ONLINE COURSE FAECAL SLUDGE MANAGEMENT
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Key note 4.4: Co-treatment of Faecal Sludge in Municipal Wastewater Treatment Plants

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Related course material | Chapter 9 in the FSM book
Presentation of Unit 4.4
Assigned reading under Unit 4.4

Faecal Sludge Management: Practices and Problems

- Proper planning of FSM is often lacking;
- Hundred thousand tons of FS are disposed of mostly untreated and uncontrolled (Strauss and Montangero, 2002)
- The major challenges on FSM are:
  - Pit/Vault emptying;
  - Haulage;
  - **Storage or treatment;**
  - **Safe disposal or re-use**

Learning objectives

After the completion of this lecture, the student will be able to:

- To evaluate and propose key considerations to co-treat faecal sludge in municipal wastewater treatment systems.

Faecal sludge characteristics

Parameter	Public Toilet	Septic Tank
Total solids (mg/L)	30,000-52,500	12,000-35,000
TVS (%TS)	65-68%	50-73%
COD (mg/L)	10,000-250,000	1,200-90,000
BOD_5 (mg/L)	7,600	840-30,000
TN (mg N/L)	-	190-1,500
TKN (mg/L)	3,400	1,000
NH_4-N (mg/L)	2,000-5,000	150-1,200
Total P (mg P/L)	450	40-300

Category	**High strength**		**Medium strength**		**Low strength**	
	Total COD (mg /L)	TN (mg /L)	Total COD (mg /L)	TN (mg /L)	Total COD (mg /L)	TN (mg /L)
Fresh faecal sludge	250,000	5,000	65,000	3,400	10,000	2,000
Digested faecal sludge	90,000	1,500	45,000	400	3,000	200

Faecal sludge fractionation

COD fractionation:

Type of FS	X_s (XC_b)	X_u	S_b	S_u	Biodegradable fraction	Unbiodegradable fraction
Fresh FS	0.31	0.47	0.15	0.09	0.43±0.10	0.57±0.10
Digested FS	0.15	0.69	0.04	0.12	0.19±0.01	0.81±0.01

N - fractionation:

Fraction	Notation	Value	
		Fresh faecal sludge	Digested faecal sludge
Free and saline ammonia	S_{NHx}	0.84	0.20
Organic unbiodegradable particulate nitrogen	$X_{U,N}$	0.01	0.05
Organic unbiodegradable soluble nitrogen	$S_{U,N}$	0.15	0.75

What are the implications of FS co-treatment?

1) Higher COD and TN loads to be treated

2) Higher TSS mass (MXt)

- Conventional aeration tanks work with ≤ 6,000 mg TSS/L

3) Aeration limitations

- Lower oxygen transfer efficiency
- Higher oxygen demand

4) pH issues

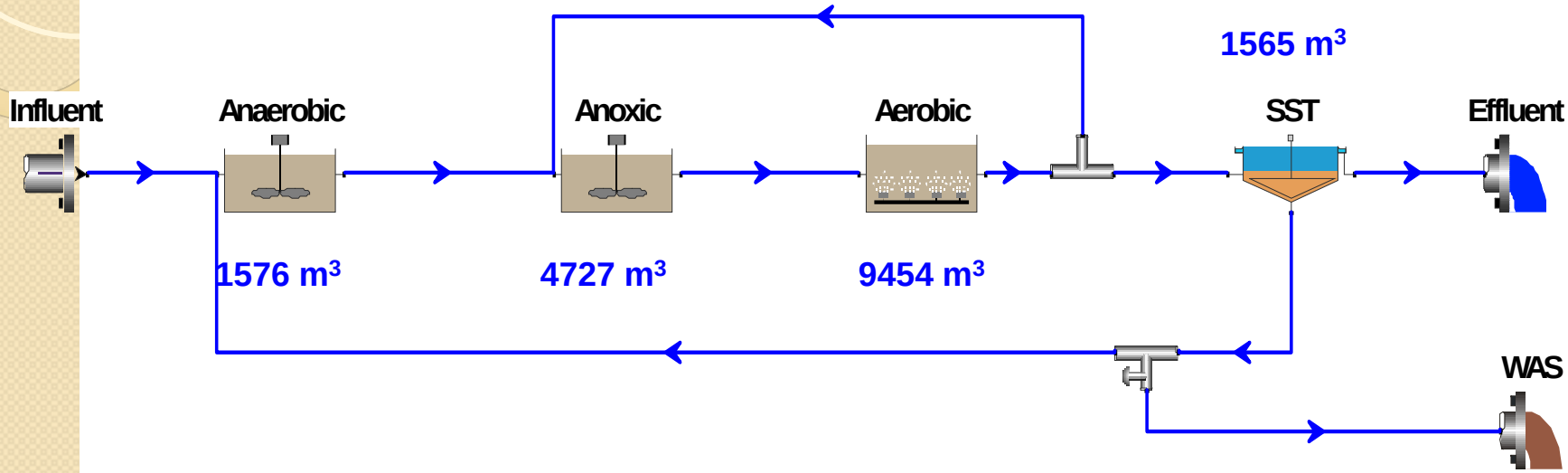
- 1mg FSA/L consumes 7.14 mg Alk/L (as $CaCO_3$)

5) Effluent quality to be met (EU water framework directive):

- TCOD = 125 mg/L
- TN = 10 mg/L; TP = 2mg/L
- TSS = 35 mg TSS/L

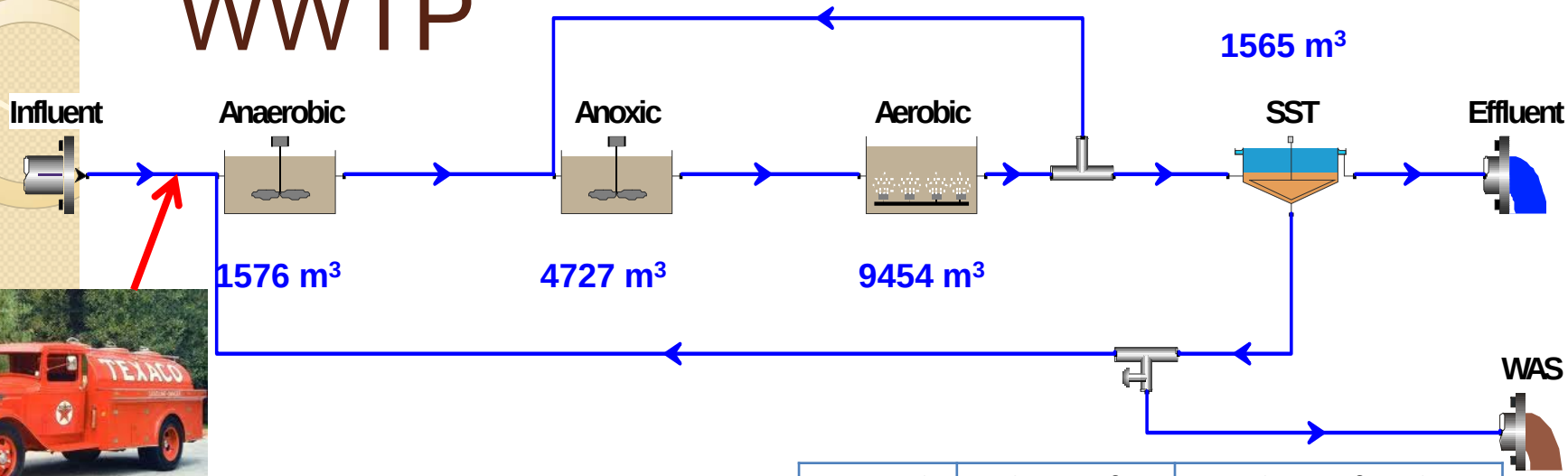
6) Overloading of Secondary Settling Tank (SST) and increase in SVI

