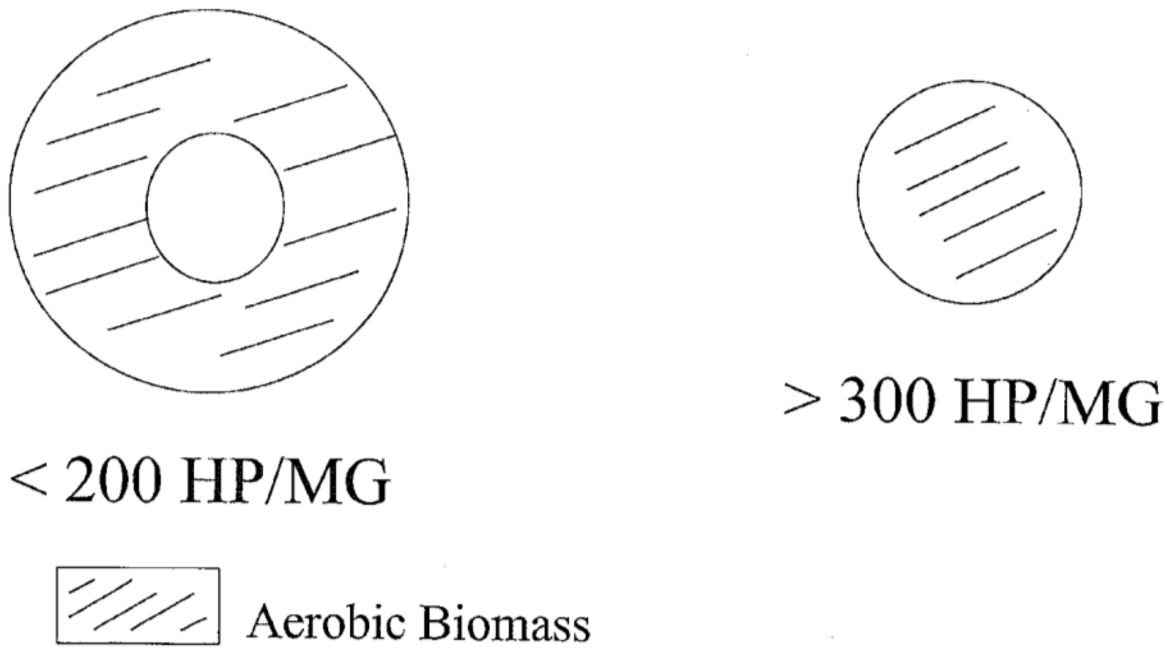
Activated Sludge Design for Industrial Wastewaters

Presented by **AquAeTer, Inc.**
W. Wesley Eckenfelder, Jr. D.Sc., P.E.

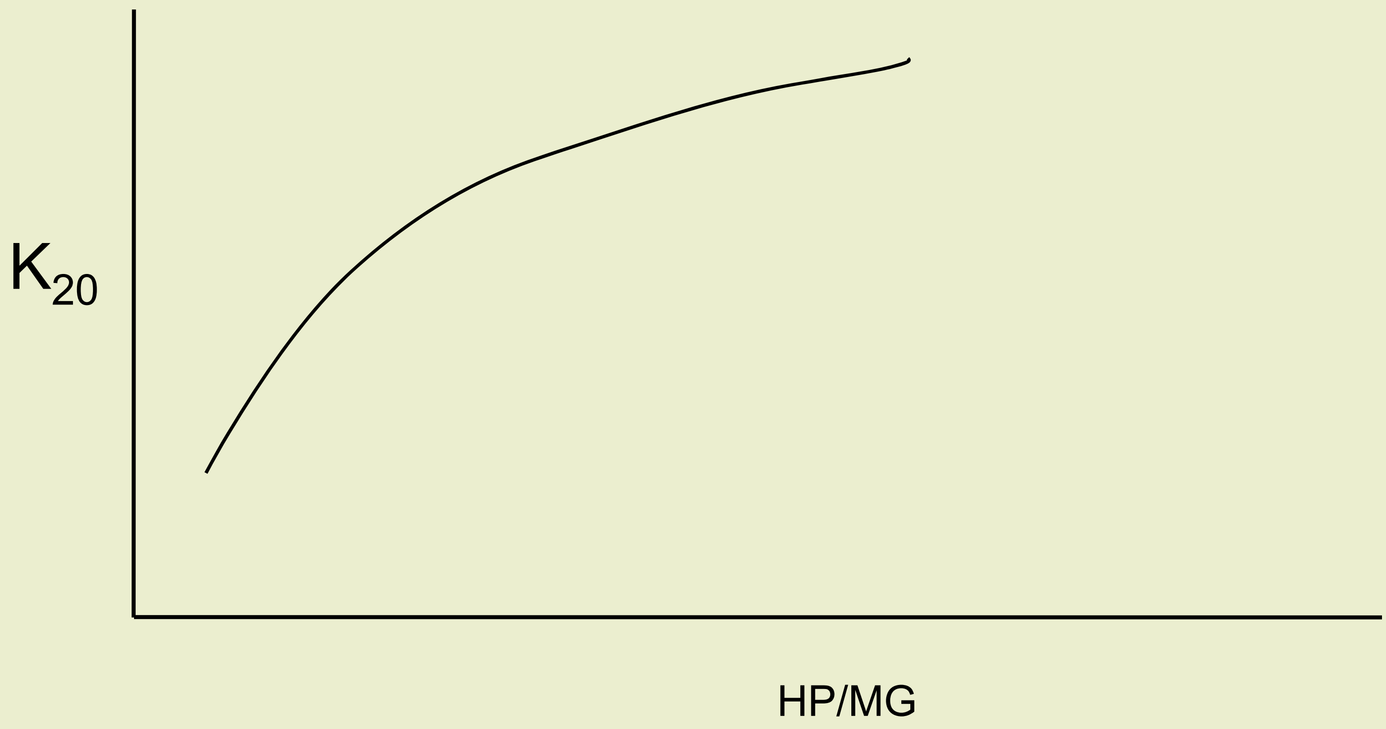
Factors affecting the Activated Sludge Design for Industrial Wastewaters:

1. Aeration Power Density affects floc size and active mass
2. MLVSS composition, active and inactive biomass, degradable and non-degradable influent VSS
3. Reaction coefficient K, a function of wastewater composition
4. Biological reaction, a function of temperature

Aerobic Biomass



Relationship Between Reaction Rate and Power Density



Variation in Kinetic Constant with Mixing Intensity

	$K(day^{-1})$
Bench	10
Pilot	5.3
Full Scale	2.8

Activated Sludge Kinetics

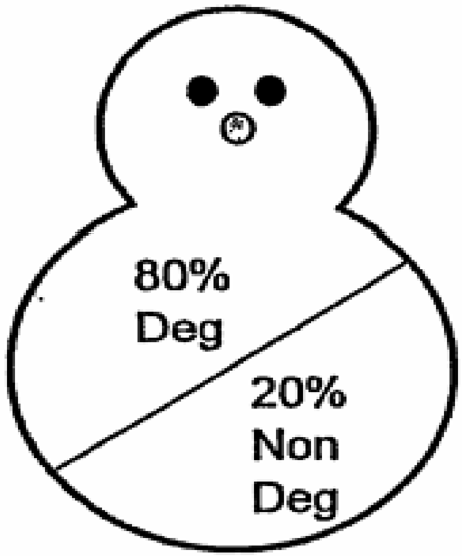
- Conventionally related to the mixed and lower volatile solids, MLVSS.
- The MLVSS however is comprised of active and inactive biomass, non-degradable influent VSS and residual degradable VSS.
- Only the Active biomass contributes to the organic removal.

- The active fraction of the biomass can be computed:

$$f_a = \frac{1}{1 + 0.2 b \theta_c}$$

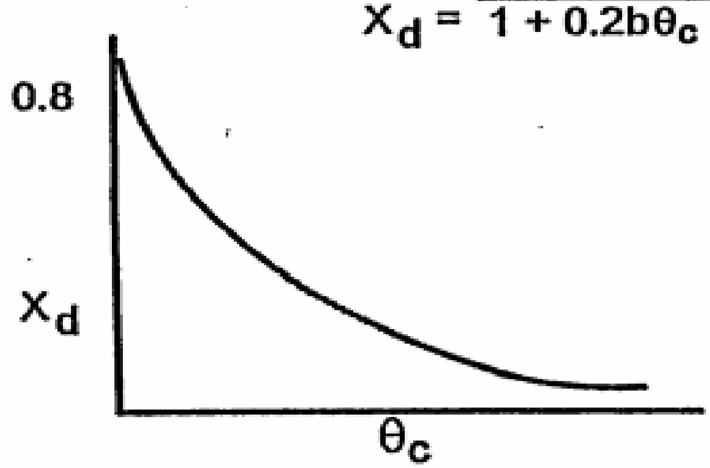
This is shown in the following figure.

