Recovery of Product from Wastewater via Liquid-Liquid Extraction

Jake Mensforth, Julio Ocampo, Beckett Stillman

Mentor: Phillip McCarter

NATION FORD CHEMICAL — America's Leader in Custom Manufacturing

CHEMICAL & BIOMOLECULAR ENGINEERING — NC STATE UNIVERSITY

1 MOTIVATION AND GOALS

Nation Ford Chemical manufactures a product that produces an aqueous waste stream of **2 million gallons per year** that contains **1% weight of product**

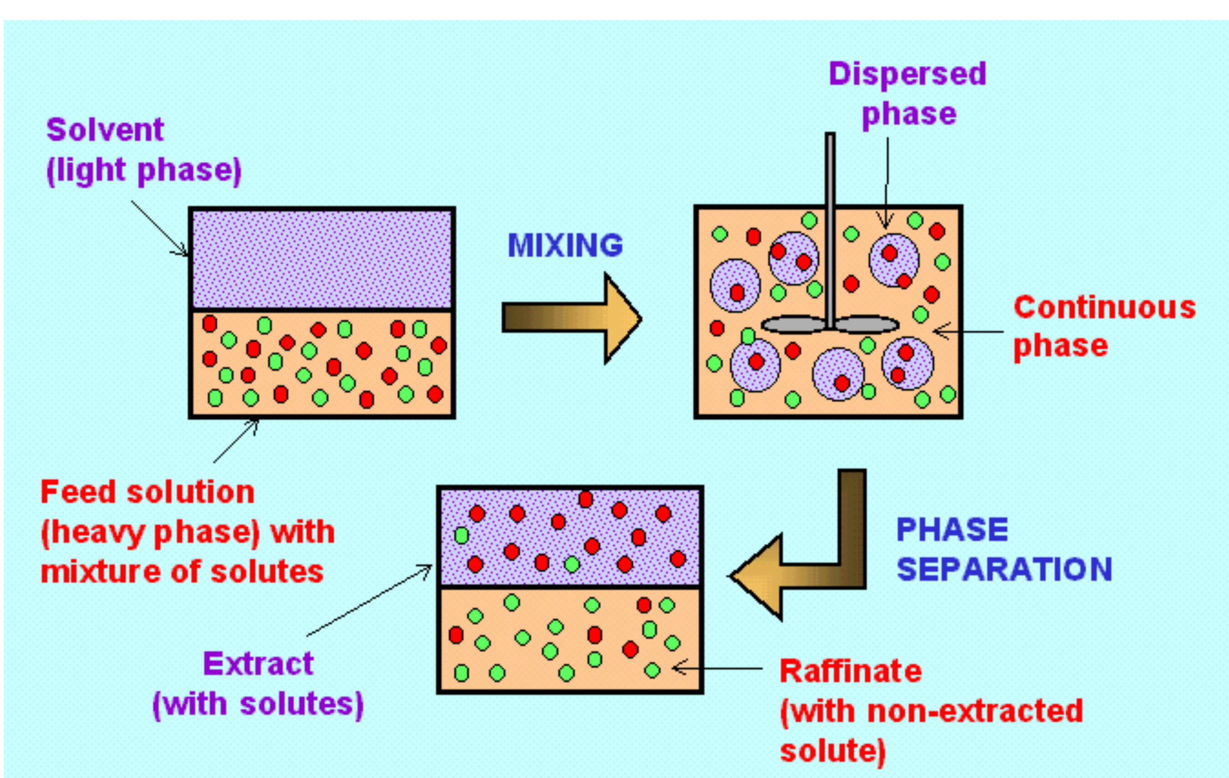
Objective

Recover the product using **liquid-liquid extraction** to:

- Improve salable product yield
- Lower water COD, less discharge costs

2 TECHNICAL BACKGROUND

Liquid-liquid extraction mixes a solvent with a feed solution and separates it into a solute-rich extract phase and a raffinate phase.

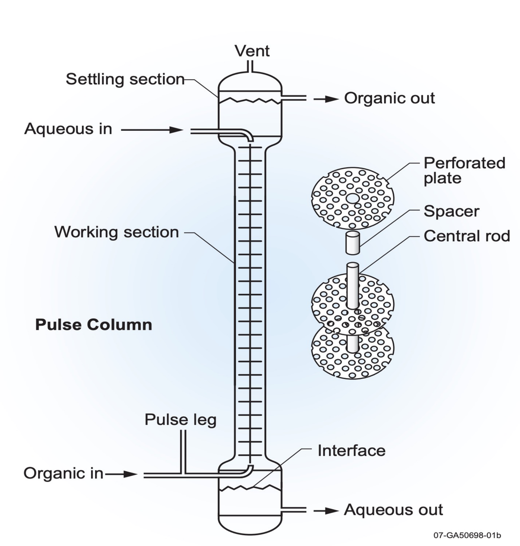


Liquid-Liquid Extraction Diagram

Separation Schematic, http://www.separationprocesses.com/Extraction/SE_001.htm.