Example: Existing conventional WWTP



Parameters	Value	Influent	Value
Flowrate (m^3/d)	20,000	Total COD (mg COD/L)	750
Temperature	20◦C	TN (mg N/L)	60
SRT (days)	10	TP (mg P/L)	15
TSS (g TSS/L)	4.5	TSS (mg TSS/L)	400

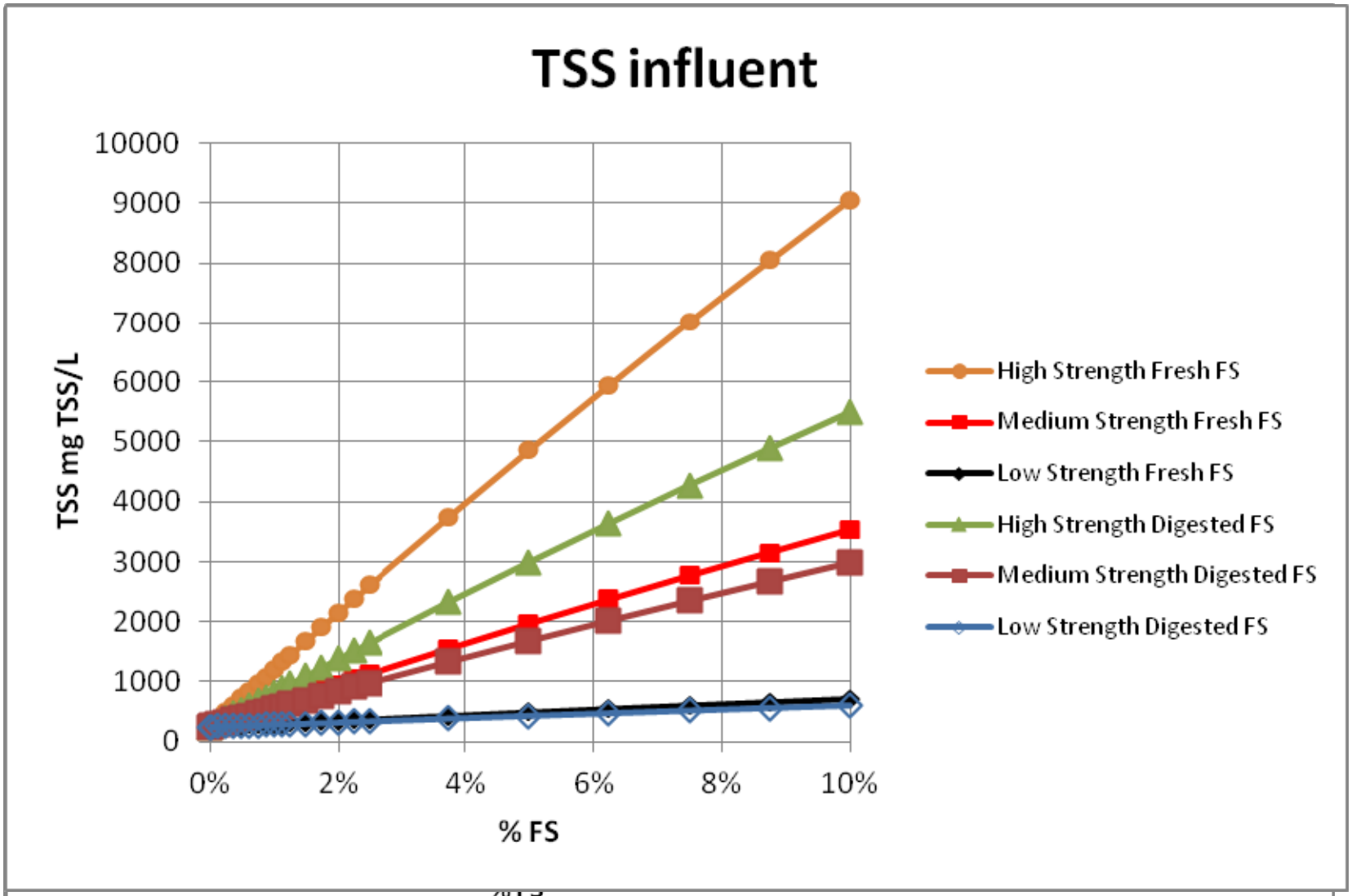
Example: Existing conventional WWTP



% Faecal sludge	Volume of FS (m^3)	Total No. of Tankers	
		5 m^3	8 m^3
0%	0	0	0
0.025%	5	1	1
0.125%	25	5	3
0.25%	50	10	6
0.375%	75	15	9
0.5%	100	20	13
0.625%	125	25	16
0.75%	150	30	19
0.875%	175	35	22
1%	200	40	25

% Faecal sludge	Volume of FS (m^3)	Total No. of Tankers	
		5 m^3	8 m^3
1.25%	250	50	31
1.5%	300	60	38
1.75%	350	70	44
2%	400	80	50
2.25%	450	90	56
2.5%	500	100	63
3.75%	750	150	94
5%	1000	200	125
7.5%	1500	300	188
8.75%	1750	350	219
10%	2000	400	250

1) Higher COD and TN loads to be treated



REACTOR SOLIDS CONCENTRATION

MX_{TSS}

- MX_V (ORGANICS)
  - MX_{BH}: OHO Biomass
  - MX_E: OHO's endogenous residue
  - MX_I: Unbiodegradable particulate COD
- MX_{IO} (INORGANICS)

