De-inking Plastic Films

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Problem Statement

- Develop de-inking process considering
  - Type of plastic film
  - Collection strategies
  - Cost of production

What is De-Inking?

- **De-inking** - removes ink, dyes, and other contaminates from a given material

Why De-Ink?

- Growth of demand in plastics leads to an increase in plastic waste
- Poor physical and mechanical properties due to residual ink

Why De-Ink?

- Removing ink increases quality
- De-inked plastic has a higher selling value

Problems with Recycled Plastic

- Strength and elongation at break are decreased
- Gases formed in extruded polymer
- Color from residual ink

Project Milestones

1. Understand mechanism
2. Separation techniques
3. Recovery issues
4. Marketability
5. Plant location optimization
6. Profitability

To Understand Ink Attachment

1. Composition
2. Surface tension
3. pH

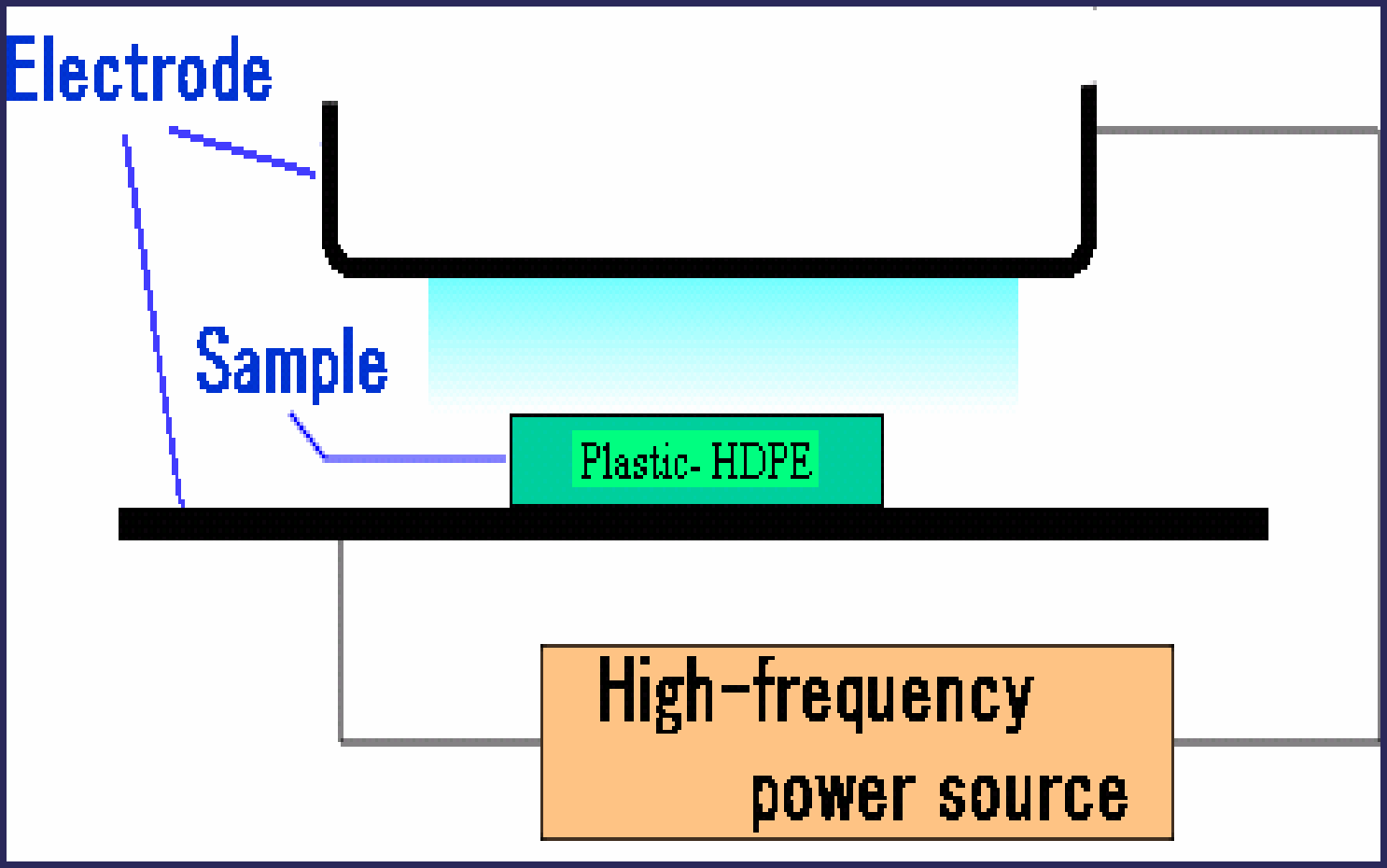
What is Ink Composed of?