Degradable and Non-degradable Fractions

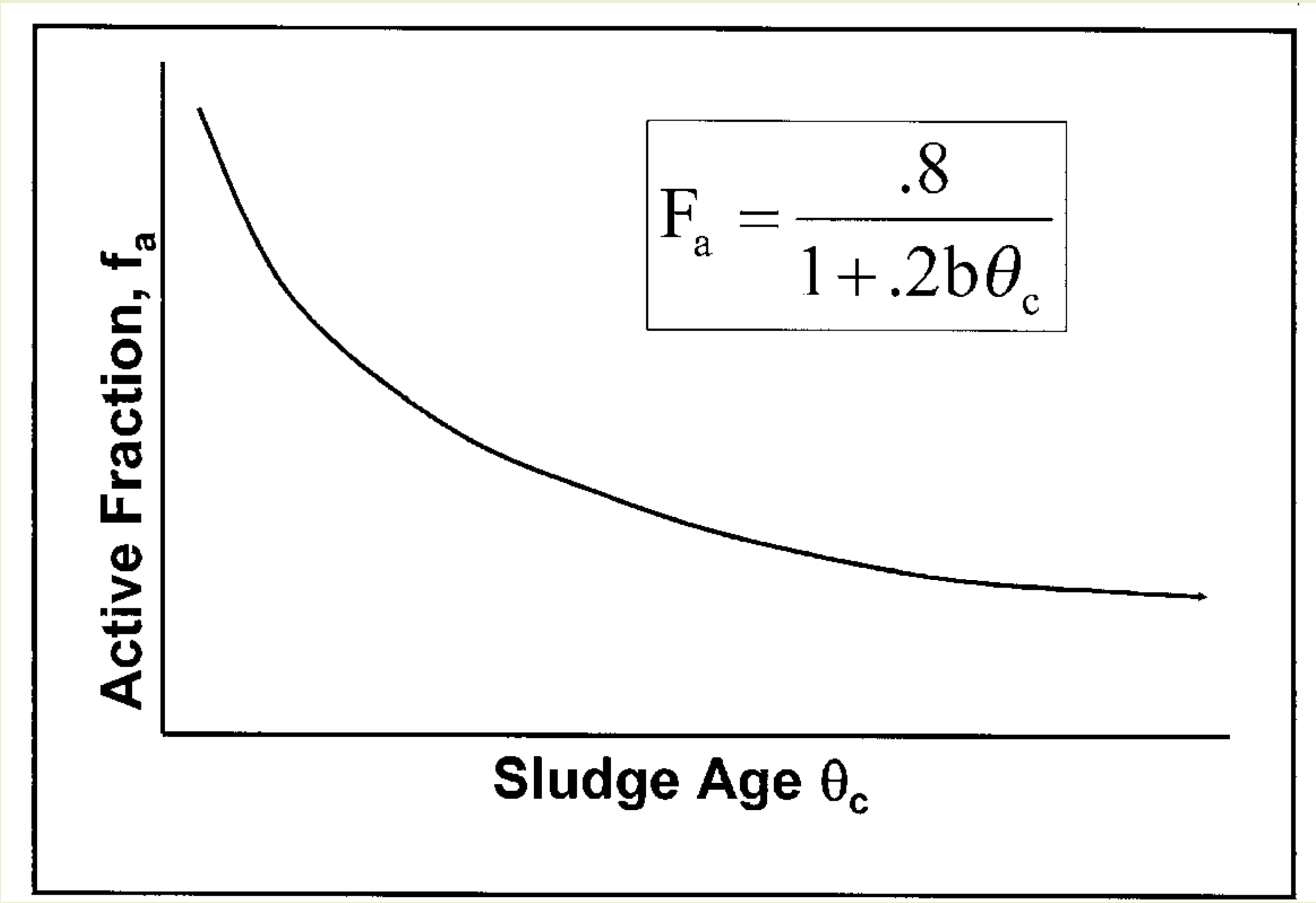


$$X_d = \text{Degradable Fraction}$$

$$X_d = \frac{0.8}{1 + 0.2b\theta_c} \qquad (5)$$

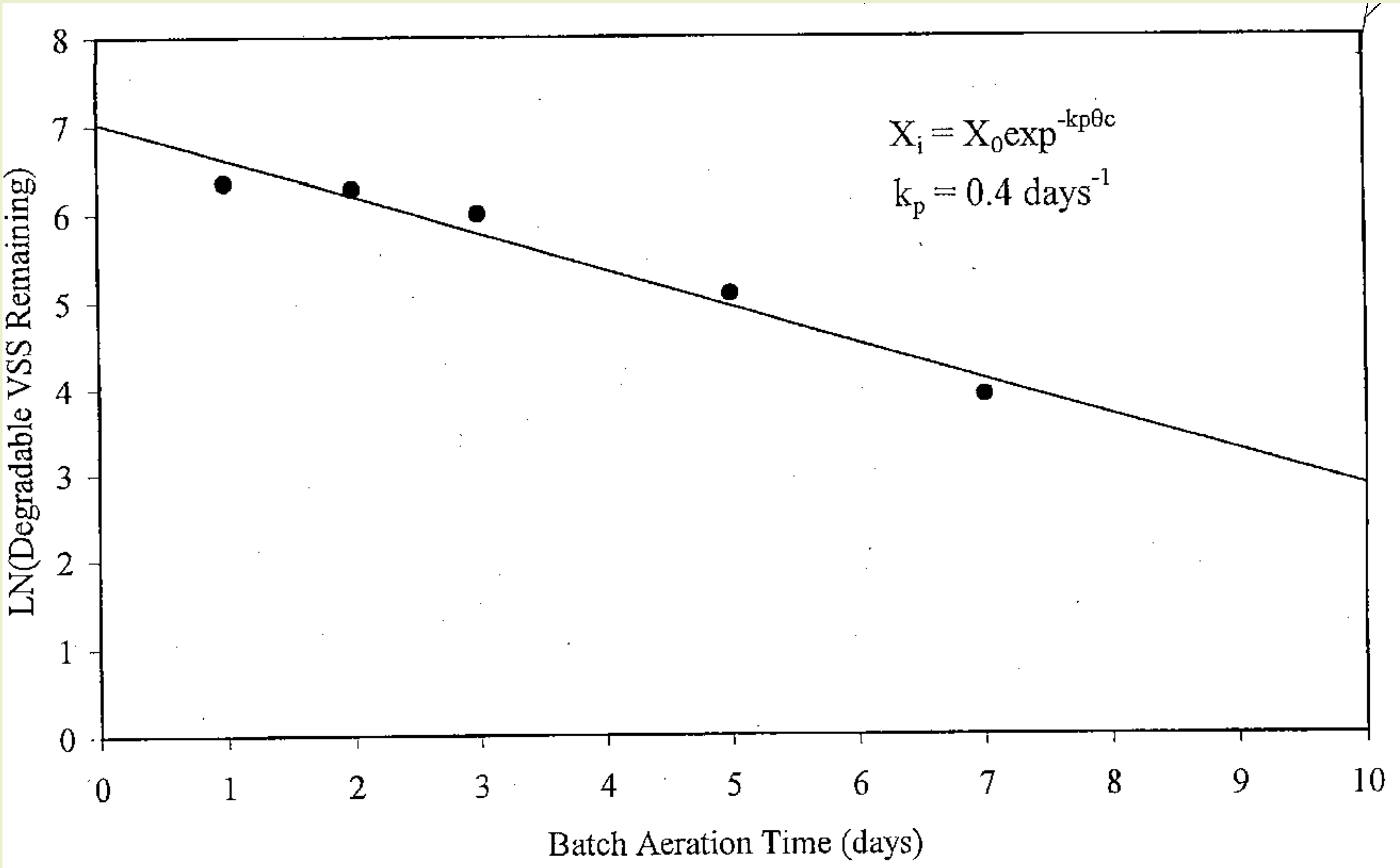


Effect of Sludge Age on Active Fraction



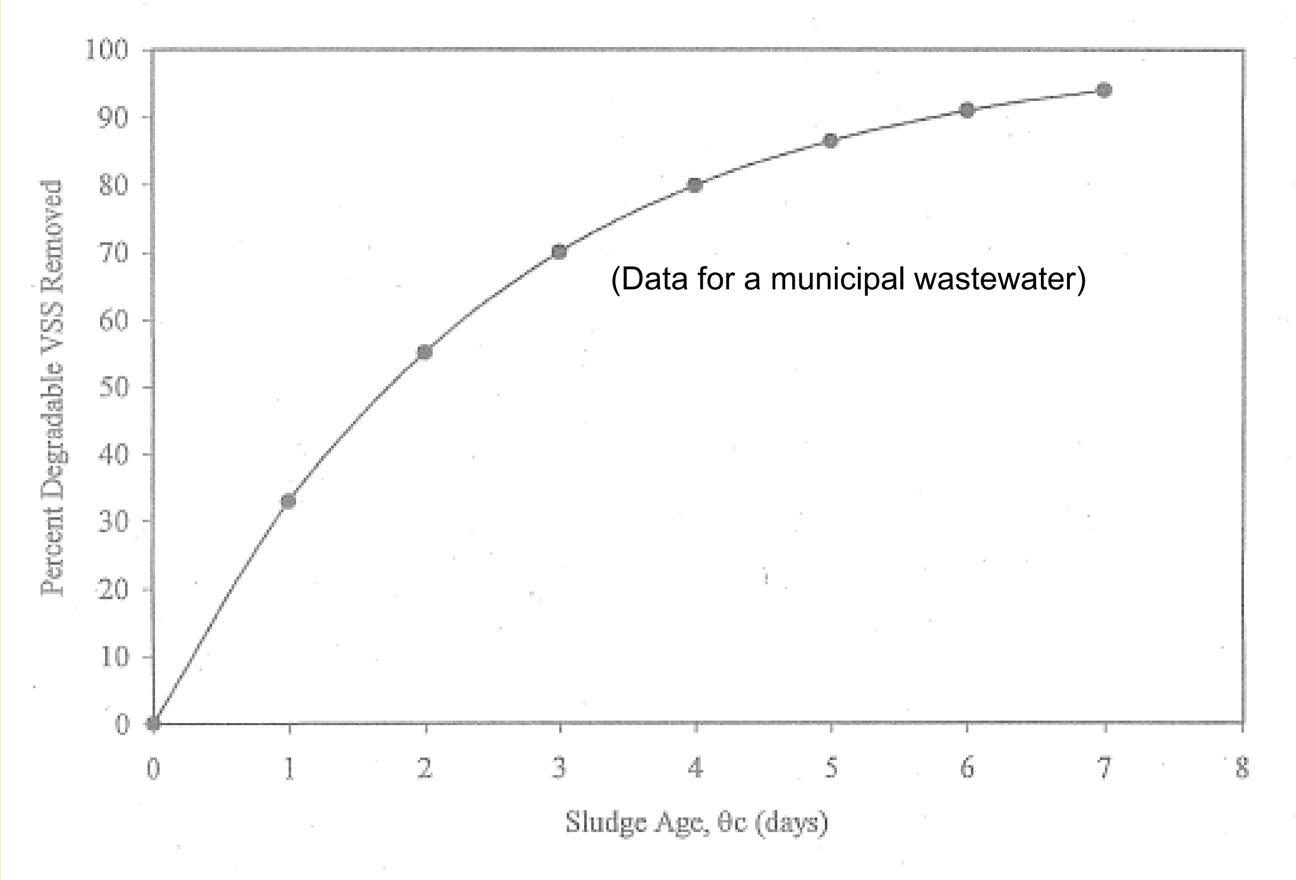
- The degradable VSS are oxidized as a function of sludge age. This follows a first order reaction.
- The degradation of municipal primary VSS is shown in the following figure.