Wastewater

Faecal sludge

$$MX_{BH} = \frac{Y_{Hv}\,(Q_i S_{bi,ww})\,SRT}{(1+b_H SRT)}$$

$$MX_{BH,fs} = \frac{Y_{Hv}\,(Q_{fs} S_{bi,fs})\,SRT}{(1+b_H SRT)}$$

$$MX_E = f\,b_H\,MX_{BH}\,SRT \quad + \quad MX_{E,fs} = f\,b_H\,MX_{BH}\,SRT$$

$$MX_I = Q\,X_{Ii,ww}\,SRT/f_{CV}$$

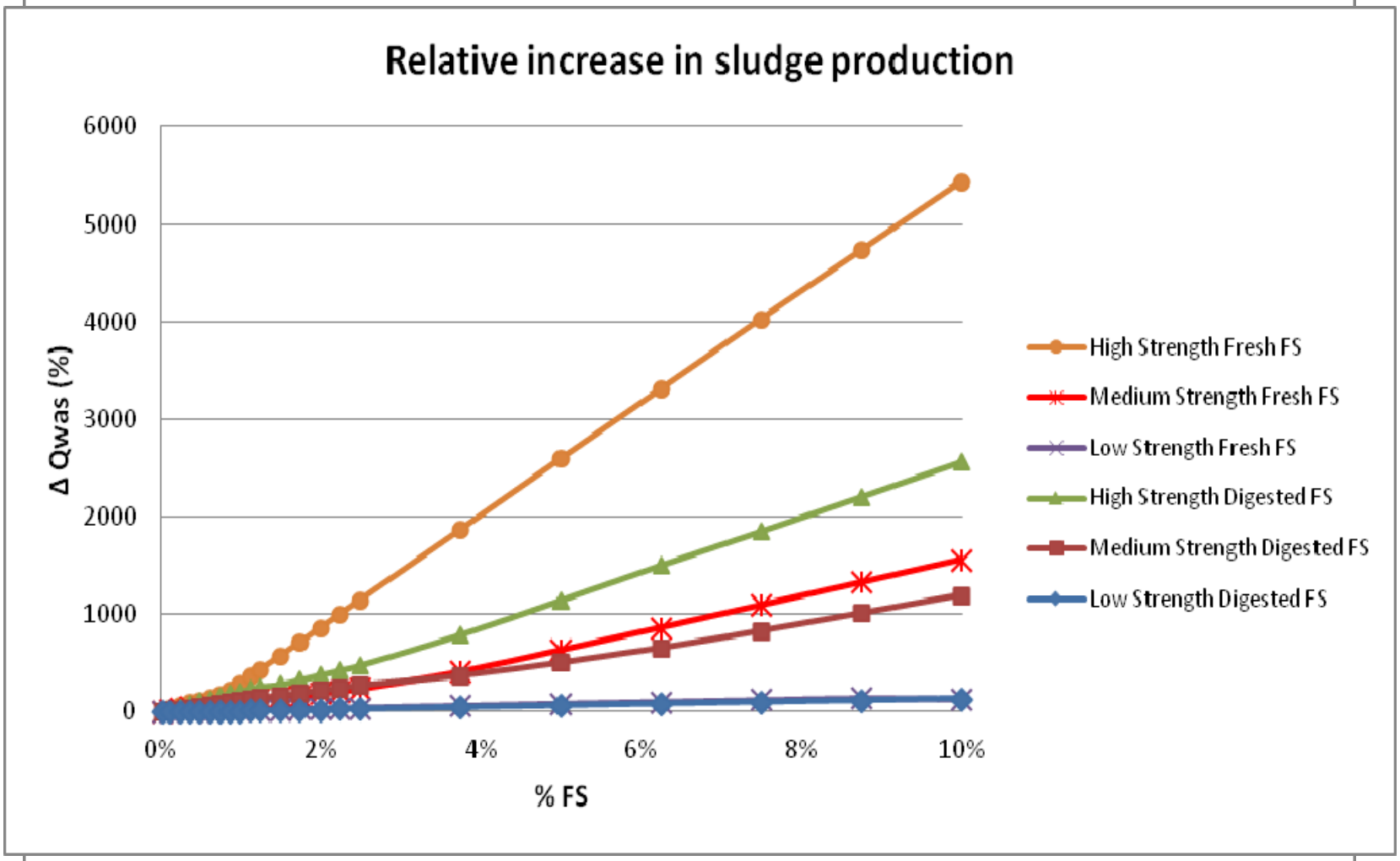
$$MX_{I,fs} = Q_{fs}\,X_{Ii,fs}\,SRT/f_{CV}$$

$$MX_{ISS} = Q\,X_{ISS,i,ww}\,SRT$$

$$MX_{ISS,fs} = Q_{fs}\,X_{ISS,i,fs}\,SRT$$

$$MX_{TSS(ww+fs)}$$

2) Higher MX_{TSS}



3) Aeration limitations/issues

Oxygen demand

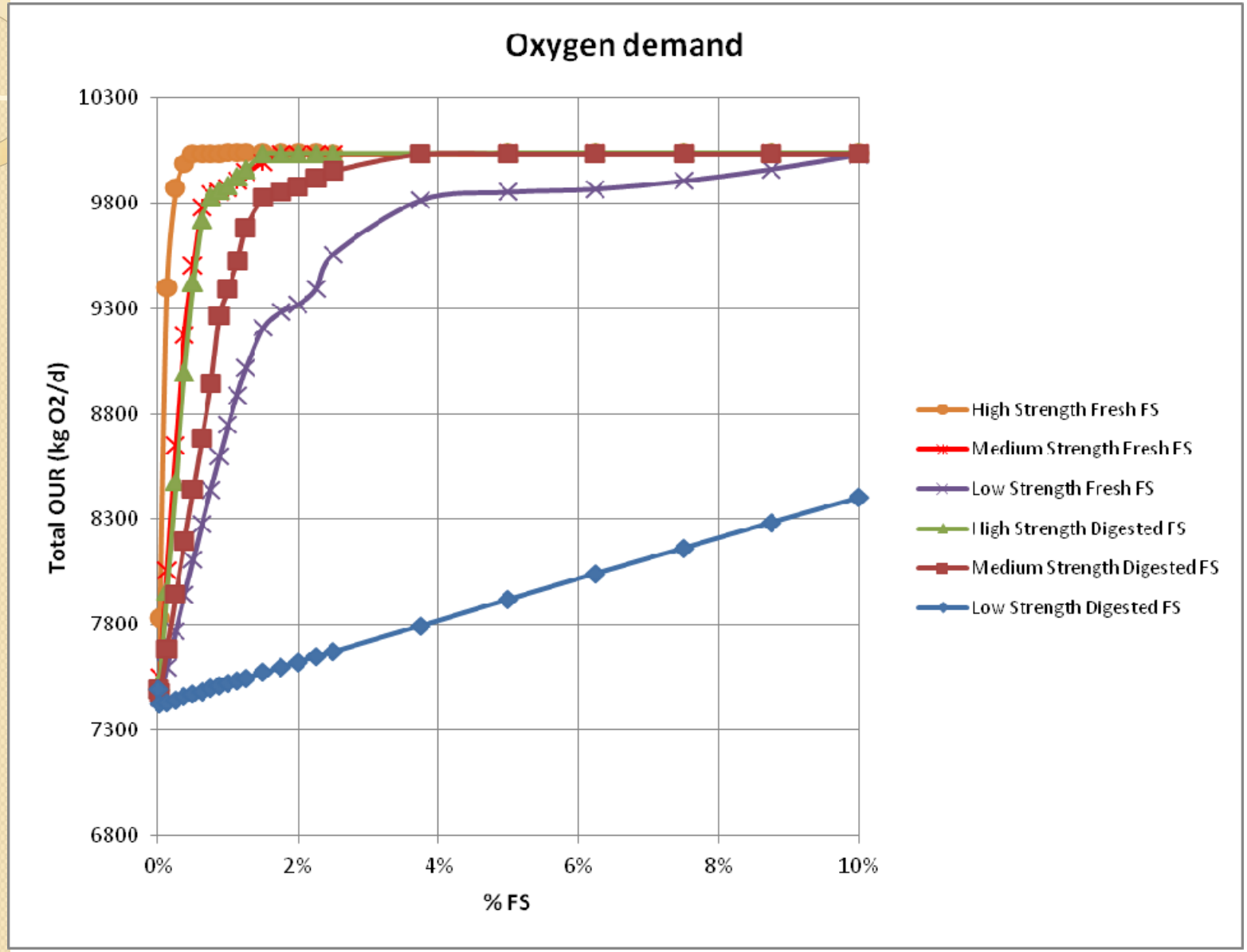
$$FO_{T,ww} = (1-Y_{COD})(Q_i S_{bi,ww}) + f_{CV}(1-f)b_H M X_{BH} + 4.57(Q_i S_{FSA,ww})$$

$$+$$

$$FO_{T,fs} = (1-Y_{COD})(Q_{fs} S_{bi,fs}) + f_{CV}(1-f)b_H M X_{BH,fs} + 4.57(Q_{fs} S_{FSA,fs})$$

