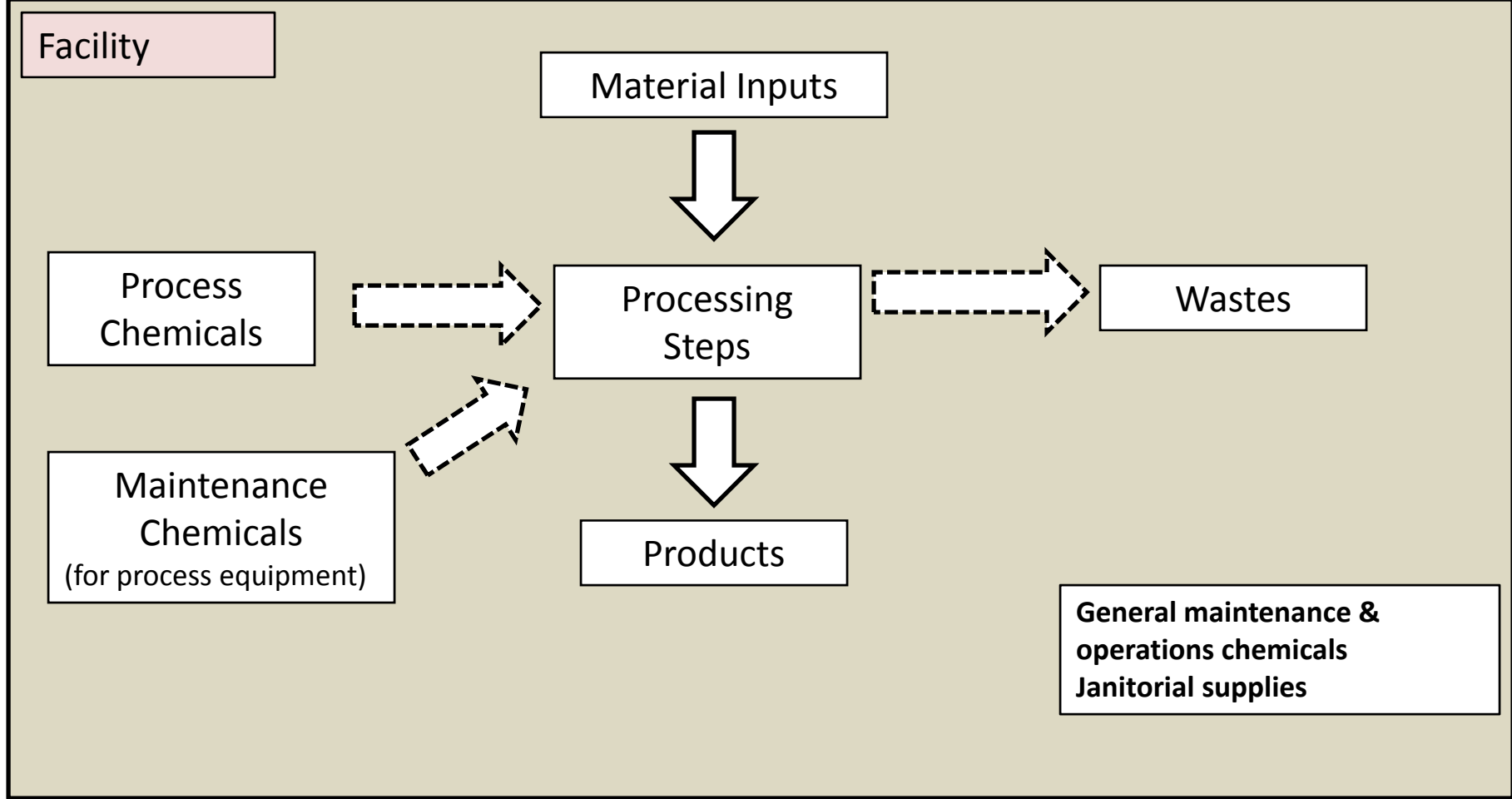
Broadly, Principles address:

- Efficiency of matter consumption and energy consumption
- Hazard of matter

E

H





- Product-level chemicals
- Process-level chemicals
- Maintenance-level chemicals
- Wastes

