

## Pollution Prevention - Fundamentals and Practice Spring Semester - 2012 Chapter 1

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## Preliminaries

- Bathrooms
- Textbook - none
- Class Structure
- Guest Lecturers
- Grading System
- Quizzes
- Field Trips
- Buddy System!
- SOA Project
- Seating Chart
- Assignments / Web Site –  
[www.indigowatergroup.com](http://www.indigowatergroup.com)

Examples – from  
my background  
and perspective

## Objective of the Course

- Reorient student's outlook to incorporate society's interest in environmental quality and sustainability into engineering education
- Encourage a stronger environmental ethic among engineering students
- Understand environmental processes and their impacts.

*"We have learned the inherent limitations of treating and burning wastes. A problem solved in one part of the environment may become a new problem in another part."*

*We must curtail pollution closer to its origin so that it is not transferred from place to place."*

William Reilly  
former U.S. EPA Administrator  
1990

## Major Environmental Laws

- 1955 – Clean Air Act (CAA)
- 1969 – NEPA, National Environmental Policy Act
- 1972 – Clean Water Act (CWA)
- 1974 – Safe Drinking Water Act (SDWA)
- 1975 – HMTA, Hazardous Materials Transportation Act
- 1976 – RCRA, Resource Conservation and Recovery Act
- 1976 – TSCA, Toxic Substances Control Act
- 1980 – CERCLA, Comprehensive Environmental Response, Compensation, and Liability Act
- 1984 – EPCRA, Emergency Planning and Community Right to Know Act
- 1990 – Oil Pollution Act

## Rule of Thumb 1

- Your professional success rests on  
What you know, AND  
Who you know
- Both are essential and equally  
important

## The Industrial Revolution

- Home □ power-driven machines (textile industry)
- Water power to steam
- Wood to coal
- Power loom; men □ women
- Steam ship and locomotive
- Aviation and communications



## The Next Revolution

- Previously people were limited and resources were plentiful
- Now, things are the other way around
- The system must optimize around the scarcest commodity

Reading: Natural Capitalism

## Natural Capitalism

- Four Types of Capital
  - Human Capital
  - Financial Capital
  - Manufactured Capital
  - Natural Capital

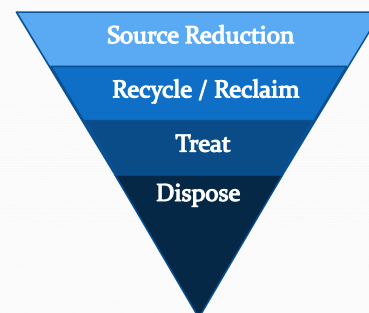
## What is Pollution Prevention?

- Reducing or eliminating toxic materials
  - Replacing a material in the production line
  - Reformulating the product
  - Installing new or modifying existing process equipment
- Closed loop (on-site) recycling
- Developing new technology that helps others implement P2
- Involves holistic approach