1. Pigments
2. Binders
3. Carriers
4. Additives

Surface Tension

- Caused by cohesion forces
- Broken when cohesive forces are overcome by a stronger force
- Surfactants create this atmosphere

Corona Discharge



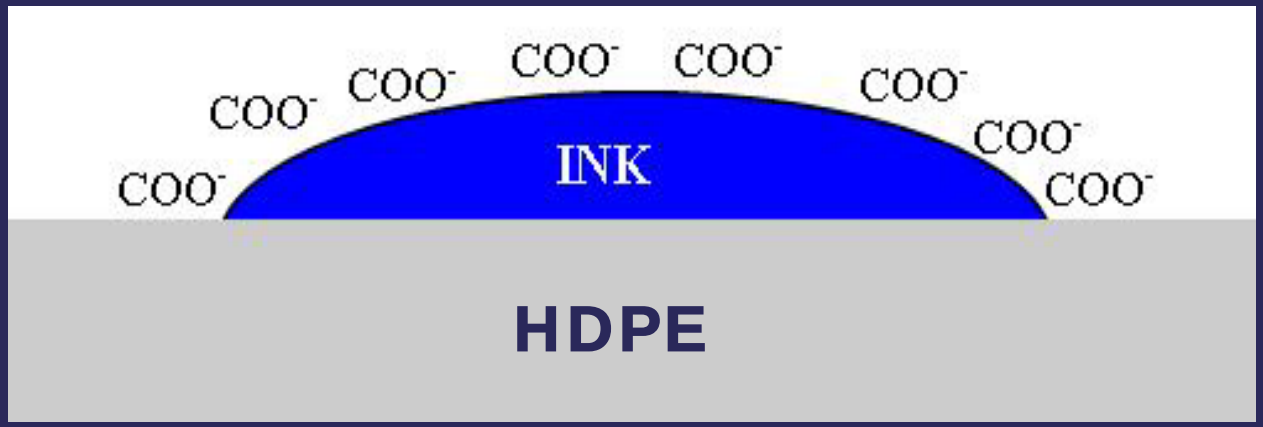
pH

- Causes the binder to agglomerate or extend
- Isoelectric point - pH at which the number of anions and cations are equal

