Better Plants
U.S. DEPARTMENT OF ENERGY

#4: Introduction to Activated Sludge Biokinetics

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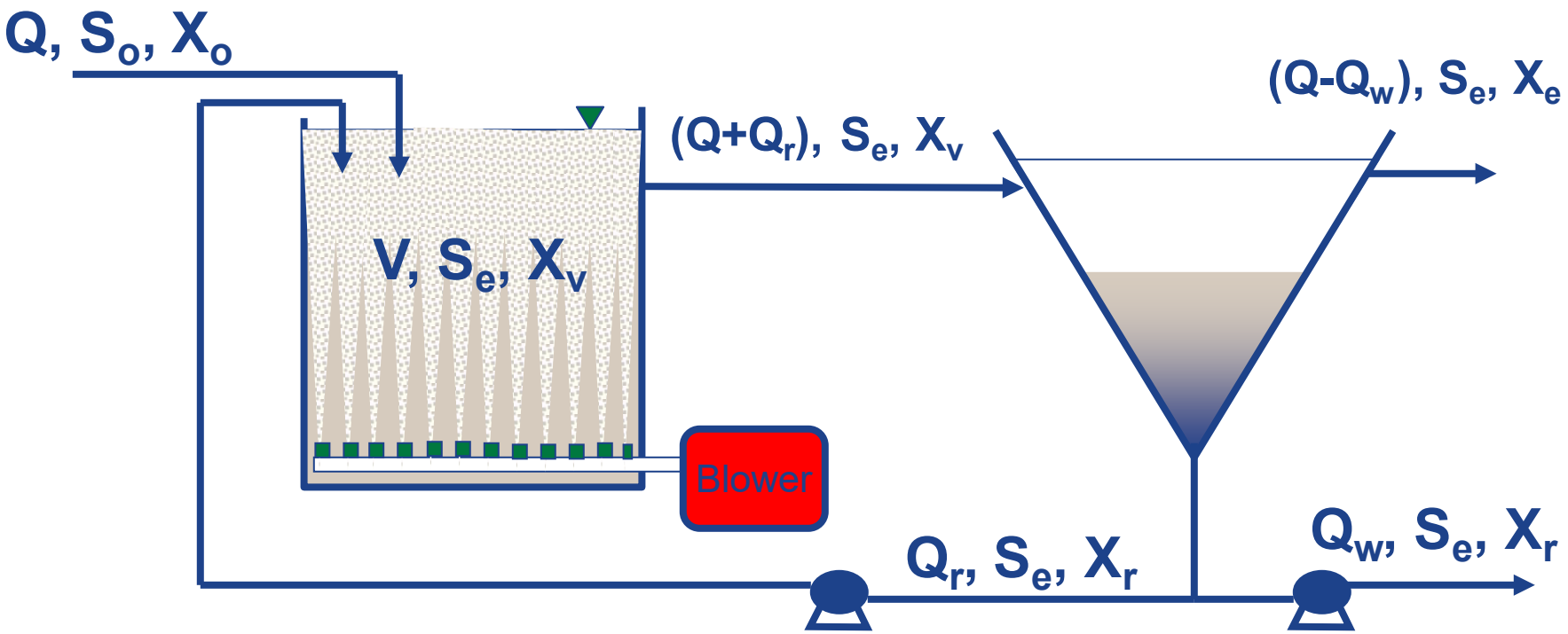
Predicting Performance of the Activated Sludge Process Using Biokinetic Relationships