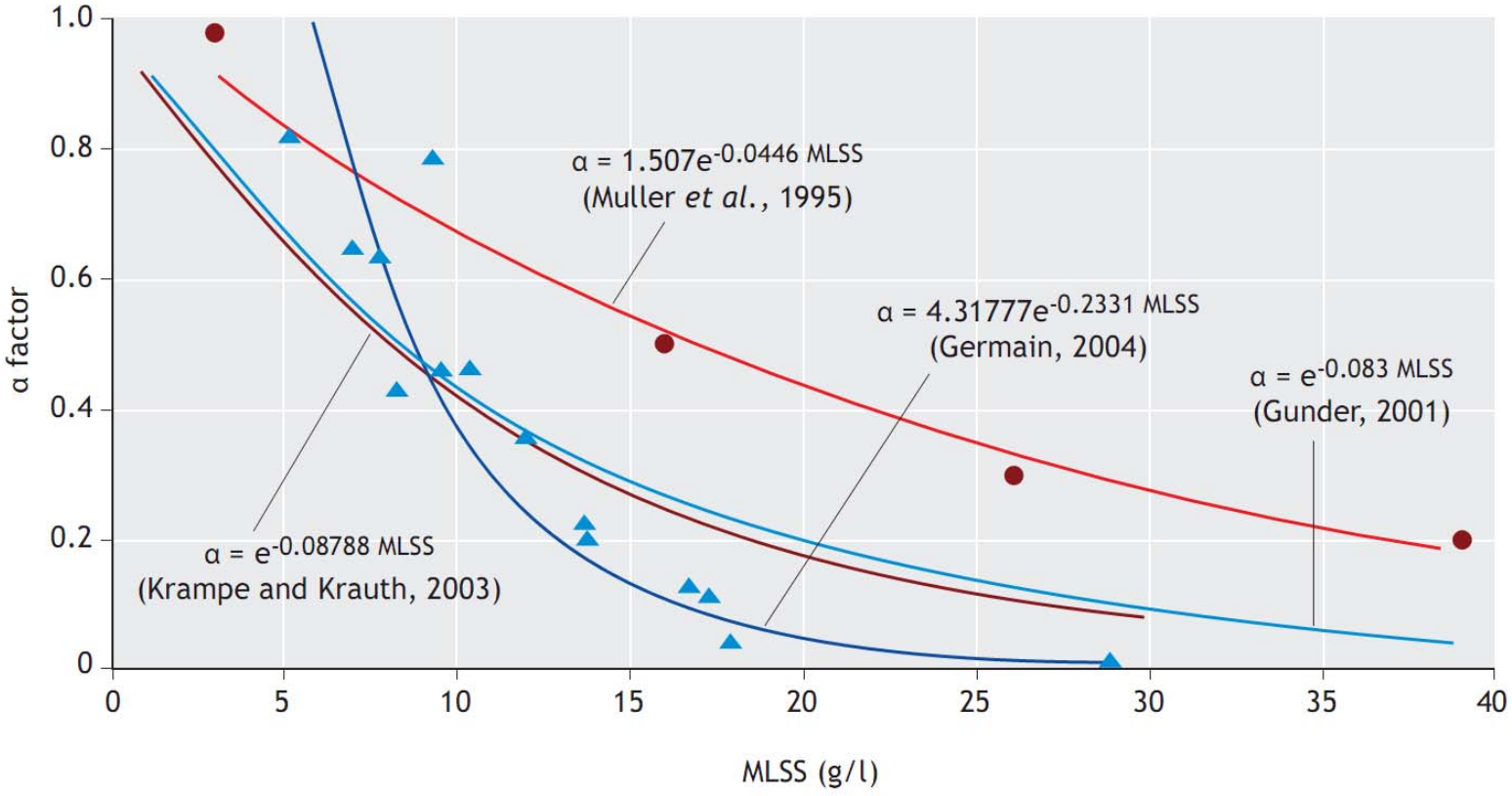
$$FO_{T\ (ww+fs)}$$

3) Aeration limitations/issues

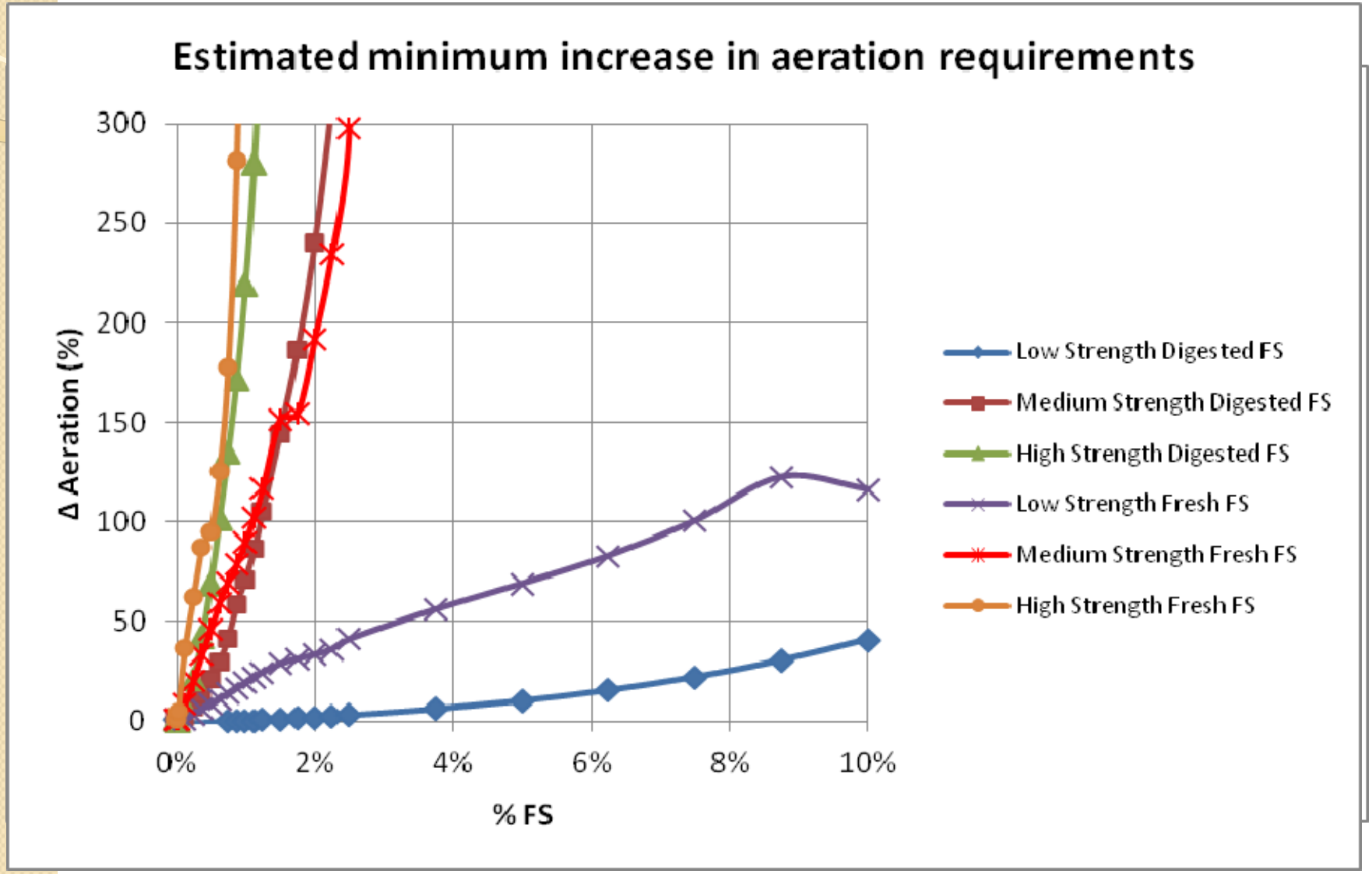


3) Aeration limitations/issues

Reduction in the oxygen transfer efficiency (OTE) as a function of α