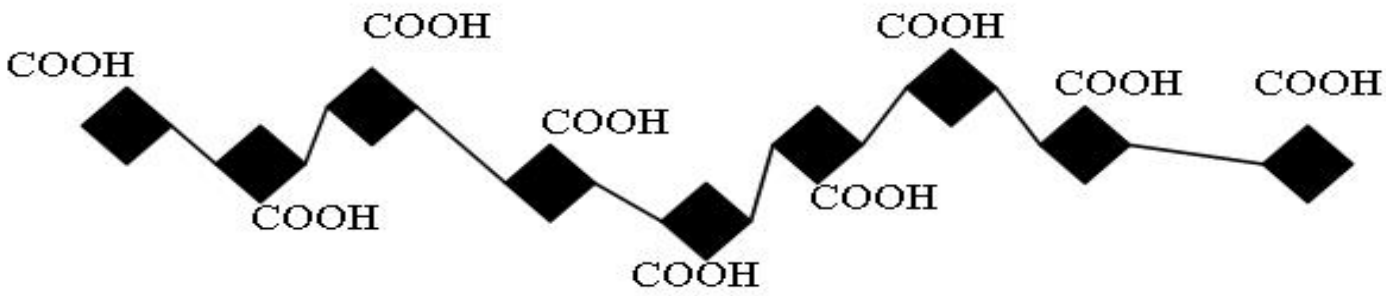
Ink Detachment

1. Deprotonation
2. Surface adsorption
3. Ink detachment
4. Solubilization and stabilization

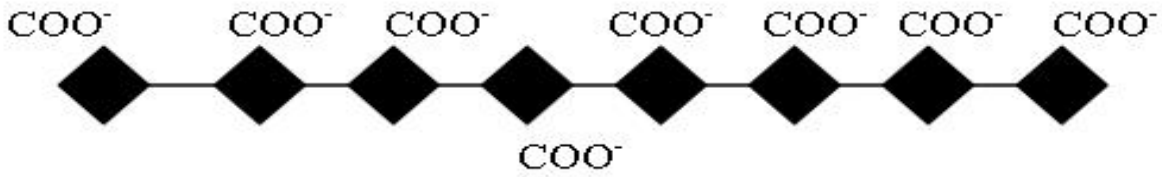
Deprotonization



Low pH

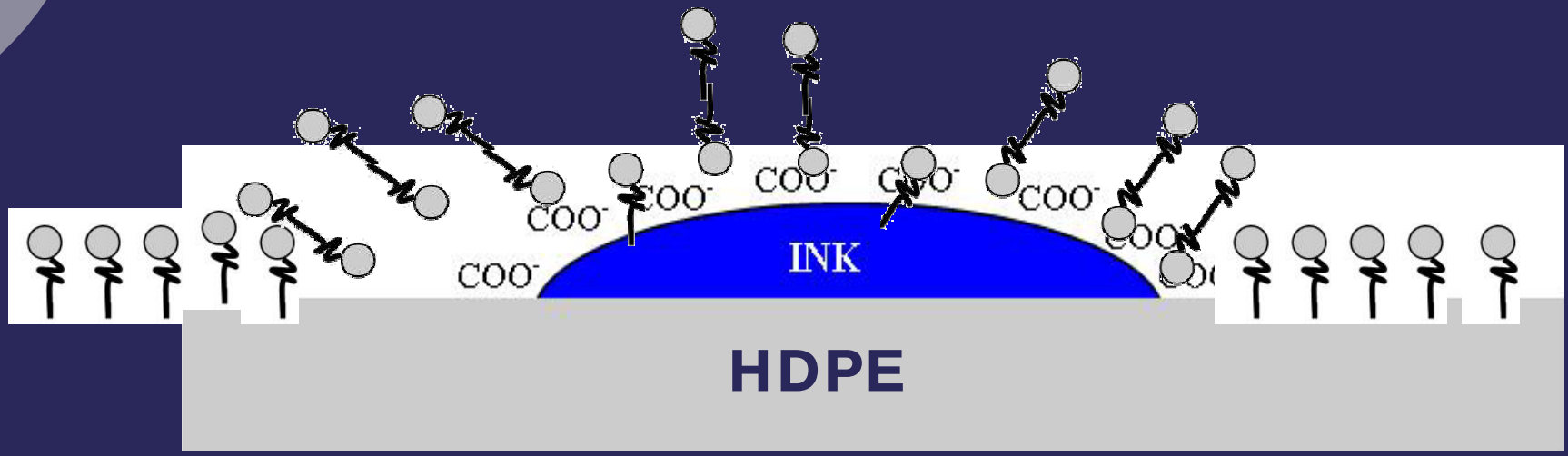


High pH



[8]Gecol, Hatice , Colloid Polymer Science 2004

Surface adsorption



Raw Materials

- Plastic
  - Why pick Wal-Mart bags?
    - Water-based ink
    - Made of HDPE
    - Wal-Mart donates used bags

Raw Materials

- Base
  - Isoelectric point - pH of a solution at which the net charge of a molecule is zero
    - 3.1 for carboxylic acid
  - A pH of 12 is used

Raw Materials

- Deionized water
  - Eliminates ions that could react with the deprotonated carboxylic acid groups