Kp Determination using MWS Primary Effluent and MLSS



Oxidation of Degradable VSS

- Degradable particulate VSS degradation is a function of sludge age, $\theta_{c.}$
- A majority usually degrades within a 10-day sludge age.



- The VSS are completely degraded with a sludge age of 10 days. The degradation properties of industrial VSS would have to be experimentally determined.

- Non-degradable primary VSS will accumulate in the ML.

- The fraction of non-degradable VSS in the ML can be calculated:

$$f_{ND} = \frac{v_i \theta_c}{xvt}$$

$x_i =$ Influent non degradable VSS

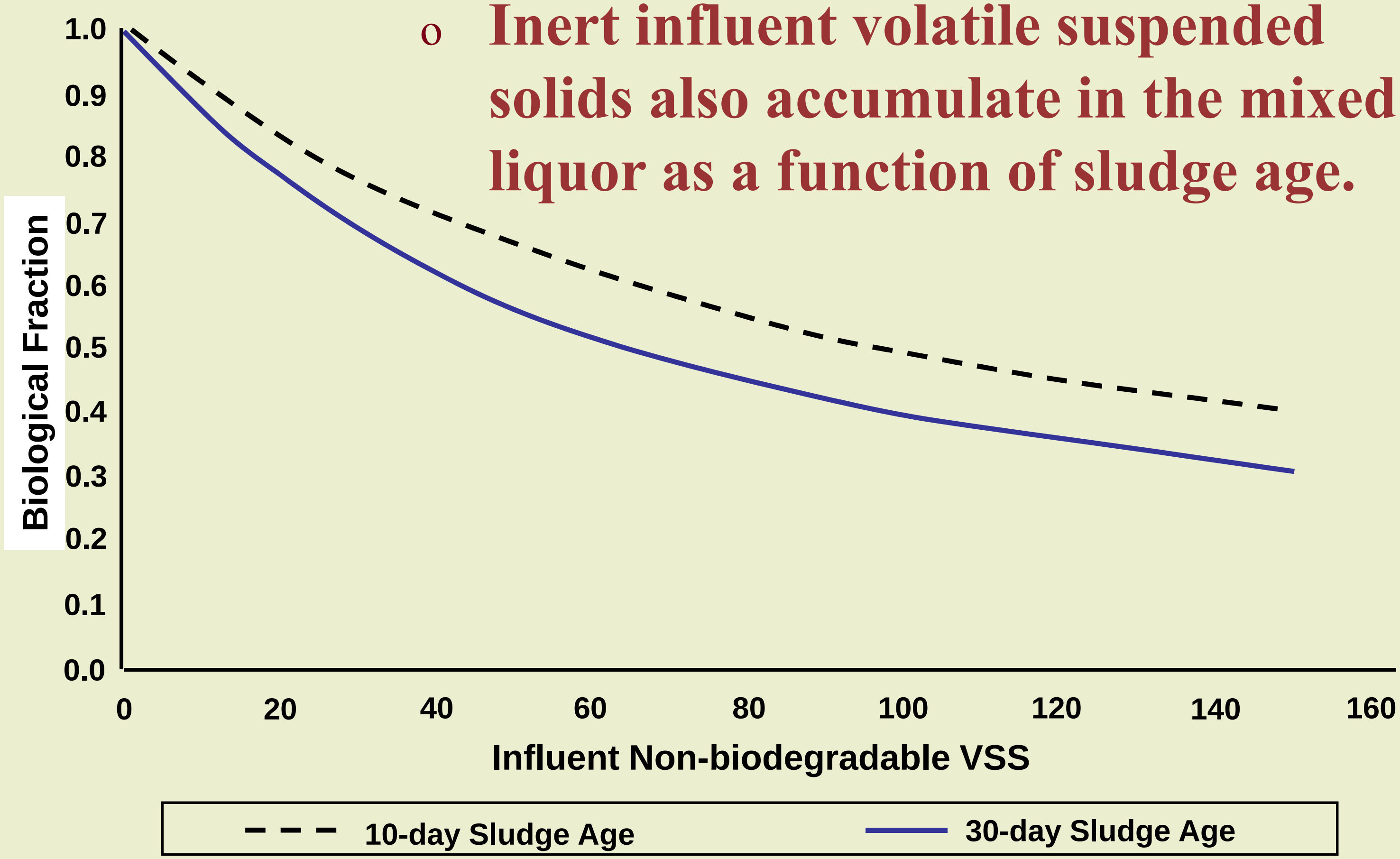
$x_v =$ MLVSS

$t =$ Hydraulic detention time

- This relationship is shown in the following figure.

Biological Fraction of Mixed Liquor Volatile Suspended Solids (MLVSS)

- Inert influent volatile suspended solids also accumulate in the mixed liquor as a function of sludge age.



Calculation of Active Biomass

MLVSS = 2500 mg/L

Non-degradable VSS = 30 mg/L

Sludge Age = 20 days

Detention Times = 1.5 days

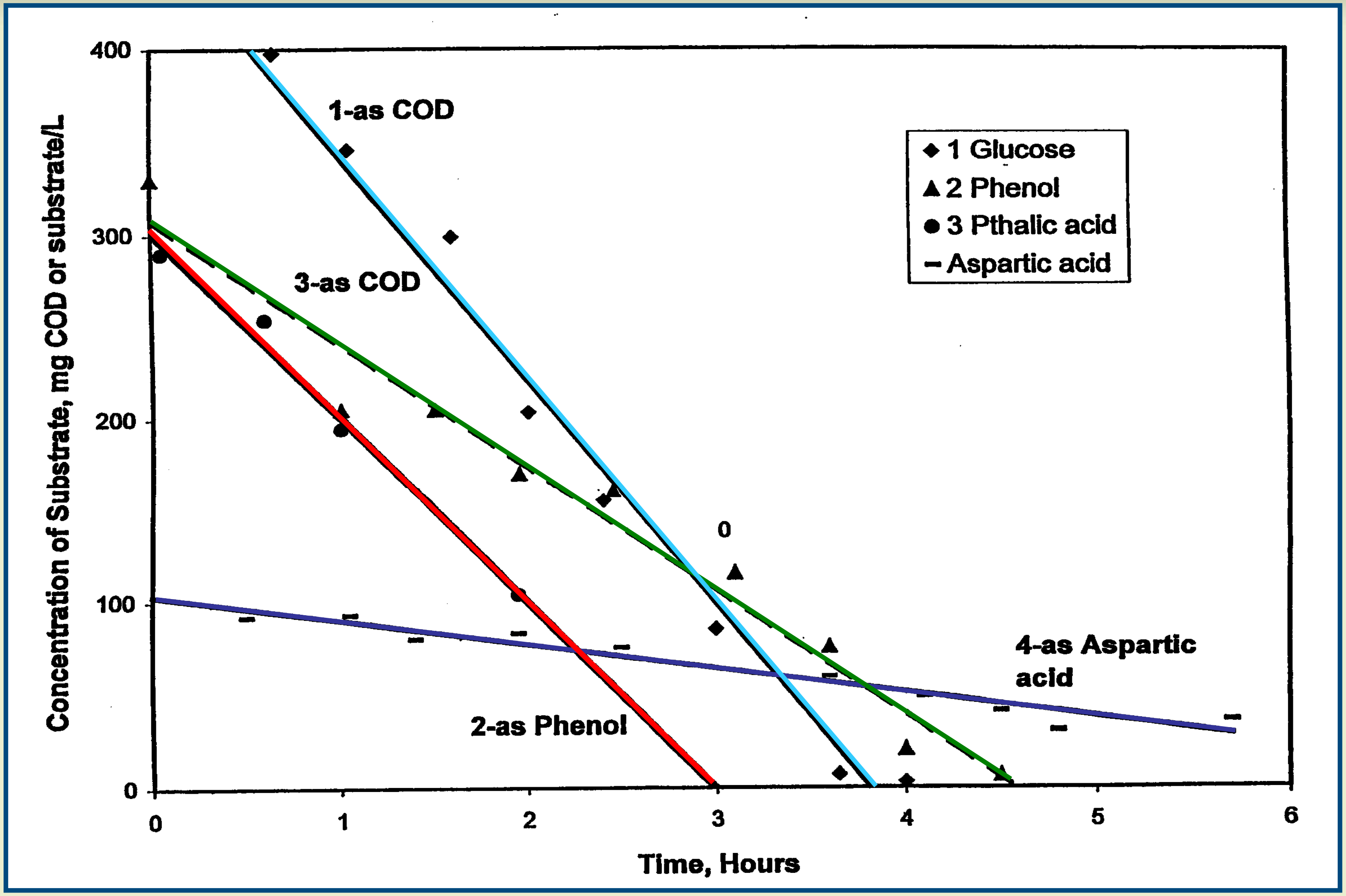
Non-degradable MLVSS = $\frac{30 \cdot 20}{2500 \cdot 1.5} = 0.16$