Key considerations

- Everything (all matter) is made of chemicals
- The properties of a chemical (chemical, physiological, toxicology) are determined by the structure of the chemical; the type and arrangements of atoms of one or more elements
- Sheer number and volumes of chemicals flowing through commerce (both natural and synthetic)
- Environmental impacts and human health impacts are largely mediated through chemicals
- A chemical can impact the environment/human health in many ways i.e. multiple aspects that contribute to its “environmental footprint”
- Life cycle perspective: the same chemical may have environmental/human health impacts that differ in both degree and kind depending on the life cycle stage of the chemical
- Thus the “greenness” of a chemical, material or process relates to the “size” of its “environmental footprint”
- “Greenness” is a relative term

Human Health and Ecosystem Impacts

Life Cycle Impact Categories

- Resource depletion
- Land Use
- Global warming
- Stratospheric ozone depletion
- Acidification
- Eutrophication
- Smog formation
- Ecotoxicity
- Human health

Human Health

- Carcinogenicity
- Mutagenicity
- Reproductive toxicity
- Developmental toxicity
- Teratogenicity
- Endocrine disruption
- Respiratory sensitization
- Asthmagens
- Neurotoxicity
- Hepatotoxicity
- Systemic toxicity
- Skin irritation

Ecotoxicity

- Persistence
- Bioaccumulation
- Fugacity
- Toxicity

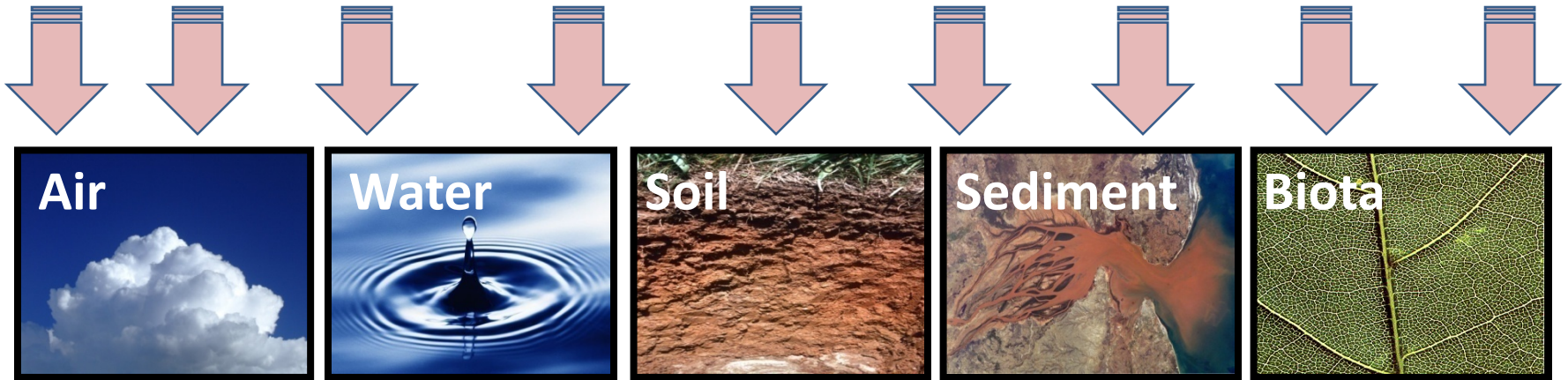
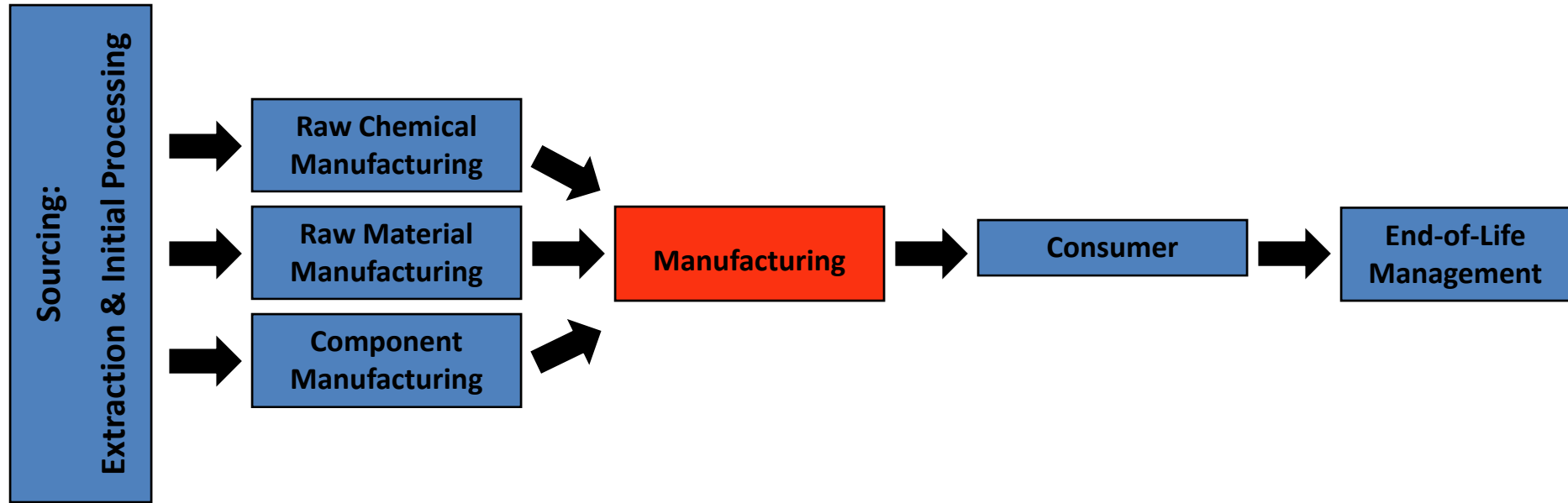
Physical Hazard (Safety)