## What P2 is NOT?

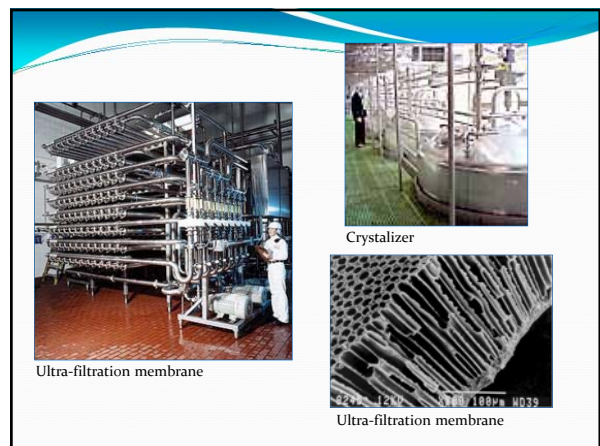
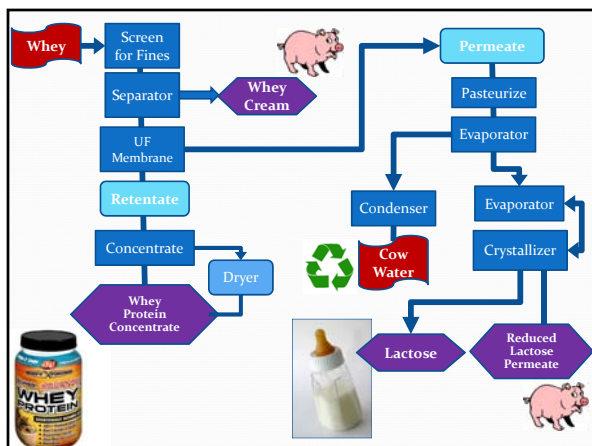
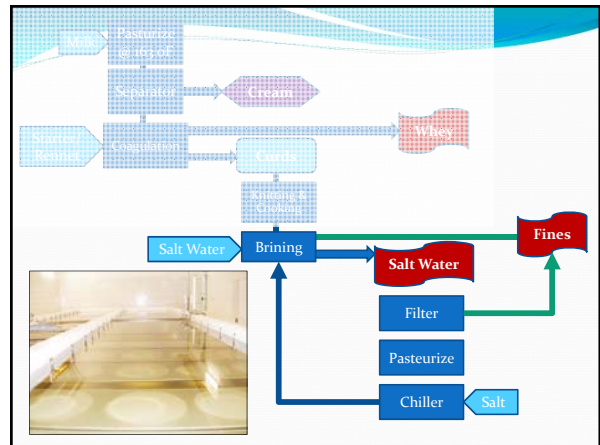
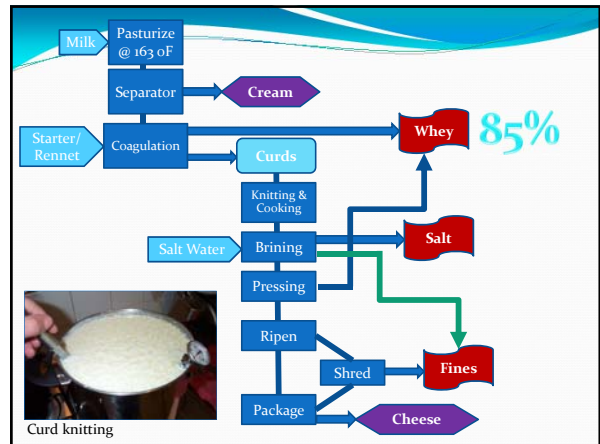
- **End of pipe treatment**
- Incineration or disposal
- Burning waste for energy recovery
- Transferring waste from one medium to another
- Incorporation of waste into products or by- products

## P2 Hierarchy



## Manufacturing Cheese

- Curds = 15% while Whey = 85%
- Whey Characteristics
  - BOD of 30,000 – 50,000 mg/L
  - 5% to 6% total solids
  - 70% of solids are lactose
  - 4% to 9% of solids are protein and minerals
- Internal recycling and recovery of “waste products” for P2
- Still need some wastewater treatment



## That's not the whole story

- Clean in Place (CIP)
  - Nitric acid
  - Phosphoric acid
  - Sodium hydroxide
  - Hot water
- Acids and “cow water” used multiple cycles
- Eventually – all water goes to wastewater treatment plant (WWTP)
  - *Resource recovery happens even here!*



## Rule of Thumb 2

- One of the best ways to meet the best and brightest in your field is to **VOLUNTEER**
- Moderate a session at a conference
- Join a committee
- Collect business cards

## Recycling vs. P2

- EPA didn't used to consider recycling or reprocessing as Pollution Prevention
- Many States do include recycling and reuse in their definition of P2
- In this course, a broader version of P2 that includes recycling and reuse of materials will be followed

## ShetkaStone

- All Paper Recycling based in Minnesota
- All types of recycled paper accepted, plants, and cloth fibers
- Paper products account for 40% of solid waste in U.S.
- Products produced include:
  - Shetkastone (countertops, benches, molding)
  - Ceiling Tiles
  - Decorative Screens
- 100% sustainable life cycle
- Cost somewhere between Corian and Granite



