

# Innovative Water Conservation Measures – Rainwater to Winery Practices

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# Outline

- Metrics for Water Use
- Water Footprints and Scaled Water Footprints
- Changing Winemaking Practices
- Alternative Winemaking Practices
- Alternative Cleaning Chemistry
- BOD and COD of Cleaning Chemistry
- Innovation and Adoption

# Winery Water Metrics

- Water Foot Prints
  - Surface Area to be Washed, Tanks, Barrels, Equipment
  - Number of Wine Transfers
  - Cleaning Protocol
  - L Water per L of Wine, L water per Ton of Grapes
- Scaled Water Foot Prints
  - Scaled as Area per Volume,  $1/V^{0.333}$
  - Breakout by Operation
- Number of Times Used (NTU)
  - One is the Base Case

# Winery Water Footprints

Water Footprints

Scaling of Water Footprints

Practices and Efficiency

Self-Sustainable Water Use

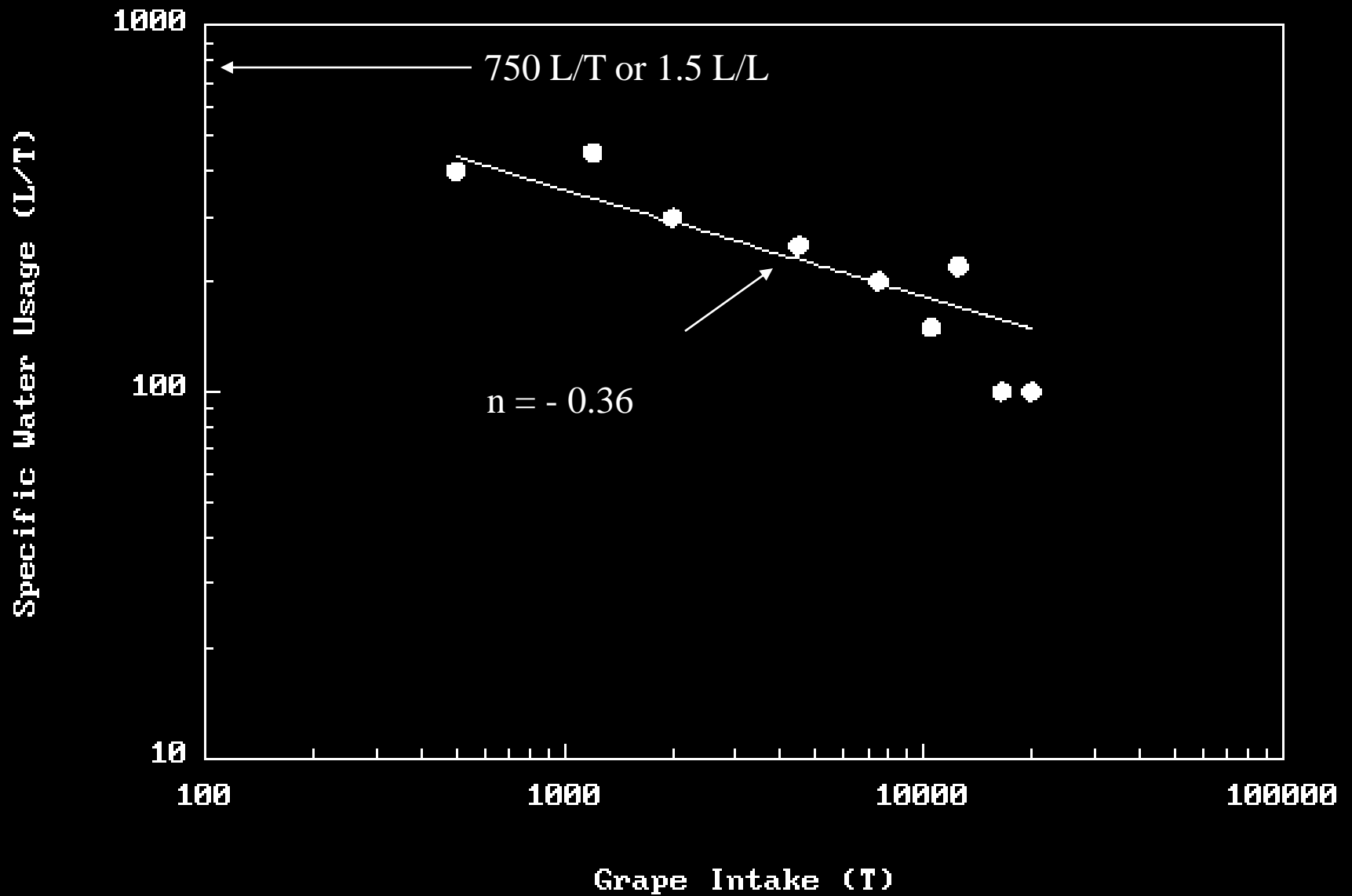
# Surface Area per Volume

- Water Use  $\propto$  Surface Area (A)
- Water Use per Volume  $\propto$  to A/V

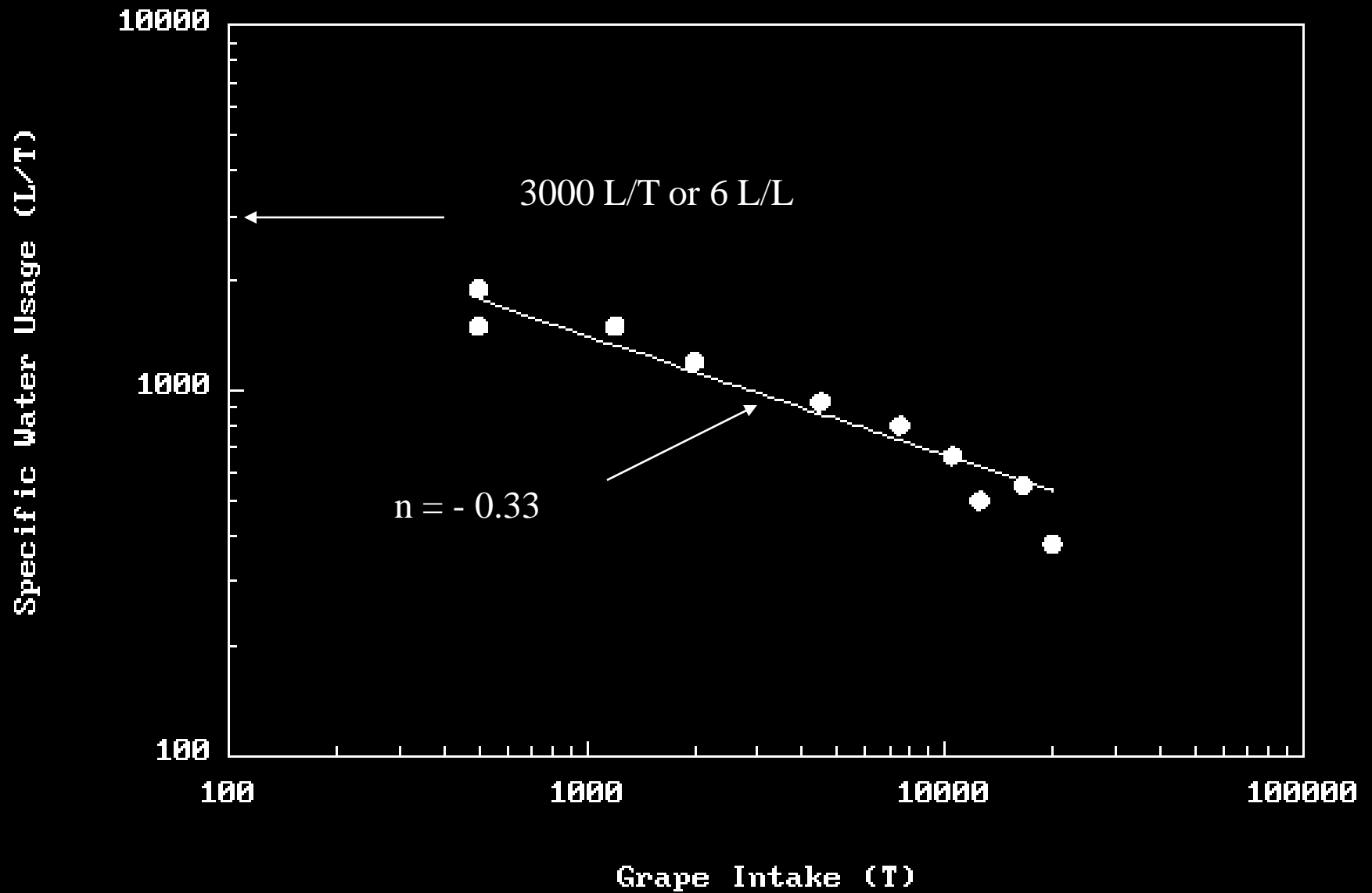
$$A/V \propto [V]^{0.67}/[V]^{1.0} \text{ or } [V]^{-0.33}$$

- Log-Log Plot of Water Use vs Volume would have a slope of -0.33 due to Wall Area per Volume
- Log-Log Plot would have a slope of 0.0 if same water use per volume
- Actually looks like -0.36 (seasonal) -0.33 (annual)