- Flammability
- Radioactivity
- Oxidizer
- Water-reactive
- Corrosive
- Explosivity

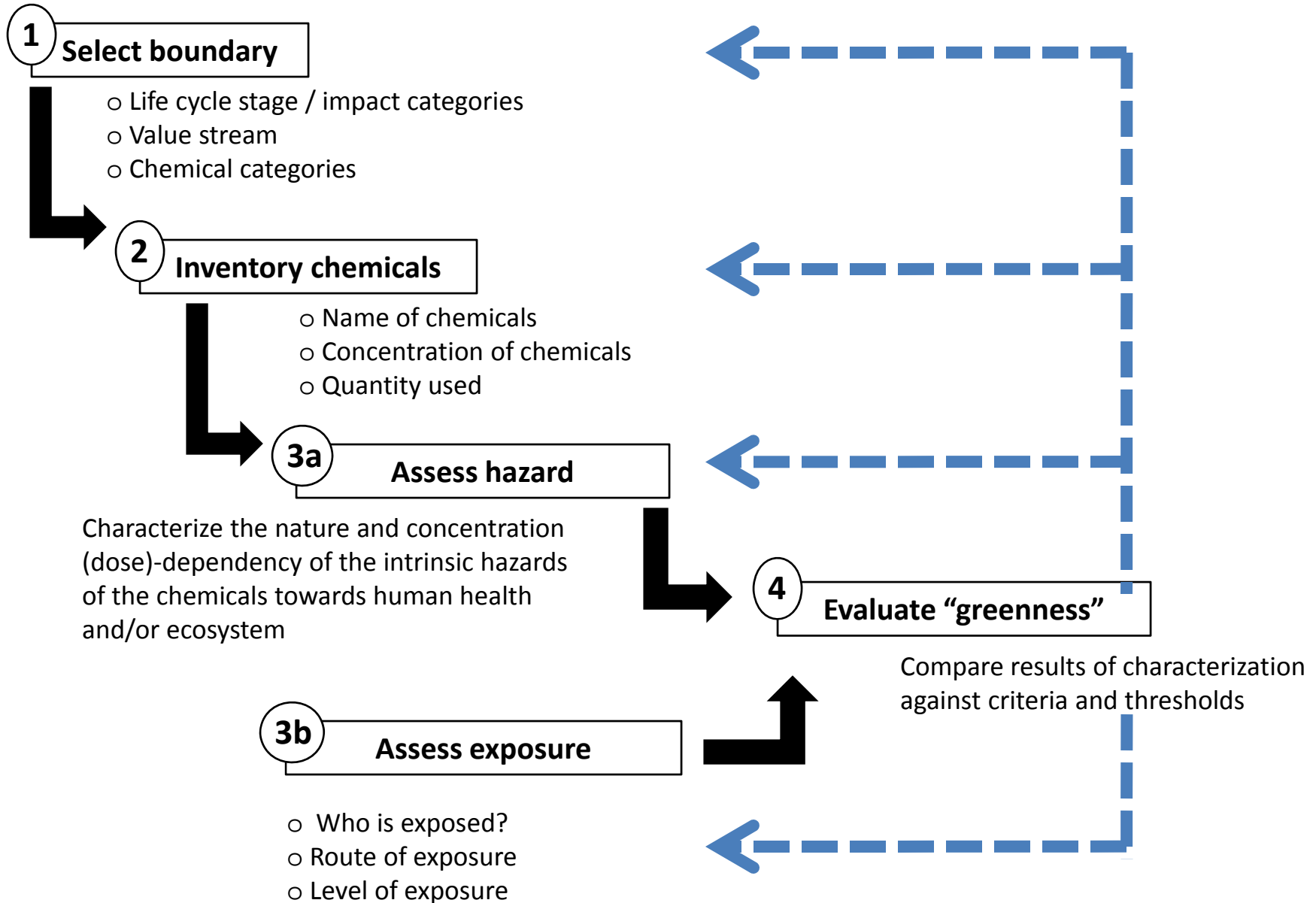
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Life Cycle of Product Chemistry