## Shetkastone

- A ton of paper makes 400 sf of material 1.5 inches thick
- Proprietary process described as:
  - Segregate by color
  - Shredding and pulping
  - Addition of water based polymers
  - Pressing and curing
  - Polish
- Uses hydrogen bonding
- No toxic glues or formaldehyde
- 30+ year life expectancy

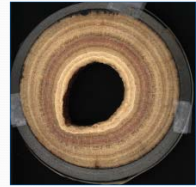
## Phosphorus

- U.S. has 50 to 100 year supply
- U.S. supplies ~45% of world supply
- Produced 29 million tons in 2007
- **Critical for farming**
- Most phosphorus is single use
- Lost in run-off
- Discharged to WWTP



## Struvite

- Struvite is magnesium ammonium phosphate –  $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$
- Created during anaerobic wastewater treatment
- A nuisance and a waste!!!
- Landfill, incinerate, or land apply
- *Can be recovered and sold as fertilizer additive*



## P2 Rules of Thumb - Bishop

- **Prevent creation of the waste**
- Minimize handling of toxins
- Operate at higher efficiency
- Improve product quality
- Absorb past wastes into current operations

27

## What is Waste?

- Legally defined in RCRA
- Solid product left over at the end of a process or action
- Solid waste means any garbage, refuse, sludge, from a waste treatment plant, water supply treatment plant, from a waste treatment plant or air pollution control facility and other discarded material, *including solid, liquid, semi-solid, or contained gaseous materials* resulting from industrial, commercial, mining and agricultural activities and from community activities.

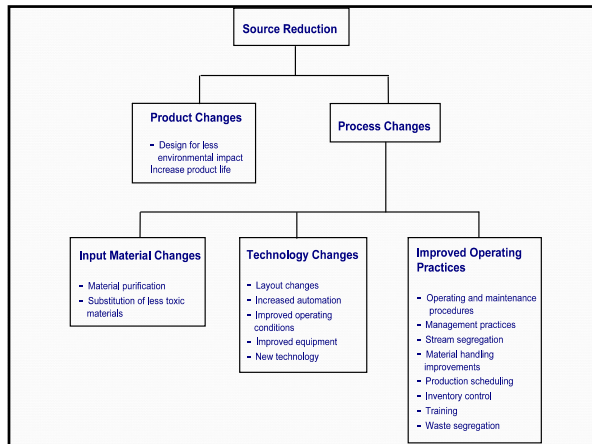
*A waste is a  
resource  
out of place*

29

## P2 Rules of Thumb - Bishop

- **Prevent creation of the waste**
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30



## Avoiding Waste Creation

- **Convert byproduct streams back to raw materials**
- Select raw materials that generate valued byproducts
- Decrease energy input
- Update the material balance

32

## Byproducts to Raw Materials

- **Dezinc galvanized steel**
- **Produce caustic from soda ash: NaOH from Na<sub>2</sub>CO<sub>3</sub>**

33

## Dezinc Galvanized Steel

- $\text{Zn}^0_{(s)} + 2\text{NaOH}_{(liq)} + \frac{1}{2} \text{O}_2 \rightarrow \text{Na}_2\text{O} \cdot \text{ZnO}_{(aq)} + \text{H}_2\text{O}_{(g)}$
- $\text{Na}_2\text{O} \cdot \text{ZnO}_{(aq)} + \text{H}_2\text{O}_{(g)} + \text{power} \rightarrow \text{Zn}^0 + 2\text{NaOH}_{(liq)} + \frac{1}{2} \text{O}_2$

34

## Electrowinning / Refining



When an electrowinning unit is in operation, the electrical potential applied to the electrodes causes dissolved metals and other positively charged ions to migrate toward and plate onto the cathodes. As metals deposit on the cathodes, the metal buildup decreases the deposition rate. When the metal deposition rate is no longer sufficient, cathodes are removed from the electrolytic cell for on-site or off-site metal recycling.