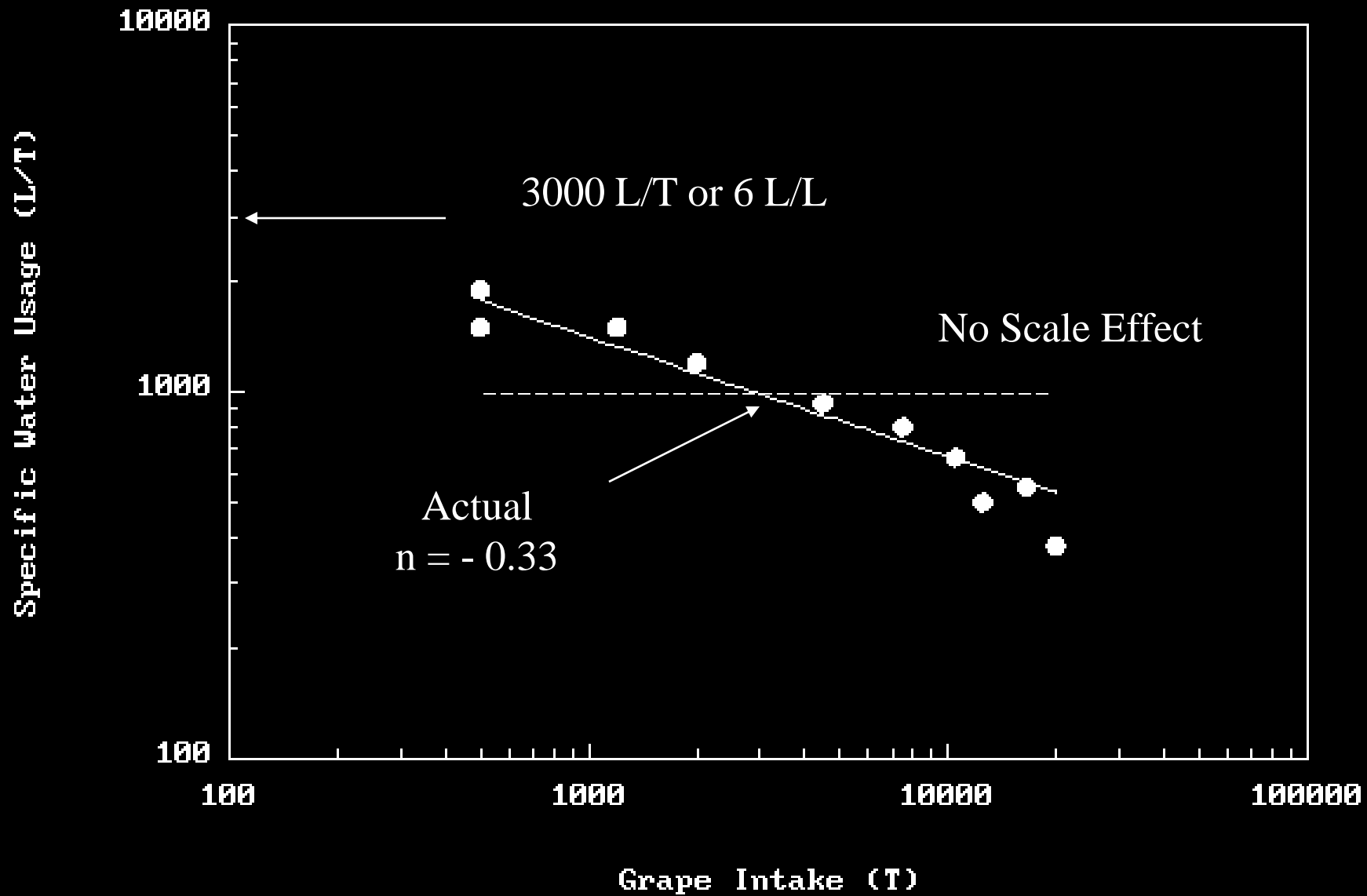
# The Seasonal Water Usage by Wineries.



# The Annual Water Usage by Wineries.



# The Annual Water Usage by Wineries.



# Winery Water Use Functions

Annual Water per Ton:

$$[L/T] = 1000 * [T/3000]^{-0.37}$$

Seasonal Water per Ton:

$$[L/T] = 250 * [T/3000]^{-0.36}$$

Data collected from 1978 harvest

Scale effect is strong, “lower footprints” in large wineries should not be confused with “efficiency of use”

# Water Value

- Future Shortage of Supply, Present Poor Quality
- The Development and Conditioning Cost of Water
- The Cost of Using Water
- The Cost of Waste Disposal
- A Negative Value, What is the Value?
  
- Installed Cost, ROI and Life Cycle Analysis?
- Clean water has a higher Value
- The Rainwater Option

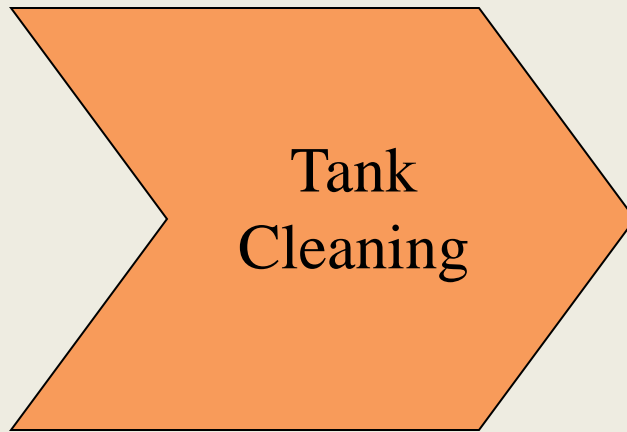
# Rain-water vs Well-water

- Chlorine Free, Without Deposits
  - Carbon Beds
  - Softener Waste Stream (Saturated NaCl)
  - Demineralizer Waste Streams (NaOH and HCl)
  - Silica remains to form deposits
- Rainwater Tanks
  - Dust, Bird Droppings, Aerobic Molds, Bacteria
  - MF, UF and RO filtration sequence and Storage
- Delivery Pipework, Rainwater Tanks as Building Components

# Changing Winemaking Practices

Water Used  
Cleaning Chemistry  
Re-Use

# Winery Water Footprint Example



Number of Cleanings  
[2 to 10]

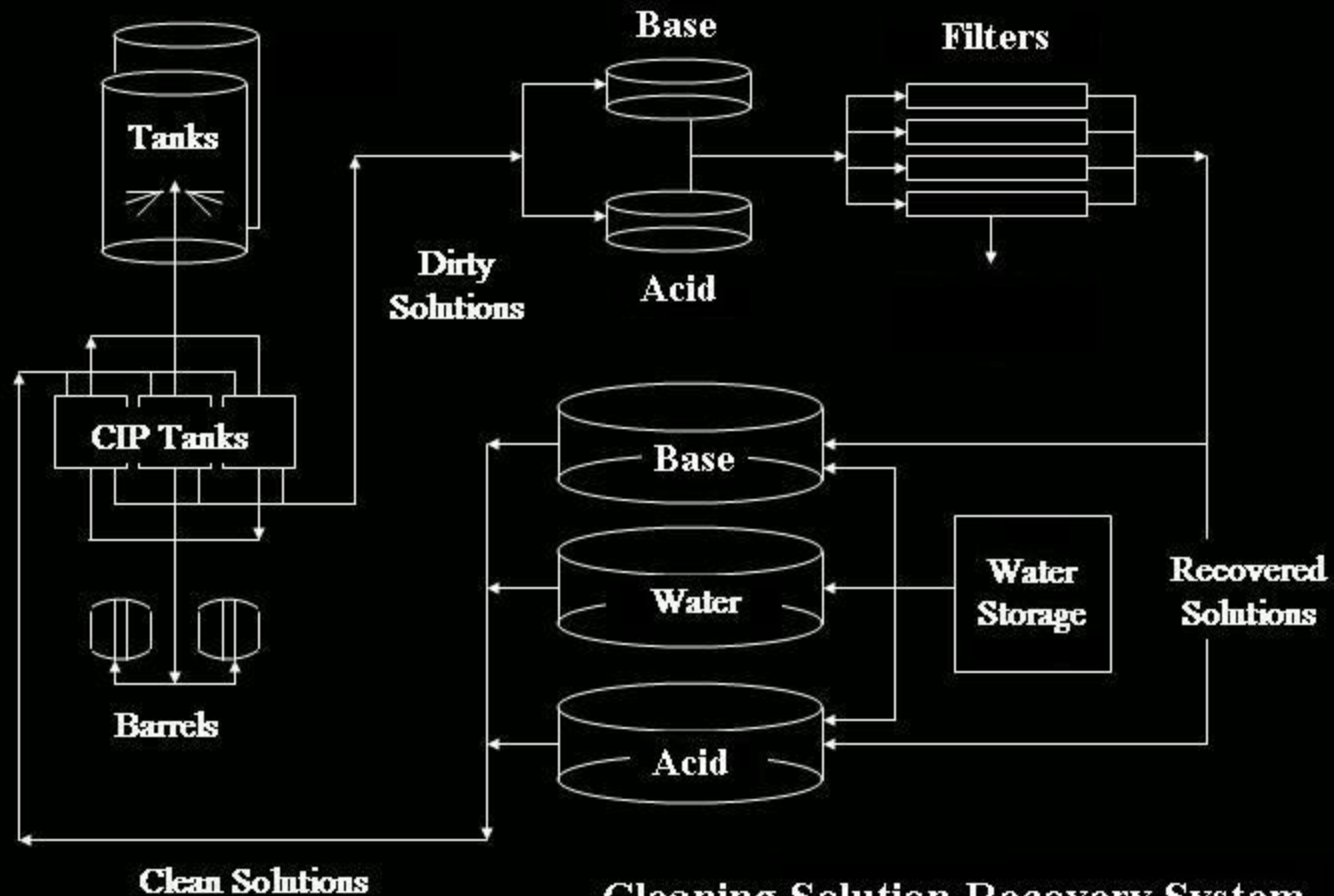
Volume per Cleaning  
[L]