Active Biomass $fi = \frac{1}{1 + 0.02 \cdot 20} = 0.71$

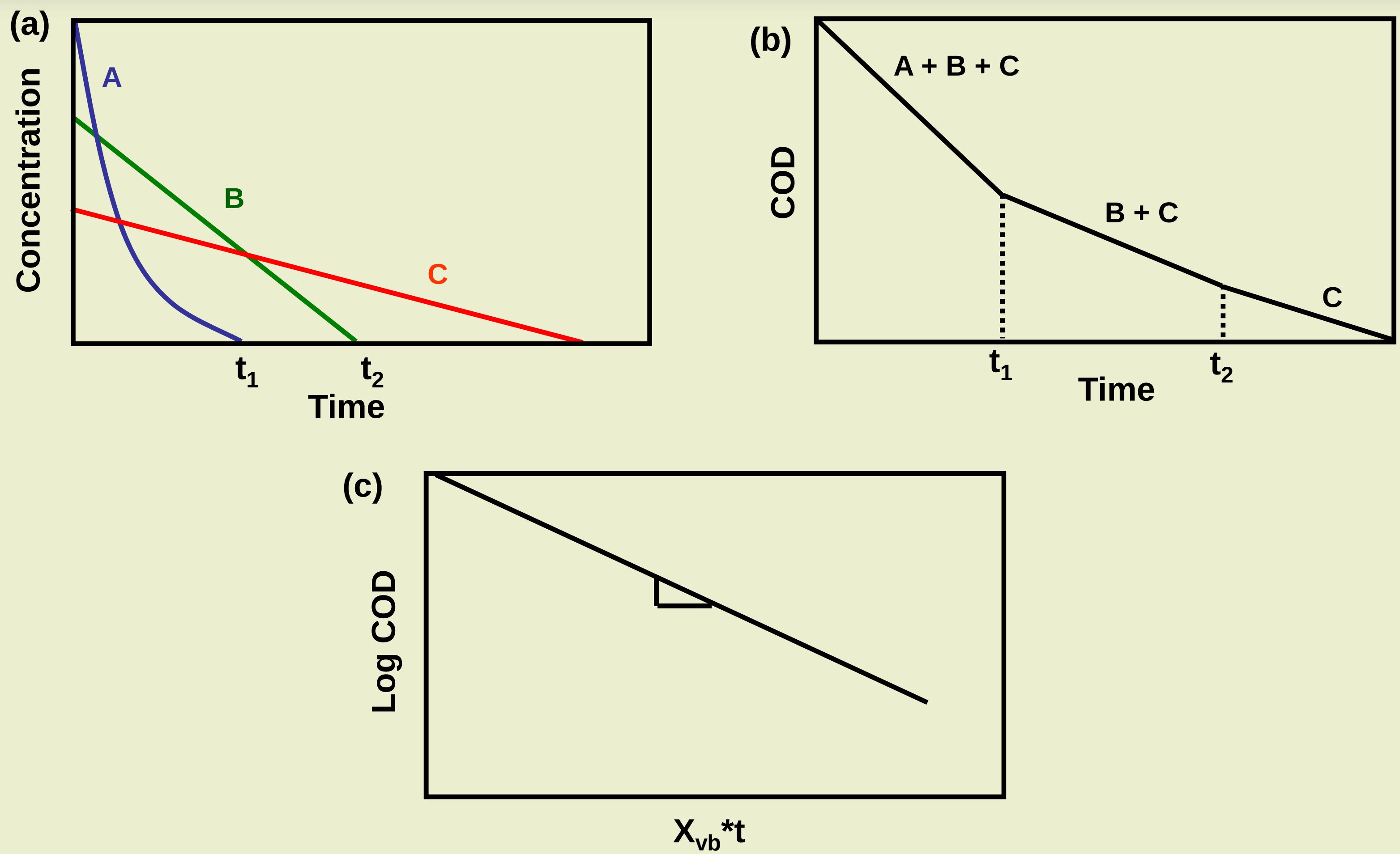
Active Biomass= $2500 \cdot 0.84 \cdot 0.71 = 1{,}526 m / l$

- Most wastewaters consist of multiple organics of variable degradation rates.
- In an acclimated system most of these organics are degraded simultaneously, but at different rates.

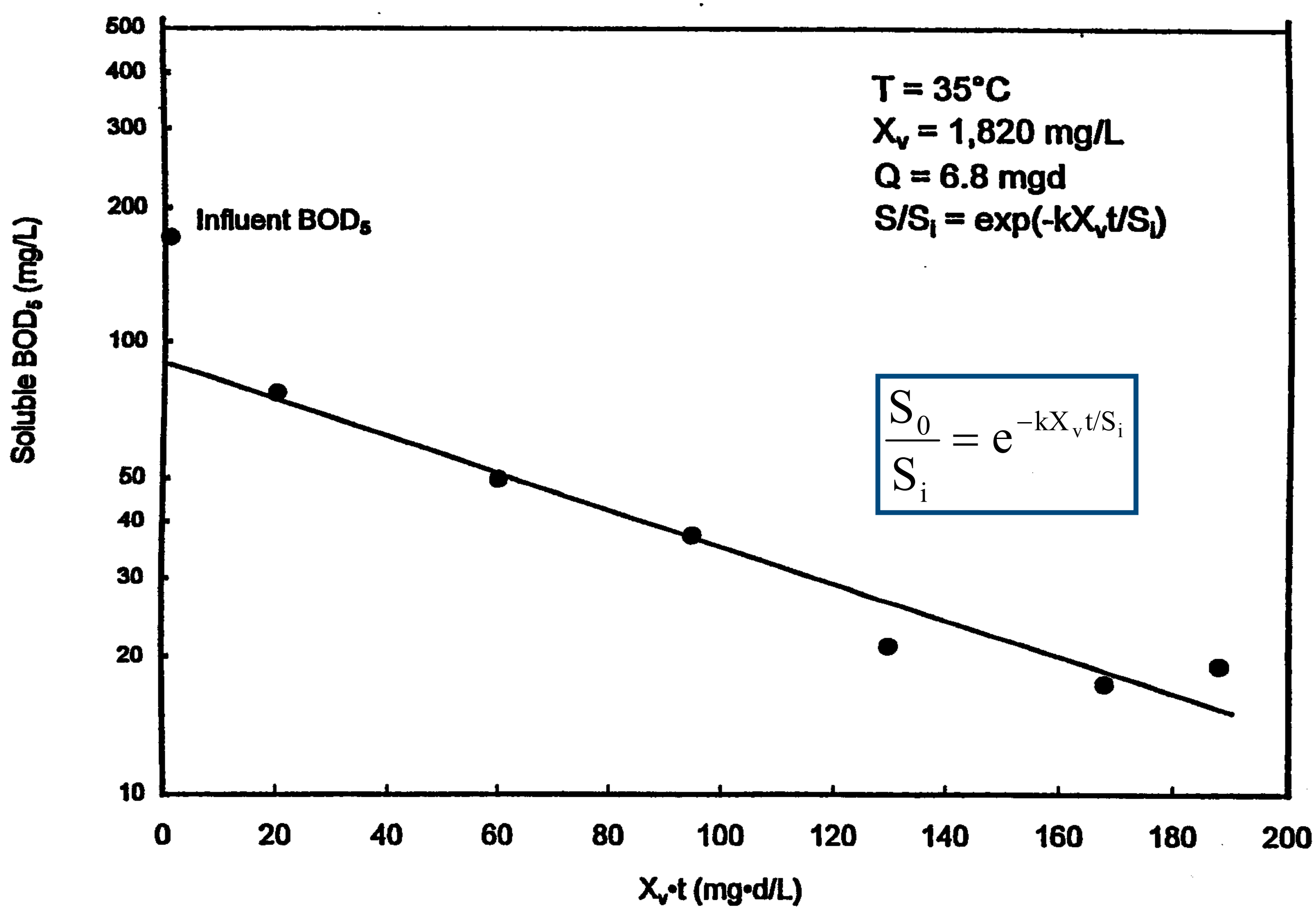
Zero-order Removal Rates for Specific Substrates



