Increase Safety of Hazardous Chemicals

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ISHC Project Tasks

- Define Inherently Safer Technology (completed)
  - DHS needed single clearly stated, science based definition that has not been subjected to the desires of various interest groups
- Develop metrics for ISHC evaluation (August 2010 start)
  - There is currently no method to evaluate how changes in a process effect the entire supply chain
  - Metrics are needed to quantify the impact of changes on process safety and security throughout the supply chain
- Gap analysis (November 2010 start)
  - Initially intended to produce a baseline of the current body of knowledge of toxic chemical production, transportation, storage, and use
  - Resources have been refocused to support the timely completion of a fully functional metrics capability
  - Collect process data for test cases to validate/ refine metrics for a select set of chemicals

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Safer Design Strategies

- *Inherent* - Eliminate or modify the hazard by employing one of four ISD strategies
- *Passive* - Minimize hazards by process and equipment design features that reduce the frequency or consequences of incidents *without* the active functioning of any device.
- *Active* - Using controls, safety interlocks, and emergency shutdown systems to detect and correct process deviations.
- *Procedural* -Using operating procedures, administrative checks, and emergency response to prevent or minimize effect of an incident.

Inherent	Passive	Active	Procedural

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The IST Definition

Inherently Safer Technology (IST), also known as Inherently Safer Design (ISD), **permanently eliminates or reduces hazards** to avoid or reduce the consequences of incidents.

IST is a philosophy, applied to the design and operation life cycle, including manufacture, transport, storage, use, and disposal.

IST is an **iterative process** which considers options, including eliminating a hazard, reducing a hazard, substituting a less hazardous material, using less hazardous process conditions, and designing a process to reduce the potential for, or consequences of, human error, equipment failure, or intentional harm.

Overall safe design and operation options cover a spectrum from inherent through passive, active and procedural risk management strategies. **There is no clear boundary between IST and other strategies**.

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Properties of IST

IST's are relative:
A technology can only be described as inherently safer **when compared to a different technology**, including a description of the hazard or set of hazards being considered, their location, and the potentially affected population. **A technology may be inherently safer than another with respect to some hazards while being inherently less safe with respect to others**, and may not be safe enough to meet societal expectations.

IST's are based on an informed decision process:
Because an option may be inherently safer with regard to some hazards and inherently less safe with regard to others, decisions about the optimum strategy for managing risks from all hazards are required. The decision process must consider the entire life cycle, the full spectrum of hazards and risks, and the potential for **transfer of risk from one impacted population to another.** Technical and economic feasibility of options must also be considered.

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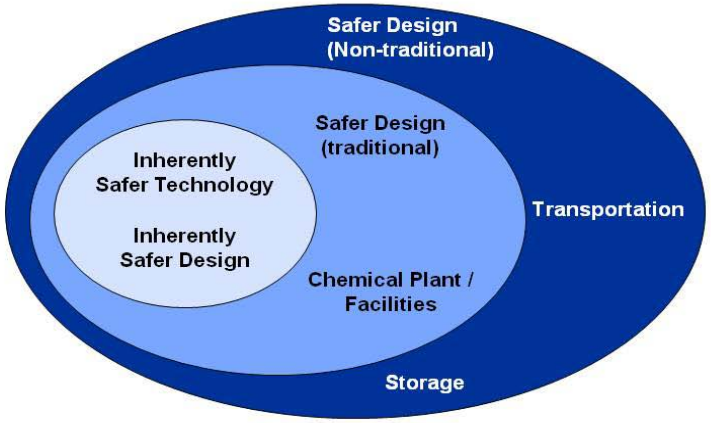
Hierarchy of IST and Safer Design

- IST is a component of Safer Design
- IST is a complicated concept because there is no clear boundary between IST and Safer Design
- ISHC examines the entire chemical supply chain and life cycle
- IST and Safer Design has been limited to chemical production and manufacture
- IST and Safer Design must be applied to the entire chemical supply chain to be effective



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Defining Inherently Safer Technology

- IST has received significant attention as a potentially valuable tool in managing security risks for hazardous material handling operations of all types
- No consensus definition of IST
- Current definitions driven by example
- The definition should span the full lifecycle of the chemical enterprise including:
  - manufacturing and use
  - storage
  - Transportation
- Assemble a committee of highly respected experts to evaluate the many IST concepts being discussed in the technical and political arena. Committee will include representatives from:
  - Independent non-profits
  - Industry
  - Academics