Number of Re-Uses  
[0 to 10]

$$\frac{\sum_{n \text{ Lots}} \# \text{ Cleanings} * \text{Volume}}{\text{Number of Uses}}$$

or

$$\frac{\sum_{n \text{ Lots}} \# \text{ Cleanings} * \text{Volume}}{\text{Number of Uses}} \quad \text{Tons or Liters}$$



**Cleaning Solution Recovery System**

# Alternative Winemaking Practices

Adopting technologies that enable  
fewer tank transfers

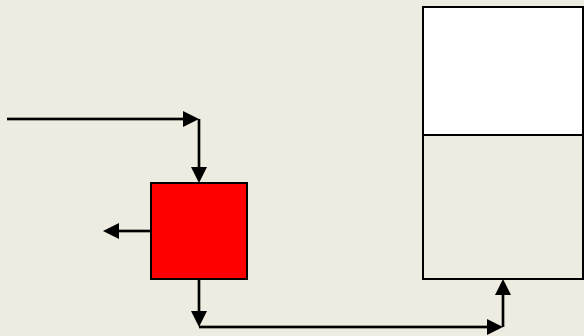
# Some Examples of Sustainable Technology

## 4 Examples:

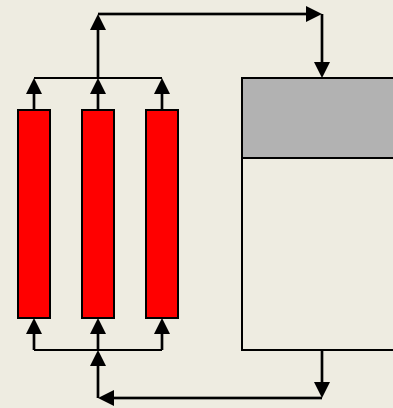
- In-line White Juice Flotation
- Protein Adsorption Columns
- Fluidized-Bed Crystallizer for Potassium Bitartrate
- In-Tank Blending Systems

Saves at least 4 tank washings for each tank  
of White Wine

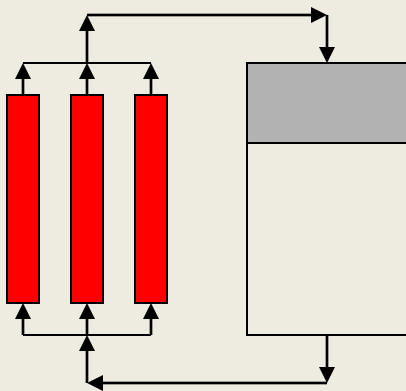
Saves at least 2 tank washings for each tank  
of Red Wine



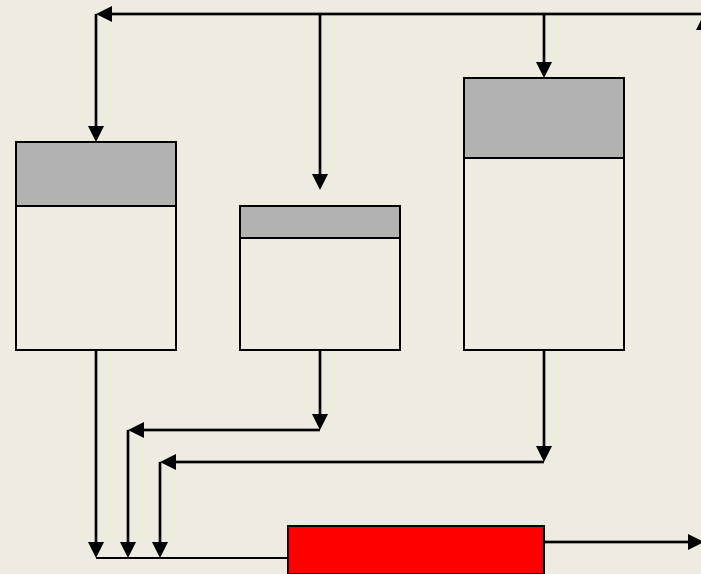
Flotation Cell



Protein Adsorption Column



KHTa Fluidized Bed



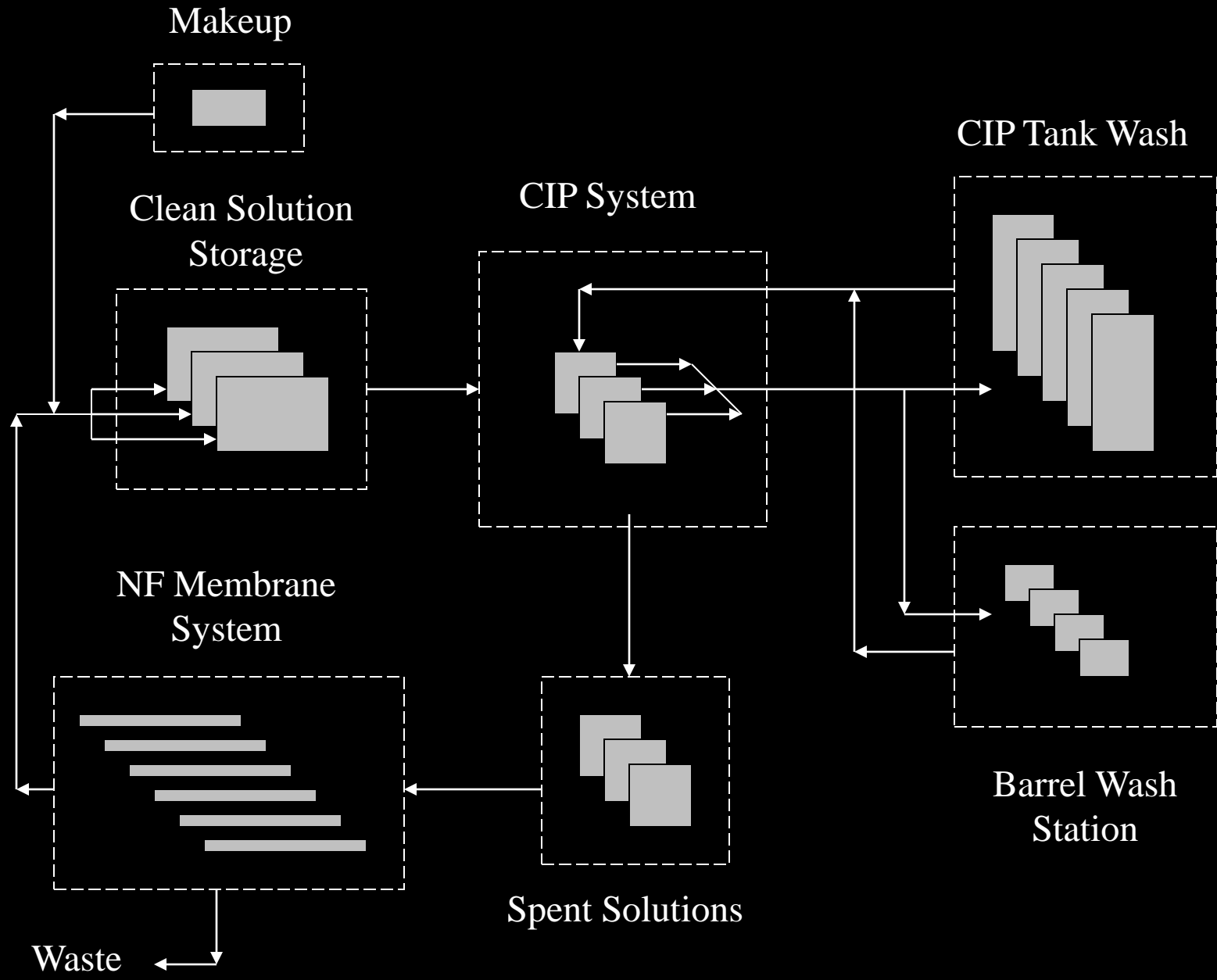
In-Tank Blending

# Practices, Tank Transfers and Tank Cleaning

- Avoid treatments that require clarification
  - Settling and racking of white juices
  - Bentonite fining in tanks
  - Tartrate stabilization within tanks
  - Addition of solids
- Eliminate Use of Blending Tanks

# Recovery and Re-Use of Cleaning Solutions

Dramatic Reduction in Water  
Requirements,  
Self-Sustainable with respect to Water