Schematic Representation of Multi-component Substrate Removal

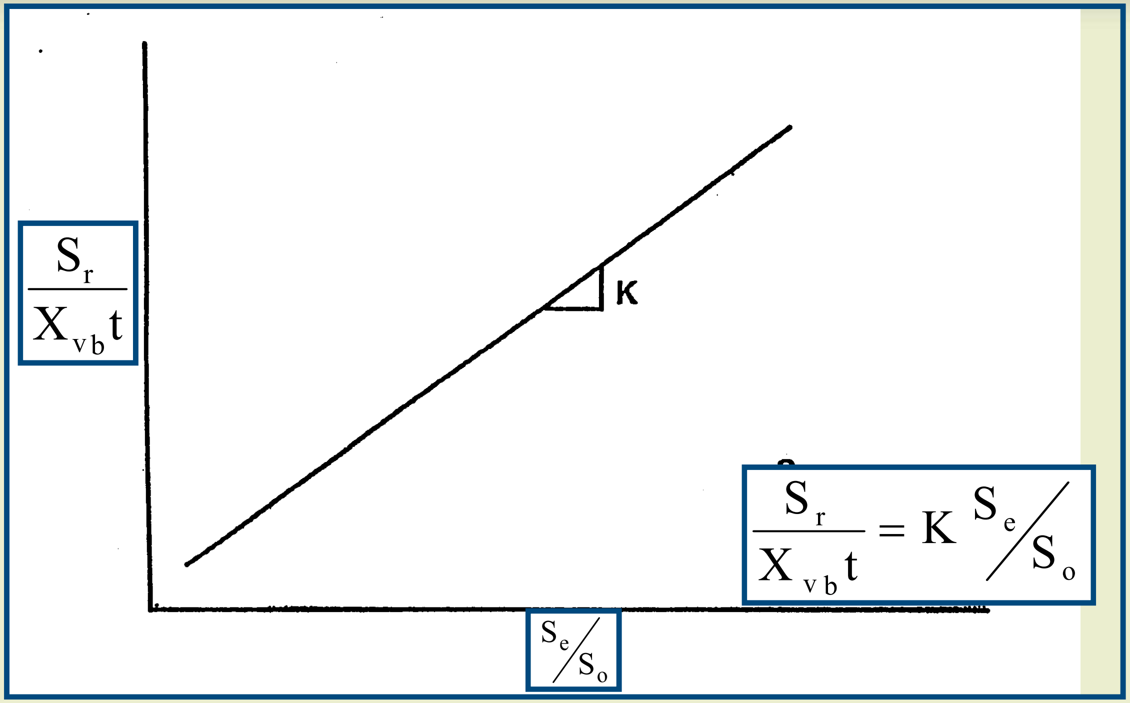


Plug Flow Removal Kinetics



$$\frac{S_0}{S_i} = e^{-kX_v t/S_i}$$

Biodegradation Coefficient (K) (Complete Mix System)

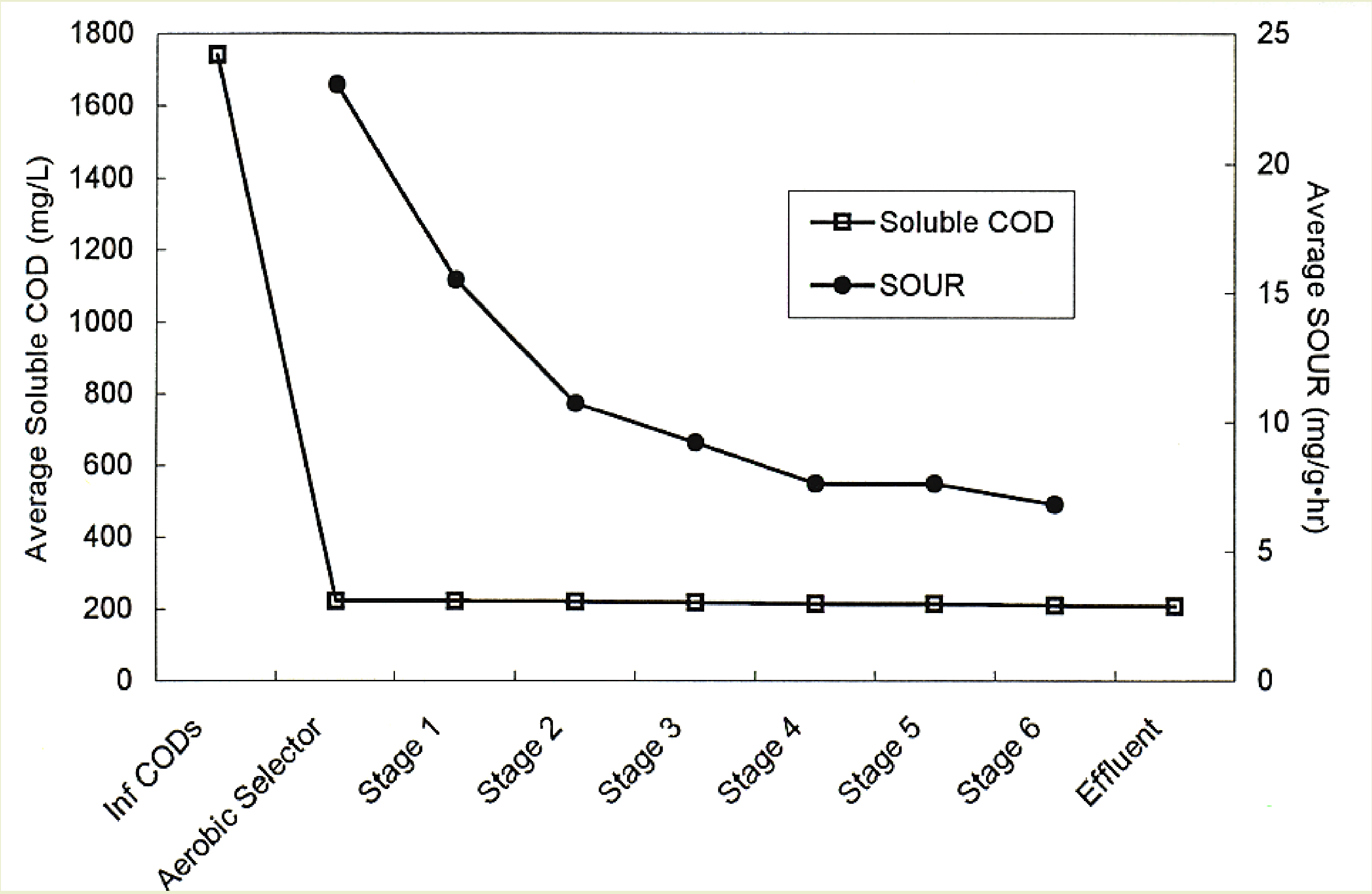


$$\frac{1}{\theta_c} = a\,K\,S_e/S_o - bX_d$$

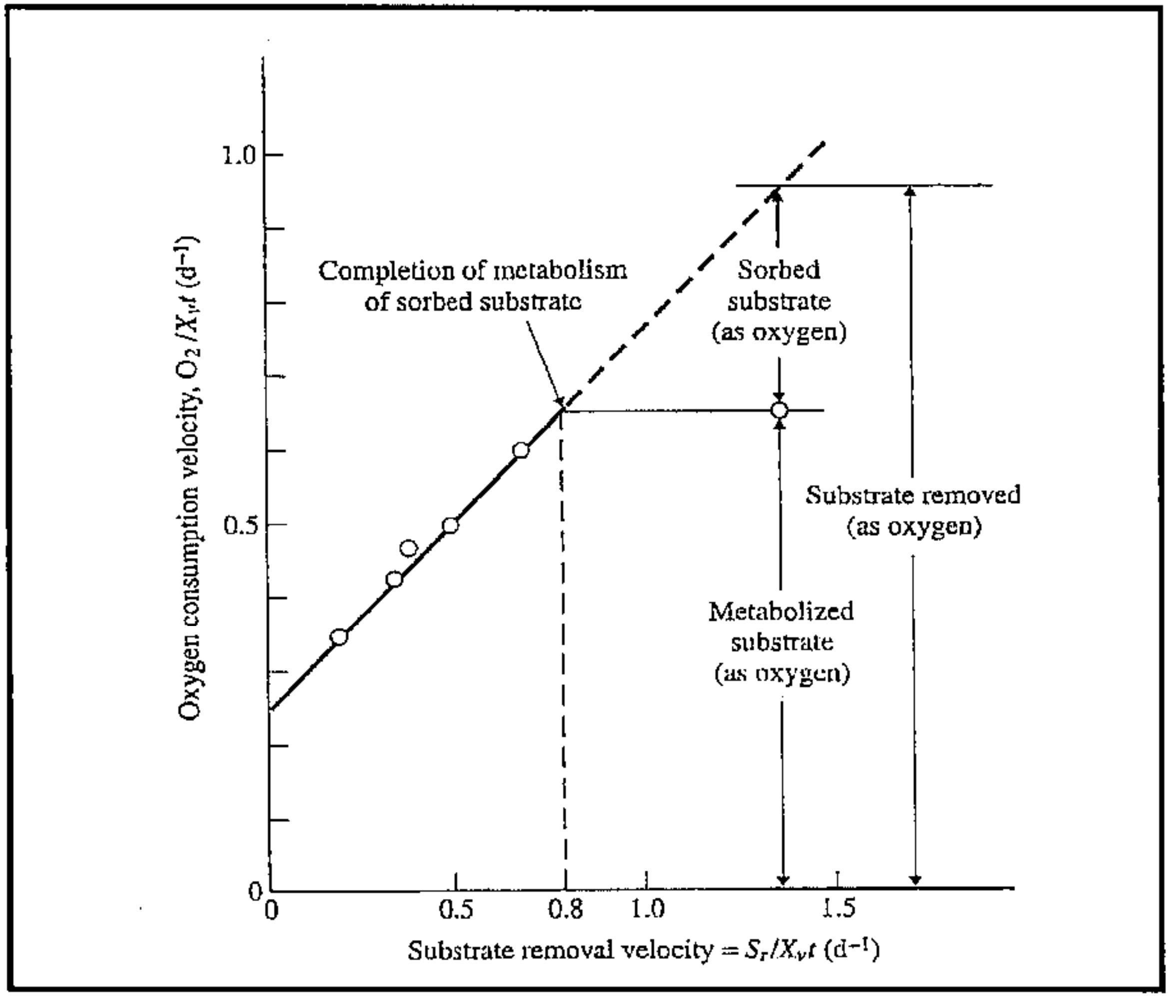
- In a batch or plug flow system the degradation follows a pseudo first order reaction.