Activated Sludge: Basics of Design



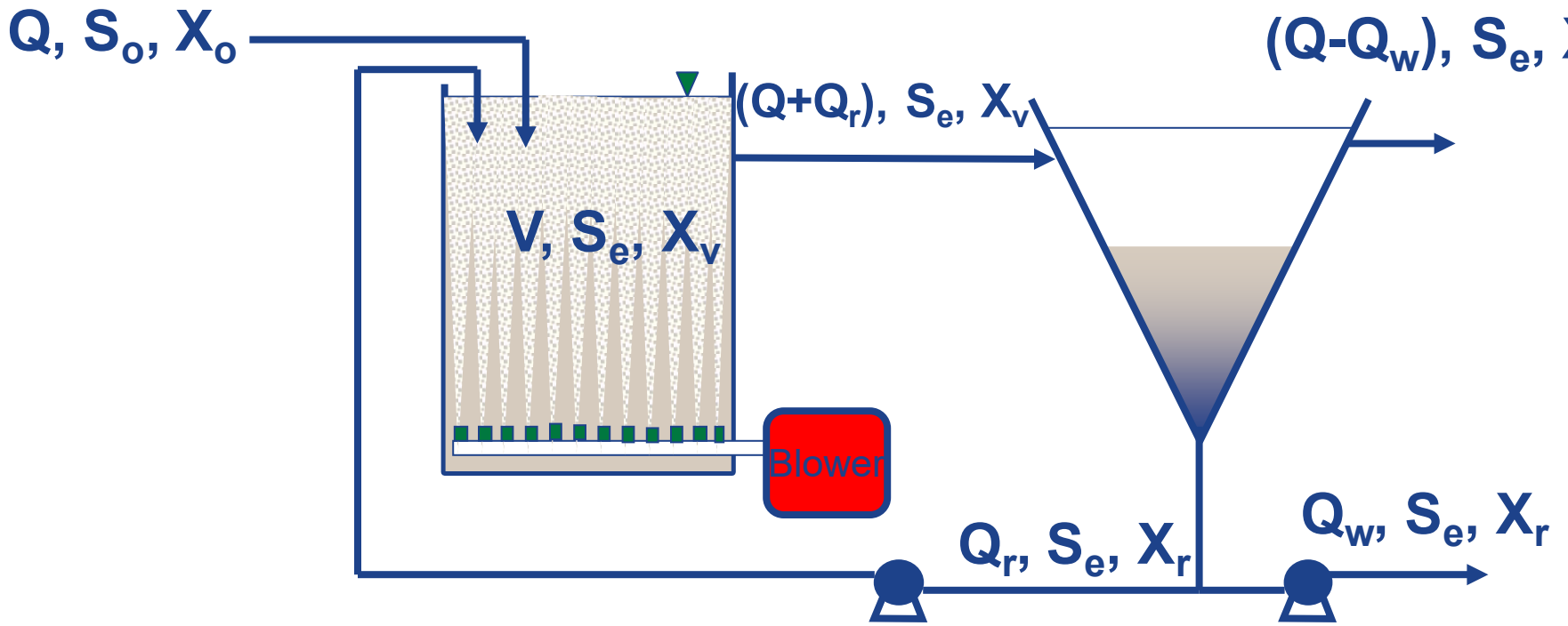
Biological Reactor with Aerated Mixed Liquor (diffused aeration)

Remember:

θ_c = MCRT = SRT = sludge age

It is how long in days (on average) the biomass stays in the activated sludge system until the biomass exits the system as waste activated sludge solids or as TSS in the effluent.

Determining θ_c Using Plant Data



$$\theta_c = \frac{XV^*}{Q_w X_r + (Q - Q_w)X_e} \approx \frac{XV}{Q_w X_r}$$

*Solids Inventory also may include clarifier sludge solids

The Activated Sludge Process: Biomass Growth

$$\mu = \frac{1}{\theta_c} + k_e$$

θ_c = mean cell residence time or sludge age

μ = specific growth rate of biomass

Activated Sludge Design: Biokinetic Constants

μ_{max} = maximum specific growth rate

K_s = saturation constant

k_e = microbial decay coefficient ($k_e = k_d$)

