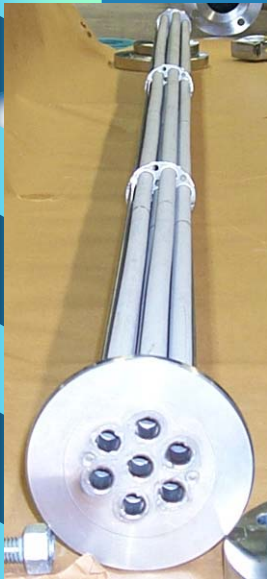


Appropriateness of mechanistic and non-mechanistic models for ultrafiltration of mixed waste



Henry Foust
2007 American Institute
of Chemical Engineers
Annual Meeting

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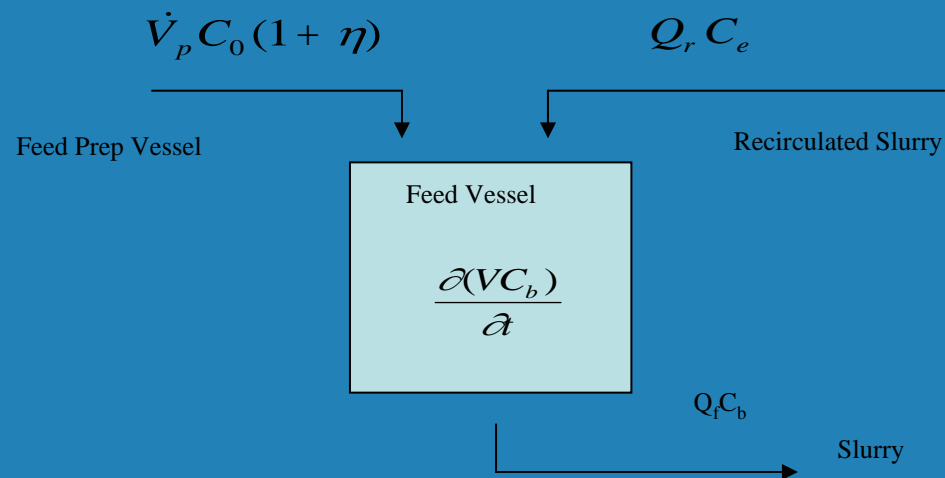
- Determination of fastest method to dewater
- **Determination of equation for permeate rates during dewatering that addresses scale**
- Determination of equation for permeate rates during wash step that addresses scale
- Determination of minimal membrane surface area for a given dewatering, wash or cycle time
- Production Maximization for solids and sodium using an appropriate optimization scheme and models for cycle time, solid and sodium production



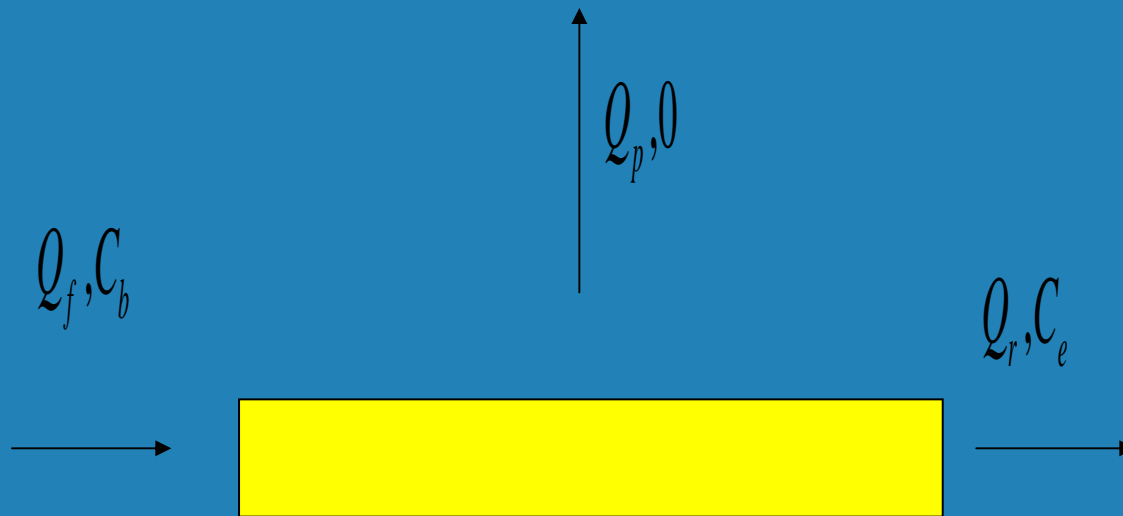
Question for this research

- **Is it appropriate to utilize regression models for permeate rates at different scales?**
- **Is there a mechanistic approach that better addresses issues of scale from a bench (pilot) scale study to a full-scale apparatus?**