- In a complete mix process the organic removal rate is a function of the fraction or organic remaining, since the biomass removes the more readily degradable first.

Plug Flow Simulation Preceded by Aerobic Selector



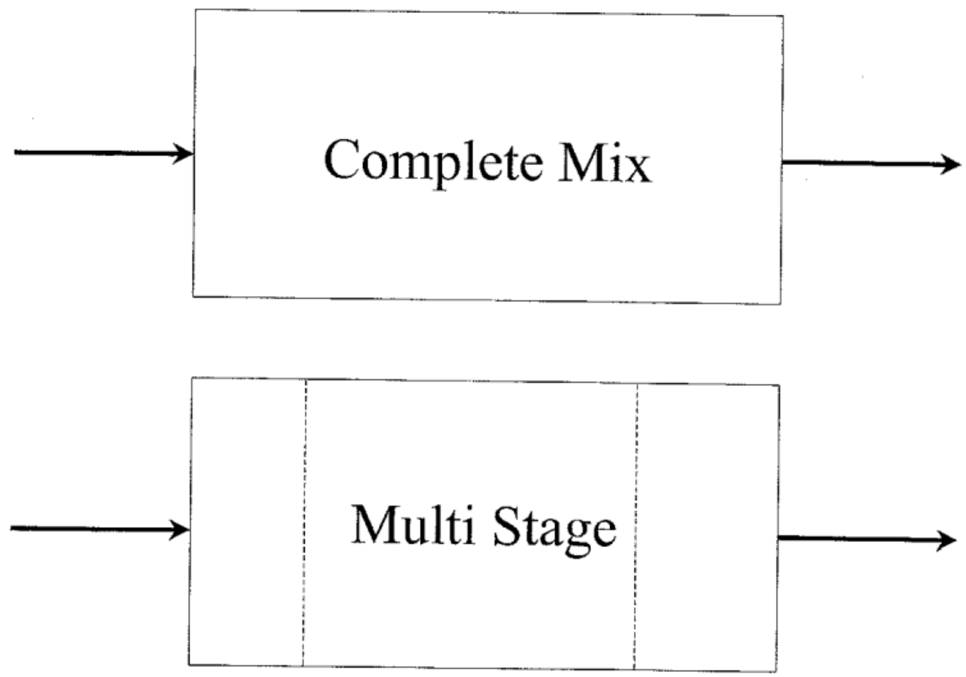
Stabilization time required for sorbed substrate



- This relationship is :

$$\frac{sr}{x_{va}\, t} = k_a \frac{se}{so}$$

- Optimal design of activated sludge for industrial wastewater is a multistage system. A maximum removal rate is achieved in the first stage at high organic concentration. The limitation is a maximum power density of 750 HP/mg of aeration volume.



Complete Mix
Multi Stage

Activated Sludge Process Design

$S_o = 500$ mg/L

$S_e = 20$ mg/L

$X_{V(active)} = 2000$ mg/L

$K_{d_{20}} = 5$ days^{-1}

$TKN = 75$ mg/L

Comparison of Plug Flow and Complete Mix

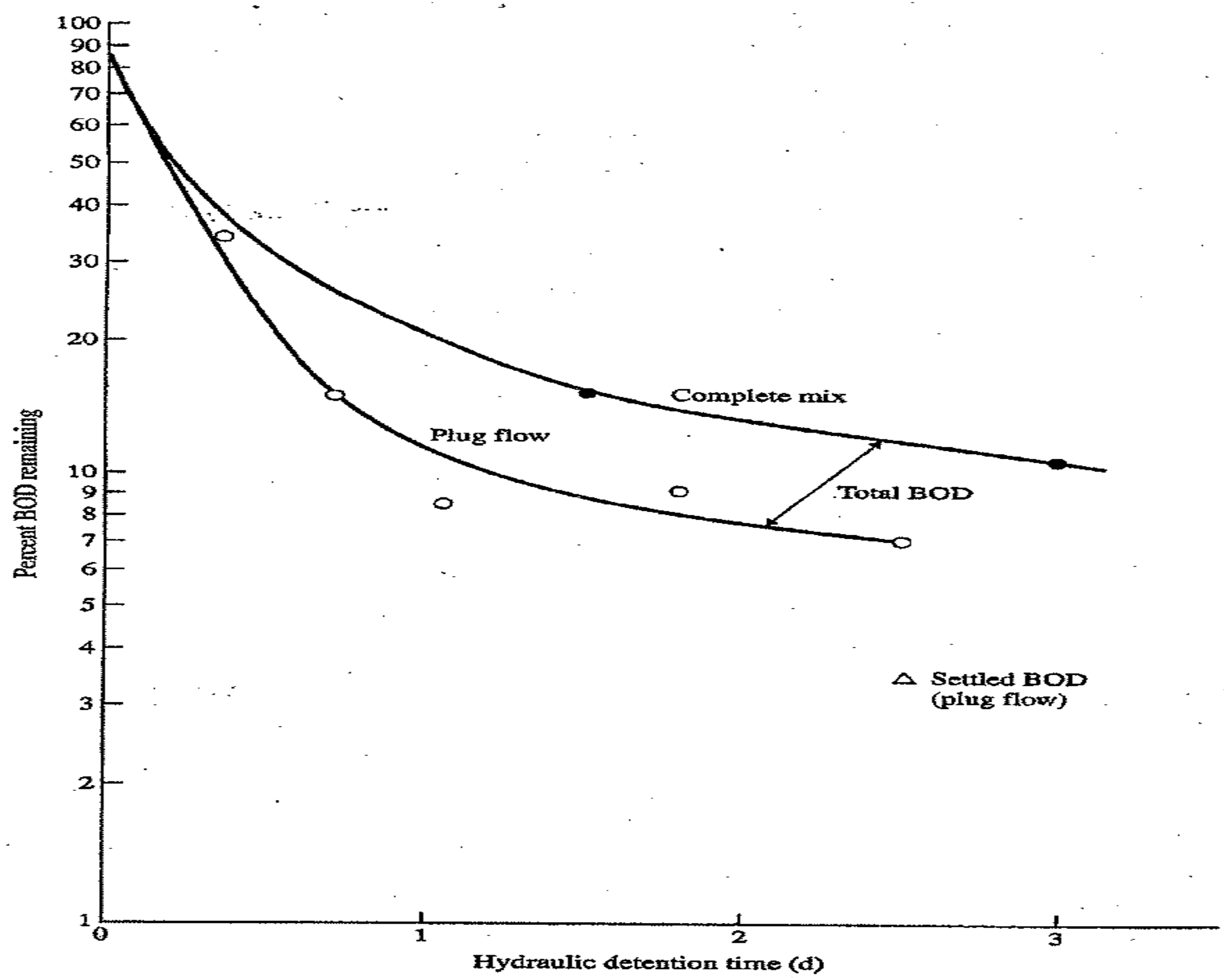
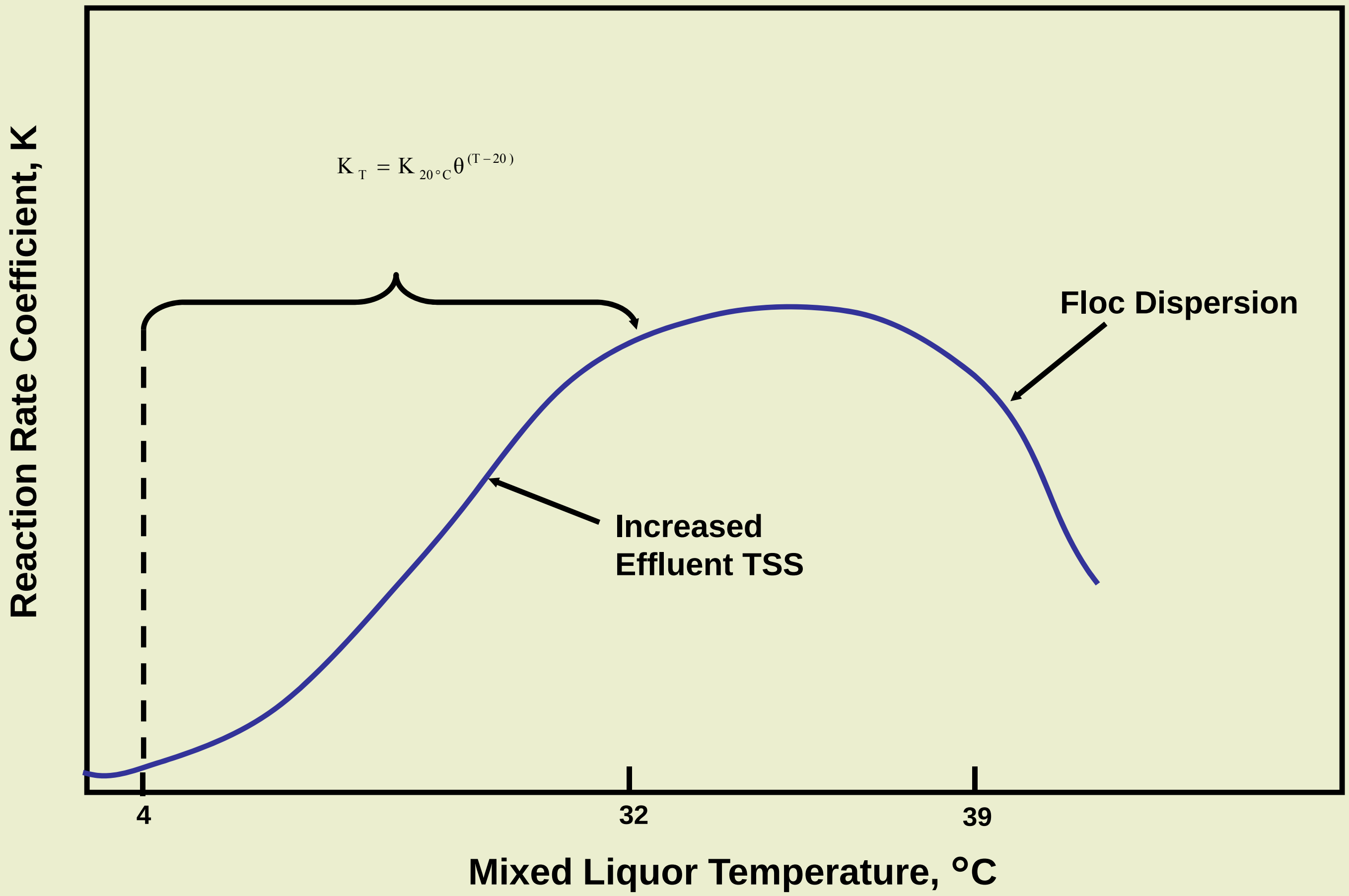