35

## Tankhouse Starter Sheets



36

## Caustic from Soda Ash

- $\text{CaO}_{(s)} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{heat}$
- $\text{Na}_2\text{CO}_3_{(aq)} + \text{Ca(OH)}_2_{(s)} \rightarrow$   
 $2\text{NaOH}_{(aq)} + \text{CaCO}_3_{(s)}$
- $\text{CaCO}_3_{(s)} + \text{H}_2\text{O} + \text{heat} \rightarrow$   
 $\text{Ca(OH)}_2_{(s)} + \text{CO}_2_{(g)}$

37

## Avoiding Waste Creation

- Convert byproduct streams back to raw materials
- **Select raw materials that generate valued byproducts**
- Decrease energy input
- Update the material balance

38

## Raw Materials Selection

- **HCl from NaCl vs KCl using sulfuric acid**
- **Neutralize with  $\text{Mg(OH)}_2$  rather than  $\text{Ca(OH)}_2$**

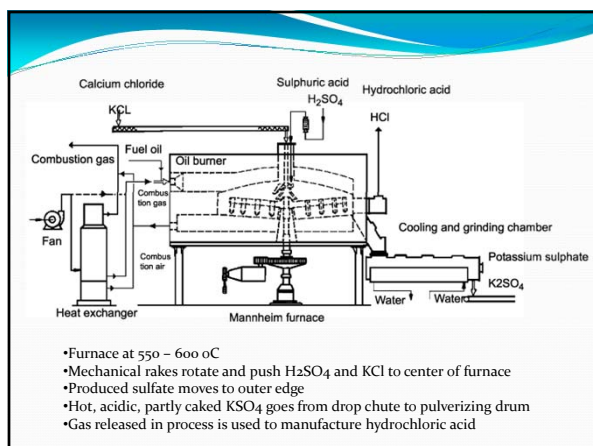
39

## Common Salt vs Potash

### The Mannheim Furnace

- $2\text{NaCl} + \text{H}_2\text{SO}_4 + \text{heat} \rightarrow$   
 $\text{Na}_2\text{SO}_4_{(s)} + 2\text{HCl}_{(gas)}$
- $2\text{KCl} + \text{H}_2\text{SO}_4 + \text{heat} \rightarrow$   
 $\text{K}_2\text{SO}_4_{(s)} + 2\text{HCl}_{(gas)}$

40



## Gypsum vs Fertilizer

- $\text{Ca(OH)}_2 + \text{H}_2\text{SO}_4 \rightarrow$   
 $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}_{(s)}$
- $\text{Mg(OH)}_2 + \text{H}_2\text{SO}_4 \rightarrow$   
 $\text{MgSO}_4_{(s)} + 2\text{H}_2\text{O}$