Mass Balance for Slurry Holding Vessel



Mass Balance for Membrane Tube



Governing Equations for C_b and V

$$\frac{\partial(VC_b)}{\partial t} = V \frac{\partial C_b}{\partial t} + (\eta - Q)_p C_b = C_0 \eta$$

$$\frac{\partial V}{\partial t} = \eta - Q_p$$

V is slurry tank volume, C_b is the bulk phase concentration of solids, η is the feed rate into the UFP, C_0 is the bulk phase concentration into the UFP, and Q_p is the time-varying permeate rate.

Assumed density of liquid and solid remained constant during dewatering operations, 100% solid retention, and no mass accumulation in membrane tubes.

Diafiltration

It has been shown that the fastest way to run the UFP for dewatering is to keep the volume of slurry constant (Foust, 2005)

This condition results in a simpler dynamic model

$$\frac{dC_b}{dt} = \frac{Q_p}{V} C_0$$

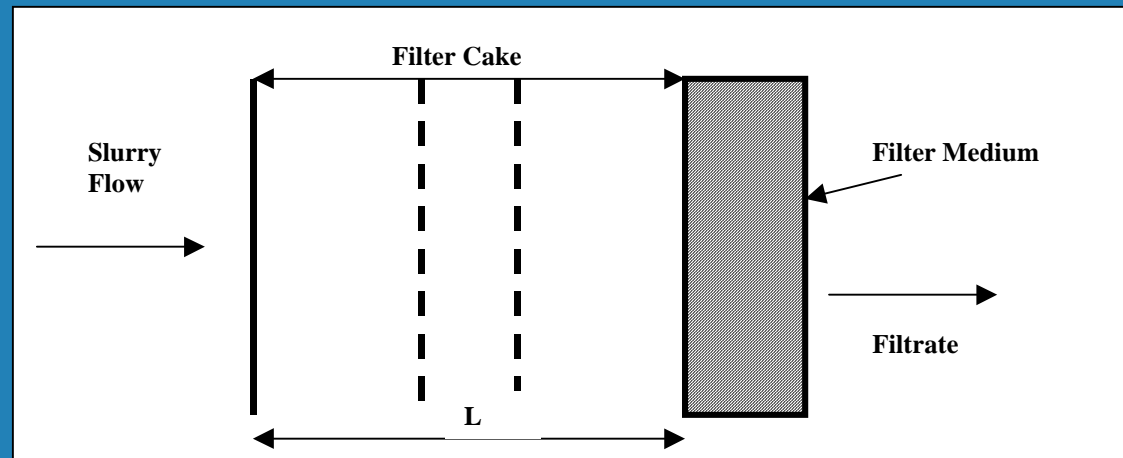
But what is an appropriate model for Q_p ?

Two approaches - Non-mechanistic and mechanistic

- Mechanistic is a physically based
- Non-Mechanistic is a regression approach

Mass Balance Equation (Mechanistic Approach)

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Permeate Rate Model (Mechanistic Approach)

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$$t = aV^2 + bV \quad a = \frac{\mu\alpha C_s}{2A^2\Delta p}, b = \frac{\mu R_m}{A\Delta p}$$

Where, μ = viscosity of filtrate

$$\alpha = \frac{K_1(1-\varepsilon)S_o^2}{p_p\varepsilon^3}, \text{ known as Specific Cake Resistance}$$