Y = biomass yield constant

k = maximum specific substrate utilization rate

$\mu_{max} = Yk$

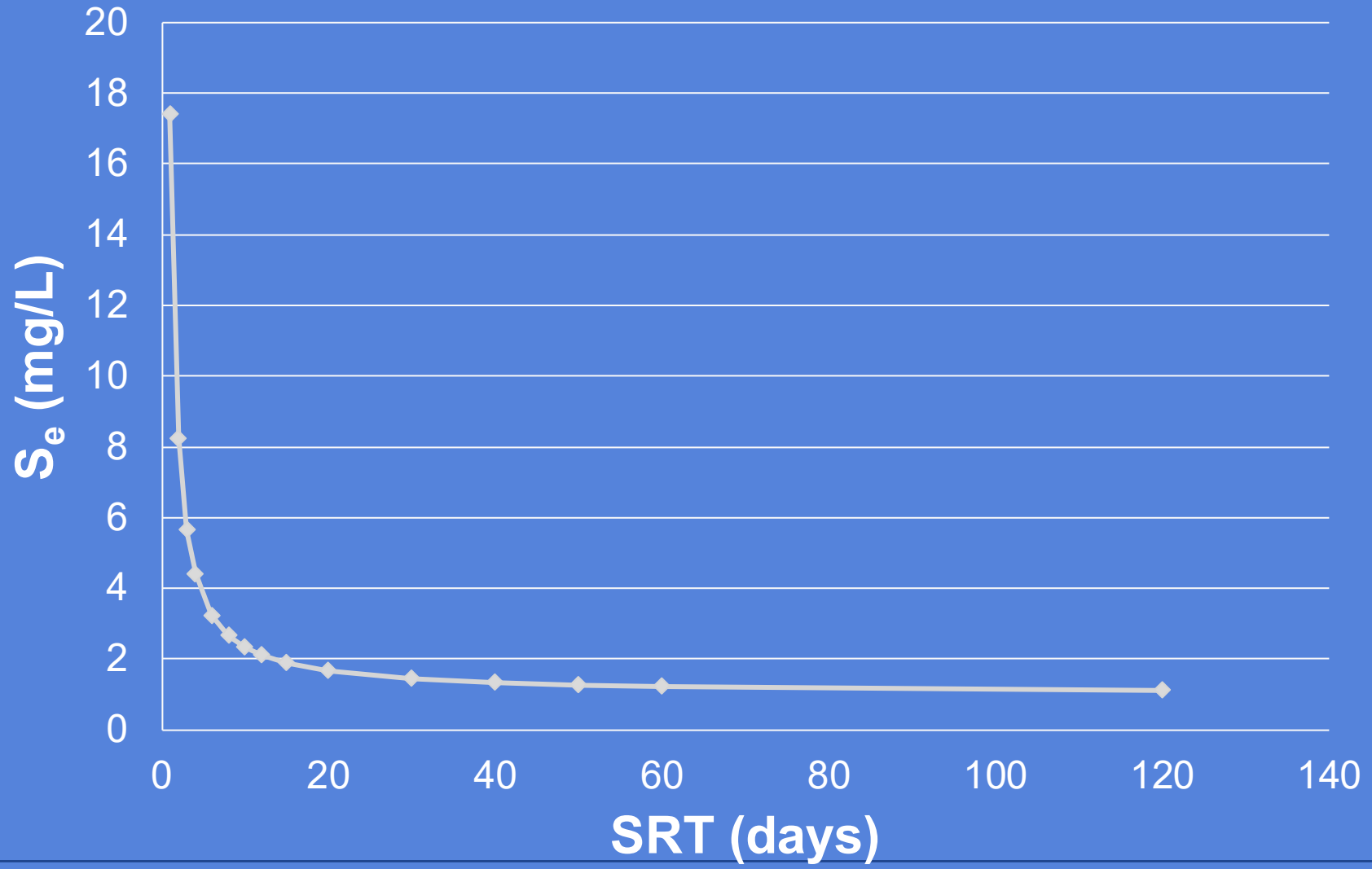
Determining S_e Using Biokinetic Approach

$$S_e = \frac{K_s(1+k_e\theta_c)}{\theta_c(\mu_{max}-k_e)-1}$$

S_e does not include $CBOD_5$ contributed by solids.