- **Be applicable to a broad definition of "technology";**
- **Consider the full range of hazards of concern associated with a process or product; and**
- **Be useful in a risk/economic/benefit context.**

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Metrics Task

- A technology or chemical can only be described as safer than a different technology or chemical when all hazards associated with a specific site and operation are considered
- A set of metrics are being developed which help assess and compare the total hazard change throughout the chemical supply chain when there is a change at some point within the supply chain
  - A change to a single aspect of an interconnected process to accomplish a specific objective, even one which appears to be highly desirable, may have unanticipated consequences which may be undesirable
  - Implementation of IST will necessarily require a full evaluation of the entire process and everything related to it

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Purpose of the Metrics and Current Limitations

- What this effort is:
  - Measurement of the hazard across nodes in the chemical supply chain
  - Relative hazard index (metrics)
  - An interim solution
- What this effort is not:
  - This is not a risk assessment
  - Current metrics do not include preventive or mitigative features

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Approach

- Analyze the chemical supply chain and define functional units or nodes that can operate independently
- Define a set of metrics applicable across all nodes that can evaluate safety and security issues related to its function
- Suggest a method for considering the contribution of each node to the overall safety and security of the entire supply chain

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Five Typical Supply Chain Nodes Identified

1. Process inventories at production facilities
2. Storage inventories at production facilities
3. Transportation from point of production to point of use
4. Storage at the point of use
5. Use of the material
6. Others

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The Relative Hazard Index (RHI)

- An RHI has been developed for each node in the supply chain
- The RHI is the product of five metric terms:

$$RHI = F_{tox} F_{qty} F_{red} F_{PP} F_{pop}$$

which includes terms for:

  - F_{tox} for toxicity
  - F_{qty} for quantity in use, storage or transportation
  - F_{red} for release quantity reduction
  - F_{PP} for processing or storage conditions
  - F_{pop} for population density

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Metrics Formulae and Application

- Each metric is normalized on a scale of 1 to 10
- Each node in a chemical supply chain is treated independently
- RHI score is based on a toxic release endpoint (LC_{50})
- RHI scores can range from 1 to 100,000
- RHIs only have meaning when directly comparing one process or supply chain step to another

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Input Data for the Metrics

- F_{tox} for toxicity
  - Metric input: LC50 (ppm) for 4-hour exposure
  - Places toxicity on a logarithmic scale ranging from 1 to 10
- F_{qty} for quantity
  - The quantity term of the metrics equation is the sum of all major potential sources of TIH release from a manufacturing site
  - Includes use, storage or transportation
- F_{red} for release quantity reduction
  - Allows for mitigation actions, active or passive

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Input Data for the Metrics, cont'd

- F_{PP} for process parameters
  - This metric is based on physical properties of the compound under consideration

    F_T is based on the boiling point of the compound and temperature at which it is being processed or stored, addresses rainout

    F_P is determined by operating or storage pressure

    F_{VP} is based on the vapor pressure of the compound at the processing or storage temperature, address evaporation
  - Metric input: D_{max}: Maximum local population density in people / mi^2 "worst pie slice" within 90 degree arc and 2 mi distance) at facility or along course of shipment route

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Example: Alkylate Production

- Alkylate is a key component in cleaner burning gasoline
- Gasoline contains 10-15 % alkylate
  - Lowers the levels of benzene, aromatics, and sulfur
  - Reduces the amount of ozone forming volatile organic compounds (VOCs) found gasoline
- The alkylate is produced from unusable refinery by products (propylene, butylenes, and amylenes and isobutane)
- Production requires strong acid catalyst
- Only two alkylate production technologies available
  - Sulfuric acid (H_2SO_4)
  - Hydrofluoric acid (HF)