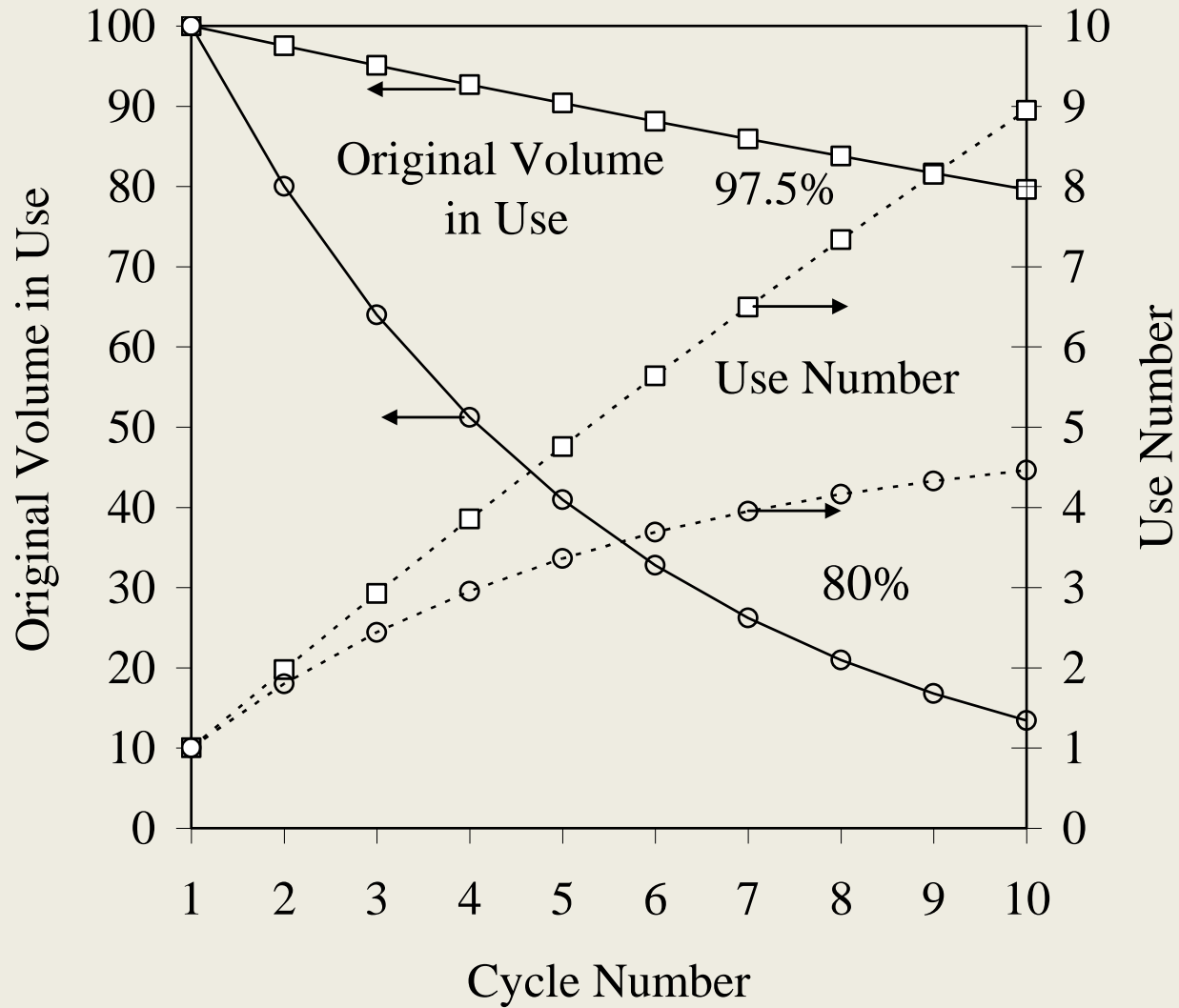
## The Number of Uses for Water

**Recovery      0.90**

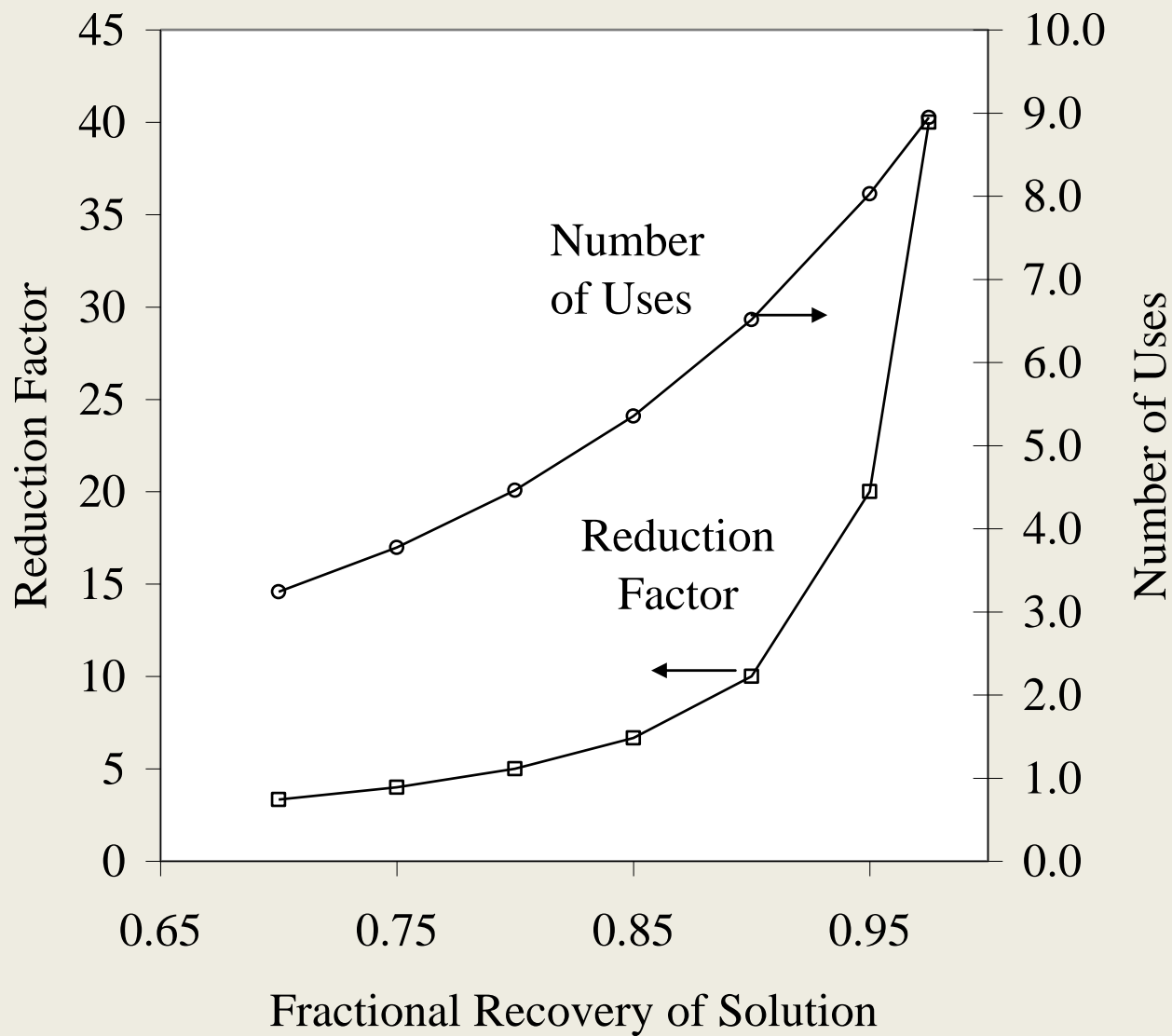
<b>Cycle #</b>	<b>Initial Volume</b>	<b>Use Number</b>	<b>Makeup</b>	<b>Cum. Saving</b>
1	100.00	1.00	0.00	0.00
2	90.00	1.90	10.00	90.00
3	81.00	2.71	10.00	180.00
4	72.90	3.44	10.00	270.00
<b>5</b>	<b>65.61</b>	<b>4.10</b>	<b>10.00</b>	<b>360.00</b>
6	59.05	4.69	10.00	450.00
7	53.14	5.22	10.00	540.00
8	47.83	5.70	10.00	630.00
9	43.05	6.13	10.00	720.00
<b>10</b>	<b>38.74</b>	<b>6.51</b>	<b>10.00</b>	<b>810.00</b>

<b>% Recovery</b>	<b>90.00</b>	<b>90.00</b>
<b>Volume</b>	<b>900.00</b>	
<b>Makeup</b>	<b>90.00</b>	
<b>Saved</b>	<b>810.00</b>	
<b># Uses</b>	<b>6.51</b>	
<b>Reduction Factor</b>	<b>10.00</b>	

# Water Recovery Variables (Basis of 100 Volumes)



Effect of Recovery (10 Cycles)



# Clean-In-Place Systems

Fixed, Automated Lines for Large Fermentors,  
Automated Washing Stations for Small  
Fermentors and Barrels

Movable Solution Tanks for Recovery and Re-Use



A 3 Tank CIP System

# A Clean-In-Place (CIP) System

- Automated and Reproducible Cleaning
  - Swab or Spray Evaluation, Standards
- Modification of Tanks
  - Spray Ball, Solution Outlet, Pump, Lines, Internals
- Cleaning Stations
  - Barrel Washing Systems, Presses, Filters, Bottling Line
- Recovery of Separate Solutions
- Essential for Solution Recovery and Re-Use Strategy

# Alternative Cleaning Chemistries

Peracetic Acid, PAA

Hydrogen Peroxide

Hot, low pH Water

Hydrogen Peroxide and low pH?

