Value Proposition and Modeling of Water Wash Debottleneck

Recall from the introductory article that a well-framed value proposition follows these principles:

- Describe the situation
- Identify the need
- Develop a model
- Probe for solutions
- Identify value points
- Quantify pricing and cost assumptions
- Evaluate proposed solutions

This example applies these principles to a simple operational debottleneck.

Background to this Example

Water washes of organic streams are common in the chemical and refining industry to remove contaminants such as acids, bases, or other water soluble species that are incompatible with the product specification or downstream processing. In this example, we'll construct a model of the wash process using hypothetical stream properties. Using this model, we'll investigate several options to satisfy a planned capacity increase throughout the facility. The value proposition for each alternative is based on costs for the make-up water, the organics lost to the wastewater, and wastewater treatment.

Water Wash Description

The wash step consists of a single stage mixer / settler which removes an unwanted solute from an organic phase, and the resulting wastewater is biotreated. The setup is shown in Figure 1. To get good mixing and ensure the solute is washed, a maximum value is placed on the organic: water feed ratio, which necessitates the use of an aqueous recycle pump.

Identify the Need

To set the stage, a 30% plant debottleneck is proposed to meet growing demand. The plant engineer suspects a water wash step as a potential problem and investigates solutions. The concentration of solute does not change for the proposed 30% increase in organic flow, *but the organic stream must maintain specification on the solute impurity with the increase in throughput*.

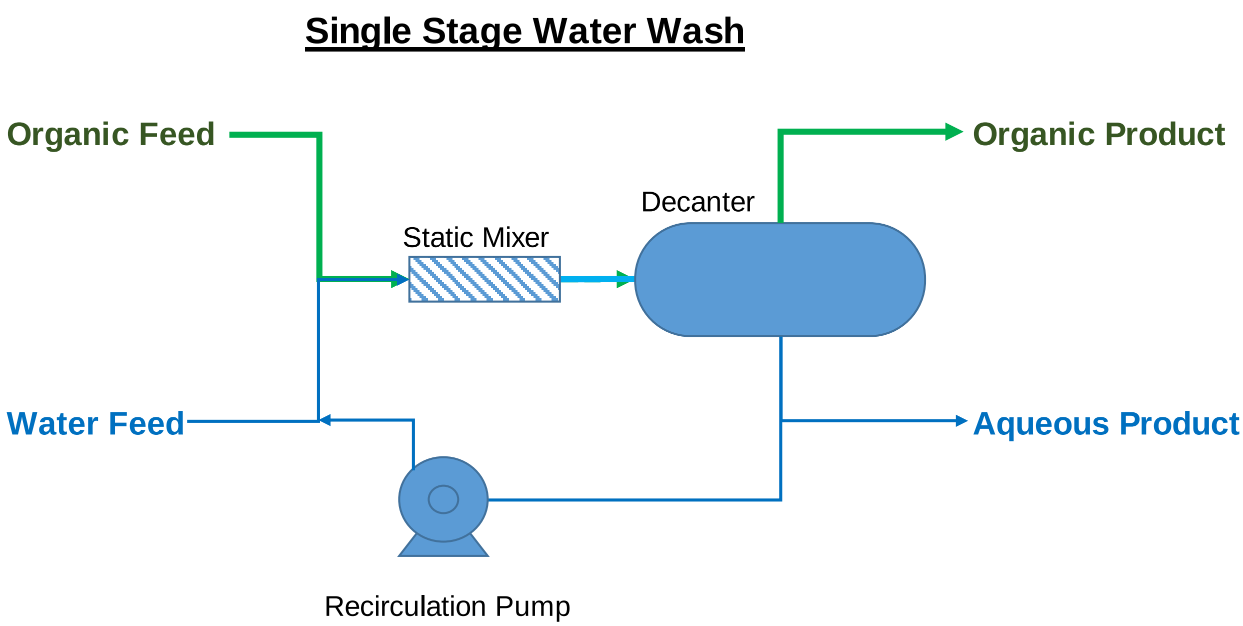

Figure 1 Process Diagram for Current Water Wash Example

A simplified model

To model the process, we assume the *two phases are in equilibrium with some entrainment*, which is determined empirically from plant trials and is correlated with residence time in the decanter. The table below lists the modeling parameters that describe phase behavior along with some hypothetical values used for this example.