42

## Filter Press @ Encycle



43



## Belt Filter Press at Parker



## Avoiding Waste Creation

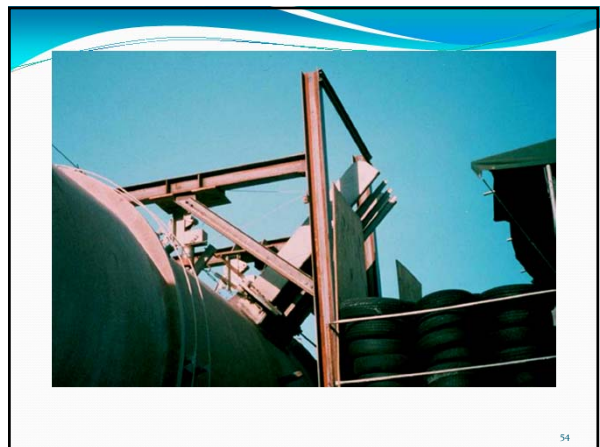
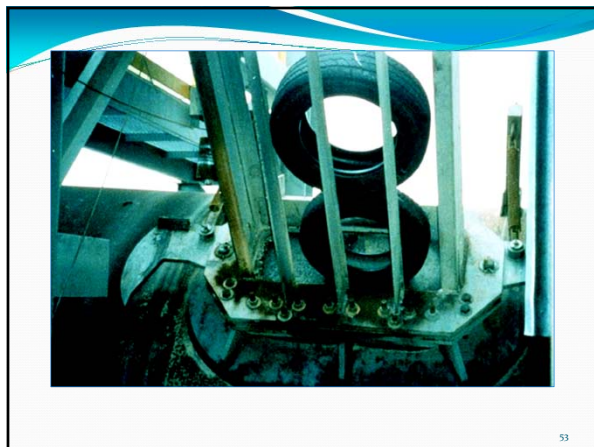
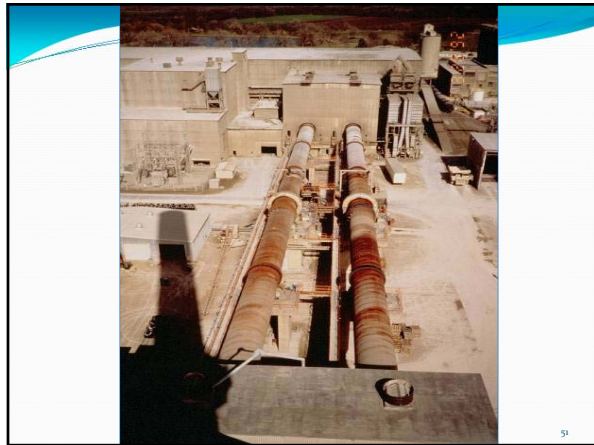
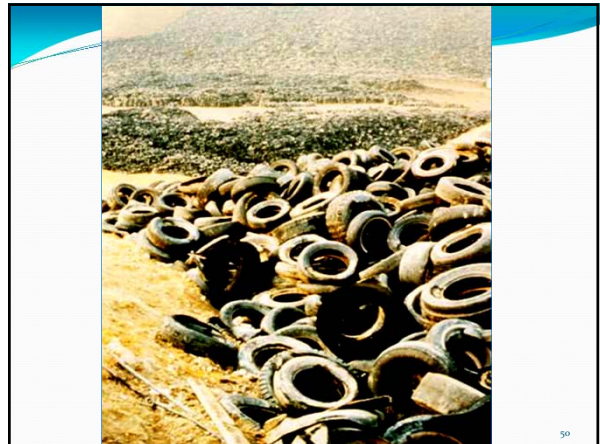
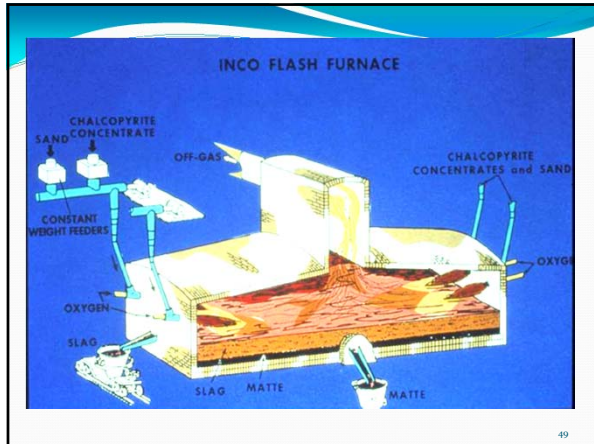
- Convert byproduct streams back to raw materials
- Select raw materials that generate valued byproducts
- **Decrease energy input**
- Update the material balance

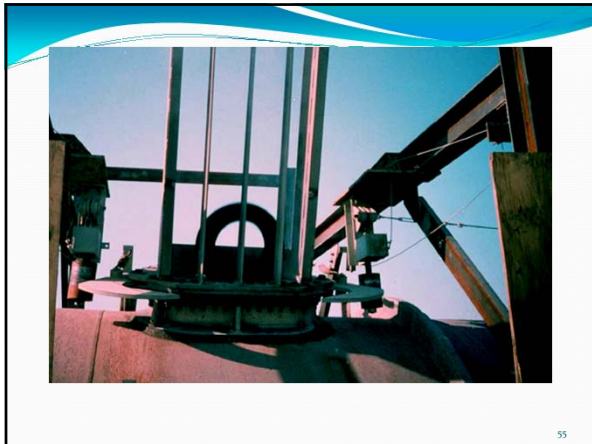
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## Decrease Energy Input