To increase yield of extraction:

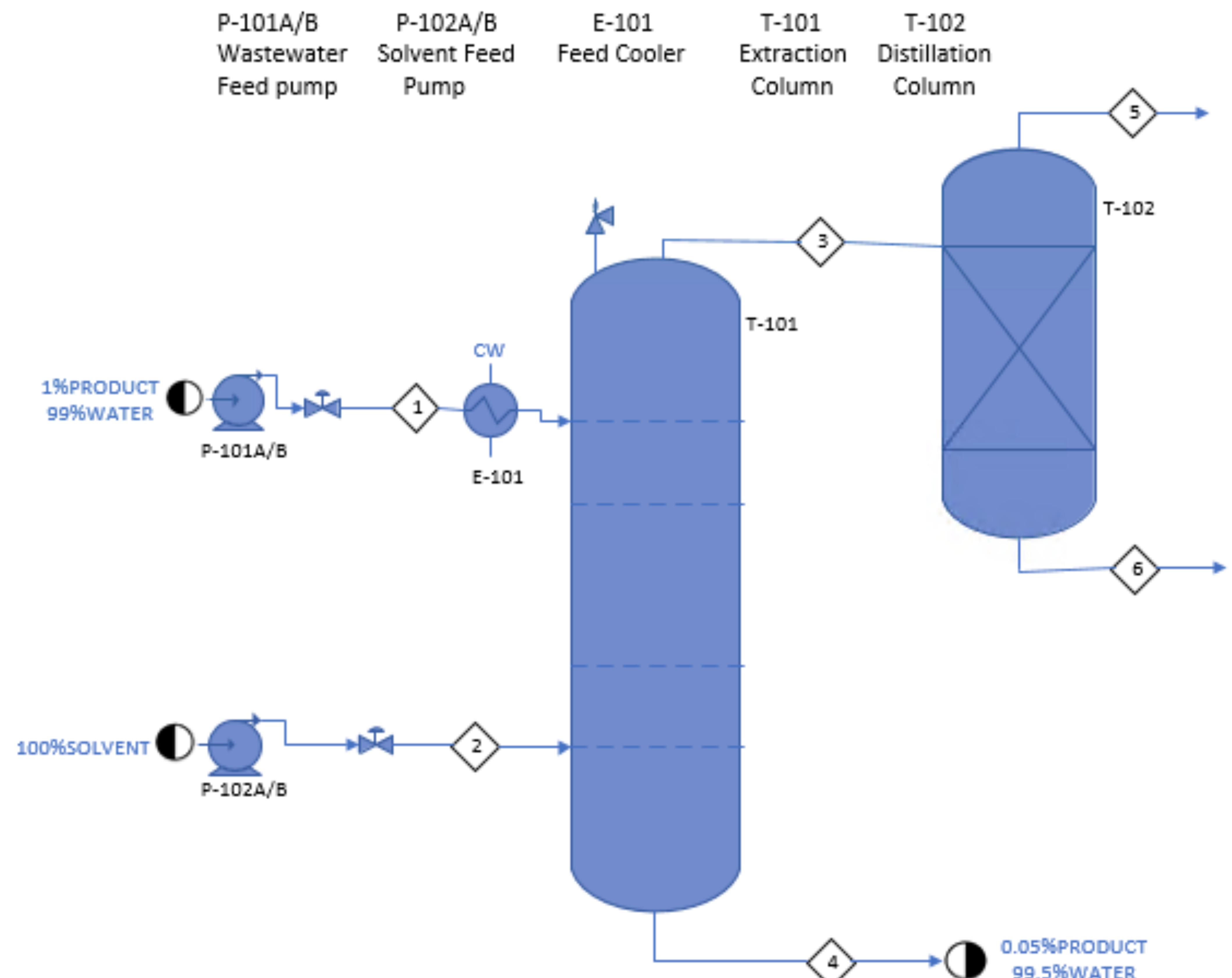
- ↑ Increase the **number of column stages**
- ↓ Decrease the column **temperature**
- ↑ Increase the **feed rate of solvent**
- ↑ Increase **phase contact** by using a pulsed column



Law, Jack D, and Terry A Todd. "Liquid-Liquid Extraction Equipment." *Idaho National Laboratory*, 2006.