Raw Materials

- **Surfactant -** linear molecule that modifies surface tension

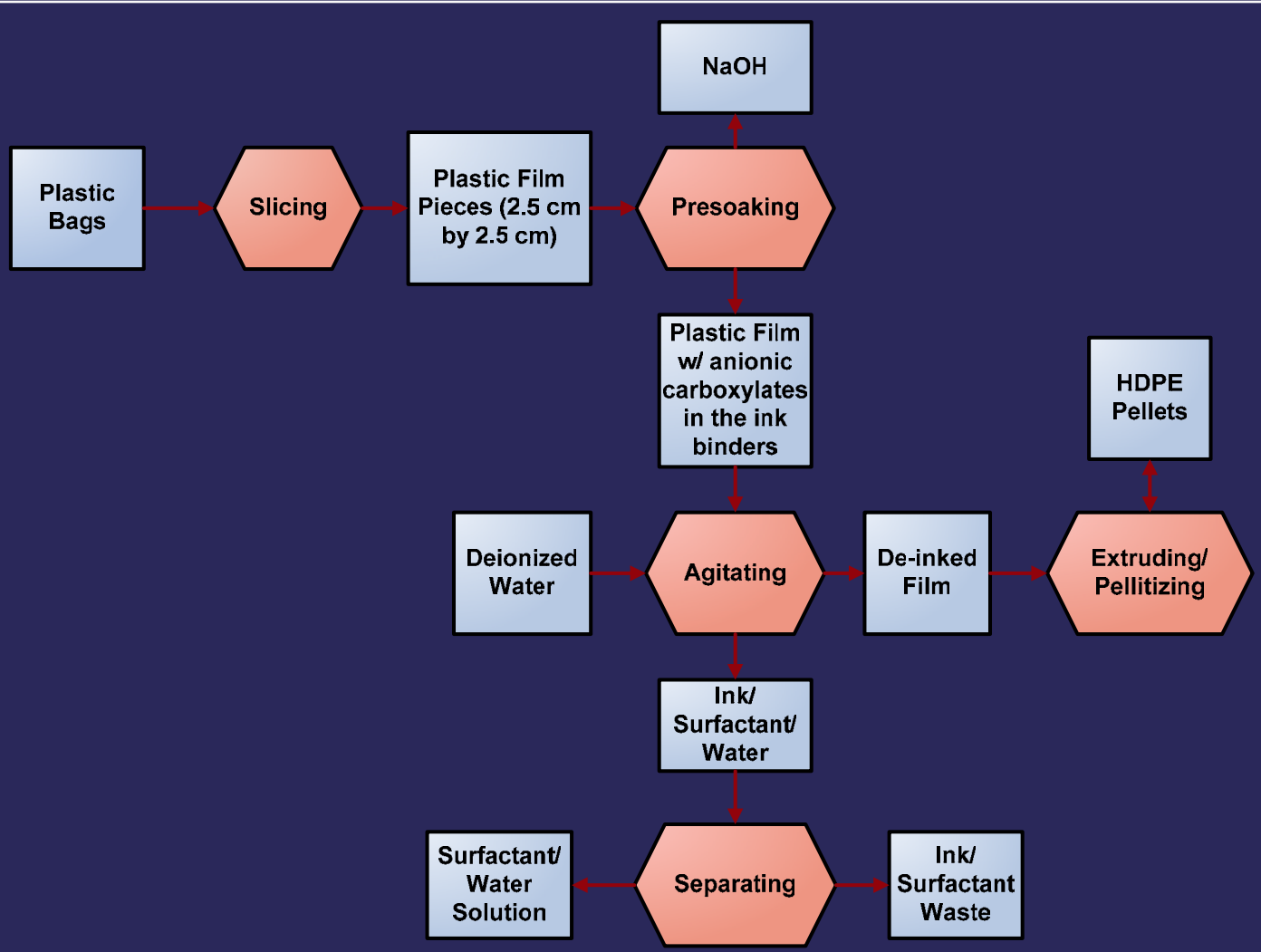
  - Four types of surfactant:
    1. Cationic
    2. Anionic
    3. Amphoteric
    4. Nonionic