- Flash smelting of sulfides
- Production of cement
- Waste to NiCu concentrate

48





55

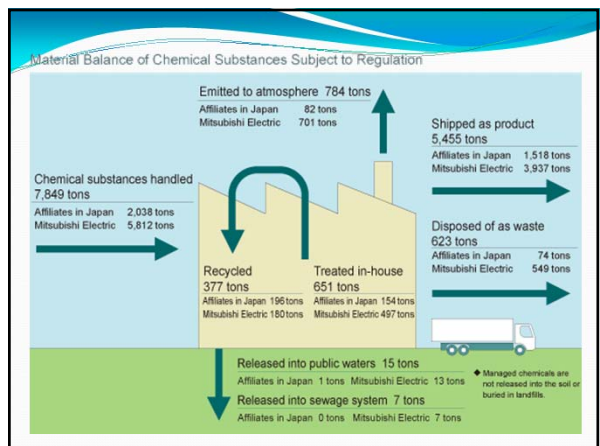
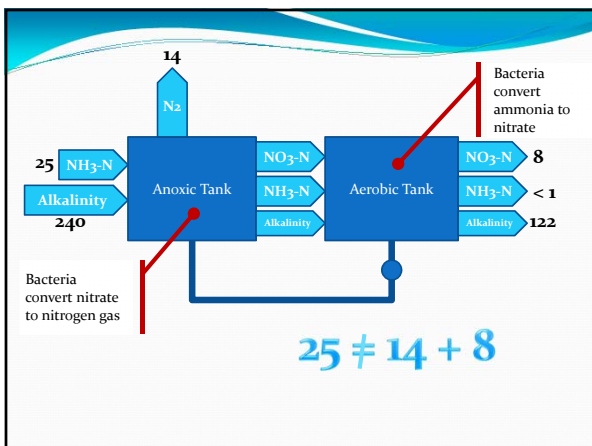
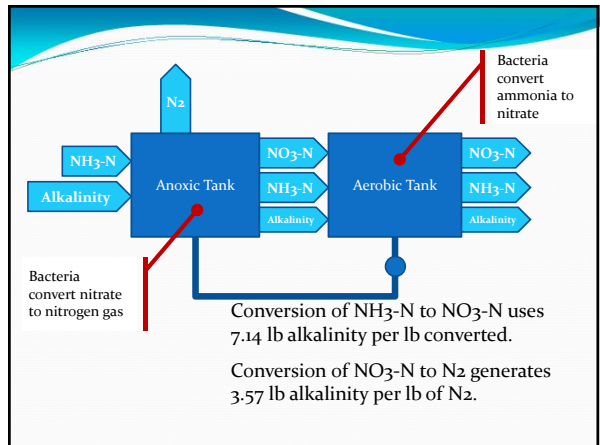


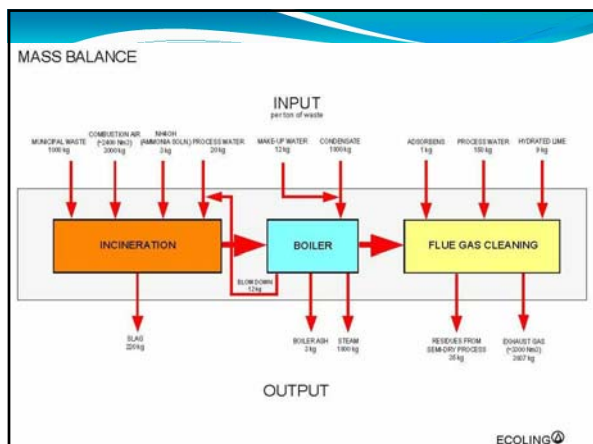
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### The Material Balance

- *A prime means of enforcement*
- Defines rate and composition of process inputs and outputs
- Interacts with the energy balance
- Provides understanding of process control constraints
- Helps to locate fugitive emissions and waste/lost product

57





## P2 Rules of Thumb - Bishop

- Prevent creation of the waste
- **Minimize handling of toxins**
- Operate at higher efficiency
- Improve product quality
- Absorb past wastes into current operations