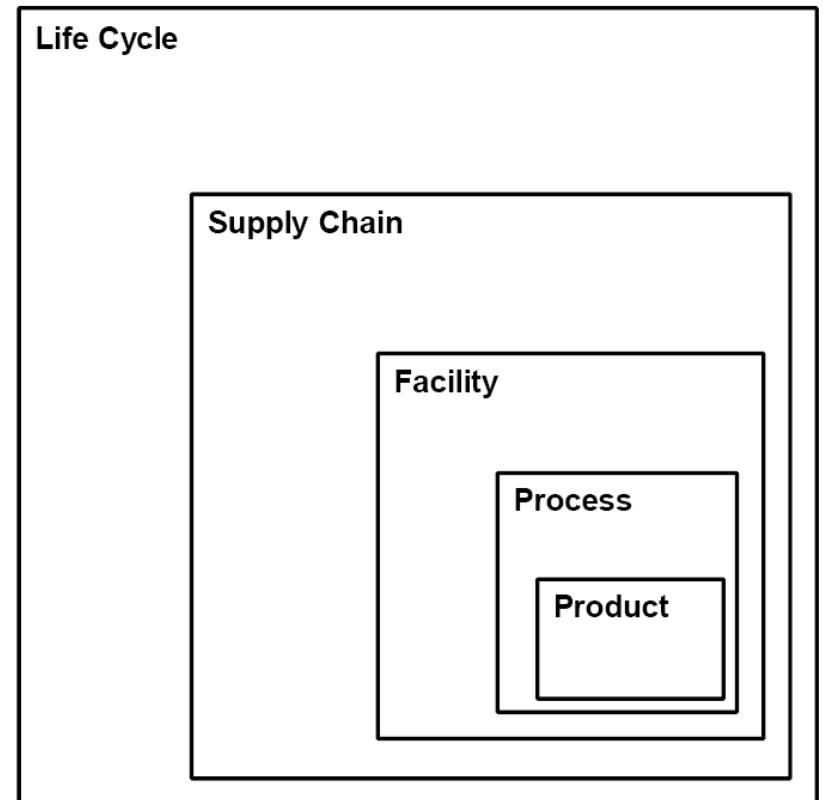


Roadmap for Chemical Assessment



Step 1: Select Boundary

- Life cycle stage
- Value stream
- Chemical categories
 - Product-level
 - Process-level
 - Maintenance/Operations-level
 - Wastes, emissions & discharges
- Life cycle impact categories



Step 2: Inventory Chemicals

Parameters:

- Name of chemicals
- Concentration of chemicals
- Quantity used

Data Sources:

- Material Safety Data Sheets
- Chemical disclosure initiatives
- Supply chain initiatives:
 - Material declarations
 - Certifications & standards

Case Study: MSDS-reportable chemicals

	Level 1	Level 2
Number of chemicals	2	22
Mass accounted, %	<3.0	99.39
Number of flagged chemicals	0	3

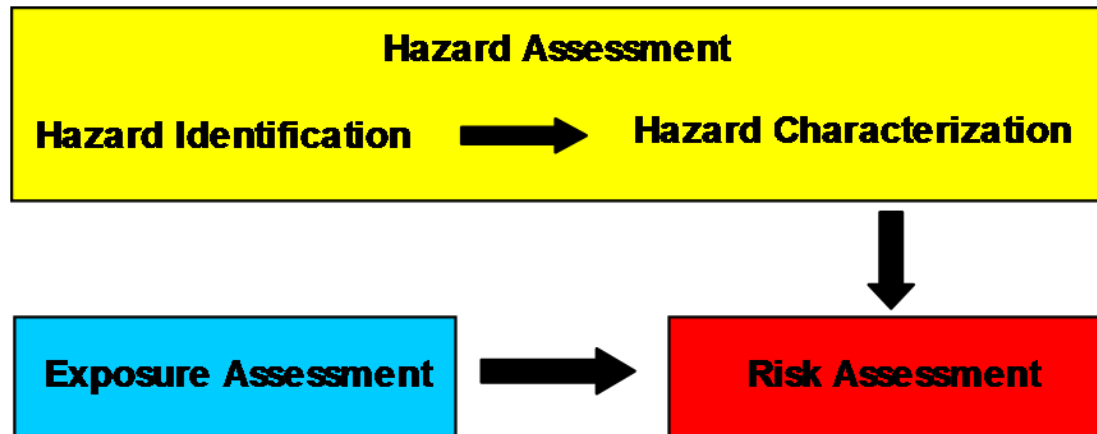
Level 1: The OEM Level = The MSDS shipped with the product formulation, as received by the OEM

Level 2: The Tier 1 Level = The MSDSs for each component used by the manufacturer of the product formulation (i.e. the Tier 1 supplier to the OEM)

Step 3: Hazard & Exposure Assessment

$$\text{RISK} = f \{ \text{HAZARD}, \text{EXPOSURE} \}$$

Risk is a function of BOTH hazard and exposure



Hazard characterization = **dose-response** assessment

Step 3a: Hazard Assessment

Hazard Identification

- An intrinsic (inherent) characteristic of a substance due to its physical and chemical properties.
- Potential to cause adverse effect on human health and the environment.
- A chemical may have multiple impacts/end-points.

Hazard Characterization

- Is the cause-and-effect relationship dose (concentration)-dependent?
- Assigns a numeric threshold value to describe potency (intensity) of effect:
 - LD₅₀: dose which causes mortality of 50% of population of test organism
 - EC₅₀: concentration which causes 50% of the maximal observed effect for a specific end-point
 - Equivalency potentials for life cycle impact categories
- Each end-point has its own dose-response relationship

Step 3b: Exposure Assessment

- Exposure concentration: What is the actual magnitude, period and frequency for which a organism comes into contact with the chemical in the real-world?
- Exposure route: How and when is an organism exposed to the chemical?
- Target group: Who is exposed to the chemical?
- Circumstantial: exposure is highly variable, influenced by given set of conditions (circumstances)
- Exposure concentrations, routes, target groups, affected end-points may vary with different uses of the same chemical (e.g. product types) and at different life cycle stages of a product

Chemical Assessment Tools

Some framing elements of a chemical assessment

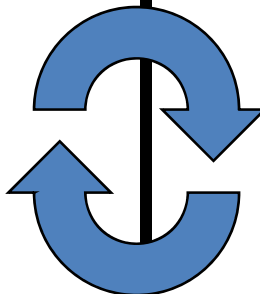
- o Hazard versus risk
- o Full risk assessment vs. screening for hazards and exposure potential
- o “Precautionary principle” vs. “adequate control”
- o Qualitative versus quantitative
- o Measured vs. modeled (predicted)