This equation is only valid for *Monod kinetics.*

S_e versus SRT

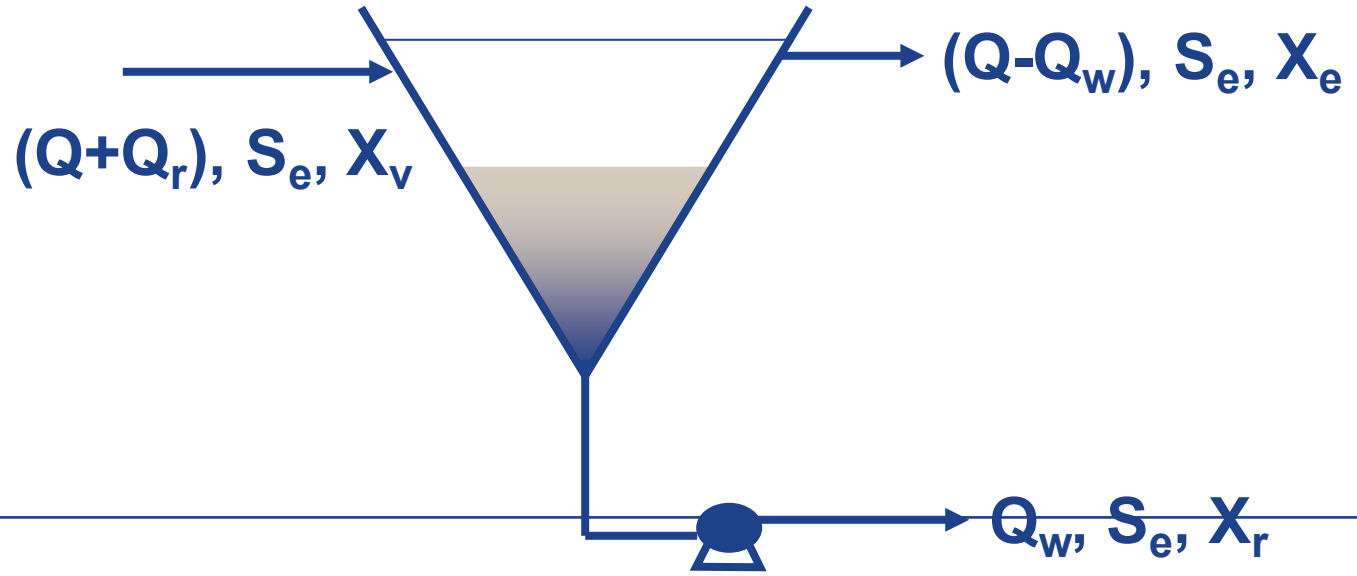


Activated Sludge Design: Determining $CBOD_{5eff}$

Step 1: Determine effluent requirement

$$CBOD_{5eff} = S_e + f\,X_e$$

where X_e = TSS in final effluent
S_e = soluble $CBOD_5$
f = g $CBOD_5$/g TSS = 0.3 to 0.6



Activated Sludge Design: Kinetic Coefficients

Step 2: Determine kinetic coefficients

Coef.	Range and units	Typical Value
$\mu_{m/20}$	2 to 10 day^{-1}	5.0 day^{-1}
K_s	25 to 100 mg/L BOD_5	60 mg/L
$k_{e/20}$	0.05 to 0.15 day^{-1}	0.08 day^{-1}
$Y_{x/s}$	0.4 to 0.8 VSS/BOD_5	0.6 VSS/BOD_5
k_{20}	5 to 12 g BOD_5/(g VSS-day)	8 day^{-1}