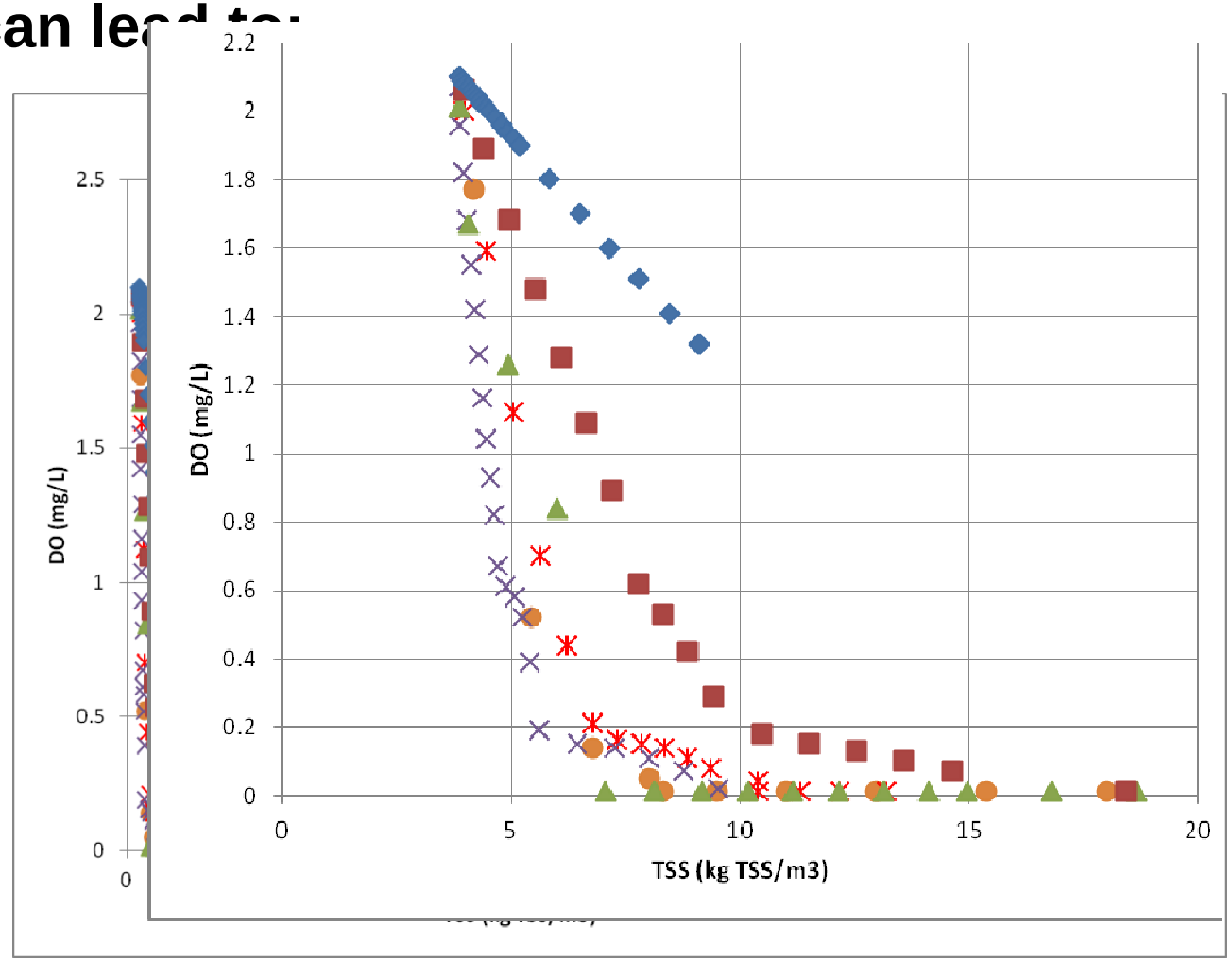


3) Aeration limitations/issues



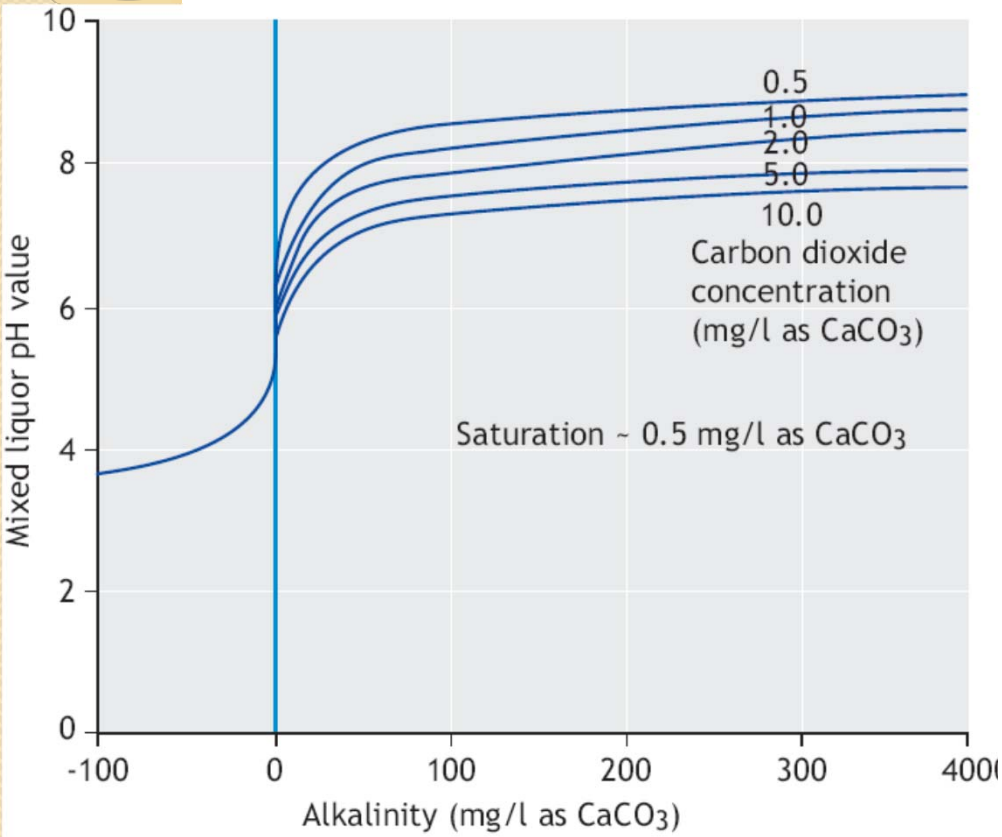
3) Aeration limitations/issues

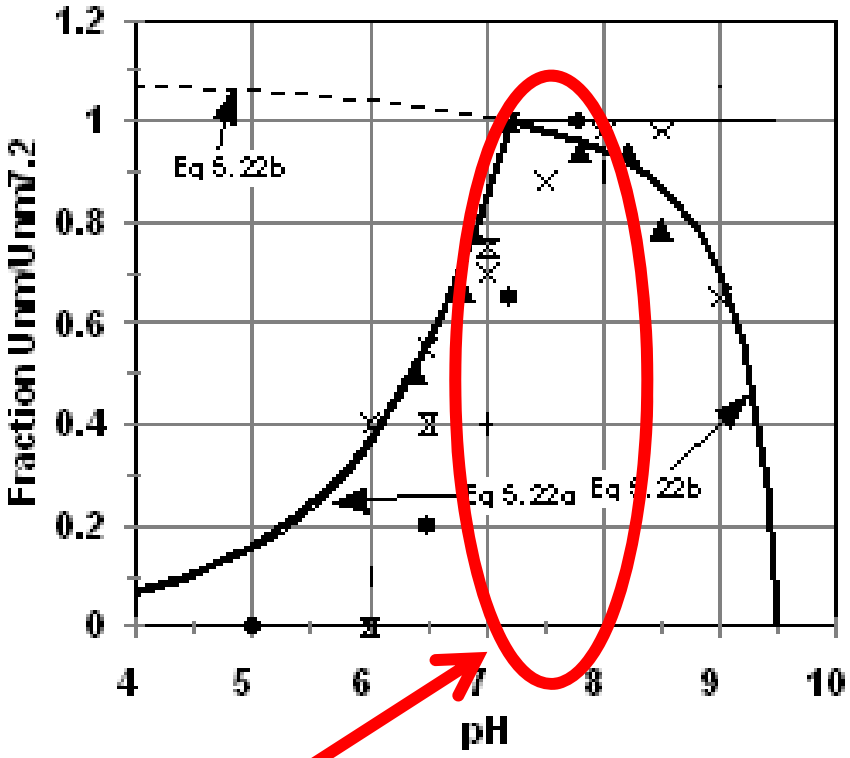
-A drop in oxygen concentration below 1.5 mg/L can lead to:



4) pH issues

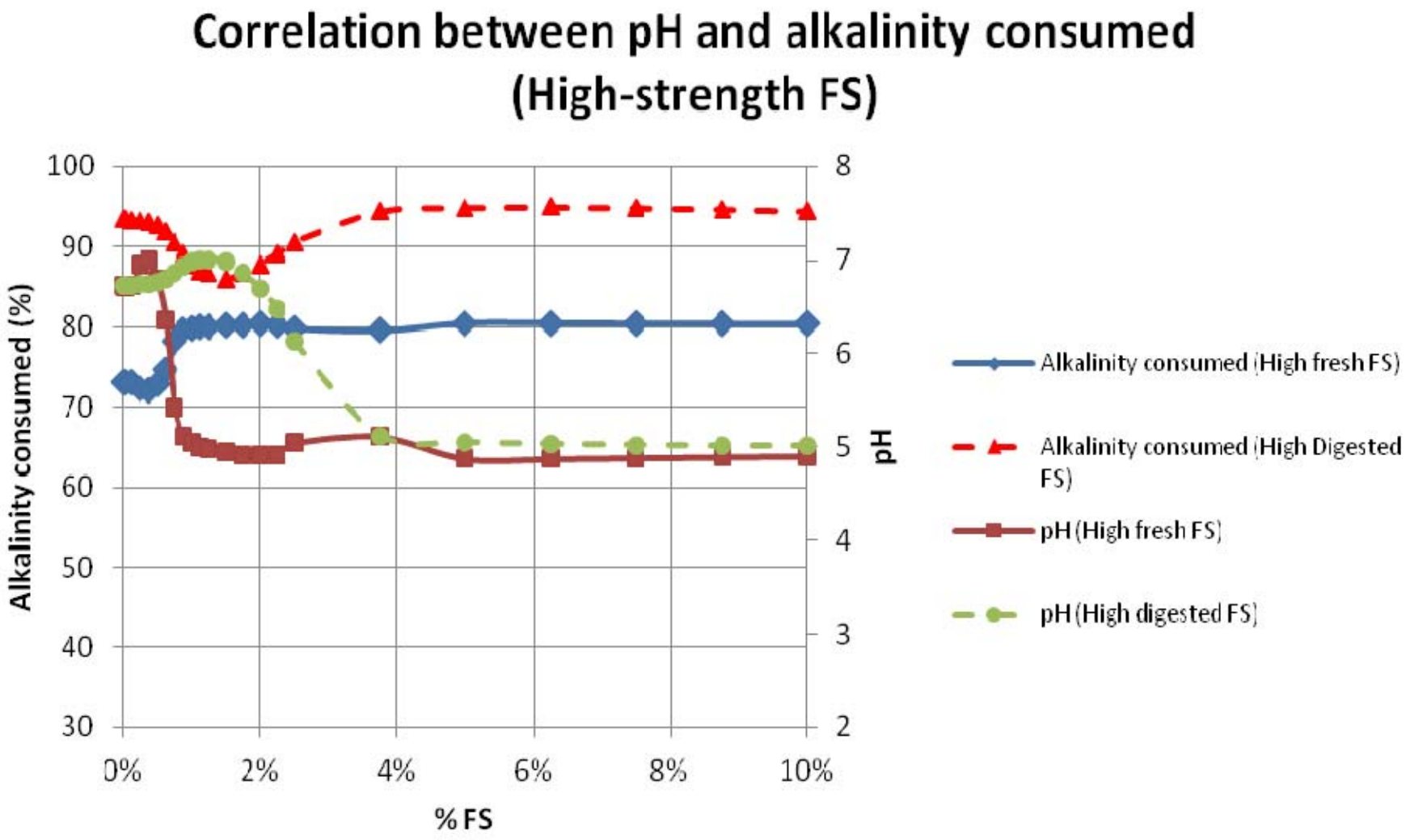
1 mg FSA/L consumes 7.14 mg Alkalinity (as $CaCO_3$)





Optimum nitrification pH range

4) pH issues


Correlation between pH and alkalinity consumed
(High-strength FS)
Alkalinity consumed (%)
100
90
80
70
60
50
40
30
0%
2%
4%
6%
8%
10%
% FS
8
7
6
5
4
3
2
pH
Alkalinity consumed (High fresh FS)
Alkalinity consumed (High Digested FS)
pH (High fresh FS)
pH (High digested FS)

5) Effluent Quality

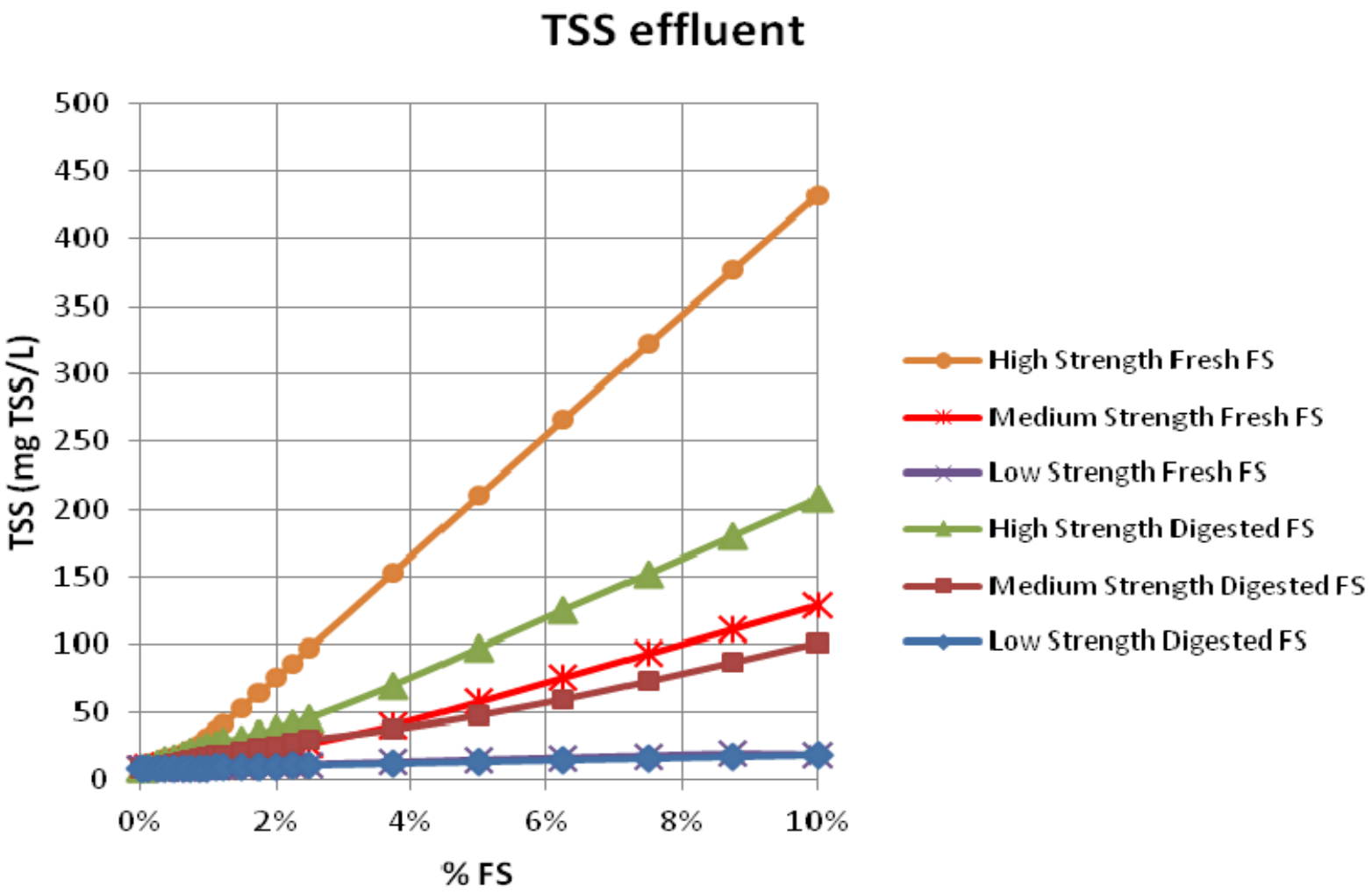
Minimum COD effluent:

$$S_{eff} = \frac{(Q_{i,ww}\, S_{USO,WW} + Q_{i,FS}\, S_{USO,FS})}{(Q_{i,ww} + Q_{i,FS})}$$

Minimum TN effluent:

$$TN_{eff} = \frac{(Q_{i,ww}\, N_{USO,WW} + Q_{i,FS}\, N_{USO,FS})}{(Q_{i,ww} + Q_{i,FS})}$$

5) Effluent Quality



5) Effects on SST

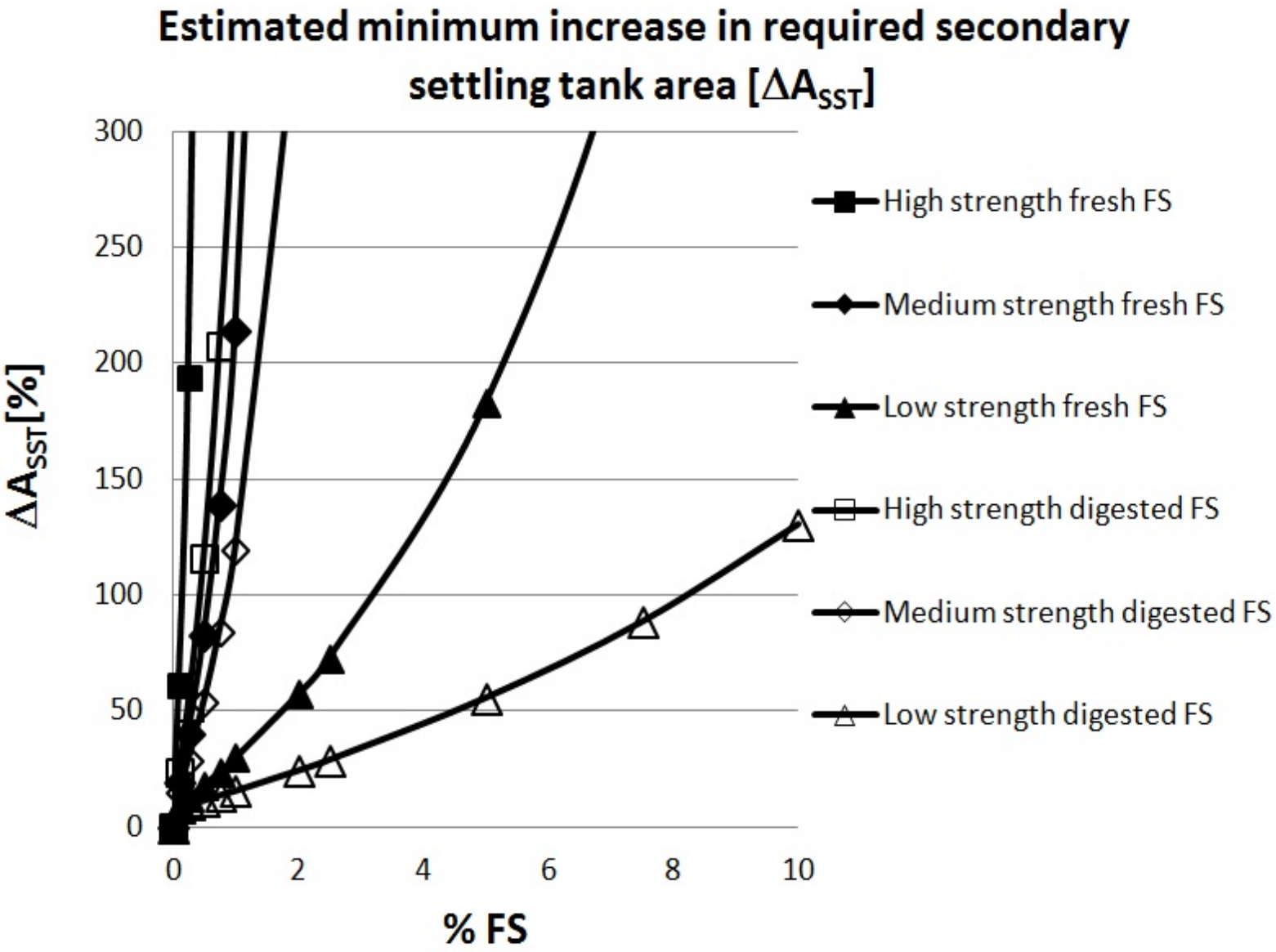
Modified from Ekama and Marais (2004):

$$A^{SST}_{MIN} = \frac{(fq,ww \cdot Q_{i,ww} + fq,fs \cdot Q_{i,FS})/24}{0.8\ V_O\ e^{(-rhin \cdot XTSS)}}$$

where:

f_q	are the peak flow factors for their discharge
V_o	is the initial zone settling velocity (in m/h) obtained from the Vesilind relationship of zone settling velocity (ZSV) tests
r_{hin}	is the hindered settling parameter (in m^3/kg) obtained from the Vesilind relationship.
X_{TSS}	is the maximum solids concentration in the reactor (in kgTSS/m^3).