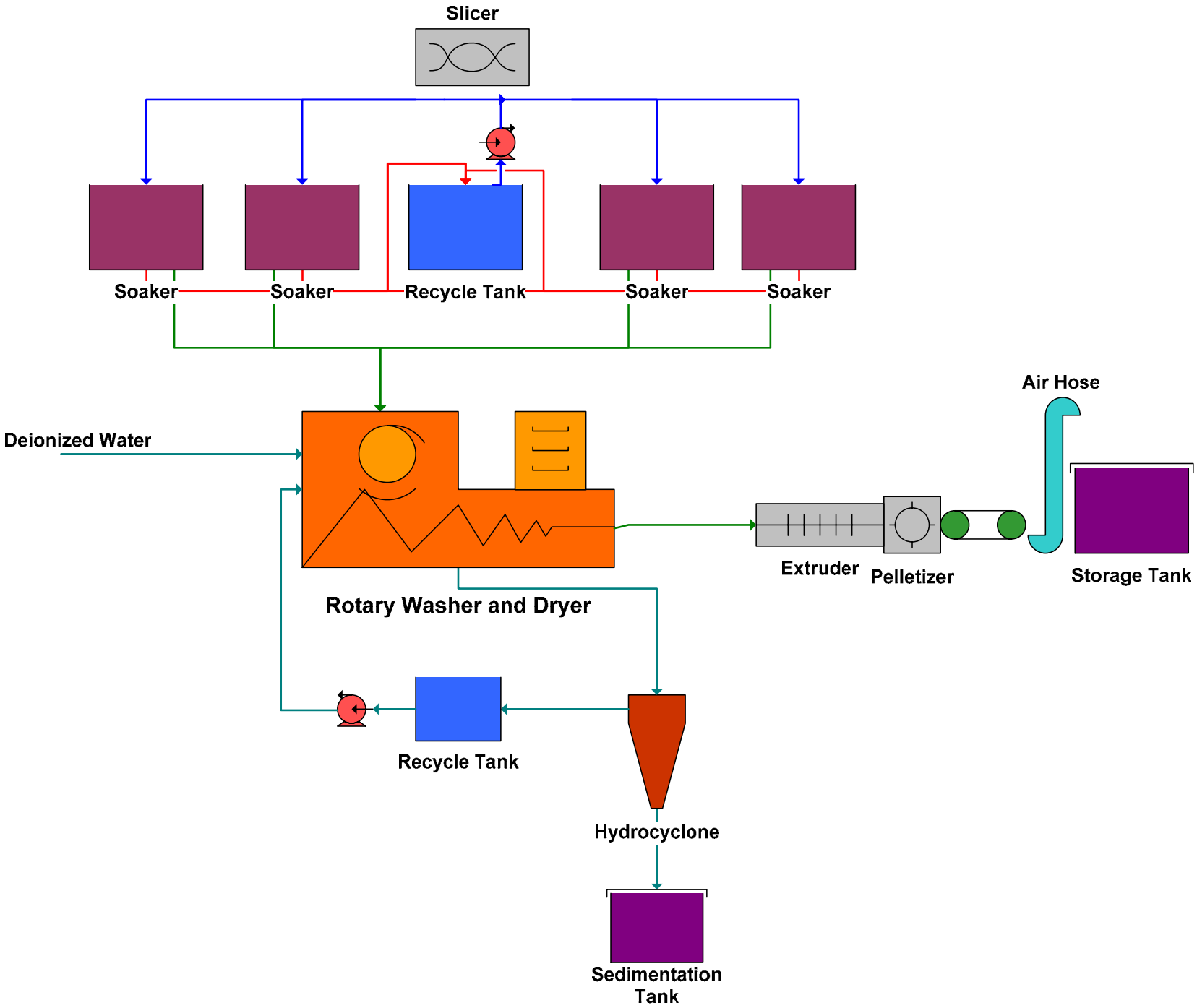
Raw Materials

- Surfactant continued
  - To increase de-inking efficiency
    1. Longer alkyl chain length
    2. Higher surfactant concentration