FIGURE 7.11
Pilot plant results for single- and multistage operation.

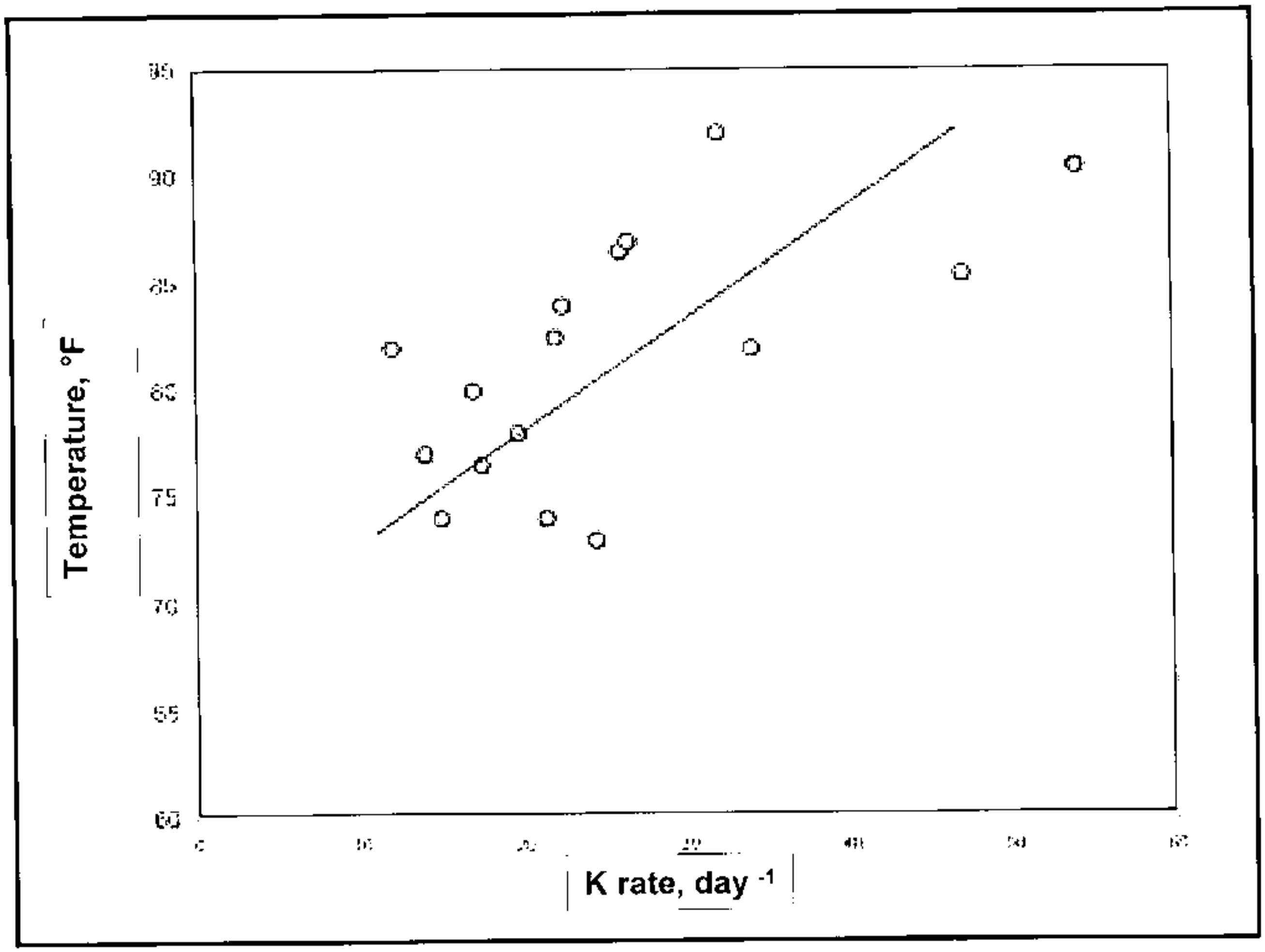
Effect of Temperature on Biological Oxidation Rate Constant, K



Temperature Coefficient

Industrial Wastewaters	1.065 – 1.10
Municipal Wastewaters	1.015
Endogenous	1.04

Effect of Temperature on the Reaction Rate for a Bleached Sulfite Mill Wastewater



Denitrification

$$\mathbf{NO_3^- + BOD \rightarrow N_2 + CO_2 + H_2O + OH^- + CELLS}$$

~3.0 g BOD are consumed/g NO_3-N reduced

~0.45 g New Cells are produced/g BOD removed

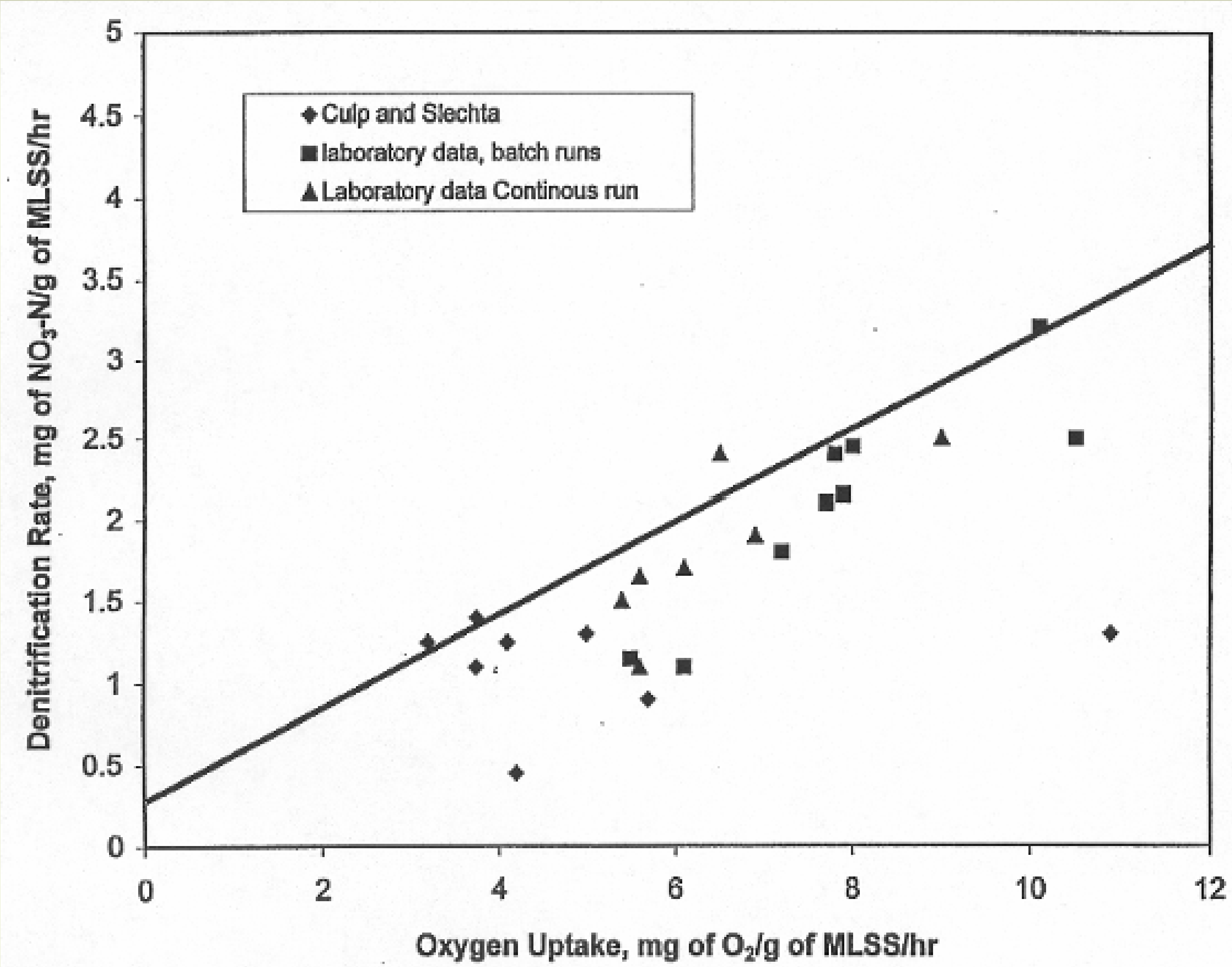
~3.57 g of alkalinity are formed/g NO_3-N reduced