Table 1 Phase Equilibrium and Entrainment Correlations for Water Wash Debottleneck

Parameter	Description	Example Value*
$K_{organic}$	Distribution of **organic** components: (wt% organic in organic phase)/(wt% organic in aqueous phase)	500
K_{solute}	Distribution of **solute** : (wt% solute in organic phase)/(wt% solute in aqueous phase)	.002
K_{water}	Distribution of **water** : (wt% water in organic phase)/(wt% water in aqueous phase)	.001
E_{org}	Entrainment of organic in aqueous phase, wt% *free organic phase* in total aqueous product	$10\ e^{(-0.55\ t)}$ *t=residence time, min*
E_{wat}	Entrainment of aqueous in organic phase, wt% *free aqueous phase* in total organic product	$12\ e^{(-0.60\ t)}$ *t=residence time, min*
		* Examples are for illustration only and do not reflect an actual case

Process conditions and specifications for this hypothetical example are in Table 2, as are equipment specifications. Decanter size affects the entrainment levels.

Table 2 Process and Equipment Data for Wash Debottleneck

Process Data			**Equipment Data**	
Solute in Organic Feed	3000 ppm		Static Mixer	5:1 max org/aq flow
Solute Spec in Product	100 ppm		Decanter	6 ft dia x 24 ft T/T
Organic Flowrate			Recirculation Pump	25 gpm max
Current Operation	100,000 lb/hr			
Future Operation	130,000 lb/hr			
Density *(for decanter residence time)*				
Organic Phase	6.5 lb/gal			
Aqueous Phase	8.4 lb/gal			

The process can be modeled algebraically with a spreadsheet. With the current operation, the spec of 100 ppm solute in the organic product can be met with 8000 lb/hr fresh water feed. However, with future operation, the required fresh water flow increases to 35,000 lb/hr in order to meet specification, due to significant increase in entrainment with the lower residence time in the decanter (see Table 3).

Probe for Solutions

Our plant engineer contemplates a new decanter as part of the debottleneck project, and sets out to model the wash with the following configurations:

1. *Keep* the existing 6'x24' decanter
2. *Replace* the existing decanter with a larger 6'x32' decanter
3. *Add* a larger 6'x32' decanter as a *second stage* of mixing/settling
4. *Add* a larger 6'x32' decanter as a *first stage* before the existing stage
5. Replace the existing decanter with *two new*, larger, mixer/settlers

Model results are in Table 3:

Table 3 Model Results: Meeting 100 ppm solute spec in washed Organic with 30% Increased Organic Feed

	Water Flow, lb/hr			**Organic Loss**	**Entrainment, lb/hr**	
Case	Fresh	Waste	Recycle	Lb/hr	Org. in Aq.	Aq. In Org.
Existing Decanter	35000	34580	0	224	152	924
Larger Decanter	10000	10211	16000	24	3	82
Add 2nd Stage	3600	2970	~23000 each stage	23	1	917
Add 1st Stage	2800	3006	~23000 each stage	7	13	86
2 New Stages	1600	1792	24400 each stage	4	1	81

Modeling results above showed that water consumption would increase 4-fold from the current 8000 lb/hr, to meet the debottleneck requirements in the existing equipment and maintain 100 ppm impurity in the organic. Also, product losses in the wastewater stream may be untenable. Recall, in addition to entrained organic, there is some organic solubility in the aqueous phase as well, so that product losses increase with wastewater flow.

Identify Value Points and Quantify Pricing and Cost Assumptions

The value propositions for installing a new decanter include:

- Reduced consumption of process water ($3/Mgal by way of example)
- Reduce loss of soluble and entrained organic into wastewater ($0.30/lb organic product value assumed)
- Reduce cost of wastewater treatment ($4/Mgal by way of example)

In addition, proposals that include larger recirculation pumps carry a down-side of additional electricity costs (taken here at 6 cents/kW-hr).

Some considerations not taken into account here should be identified as well. These include:

- Entrained aqueous phase may add downstream processing costs for the organic
- There may be some recovery value of organics from a wastewater stripper, if one exists.