3 DESIGN

Process Flow Diagram



Equipment Specifications

Tower T-101	Pump P-101	Pump P-102
Stainless Steel Sieve Trays	Centrifugal/electric drive	Centrifugal/electric drive
Height = 2.0 m	Stainless Steel	Stainless Steel
Diameter = 0.8 m	Power = 1.0 kW	Power = 1.0 kW
8 theoretical stages	80% efficient	80% efficient

Stream Table

Stream Number	1	2	3	4	5	6
Temperature (°C)	5	25	10.20	18.3	138.5	152.2
Pressure (atm)	1	1	1	1	1	1
Flow Rate (gal/h)	228.3	331.1	324.5	229.2	377.0	4.8
Component flow rates (kmol/h)						
Product	0.074	0.0	0.036	0.037	0.0004	0.036
Solvent	0.0	7.39	7.39	0.0	7.32	0.074
Water	48.39	0.0	0.075	48.32	0.075	0.0

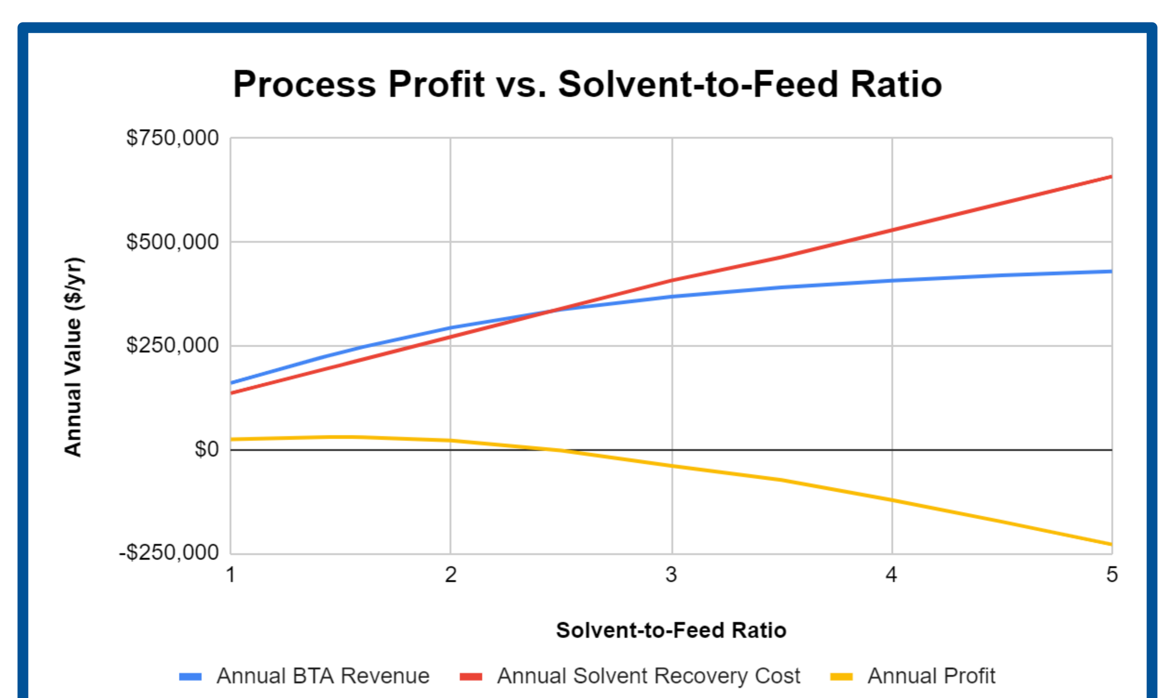
4 ECONOMIC ANALYSIS

Main economic constraint → cost of solvent recovery. The solvent is expensive and must be recycled, but the distillation to separate it from the product has high energy costs.

Aspen simulations revealed 1.45 to be the **most economical solvent-to-feed ratio**, even though it recovered less product.

However, other operating costs—cooling water in E-101, pump electricity, and the labor—must be included

With all operating costs considered, the process has a **negative ROI.**



$$ROI = \frac{revenue - COM}{TCI} * 100 = \frac{\$227{,}369 - \$804{,}000}{\$4{,}282{,}500} * 100$$

Return on Investment = -13.5%

Using CAPCOST, the total module cost of all equipment was estimated to be $850,000.

5 SAFETY

- The solvent is considered flammable & an irritant
- The product is harmful if inhaled or swallowed

HAZOP

- High flow → implement pressure relief and program pump shutdown
- Low flow → verify instrumentation functionality
- No flow → check with pump or level sensor if supply tanks are empty

6 CONCLUSIONS

1. This process should not be implanted unless a cheaper solvent recovery method becomes possible
2. Economic constraints are just as important as physical constraints when designing a process
3. Key parameters for optimizing a liquid-liquid extraction process are column temperature, number of stages, and solvent-to-feed ratio

Acknowledgements

The team would like to thank Phillip McCarter for his expertise, guidance, and time. Also, special thanks to the Chemical and Biomolecular Engineering department for their help.