# Sustainable Directions

- Elimination of agents that contribute significantly to BOD and/or COD loads
- Elimination of Chlorine compounds
- Elimination of Sodium salts
- Elimination of Phosphate, Nitrate anions
- Use moderate buffer concentrations
- Potential for Chemical recovery and reuse
- Passive Solar Hot Water (60 C)

# Sodium and Clay Soils

• Atom	Ion	Ion Diameter (Å)	Hydrated Ion Diameter (Å)
Na	Sodium	1.90	11.2
K	Potassium	2.66	7.6
Cs	Cesium	3.34	7.6
Mg	Magnesium	1.30	21.6
Ca	Calcium	1.90	19.0

Swelling promoted by highly hydrated exchangeable cations,  
ie  $\text{Na} > \text{Mg} > \text{Ca} > \text{K} = \text{Cs}$

High swelling leads to poor permeability and platelet  
disruption

# The Potassium Cleaning Alternative

- Potassium Hydroxide, KOH, pH = 11.5
- Potassium Bisulfate,  $\text{KHSO}_4$ , pH=2.5
- Use as 10 or 20 mM solutions
- No BOD or COD contributions
- No Chlorine, Phosphate, Nitrate content
- No Sodium content
- Nanofiltration recovery of solutions
- Discharged as dilute  $\text{K}_2\text{SO}_4$  solution onto So

# Cleaning Set I

Solution 1: Water Rinse, capture, filter, reuse

Solution 2: KOH Treatment, capture, filter, reuse

Solution 3:  $\text{KHSO}_4$  Treatment, capture, filter,  
reuse

1% Hydrogen Peroxide for sanitizing

Mixing solutions 2 and 3 prior to discharge,

pH = 7, No Chlorine, BOD or COD

# Cleaning Set II

Solution 1: 60 C Hot Water (or KOH),  
capture, filter, reuse

Solution 2: 60 C Hot Water (or  $\text{KHSO}_4$ ),  
capture, filter, reuse

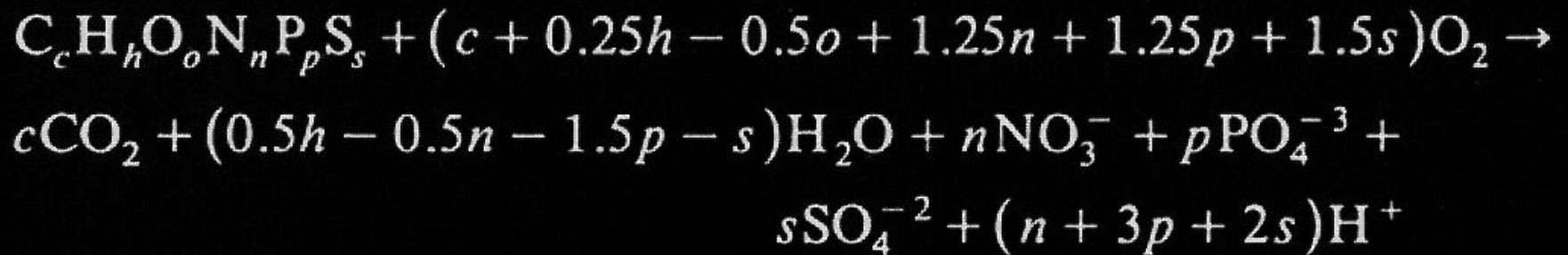
Mixing KOH/  $\text{KHSO}_4$  prior to discharge  
pH =7, No Chlorine, BOD or COD

# BOD and COD Contributions from Cleaning Chemistry

Biological Oxygen Demand, mg O<sub>2</sub>/L

Chemical Oxygen Demand, mg O<sub>2</sub>/L

# Theoretical BOD Formula



<b>Compound</b>	<b>BOD mg/g</b>
<b>Glycerol</b>	<b>1216</b>
<b>Malic</b>	<b>716</b>
<b>Tartaric</b>	<b>533</b>
<b>Glucose</b>	<b>1065</b>
<b>Ethanol</b>	<b>2082</b>
<b>Citric</b>	<b>750</b>
<b>Ascorbic</b>	<b>909</b>
<b>Arginine</b>	<b>3753</b>
<b>Proline</b>	<b>1378</b>
<b>PAA</b>	<b>632</b>
<b>Acetic</b>	<b>1067</b>

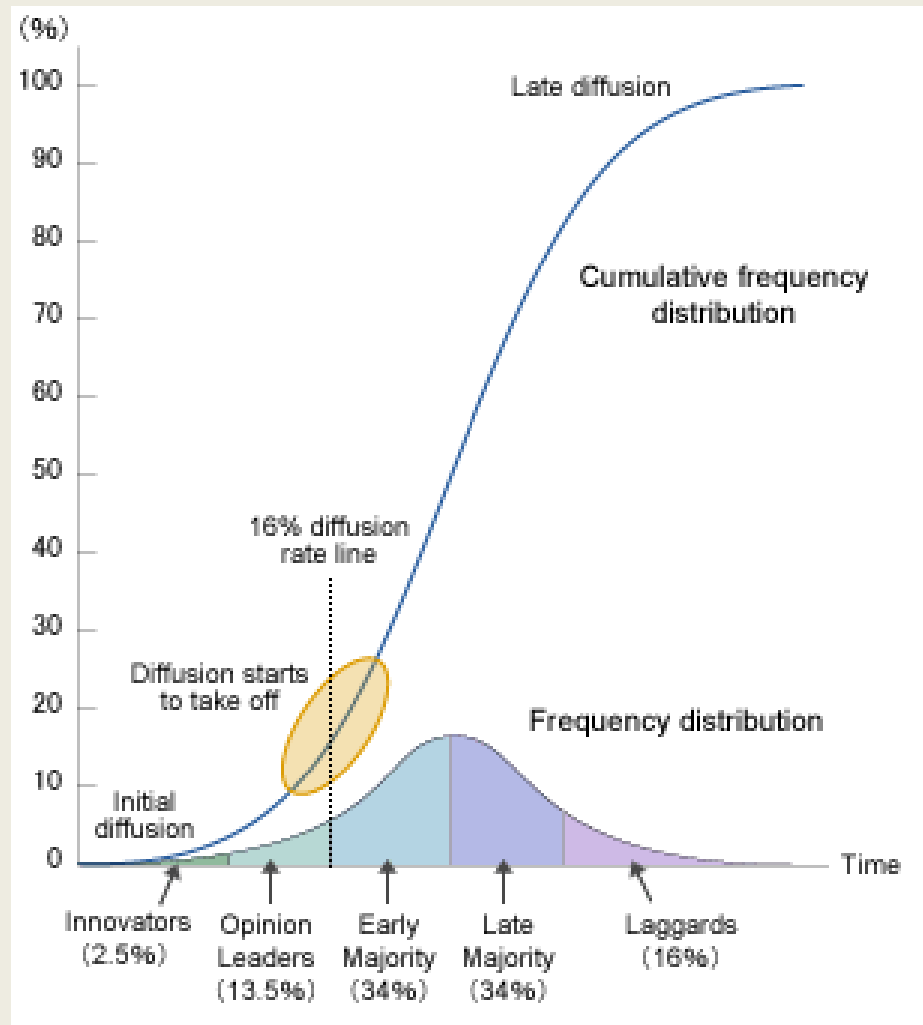
<b>Solution</b>	<b>BOD mg/L</b>
<b>Juice</b>	<b>244,473</b>
<b>Wine</b>	<b>264,433</b>
<b>1% Citric</b>	<b>7496</b>
<b>100mg/L PAA</b>	<b>63</b>
<b>100 mg/L Acetic</b>	<b>107</b>
<b>100mg/L PAA Mix</b>	<b>280</b>
<b>Winery Data</b>	<b>8000</b>



# Adoption of Innovation

How long before you adopt?