Activated Sludge Design: Determining Aeration Tank Volume

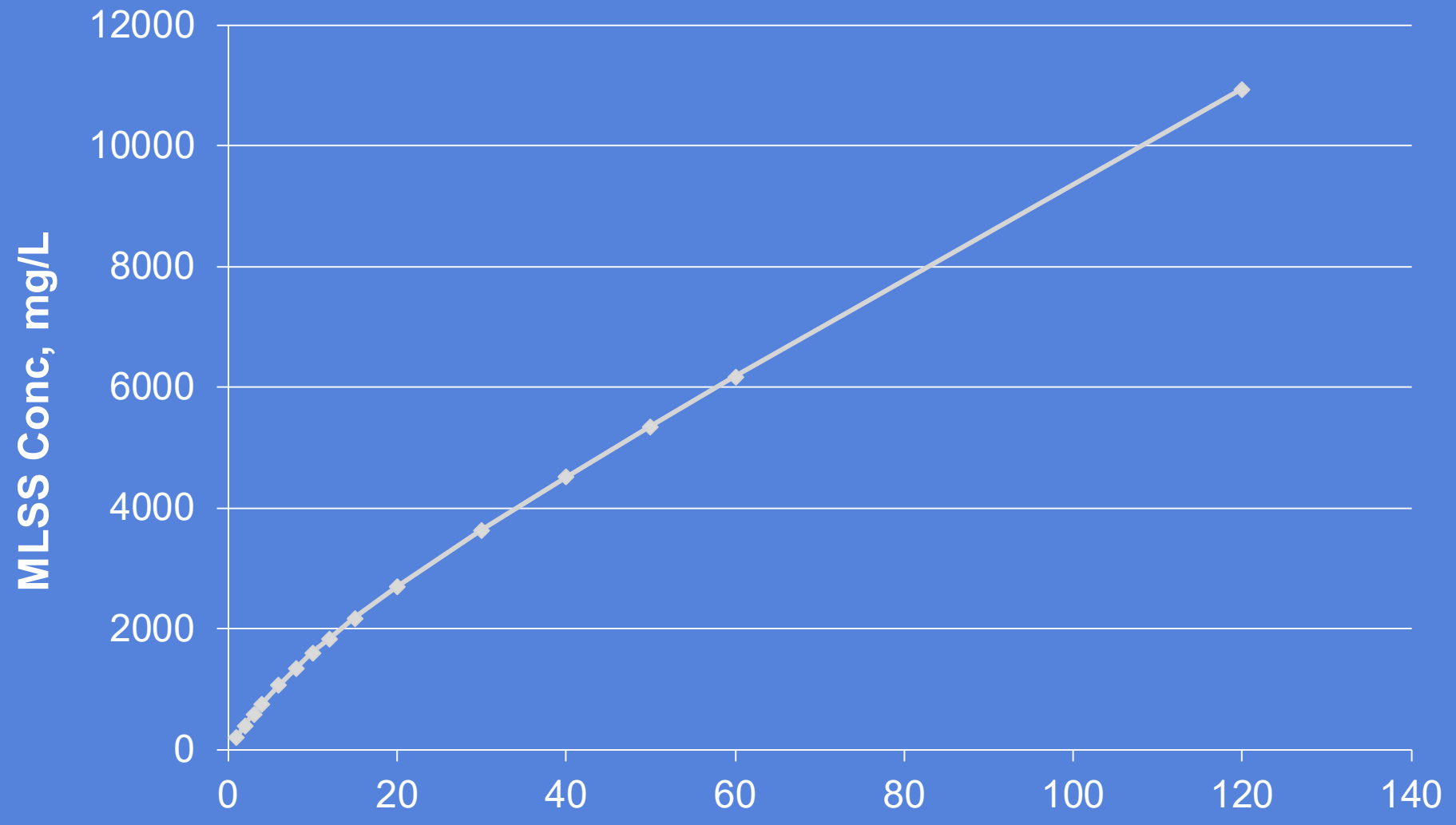
Step 3: Select MLVSS concentration in aeration basin.

Xv = 1500 to 3000 mg/L for complete mix
1500 to 4000 mg/L for extended air

Step 4: Determine aeration basin volume

$$V = \frac{QY_{x/s}\theta_c(S_o - S_e)}{X_v(1+k_e\theta_c)}$$

MLSS versus SRT – 1.0 mgd Extended Aeration Activated Sludge



Activated Sludge Design: Determining VSS Production

Step 5: Determine the mass of volatile solids to be wasted (Pxvss)

$$P_{XVSS} = A + B + C$$

A + B = biomass production = VSW

A = heterotrophic biomass
B = cell debris
C = nonbiodegradable VSS in influent

$$P_{XVSS} = \frac{QY(S_o - S_e)}{1 + k_d\theta_c} + \frac{f_d(k_d)YQ(S_o - S_e)\theta_c}{1 + k_d\theta_c} + QX_{oi}$$