5) Effects on SST

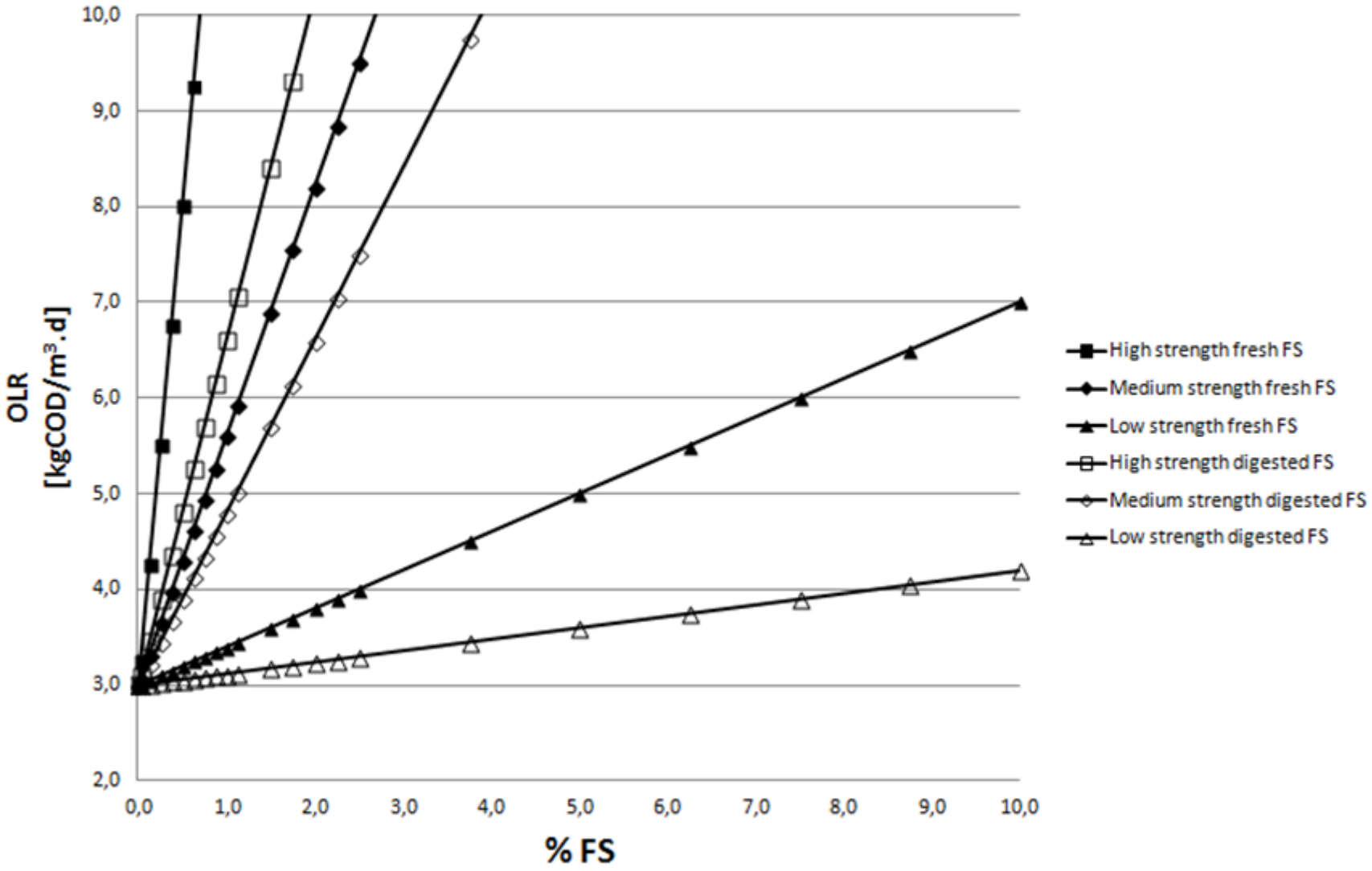


What about anaerobic FS co-treatment?

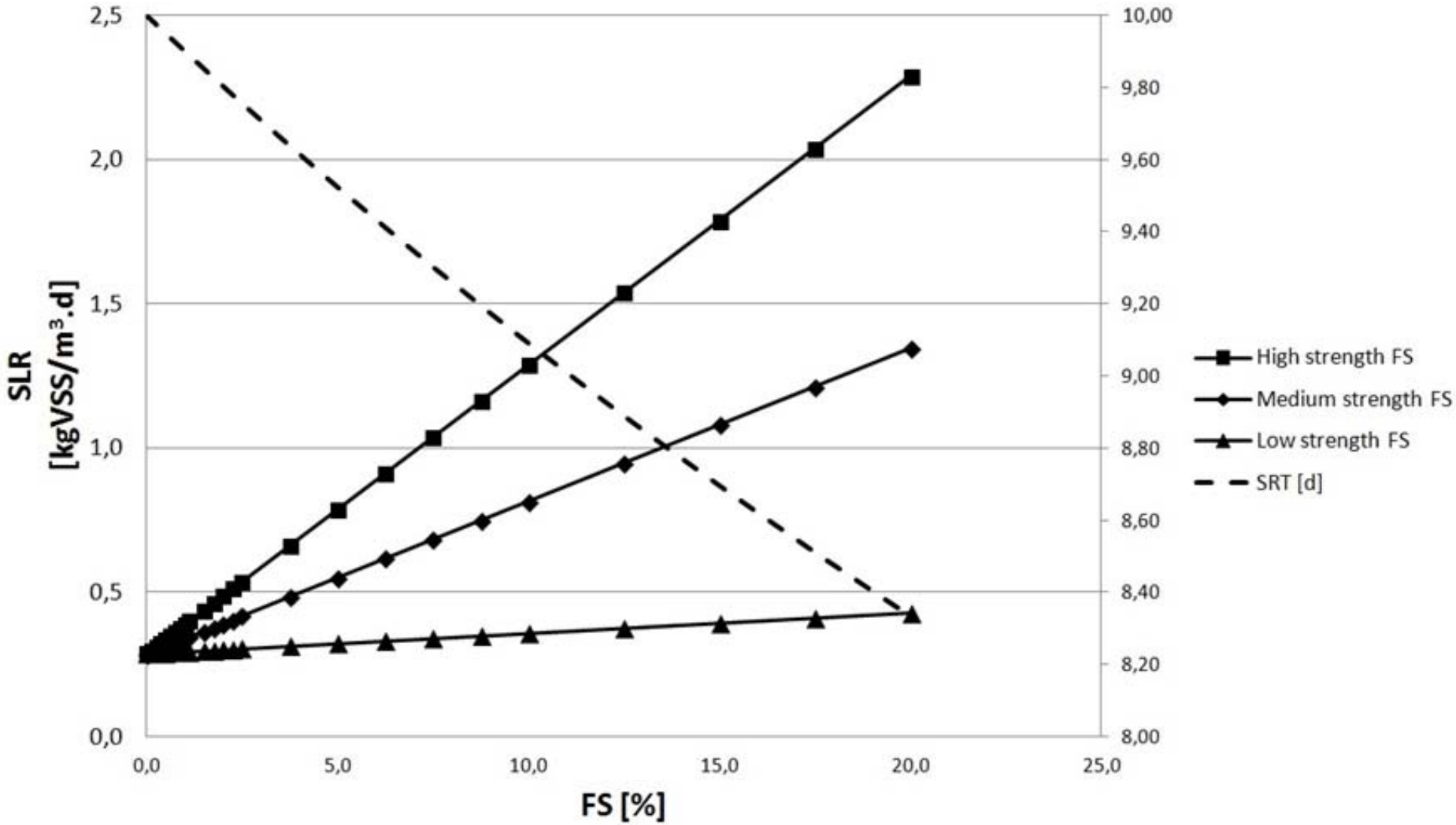
Under which circumstances does it make sense to anaerobically co-treat FS?

Is anaerobic FS co-treatment feasible?

What about anaerobic FS co-treatment?



What about anaerobic FS co-treatment?



TAKE HOME MESSAGES

Maximum FS volumes co-treated depend mostly on:

1) MX_{TSS} accumulation in the reactor
   - Preferably X_{TSS}<6g/L

2) Aeration capacity and efficiency
   - Sufficient installed capacity to cover new FO_{TOT}
   - Cope with decrease in aeration efficiency (α)

3) Enough alkalinity available
   - Alk_{eff} of at least 50 mg Alk/L (after 7.14 mg Alk consumed/mgFSA)

TAKE HOME MESSAGES

Maximum FS volumes co-treated depend mostly on:

4) Minimum required A_{SST} after FS addition

5) Meet effluent standards

6) Spare capacity of anaerobic treatment systems and long-enough SRT