Level 1: Qualitative

- Hazard identification
- Exposure potential

Level 2: Quantitative

- Hazard characterization
- Exposure characterization



Authoritative Lists

Published Literature

Databases

Modeling; Structure-Activity Relationships (SAR)

Life Cycle Thinking

Life Cycle Assessment (LCA)

Direct monitoring

Internal risk assessment

Example Resources

□ US EPA Sustainable Futures Program

- Sustainable Futures Full Assessment Protocol
- Chemical and Toxicological Databases
- The Pollution Prevention Framework: Structure-Activity Relationship (SAR) software programs:
 - EPI Suite
 - ECOSAR
 - CHEMSTEER
 - PBT Profiler

□ BEES[®] 4.0 software

- BEES: “Building for Environmental and Economic Sustainability”
- Free software based on life cycle assessment
- Developed by National Institute of Standards and Technology (NIST)

Step 4: Evaluate “greenness” of chemicals

Utilize existing criteria, thresholds, ranking/rating systems

- Industry specific
- Product (category)-specific
- General

Options

- Regulatory compliance
- Authoritative lists (Governmental, Business, Institutional)
 - Banned chemical lists
 - Priority chemical lists
 - Restricted substances lists
 - “Chemicals of concern” lists
- Certifications
- Standards
- Procurement programs
- Bid specifications
- Commercial services

Product- and Industry Sector-Specific

Buildings –

- LEED: Leadership in Energy and Environmental Design [US Green Building Council]

Cleaning Products, Formulations –

- US EPA Design for Environment (DfE): Formulator Program
 - DfE General Screen for Safer Ingredients
 - DfE Screen for Fragrances – Human Health Criteria
 - DfE Screen for Solvents in Cleaning Products
 - DfE Screen for Surfactants
- CleanGredients® database of institutional & industrial cleaning product ingredients [Green Blue]
- Greenlist™ Process (SC Johnson, Five Winds International)

Carpets –

- NSF/ANSI 140-2007: Sustainable carpet assessment

Electronics –

- IEEE Standard 1680: EPEAT environmental criteria [Institute of Electrical and Electronics Engineers]
- Joint Industry Guide (JIG)-101: Material Composition Declaration for Electronic Products

Office Furniture –

- BIFMA E3-2008: Business and Institutional Furniture Sustainability Standard
- Public Works and Government Services Canada: Minimum Sustainability Requirements for Federal Government Office Furniture [Draft]

Resilient Floor Coverings –

- NSF 332-2007: Sustainability assessment for resilient floor coverings [Draft Standard]

Textiles –

- NSF 336: Sustainable Commercial Furnishings Fabric Assessment [Draft Standard]
- OEKO-TEX® Standard 100, 200 and 1000 [International Association for Research and Testing in the Field of Textile Ecology]

Wood, Composite Wood –

- Forest Stewardship Council
- Sustainable Forestry Initiative
- Environmentally Preferable Specification CPA 3-08 [Composite Panel Association]

General: Chemical-Level

- Globally Harmonized System of Classification and Labeling of Chemicals (GHS)
- MBDC Cradle to CradleSM Certification Program [McDonough Braungart Design Chemistry LLC]
- PharosTM Signaling the Future of Material SelectionTM
- Green Screen (v1.0) for Safer Chemicals [Clean Production Action]
- NSF Protocol P352: Validation and Verification of Eco-efficiency Analyses
- IHS Dolphin
- The Wercs
- Chemical Compliance Systems

Other Resources

- Green Suppliers Network (GSN) of West Michigan
 - EPA and NIST
 - Michigan Manufacturing Technology Council, The Right Place
- Green Chemicals & Materials User Group of West Michigan
 - The Right Place
- NSF/GCI 335,336: Standard for Greener Chemical Products and Processes [NSF, Green Chemistry Institute]

A Manufacturer's Handbook for the Sustainable Use of Chemicals & Materials



Jennifer M. Granholm, Governor * Steven E. Chester, Director
Michigan Department of Environmental Quality
www.michigan.gov/deq

http://www.michigan.gov/documents/deq/deq-ess-p2-glssen-handbook-manusustainchemicals_258440_7.pdf

Thank you!

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