C_s = Mass of filtrate

A = Filter Area

Δp = Pressure Drop

R_m = Resistance of filter medium to filtrate flow

ε = Void fraction or porosity of cake

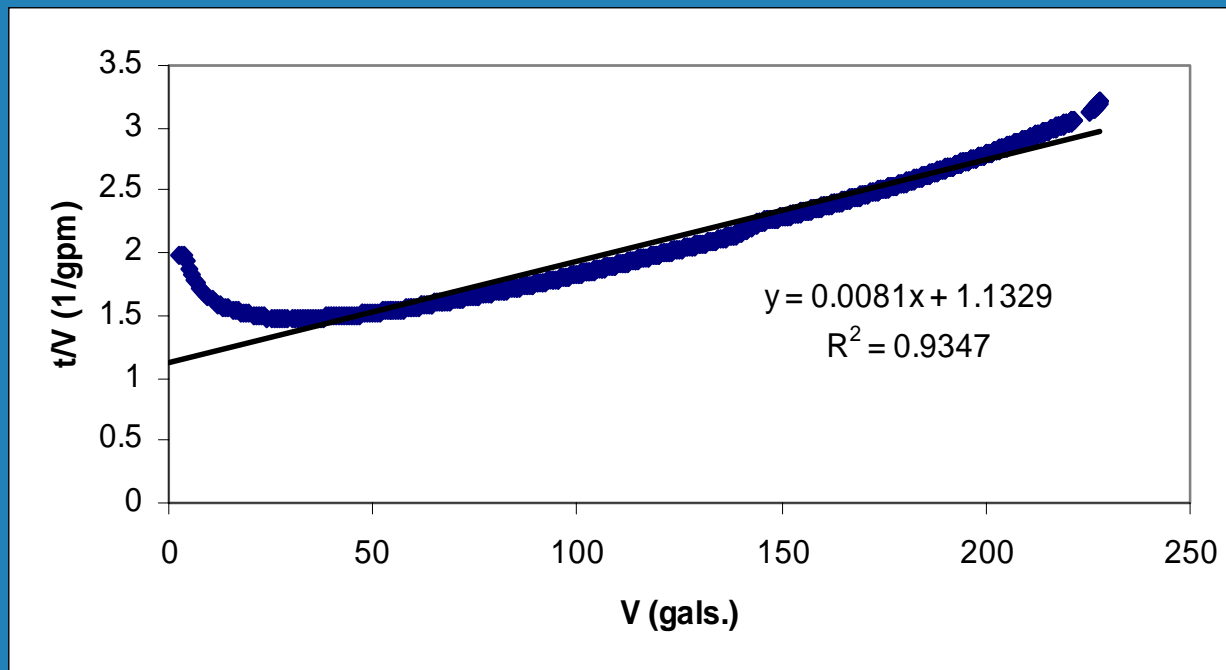
p_p = density of solid particles in Cake

S_o = Specific Surface Area of Particle per volume of solid particle

Data from Duignan (2003) (Mechanistic Approach)

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Cake Layer Dominates Operation