Activated Sludge Design: Determining TSS Production

Step 6: Determine the mass of **total** solids to be wasted (P_{XTSS})

$$P_{XTSS} = A/0.85 + B/0.85 + C + Q(TSS_o - VSS_o)$$

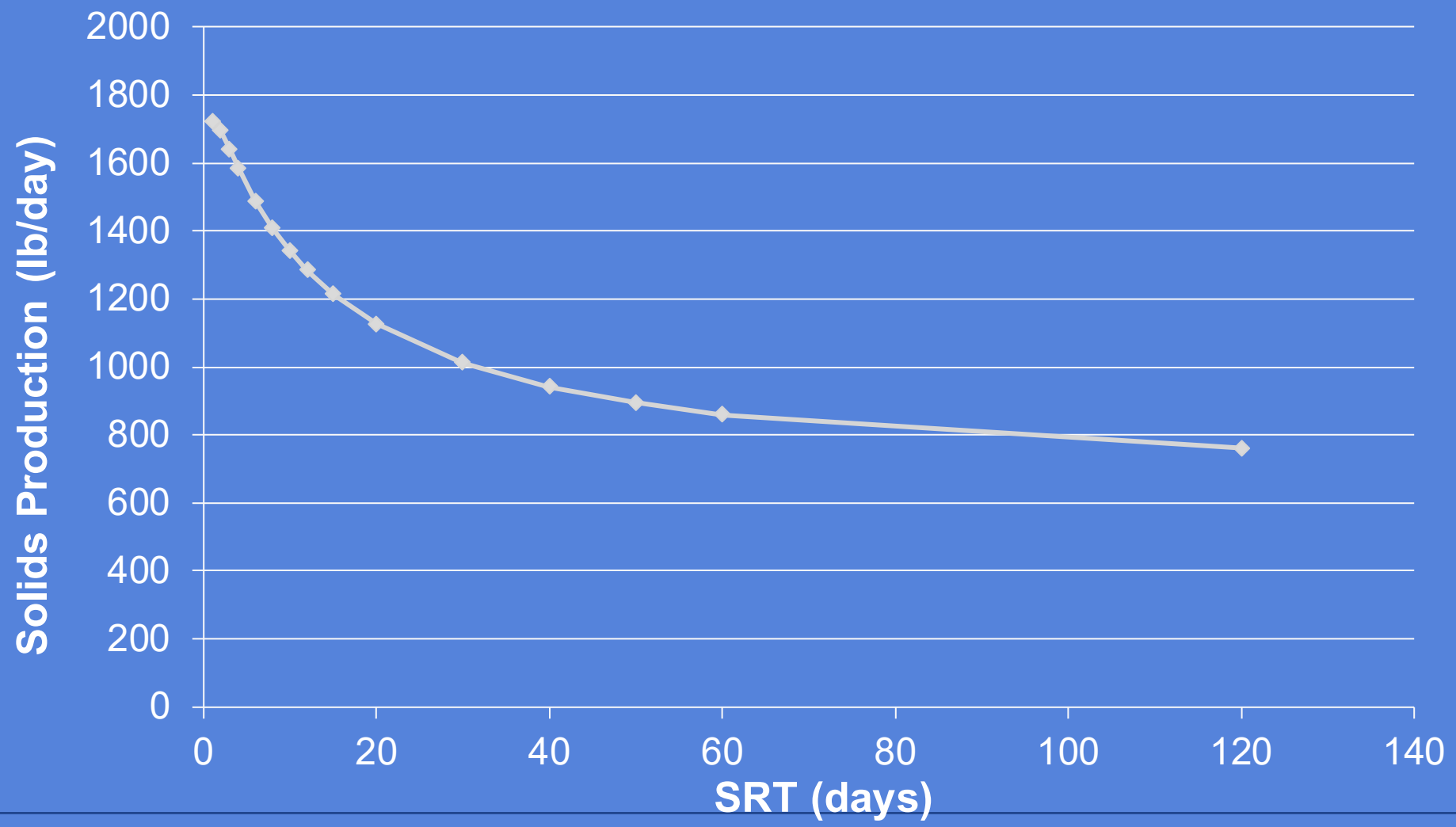
where P_{XTSS} = net waste activated sludge produced each day, mass/day

TSS_o = influent TSS concentration

VSS_o = influent VSS concentration

*The value of (TSS_o - VSS_o) is adjusted in the Bio-Tiger Model; it is called inert, inorganic TSS.