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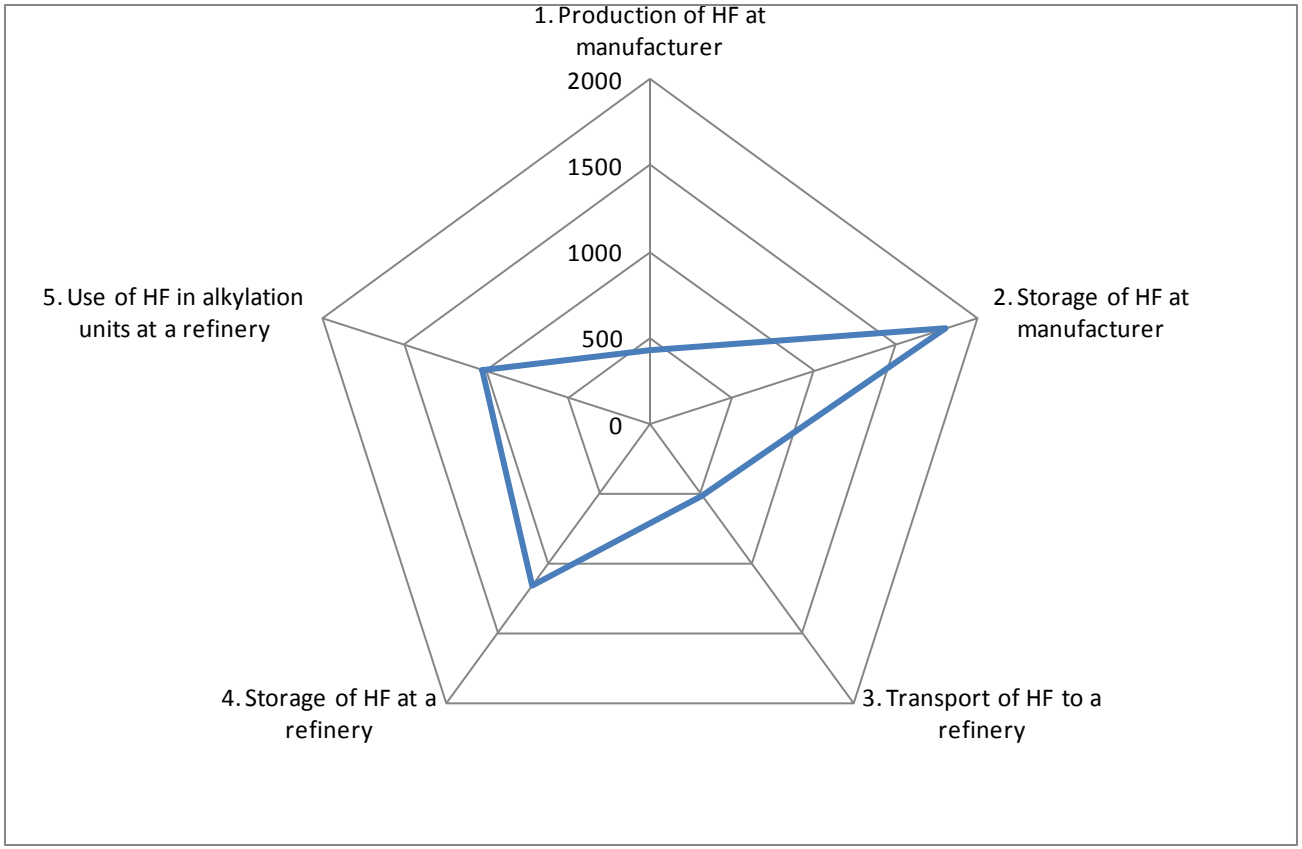
HF Metrics

Plotting the Supply Chain Step vs. the *RHI* yields:



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Metrics Capabilities

- No previous examples of supply chain metrics
- All preceding metrics were designed to compare changes in process chemistry or technology
- Captures the entire supply chain
- Can directly compare alternate processes and changes that an alternate process causes throughout the supply chain
- Can account for risk balance
- Can see movement of risk
- Ability to consider mixtures

Summary

- A technology may be inherently safer than another with respect to some hazards while being inherently less safe with respect to others
- There is currently no way to measure the increase in safety and security across the supply chain
- The Metrics equation captures the essential elements that contribute to the hazards and consequences
- Further work will refine the Metrics with respect to reduction factors, transportation and affected populations thus enabling it to measure the increase in safety and security across the supply chain
- The purpose of this program is to develop advances in science, not to develop policy

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