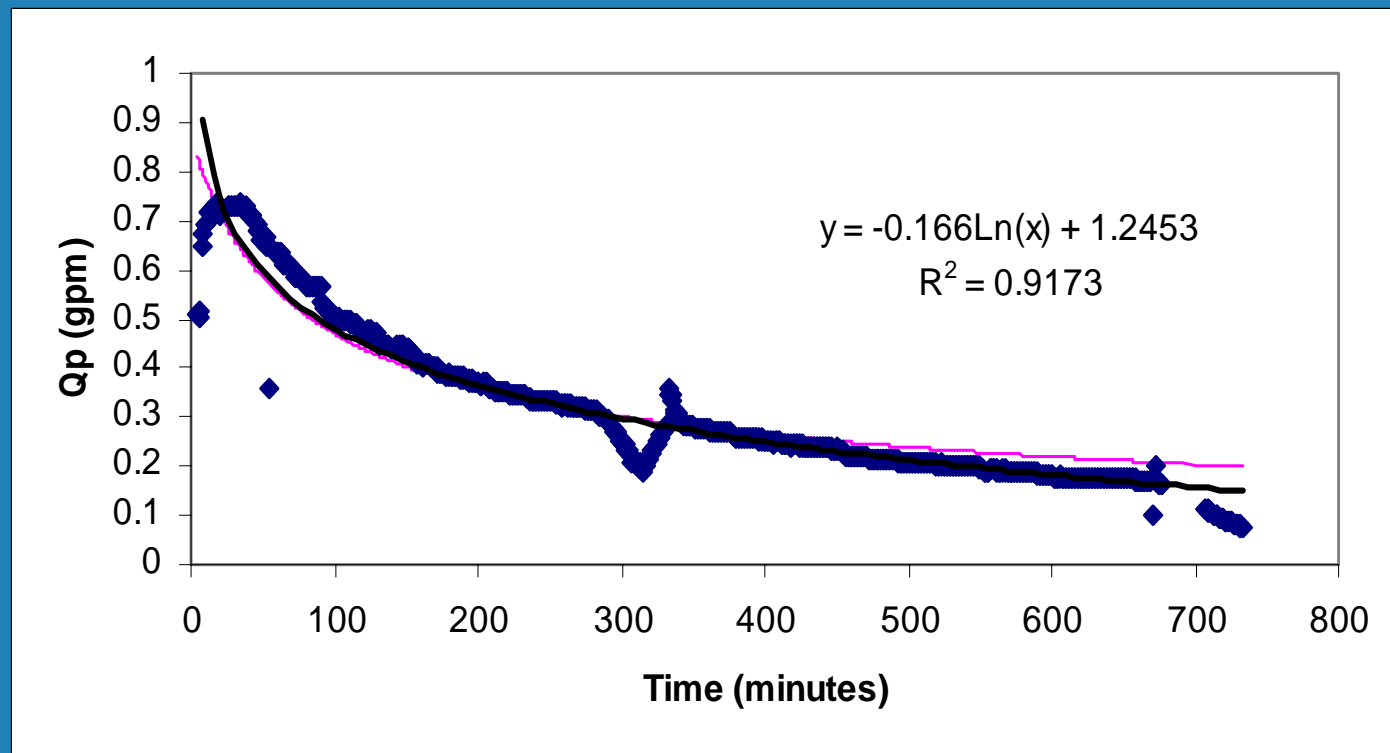


Goodness of Fit for Mechanistic Approach (Data from Duignan, 2003)

Data Set	a	b	R ²
3A	.0264	1.7741	.9906
3B	.0081	1.1329	.9347
3C	.0546	1.7878	.9719
4A	.0192	4.8083	.9381

Mechanistic vs. Non-mechanistic Approaches (Data from Duignan, 2003)

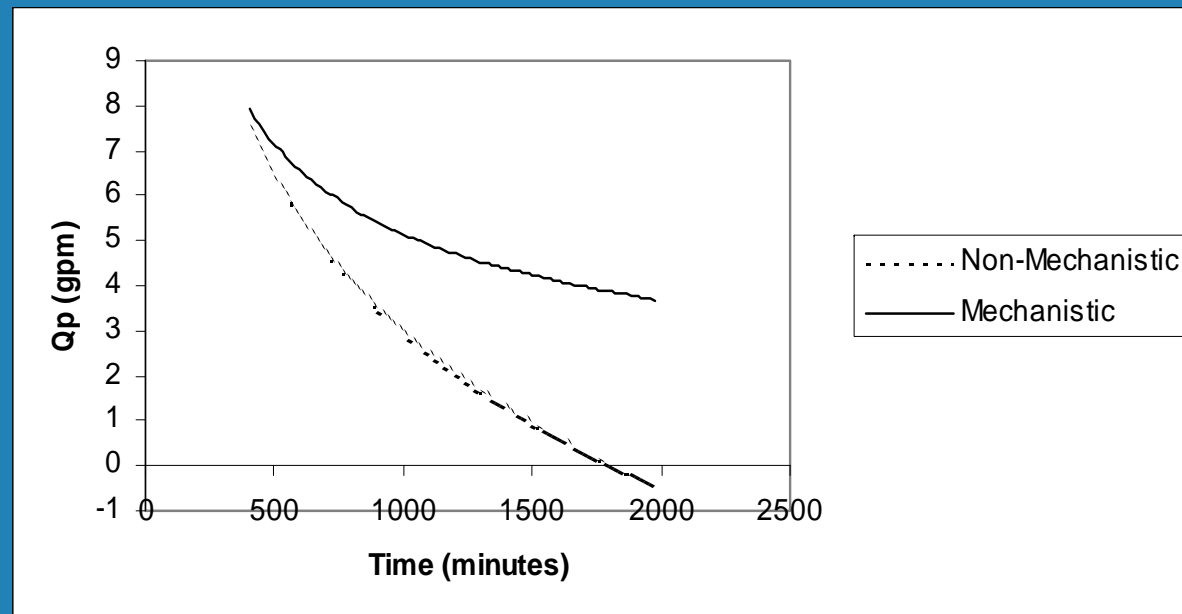
Mechanistic and non-mechanistic models fit well at this scale



