Separations Challenges for Aqueous Separations

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Outline

Types of separations (two examples):
- Liquid / solids (food pathogens)
- Volatile Component (ethanol separation)

Scale
- Microfluidic (food pathogens)
- High volume (fuel ethanol)

Challenges in aqueous separations
- Low concentrations
- High throughputs
- Recovery Efficiency
- Regeneration / reuse of separations media
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Motivation:

*develop new knowledge, technologies, and systems to detect and prevent microbial and chemical contamination of foods*”
Motivation

Detect low level of foodborne pathogen in complex and various foods and in quick and precise way.
Sample preparation is rate-limiting.
Couple to specific and rapid detection.
Benchmarks (Goals)

Concentrate sample containing bacteria

Final concentration of $10^3$ to $10^4$ cells / mL
Final viable cell count on chip > 10 cells
Concentrate cells in 30 min
Process samples in 60 min
Maintain cell viability
Introduce samples on chip, detect cells in 3 hr
CCR Method
Cell Concentration and Recovery
**CCR KiT Assembly**

Uses membranes in series to process 100 mL hot dog extract into 0.1 to 1 mL sample.
Recovery

Withdraw the liquid from the 25mm swinnex holder with the 3mL syringe

Inject liquid in microcentrifuge tubes
Concentration through Filtration: Role of Liquid Film

By membrane filtration, $10^4$ cells can be concentrated into a volume of 15 $\mu$l of liquid.

Assumption: $1\text{mg}=1\ \mu\text{l}$

Each membrane contains $\sim 15\ \mu\text{l}$ of liquid.

~700 cells/ml $\times$ 50 ml
Fluorescence Images

Initial = $7.3 \times 10^7$ cells/ml x 50 ml = $3.7 \times 10^9$ cells

1. Blank Membrane
2. *E. coli* on P66 Membrane
3. *L. monocytogenes* on P66 Membrane
SEM Images

Initial = $7.3 \times 10^7$ cells/ml x 50 ml = $3.7 \times 10^9$ cells
Petri-Dish on a Chip

Microscope Objective

Micro-fluidic Tubes

Wire-bond (with epoxy)

Edge Connector

BioChip

PC board w. heater

Bashir et al, 2006
Challenges

Rapidly Concentrate Cells
Control reduction of Flux During Filtration
Keep cells viable
Obtain small volume for introduction to Biochip
Cell capture and chemistry in microfluidic devices
Dehydration of Ethanol

Ethanol concentration from fermentation broth ranges from 8 to 13% (by weight)

Distillation enriches ethanol content to 92% or higher

Adsorption processes break ethanol-water azeotrope and remove final amounts of water

Starch based adsorbents selectively remove water from ethanol in an energy efficient manner
Corn Grit Adsorption

Starch based adsorbent identified in 1978, and developed since then.

Readily available, low cost, biodegradable, high selectivity to water → an energy-efficient way to dehydrate ethanol

Currently used as adsorbent in industry in a fixed bed adsorption systems for producing fuel-grade ethanol

Beery et al., 2001, Bienkowski et al., 1985, Hong et al., 1982, Ladisch et al., 1979
Picture of Corn Grits
Ethanol Dehydration Process

Yeast → Fermentable Sugars → Fermentation → Distillation → 92% ethanol

99.6% fuel grade ethanol

92% ethanol → Adsorption → Desorption

Corn Grits → CO₂ → Regenerant Recycle
Goals

Design, fabricate, and validate research scale corn grit adsorption system

Simulate industrial scale adsorption system

Evaluate conditions for use of corn grits as a desiccant
Corn Grit Adsorption System Apparatus
Breakthrough Run Shows Particle Size Effect

- Corn Grits 2 (D_p=1.7 mm)
- Corn Grits 1 (D_p=1.4 mm)
Particle Size Effect

Our system operates in the linear part of the adsorption equilibria. Only the surface of the particles actually come to equilibrium.

Equilibrium constant is a function of particle size of adsorbent. A function of surface area of adsorbent.

For linear part of the adsorption equilibrium:

- Adsorption is described by linear isotherm
- \( q = K \cdot C \)
- \( d_1 < d_2 \)
- \( K_1 > K_2 \)
Challenges

Energy efficiency of water removal
Balancing column pressure drop of small particles against adsorption capacity
Model complex adsorption behavior (combined wave-front behavior)
Summary

Challenges in aqueous separations

- Low concentrations
- High throughputs
- Recovery Efficiency
- Regeneration / reuse of separations media (sometimes not possible)

Opportunity:

- Fundamental studies of biomolecules, bioproducts and microbes at surfaces