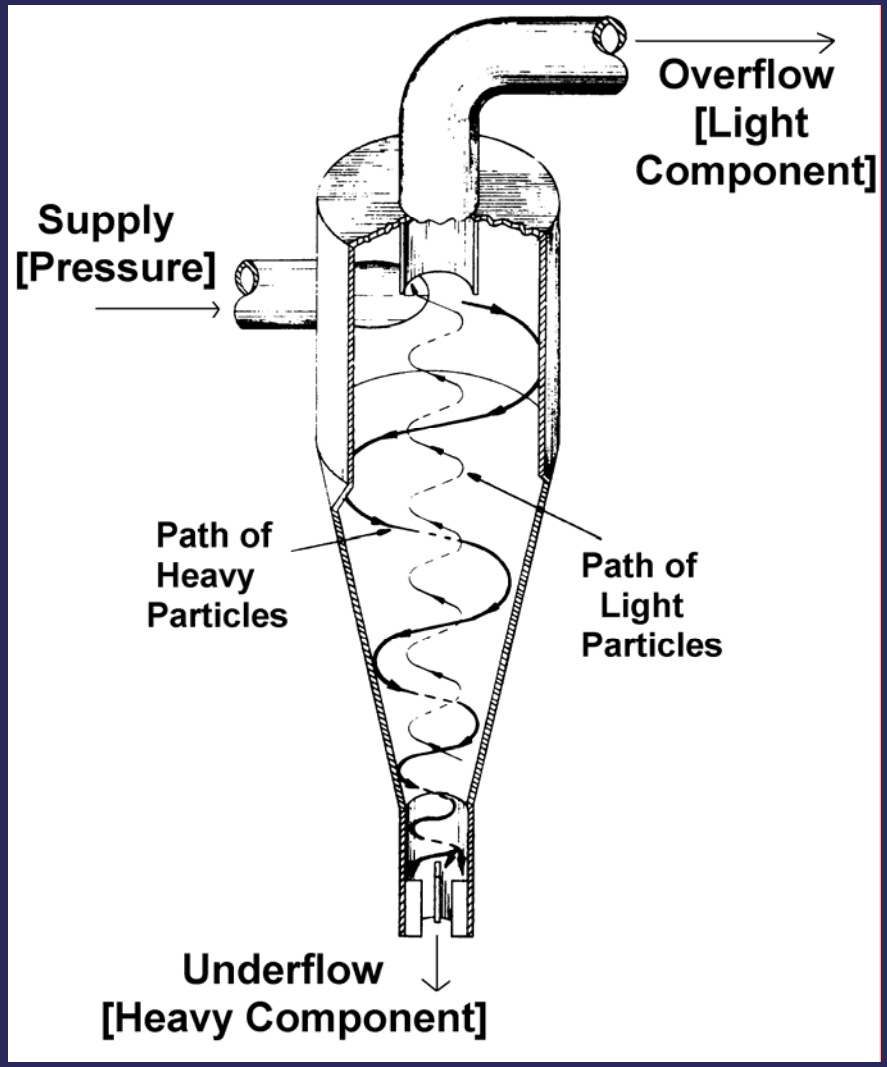
    - **Hexadecyltrimethylammonium bromide**

Raw Materials




Slicer
Soaker
Soaker
Recycle Tank
Soaker
Soaker
Deionized Water
Air Hose
Extruder
Pelletizer
Storage Tank
Rotary Washer and Dryer
Recycle Tank
Hydrocyclone
Sedimentation Tank

Solution Cleaning



- Hydrocyclone
  - Density separator

Modified Hydrocyclone

- The heavy stream exit flow can get clogged
  - Accumulation chamber resolves this problem