R_{DN} = Denitrification rate, g NO_3-N/g VSS-day

and

$$R_{DN\ T} = R_{DN\ 20°} \bullet 1.09^{(T-20)} \bullet fa$$

Correlation Between Oxygen Uptake and Denitrification Rate



$$\frac{S_R}{X_V \bullet t} = K_{DN} \bullet \frac{S_e}{S_o}$$

S_R = BOD removed

X_V = MLVSS

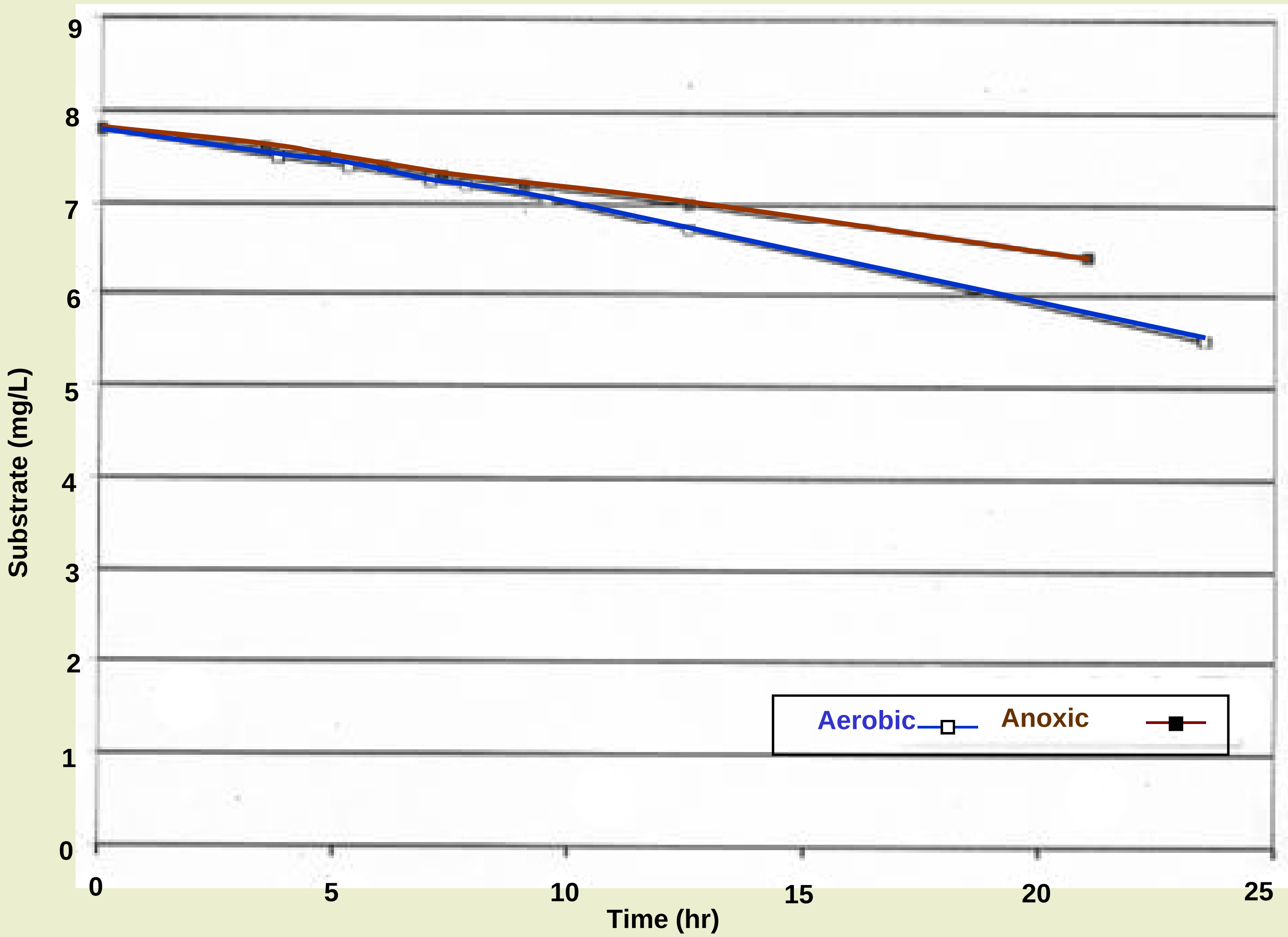
t = detention time

Se = effluent BOD

So = influent BOD

K_{DN} = anoxic reaction rate coefficient

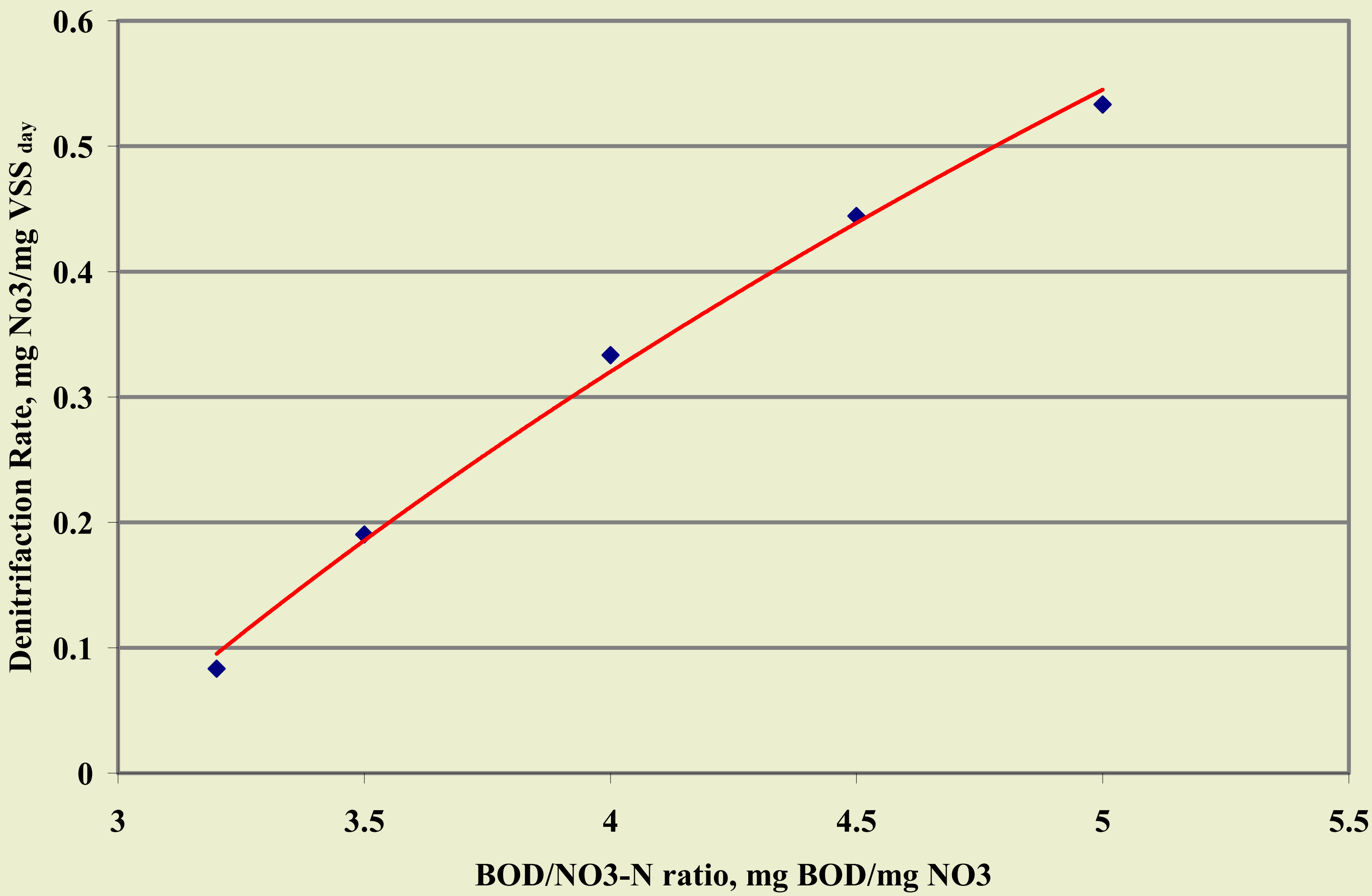
Comparison Between Aerobic and Anoxic Degradable Substrate Removal



Comparison of Aerobic and Anoxic Kinetic Coefficients (d-1)

	Anoxic	Aerobic
Pharmaceutical	9.2	21.0
Endogenous	4.4	6.3
Pulp and Paper	6.0	--

Denitrification Rate vs. BOD/Ammonia Ratio for a given K



AquAeTer, Inc.
215 Jamestown Park, Suite 100
Brentwood, TN 37027
(615) 373-8532
weckenfelder@aquaeter.com

AquAeTer, Inc.

optimizing resources – water, air, earth

For a copy of today’s presentation please visit our website at www.aquaeter.com/downloads.htm

**For More Information Contact Wes at:
weckenfelder@aquaeter.com
or call (615) 373-8532**