Sludge Production (TSS, lb/day) vs SRT - 1.0 mgd Extended Aeration Activated Sludge



Activated Sludge Design: Determining Oxygen Requirements

Step 7: Determine the oxygen requirements (CBOD and NBOD)

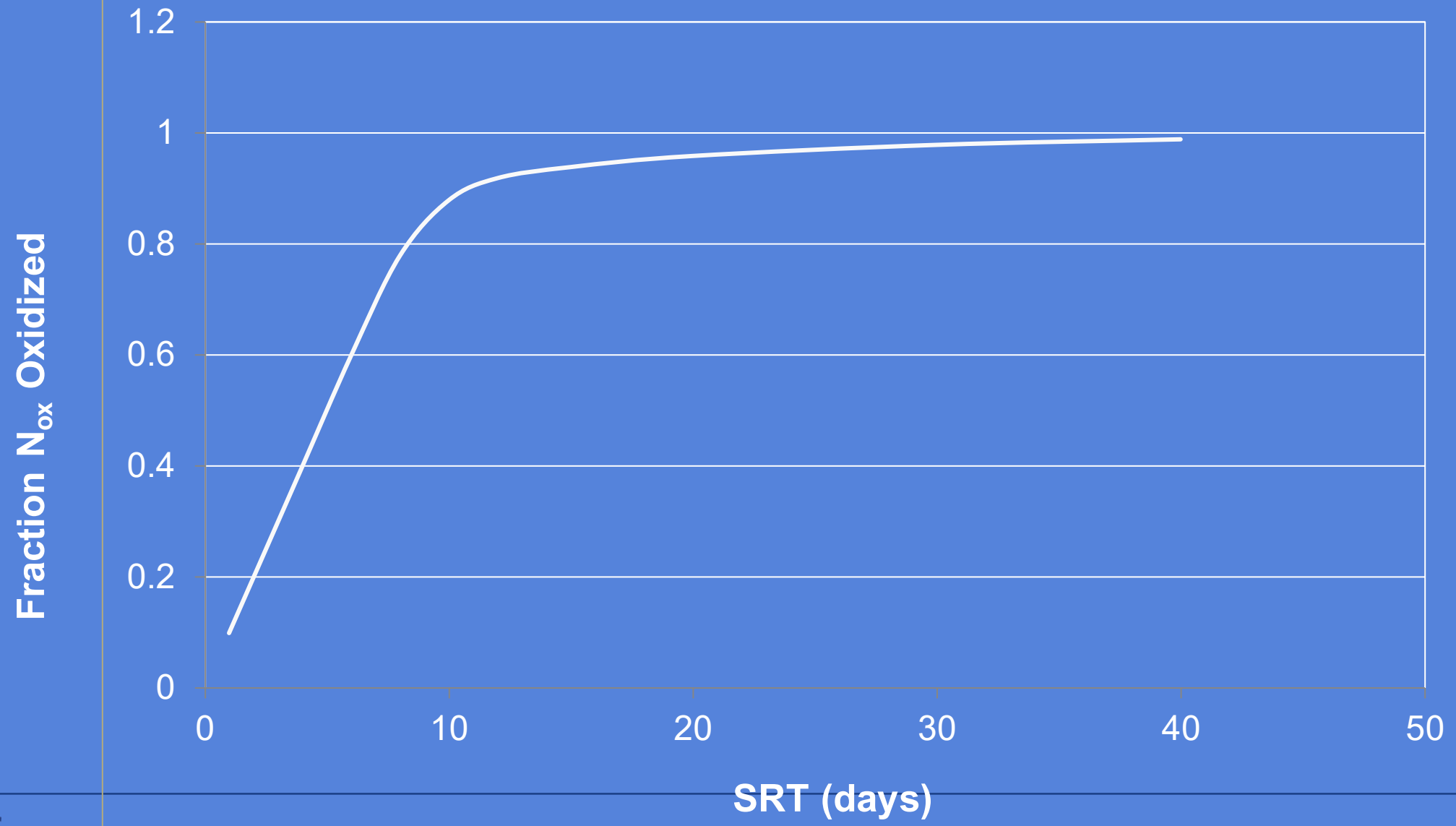
$$O_2(\text{lb/day}) = 8.34Q\left[\frac{S_o - S_e}{0.67}\right] - 1.42(\text{VSW}) + 4.33(N_{ox})(Q)(8.34)$$