Evaluate the Value Proposition of each Alternative

The engineer prepares the chart in Figure 2 showing annual operating costs, and the net value proposition for each alternative. Adding an additional stage of mixer / settler with a larger decanter is recommended, upstream of the existing mixer/settler, worth over $700,000/year in operating cost savings relative to the option that uses only the existing mixer / settler.

At this point we haven't evaluated capital costs or financial evaluation metrics for the proposal, but the approach to developing a value proposition is established.

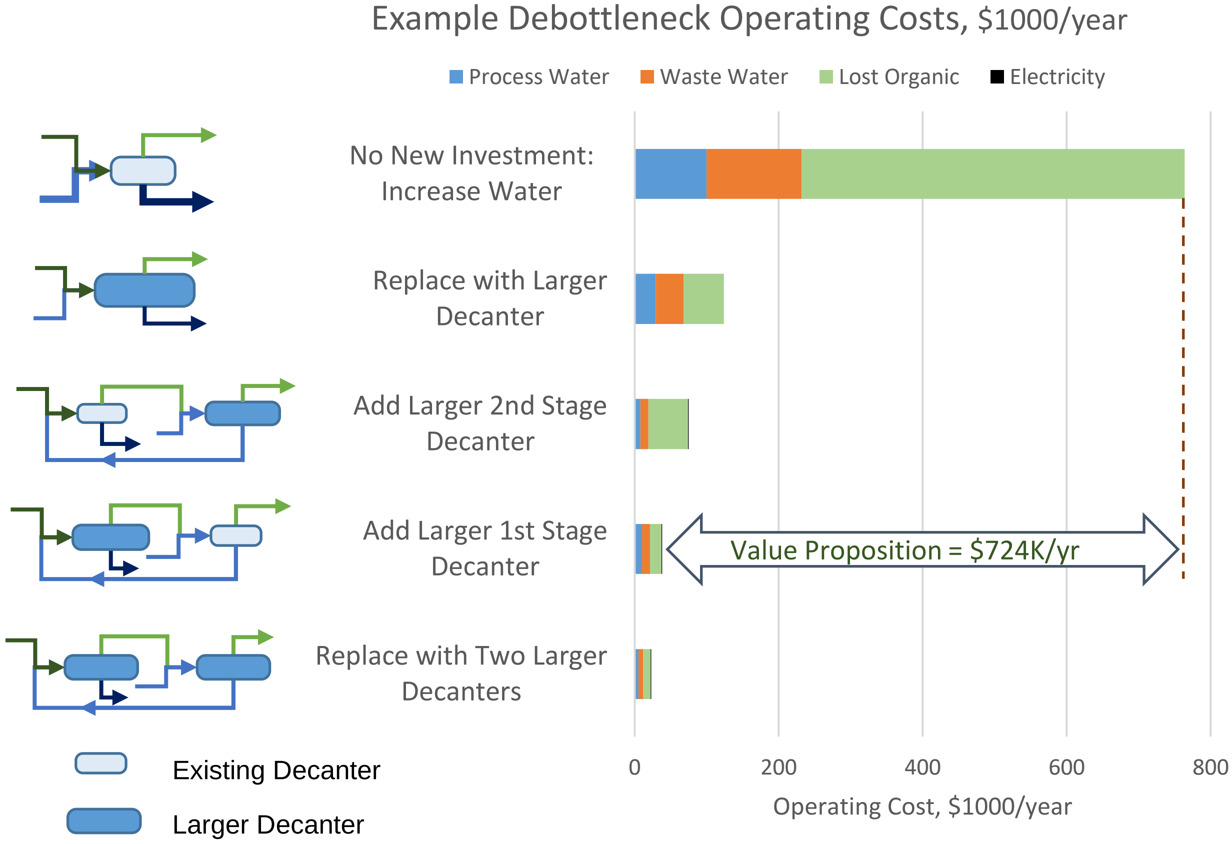

Figure 2 Value Proposition Results for Hypothetical Water Wash Debottleneck

Summary

This example shows the thought process to generate a value proposition for adding a water wash stage when faced with plant debottleneck. A simple spreadsheet model helps to analyze the impact the additional stage and its location, recognizing that there are both liquid / liquid phase equilibria and entrainment issues affecting the target product purity. An additional stage is justified based on the savings in make-up water, wastewater costs, and lost organics.