Considered Agitation Techniques

1. Multiple CSTs with net separation
2. Batch industrial washing machine

Separating Techniques

1. Froth Floatation
2. Anionic Exchange Chromatography
3. Centrifuge

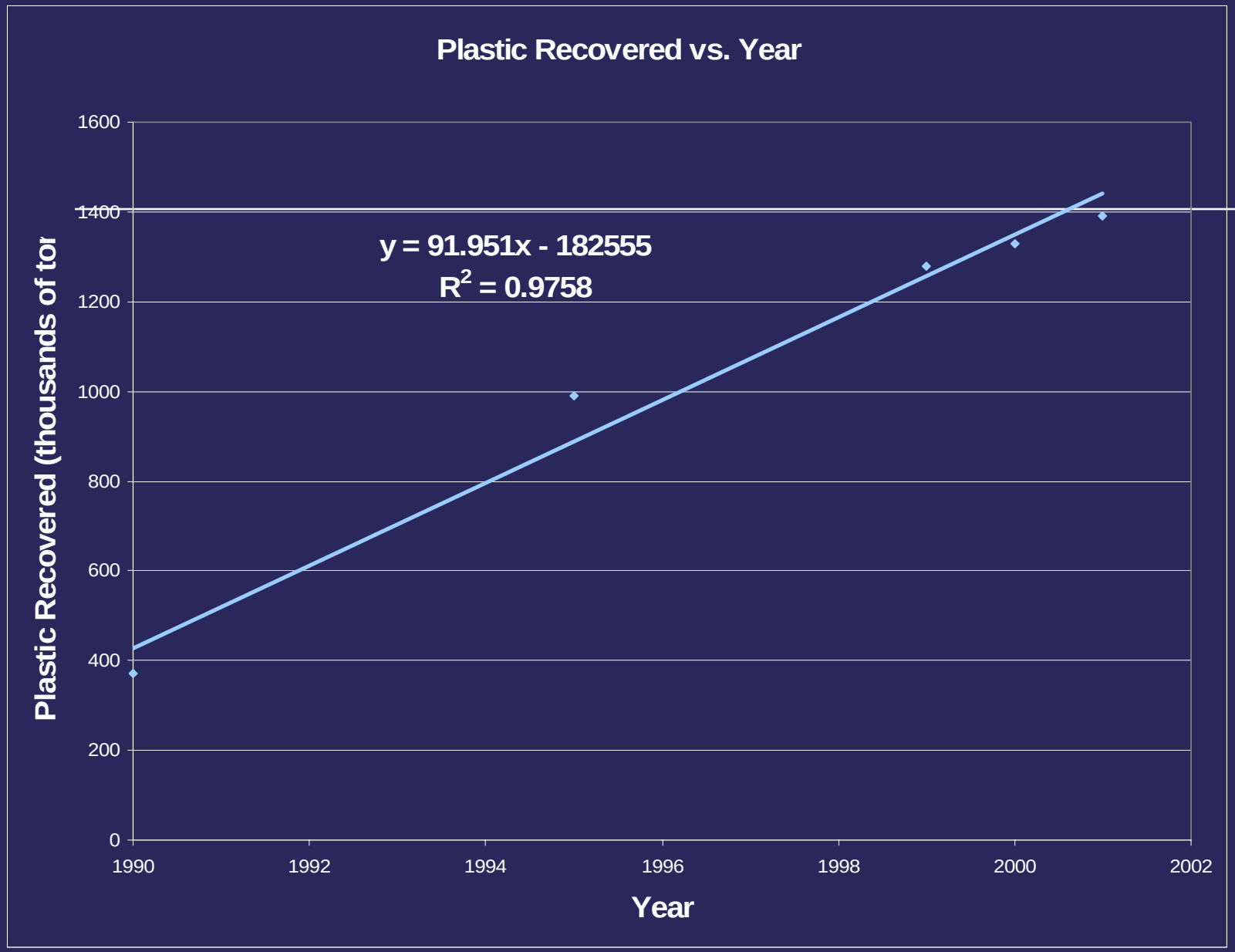
Marketability

- HDPE usage increases annually
- There is a larger demand for recycled plastic than can be met
- Nonrenewable natural resources used to make plastic are being depleted

- The economic feasibility of de-inking HDPE will likely increase in the future

Market Size

- Amount of plastic possibly recovered in 2006 is 96 thousand tons
  - 45% of plastic is film
  - 70% of plastic film is HDPE
  - Assume 15% recovery
- **Bags recovered ~ 5,000 tons/year**


Plastic Recovered vs. Year
y = 91.951x - 182555
R2 = 0.9758
Plastic Recovered (thousands of tor
1600
1400
1200
1000
800
600
400
200
0
1990
1992
1994
1996
1998
2000
2002
Year

Plant Location

- Location Model created in GAMS
  - Optimize profit by minimizing transportation costs
  - Determine optimal location
  - Infeasible solution

Plant Location

- Plant location determined using excel simulations
  1. Calculated distances
  2. Calculated bags available
  3. Compared revenue and transportation costs
     - Transportation cost = distance * cost of traveling

Plant Location

4. Determined profitability
5. Calculated total transportation cost
6. Compared NPW of possible plant locations

Plant Location

- 3 possible plant locations
  - New Rochelle, NY
  - Greenwich, CT
  - Englewood, NJ
- Optimal Plant location:
  - **Englewood, NJ**

Equipment Costs

Equipment	Price	Quantity	Total
Washer/Dryer	$236,021	1	$236,000
Soaker	$5,439	4	$22,000
Hydrocyclone	$138,886	1	$139,000
Extruder	$488,909	1	$489,000
Pelletizer	$92,917	1	$93,000
Recycle Tank	$4,958	1	$4,960
Slicer	$4,305	1	$4,300
Storage Tank	$13,257	1	$13,000
Pump	$1,750	1	$1,750
Trucks	$100,000	1	$100,000
		Total	$1,102,758

Profitability

Fixed Capital Investment	**$7,170,060**
Working Capital	**$1,265,310**
Total Capital Investment	**$8,435,400**