*Note: VSW = biomass production = A + B in previous equations

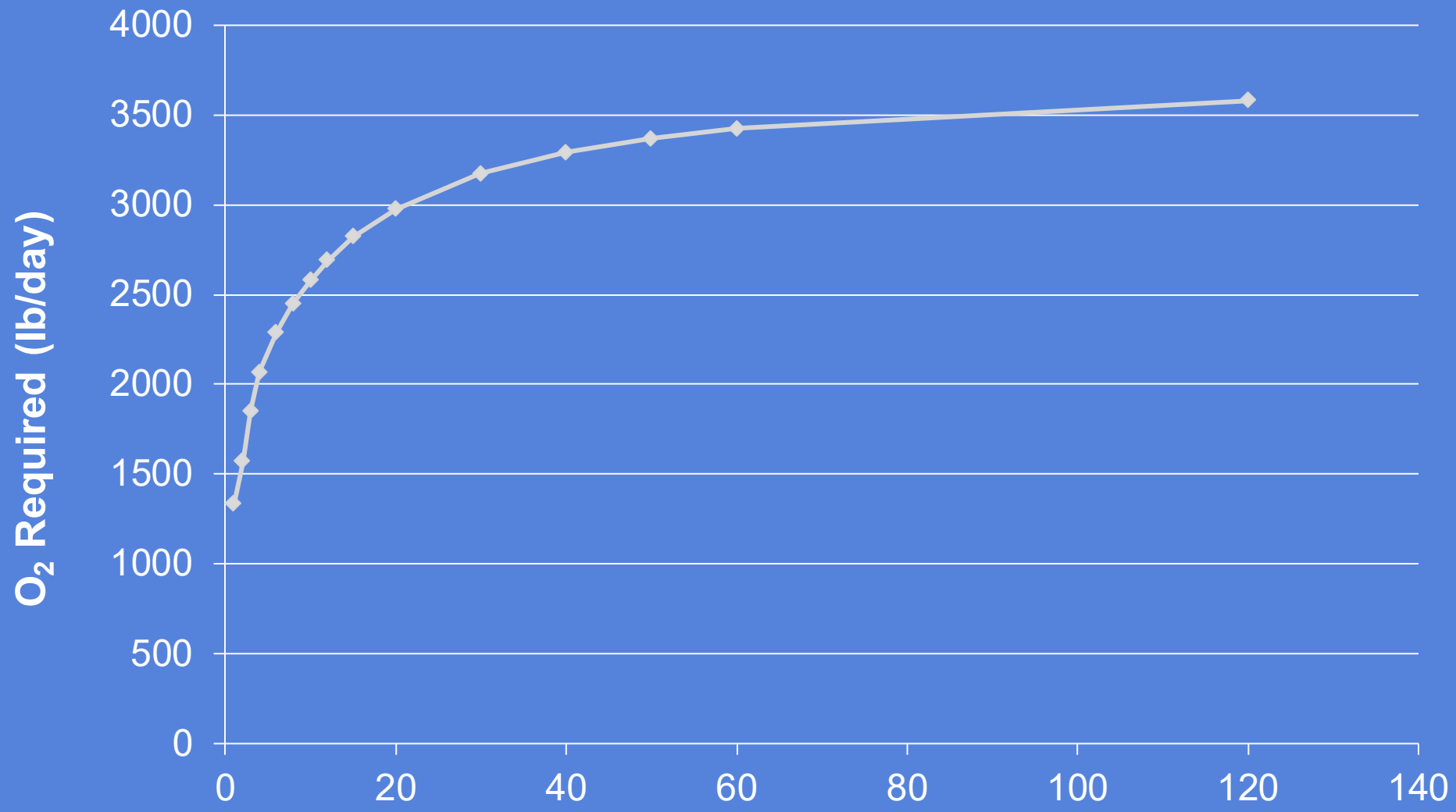
1.42(VSW) = ultimate CBOD that goes to cell growth

$4.33(N_{ox})(8.34)$ = oxygen required for nitrification

Fraction N_{ox} Oxidized at 20˚C



Oxygen Required (Carbonaceous + Nitrogenous) vs SRT – 1.0 mgd Extended Aeration Activated Sludge



Thank you!

For Questions or Comments please reach out to the following:

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