62

## Hussey Seating Company



- Goal: reduce VOCs and HAPs
- Two process changes
  - Switch to automated UV cured coating system for bleachers
  - Switch to aqueous based coatings for finished wood
- Before switch, two coatings of polyurethane were hand applied

## Benefits of P2 Changes

- VOCs reduced from 50 tpy to < 1 tpy
- HAPs reduced from 10 tpy to < 1 tpy
- Increased productivity
- Improved on-time delivery
- Before, 8 employees made 9,000 units/wk
- After, 4 employees make 14,000 units/wk

- UV system captures and recycles excess coating
- Coating use increased 20%, but units produced more than doubled
- Unit cost for coating decreased 17%
- Easier cleanup and no solvent use
- UV coating is more durable

## Environmental Test Methods

- Nessler Method for Ammonia Analysis no longer EPA approved
- Alternative chemistry for COD testing
- Substitute n-Hexane for Freon in FOG analysis
- Recycle spent hexane with distillation
- Alternate test method for nitrate – ISE versus cadmium reduction method

## Minimize Handling of Toxins

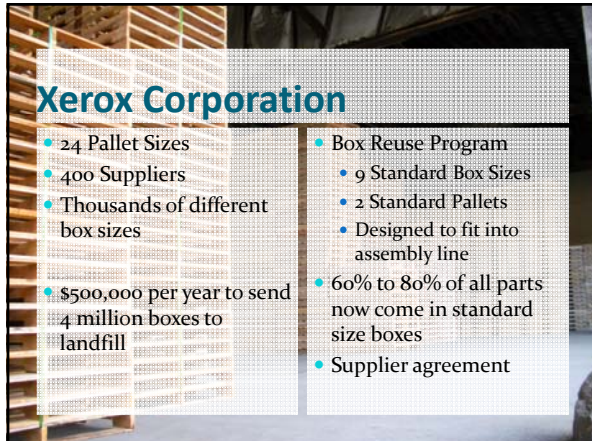
- Consumer batteries (Hg, Cd)
- Freon, DDT, PCBs
- Pb - paint, gasoline, ammo, solder
- Hg - fungicide, coal, instruments

67

## P2 Rules of Thumb - Bishop

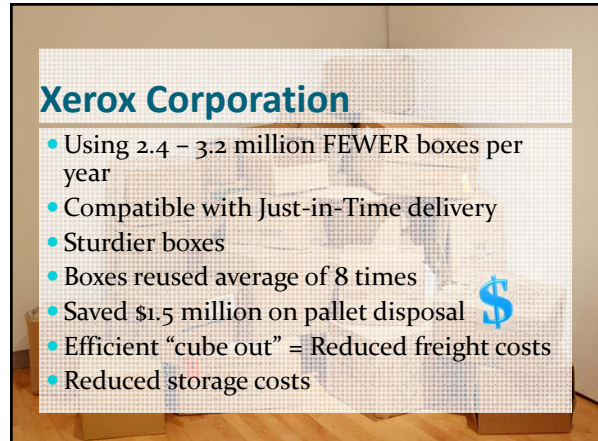
- Prevent creation of the waste
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68



### Xerox Corporation

- 24 Pallet Sizes
- 400 Suppliers
- Thousands of different box sizes
- \$500,000 per year to send 4 million boxes to landfill
- Box Reuse Program
  - 9 Standard Box Sizes
  - 2 Standard Pallets
  - Designed to fit into assembly line
- 60% to 80% of all parts now come in standard size boxes
- Supplier agreement



### Xerox Corporation

- Using 2.4 – 3.2 million FEWER boxes per year
- Compatible with Just-in-Time delivery
- Sturdier boxes
- Boxes reused average of 8 times
- Saved \$1.5 million on pallet disposal
- Efficient “cube out” = Reduced freight costs
- Reduced storage costs

## Rule of Thumb 3

- You don't need to know everything.
- Know where to find the information.
- Stay one day ahead of the client.