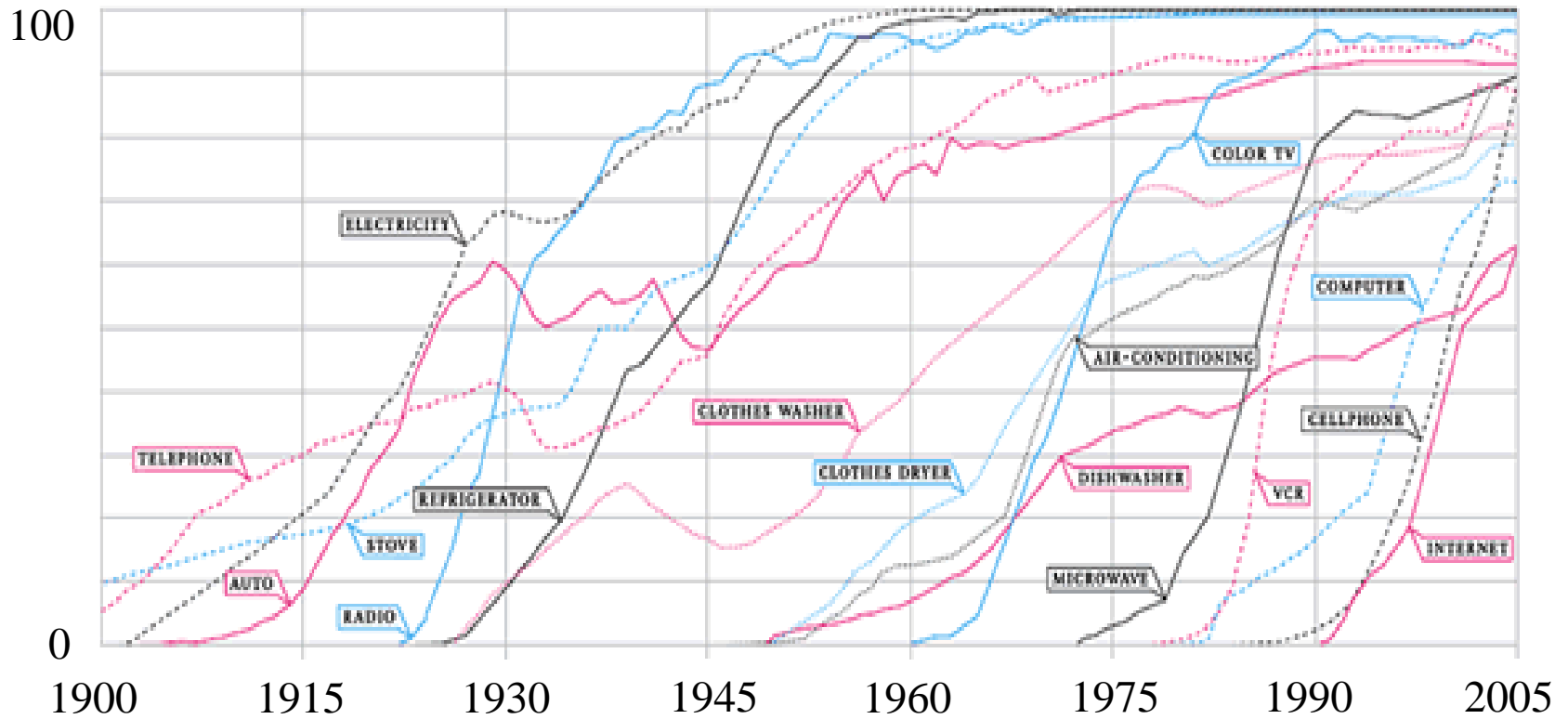
Usually 10 to 15 years for 50%  
adoption



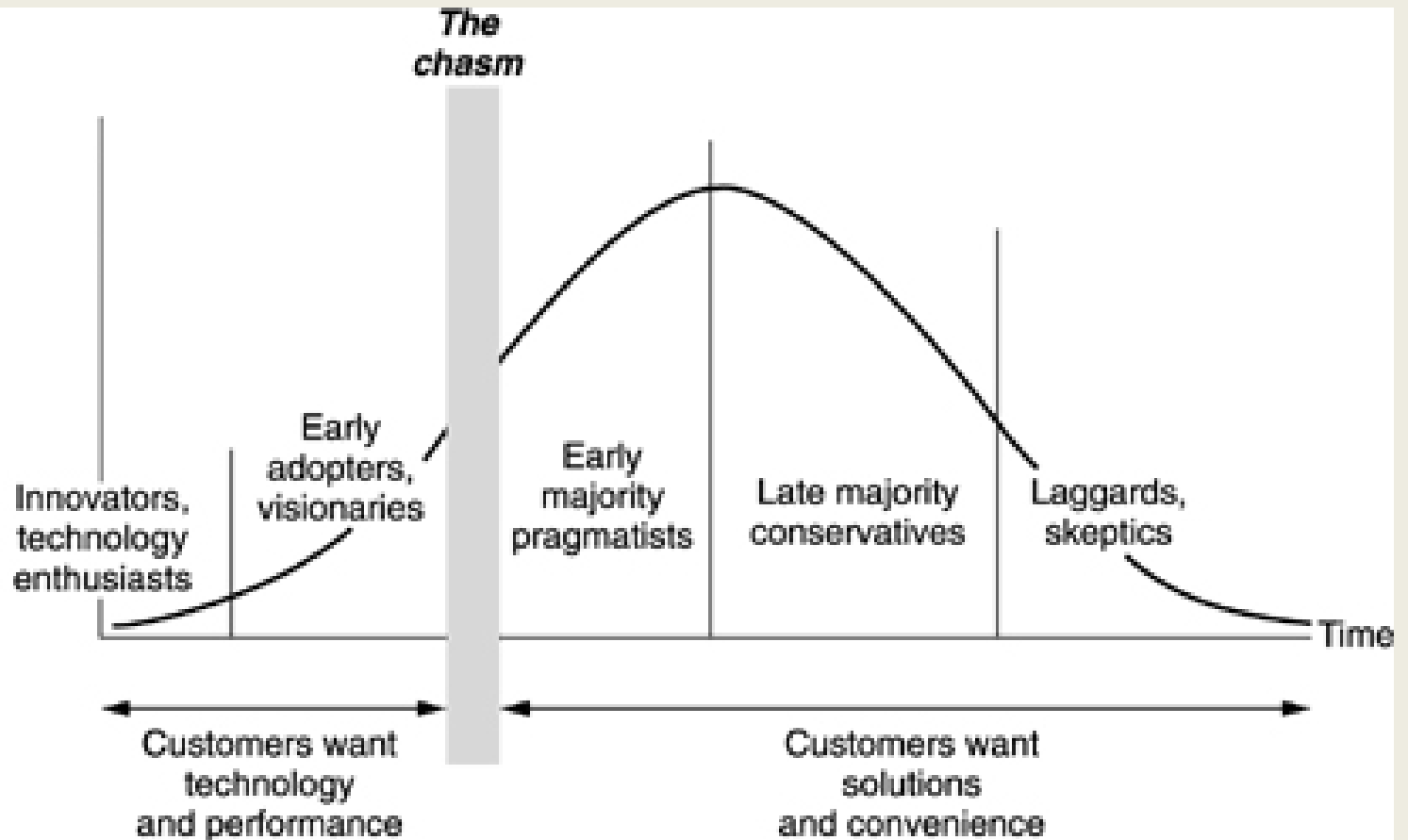
**\*Rogers, E. M. (1962), *The Diffusion of Innovation*, The Free Press, New York**

# Examples of Adoption Curves

% age of US Households



Half times of 10 to 15 years



Moore, G. A. (1998), *Crossing the Chasm*, Capstone, Oxford

# Summary

- Metrics for Water Use
- Water Footprints and Scaled Water Footprints
- Changing Winemaking Practices
- Alternative Winemaking Practices
- Alternative Cleaning Chemistry
- BOD and COD of Cleaning Chemistry
- Innovation and Adoption

# Acknowledgments

Anne Thrupp and Glenn McGourty  
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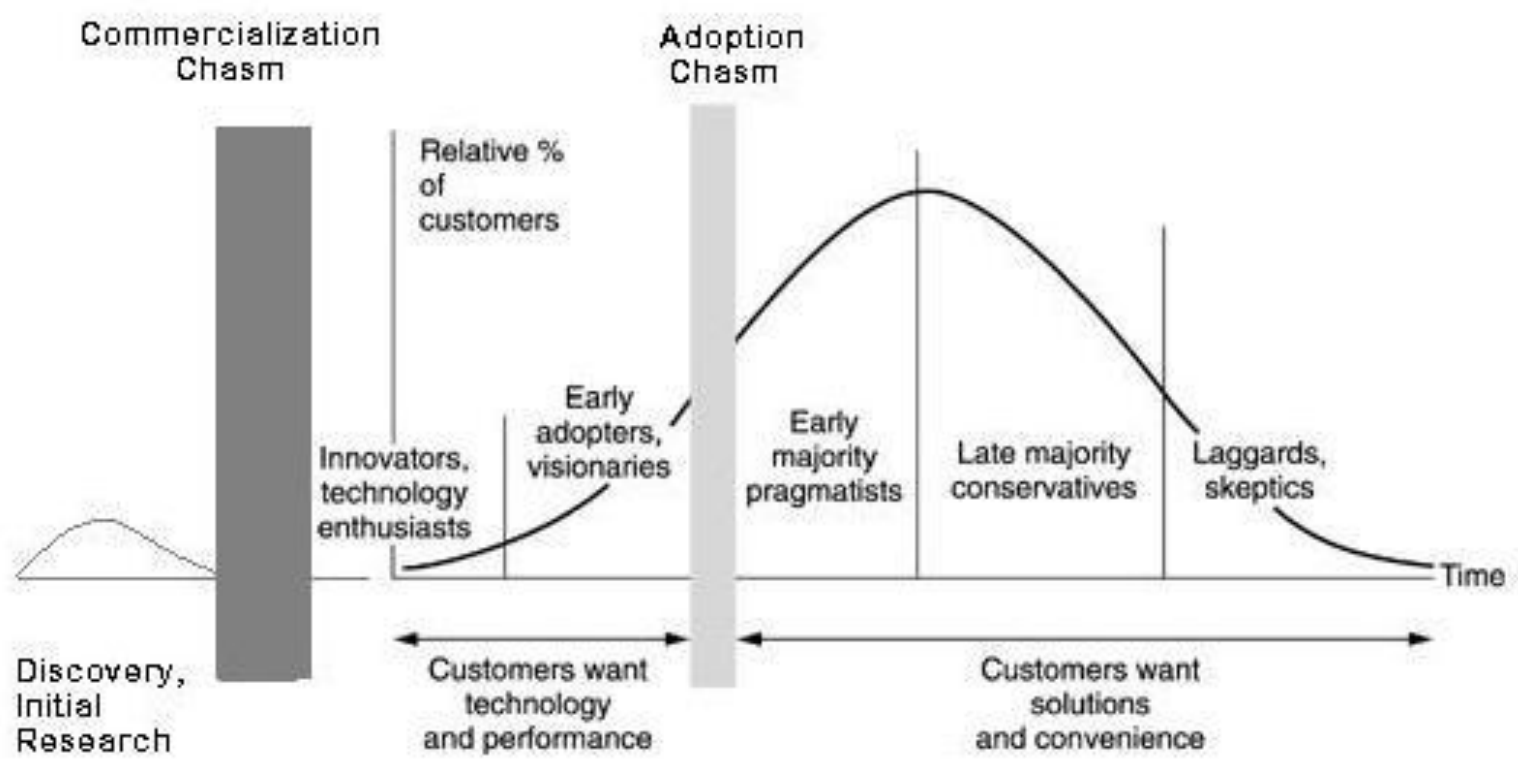
Jess Jackson and Barbara Banke