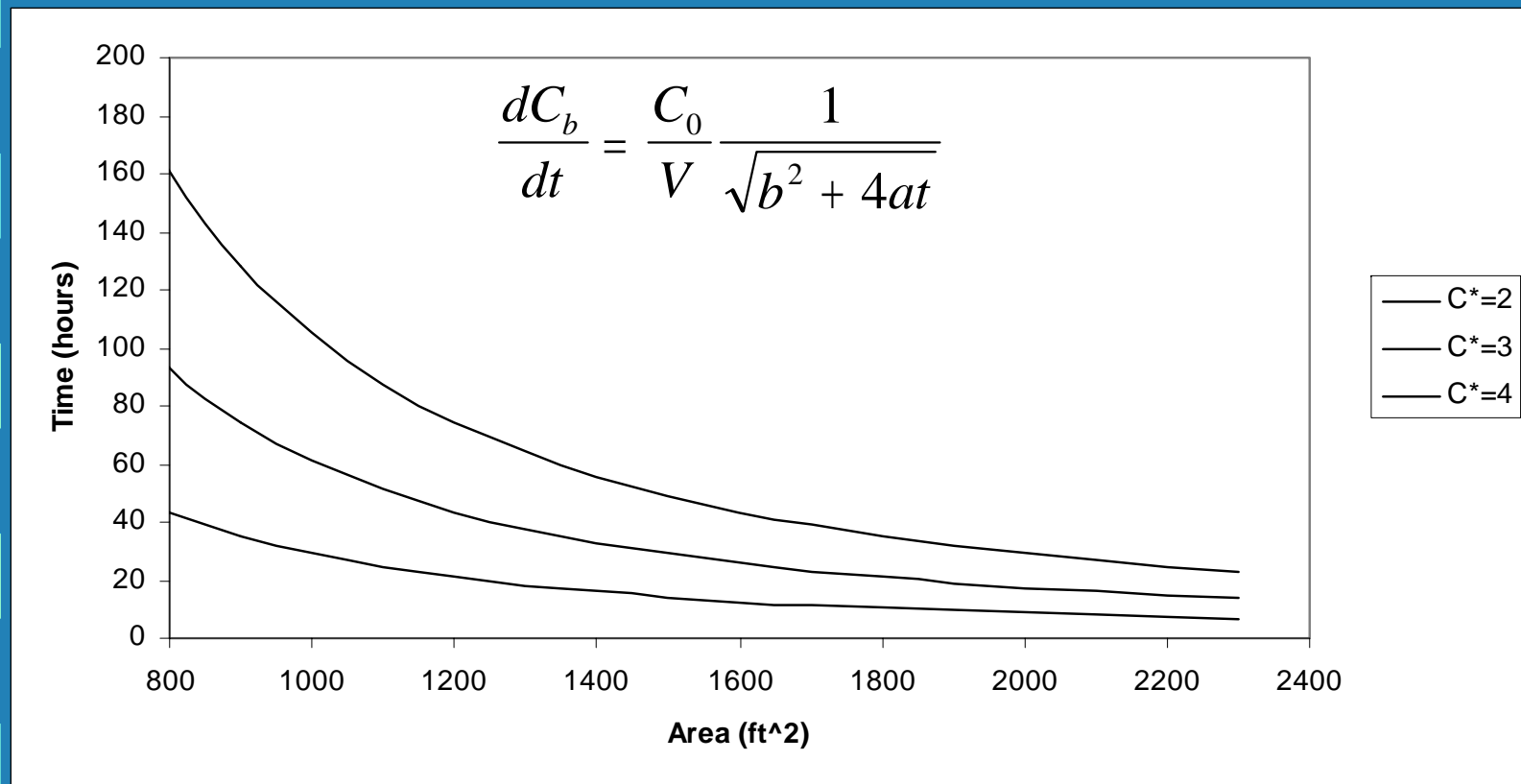
Mechanistic and Non-mechanistic Approach at larger scale

Parameters for $A = 6.7 \text{ ft}^2$	Parameters for $A = 200 \text{ ft}^2$
$a = .0081$	$a = 10\text{E-}6$
$b = 1.1329$	$b = .04$

Regression model is multiplied by ratio of two membrane surface areas.



Dewatering Design Curve (Mechanistic Approach)



Discussion/Conclusions


- Regression models are inappropriate for scaling experimental results from a pilot (bench) scale apparatus to a full-scale apparatus
- A more appropriate model for permeate rates is t/V vs. V , which has been shown to be linear for several data sets associated with the UFP at Hanford

- A mass balance equation for C_b is

$$\frac{dC_b}{dt} = \frac{Q_p}{V} C_0$$

- If the above observations prove to be true, then an appropriate model for dewatering times is

$$t = \frac{K_1}{2} \left(\frac{VC^*}{A} \right)^2 + K_2 \left(\frac{VC^*}{A} \right)$$

A decorative graphic on the left side of the page, resembling a spiral notebook binding. It features a dark blue vertical line with a series of overlapping, semi-transparent blue and green ribbon-like shapes that spiral around it. A small, light blue sphere is positioned where a horizontal line intersects the spiral.

Q&A