## Sustainability

*“Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.”*

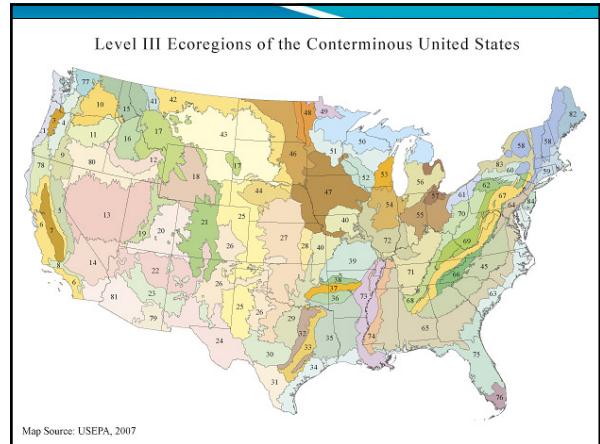
World Commission on Environment and Development, 1987

72

## Sustainability

- Sustainable waste management implies that there would be no degradation of land, water or air by wastes
- Basis for EPA's new EcoRegion concept for regulating pollutants

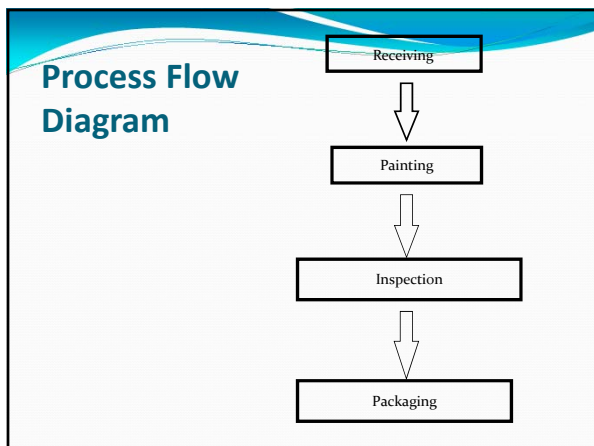
73



## Materials Balance

## Analyze Background Information and Flow Diagrams

- Waste types, volumes, and disposal costs
- Written procedures for waste handling
- Current waste reduction activities
- Purchasing records and specifications
- Process quality control data
- Process flow diagrams



## Conduct a Facility Walk-Through

- Follow the process flow diagram.
- Look for sources of waste and opportunities to eliminate, reduce, reuse, or recycle.
- Observe both normal operations and sporadic events such as cleanup and product changes.
- Ask questions.

### Key Questions

- What type of waste is it?
- Where did it come from?
- How much of it is there?
- How much do you pay to get rid of it?
- If it's raw material, how much did you pay for it?
- Is it possible to reduce or eliminate it?

### Perform a Mass Balance

**Materials In = Materials Out**

- Go back to the process flow diagram.
- Move from process to process.
- Identify all inputs and outputs.
- Determine waste volumes and costs.
- List waste reduction options.

### Perform a Mass Balance

<p><b>Inputs</b></p> <ul style="list-style-type: none"> <li>• Paint</li> <li>• Unpainted Parts</li> <li>• Energy</li> <li>• Solvents</li> <li>• Rags</li> <li>• Air Filters</li> </ul>	<div style="border: 1px solid black; padding: 10px; width: fit-content; margin: 0 auto;"> <p>Painting Process</p> </div>	<p><b>Outputs</b></p> <ul style="list-style-type: none"> <li>• Painted Parts</li> <li>• Empty Drums</li> <li>• Air Emissions</li> <li>• Waste Solvent</li> <li>• Waste Paint</li> <li>• Soiled Rags</li> <li>• Used Air Filters</li> </ul>
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### Prepare a Waste Assessment Report

- Summarize background information.
- Review waste generation and existing methods of waste management.
- List waste reduction opportunities.
- Include an economic assessment of current and proposed activities.

### Evaluate Waste Reduction Options

<ul style="list-style-type: none"> <li>• Occupational Impacts</li> <li>• Initial Cost</li> <li>• Operating Cost</li> <li>• Savings</li> <li>• Environmental Impacts</li> <li>• Production Shutdown Requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Productivity</li> <li>• Impact on Quality</li> <li>• Energy Requirements</li> <li>• Facility Modifications</li> <li>• Maintenance Requirements</li> </ul>
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