T. J. Rodgers

Jerry Lohr

My Colleagues in  
The Department of Viticulture and Enology





# Hydrogen Peroxide

Decomposes to Oxygen and Water

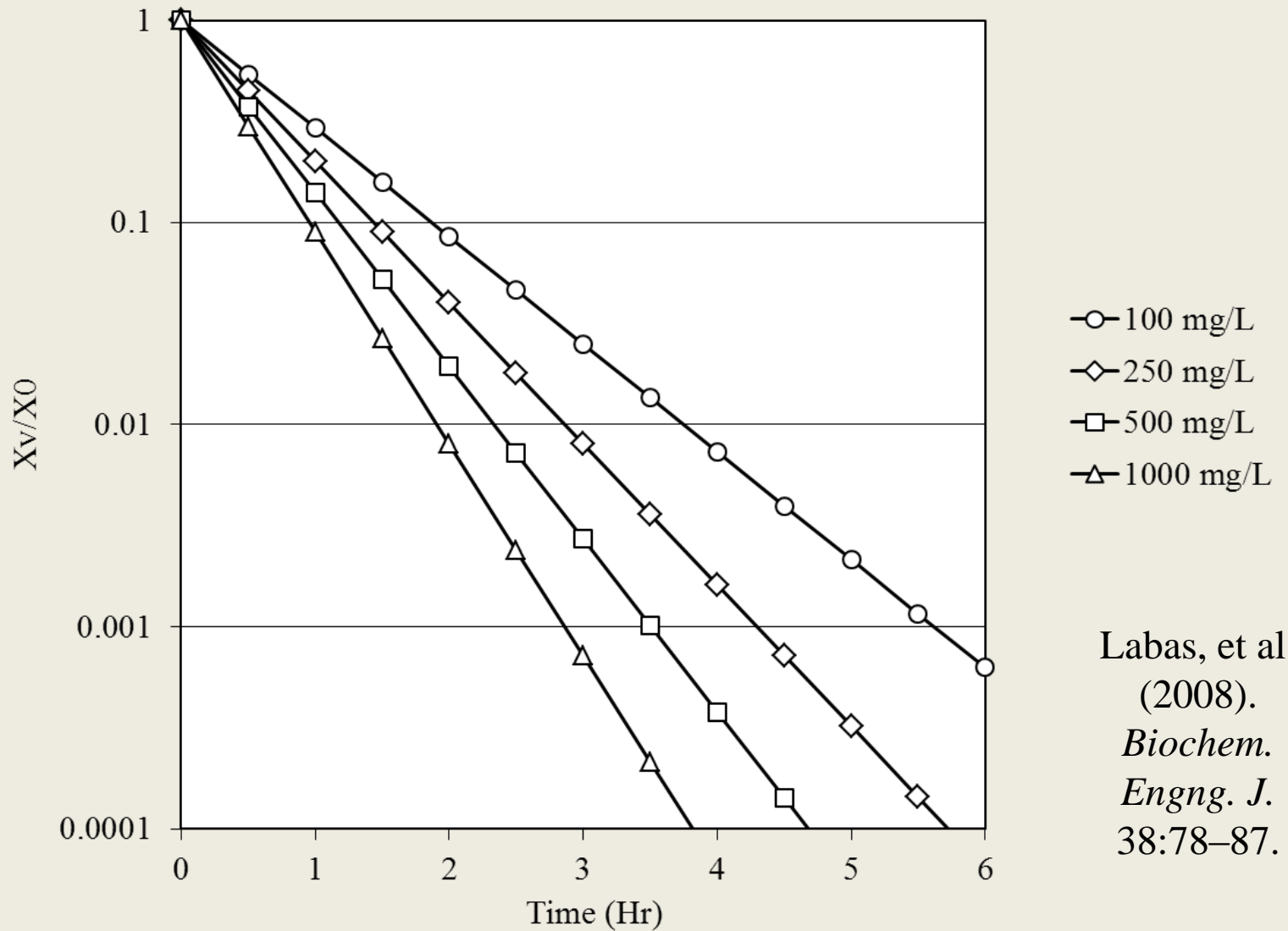
Environmentally Benign

Non-toxic to Humans

No BOD or COD Contributions

No Sodium Contribution

## Killing of *E. coli* with Hydrogen Peroxide at pH = 7.0



Labas, et al.  
(2008).  
*Biochem.  
Engng. J.*  
38:78–87.