Total Product Cost	**$6,193,917**

Profitability

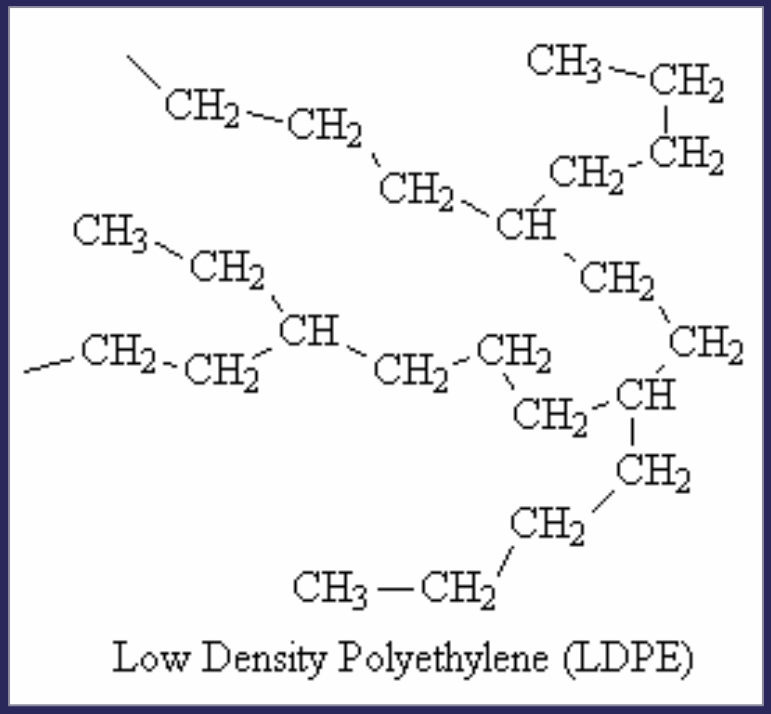
Pay-Out Time, POT	**4.2985**
Return on Investment, ROI	**16.03%**
Net Present Worth	**$1,750,826**

Recommendations

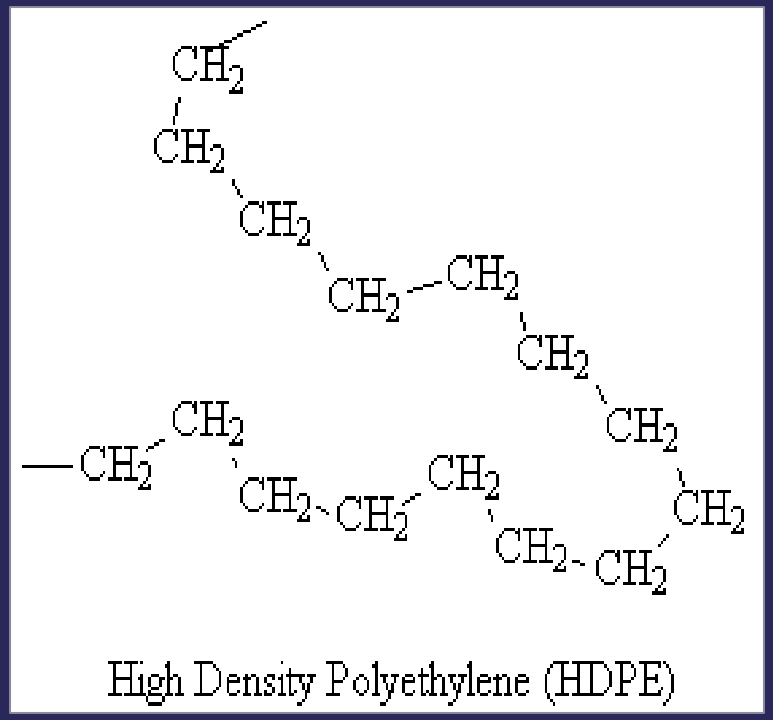
- Consider expansions and multiple plant locations
- Extend project life
- Consider de-inking other forms of HDPE

Questions?

Main Polymers Used in Plastic Film



Low Density Polyethylene (LDPE)



High Density Polyethylene (HDPE)

The branches prevent the nonlinear molecules from packing as closely as the linear, reducing their density

LDPE vs. HDPE

- HDPE is made by Ziegler-Natta vinyl polymerization
  - Uses a transition metal to initiate polymerization
- LDPE is made by free-radical polymerization
  - Uses an initiator molecule that breaks into free radicals. The unpaired electrons attack ethylene's C=C forming new radicals