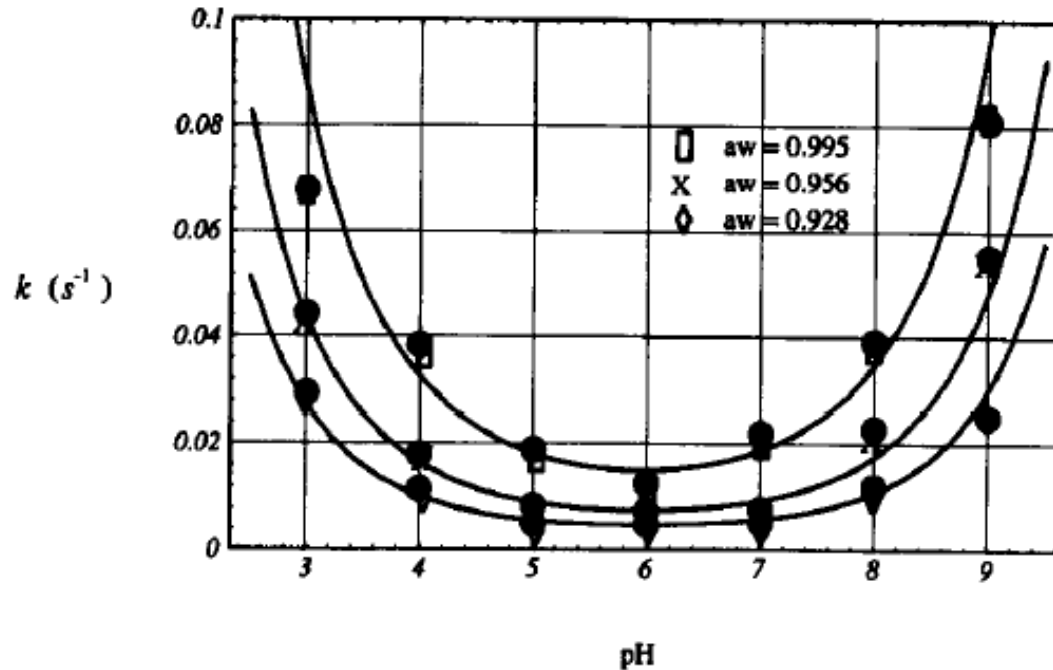
# Hot Water, Low pH

Environmentally Benign

Non-toxic to Humans

No BOD or COD Contributions

Passive Solar Hot Water

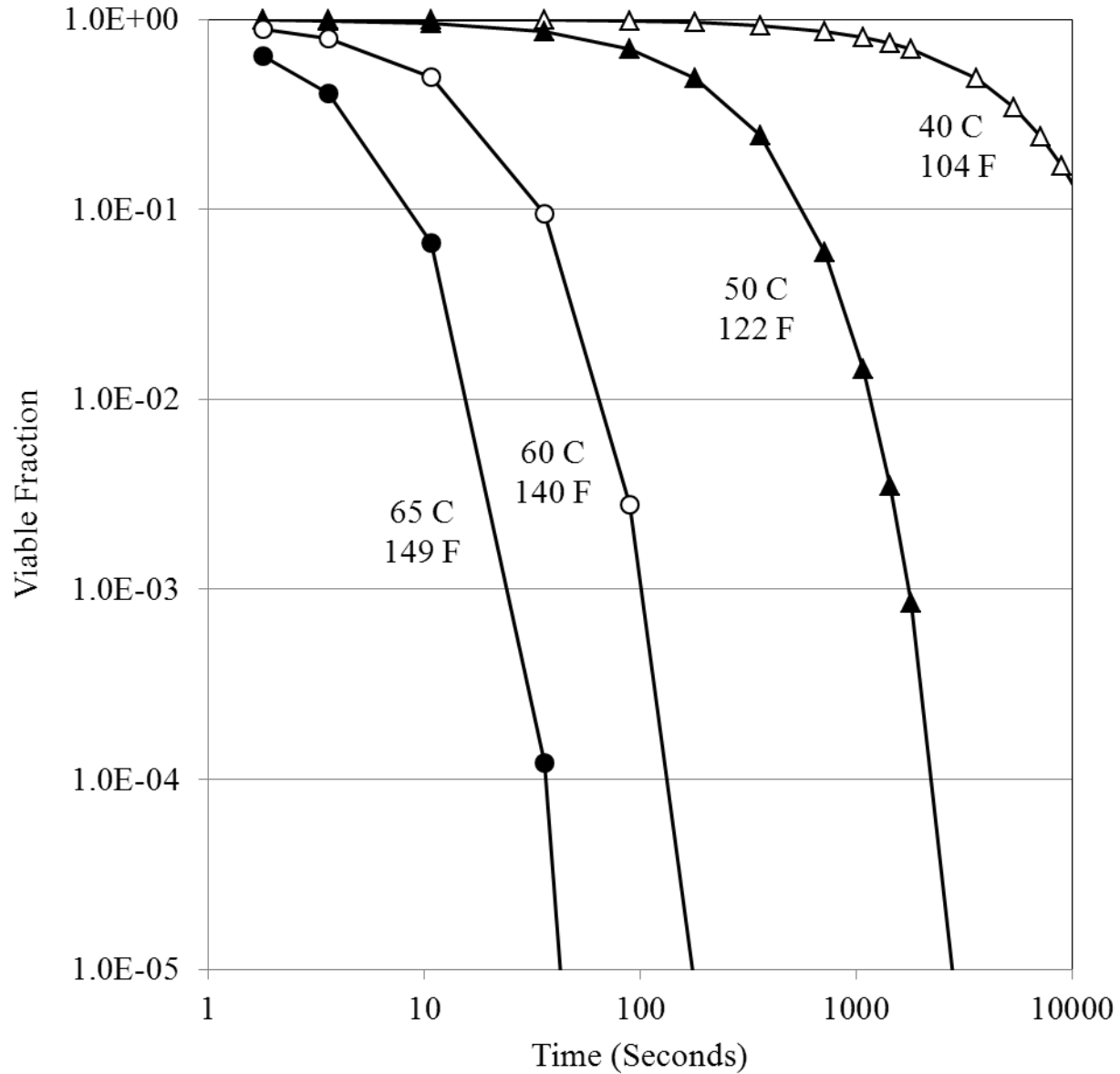


**Fig. 2.** Fit of the isothermic ( $T = 58^\circ\text{C}$ ) sterilisation model (Eq. (6)) to observed values of the inactivation rate of *E. coli*, at each of the seven pH, and three  $a_w$ , values.

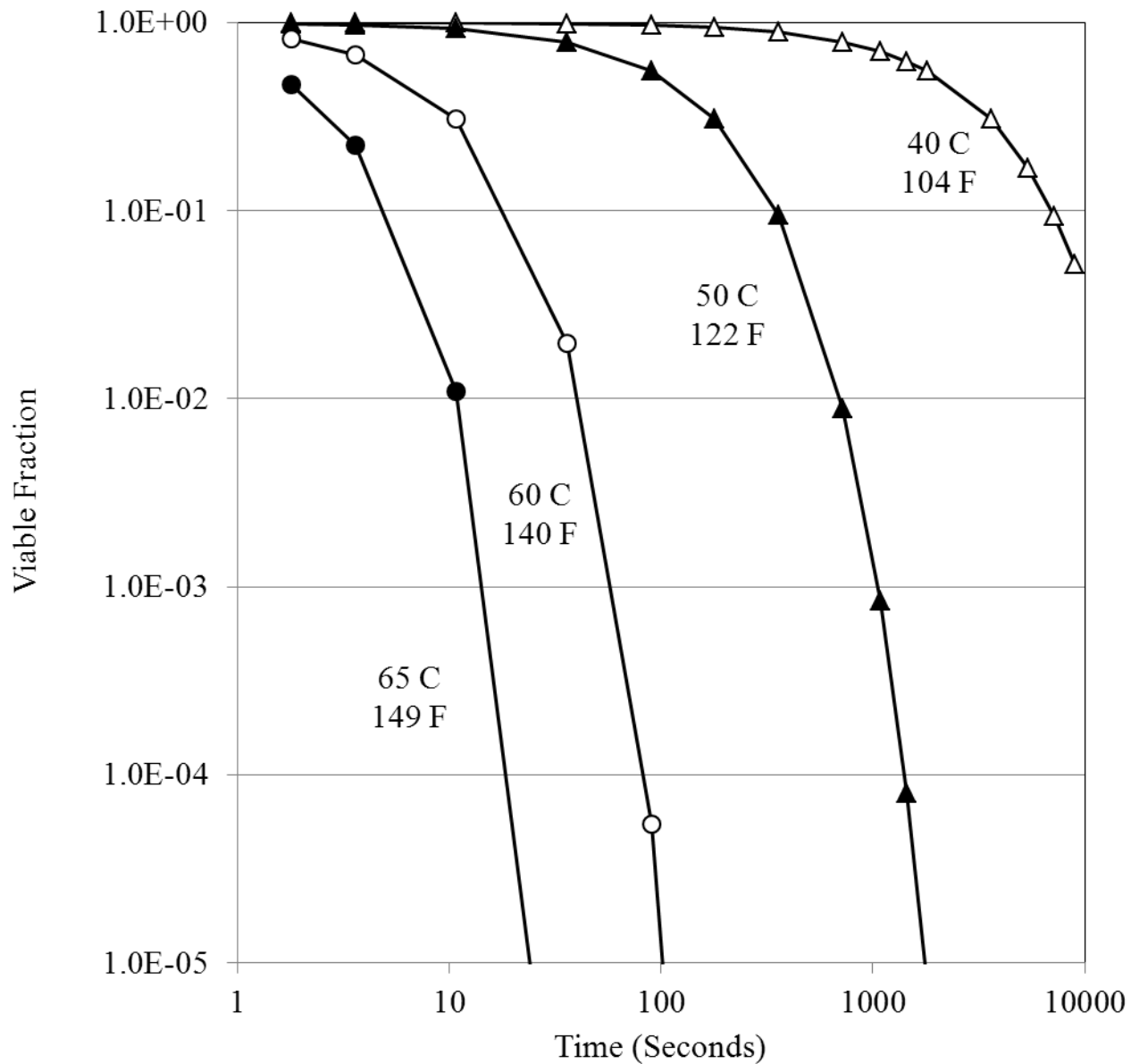
# Low pH, Hot Water

The Cerf et al. (1996) Model  
pH=7.0 and 2.0

# Surviving Fraction, E. Coli, pH=7



# Surviving Fraction, E. Coli, pH=2



# Components of Water Footprint

## 1. Number of Tank Cleanings

1. Wine Type: Red vs White
2. Wine Style: Solids Additions, Aging Practices
3. Winemaker Choices: Practices, Blending Patterns, Stability Treatments

## 2. Volume of Water Used

1. Cleaning Protocol: Chemistries, Cycle Time
2. Extent of Automation: Clean in Place (CIP)
3. Function of Scale: Surface or Volume driven

## 3. Number of Uses

1. Ability to Capture Solutions
2. Choice of Filtration Method
3. Choice of Chemistry, Filtration Method

# 1. Number of Tank Cleanings

- **Wine Type:**
  - Red Wines Out of Fermentor, Blend Tank, Bottling
  - White Wines Clarifying Juice, Out of Fermentor, Blend Tank, Bottling
- **Wine Style:**
  - Solids Additions Fining Agents, Filtration, Racking
  - Aging Practices Racking off Pieces
- **Winemaker Choices:**
  - Aging Practices Number of Rackings from Barrels
  - Blending Patterns Number of Blending Steps
  - Stability Treatments Bentonite Fining, Cold Stability

## 2. Volume of Water Used

- Cleaning Protocol:
  - Chemistries Base, Acid, Water Solutions
  - Cycle Time Rinsing, Surface Cleaning, Sanitizing
- Extent of Automation:
  - Clean in Place (CIP) CIP for Tanks and Barrels
  - Ability to Refilter Solutions
- Function of Scale:
  - Volume Used Surface Area of Tank ( $D^2$ )  
or Volume of Tank ( $D^3$ )

# 3. Number of Uses

- Ability to Capture Solutions
  - Adoption of CIP or automated Cleaning System
  - Install “Capture Tanks”
- Choice of Filtration Method
  - Pad, Crossflow or Nanofilter
  - Depends on Choice of Cleaning Chemistry
- Fractional Recovery of Solutions
  - Depends on Filtration Method

# Development of Alternative Winemaking Practices

- Research
  - Model and Sensor Developments for Protein
- Pilot-Scale Development
  - Control System Development, Automated Operation
- Demonstration Program
  - Data Collection, Benchmark Metrics, Comparisons
- Commercialization
- Adoption