The Effect of Solids Concentration on Performance of a Biofloc System for Tilapia

John A. Hargreaves

Baton Rouge, LA

Wai-Hing Wong

Wisconsin Department of Natural Resources
Madison, WI

Overview:

- *system configuration and operation*
- *experimental protocol*
- *basic system performance data*
- *main effects on water quality*
  - *solids concentration*
  - *feed loading*
- *fish performance data*
- *system collapse*


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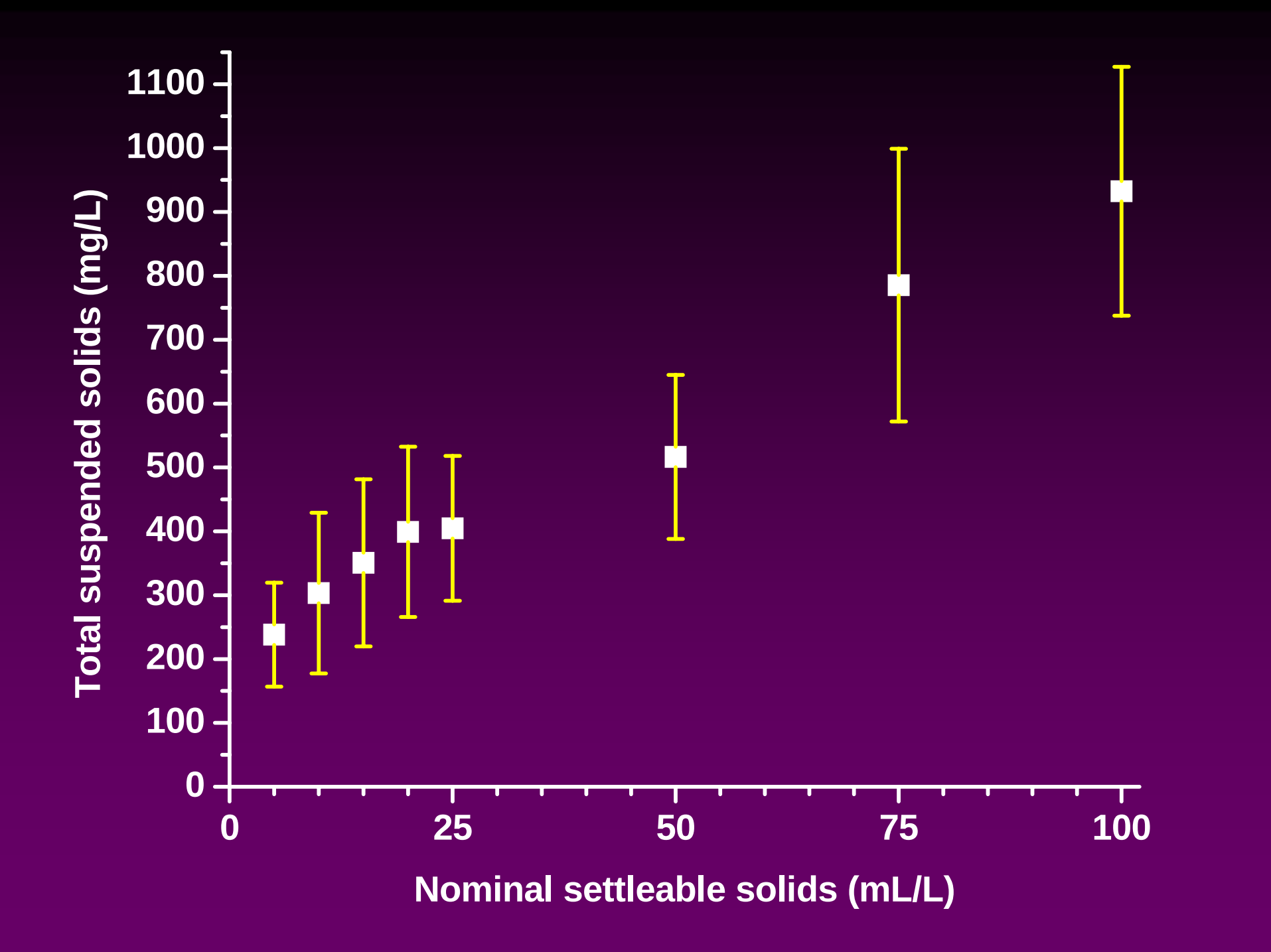
Aquaculture Research Station


80 L
1500 L

Experimental protocol:

- ***each tank assigned one of eight nominal settleable solids concentrations***


Total suspended solids (mg/L)
1100
1000
900
800
700
600
500
400
300
200
100
0
0
25
50
75
100
Nominal settleable solids (mL/L)

Experimental protocol:

- *each tank assigned one of eight nominal settleable solids concentrations*
- ***settleable solids measured daily***

Experimental protocol:

- *each tank assigned one of eight nominal settleable solids concentrations*
- *settleable solids measured daily*
- ***if settleable solids exceeded target, then solids settling/recirculating columns were operated***

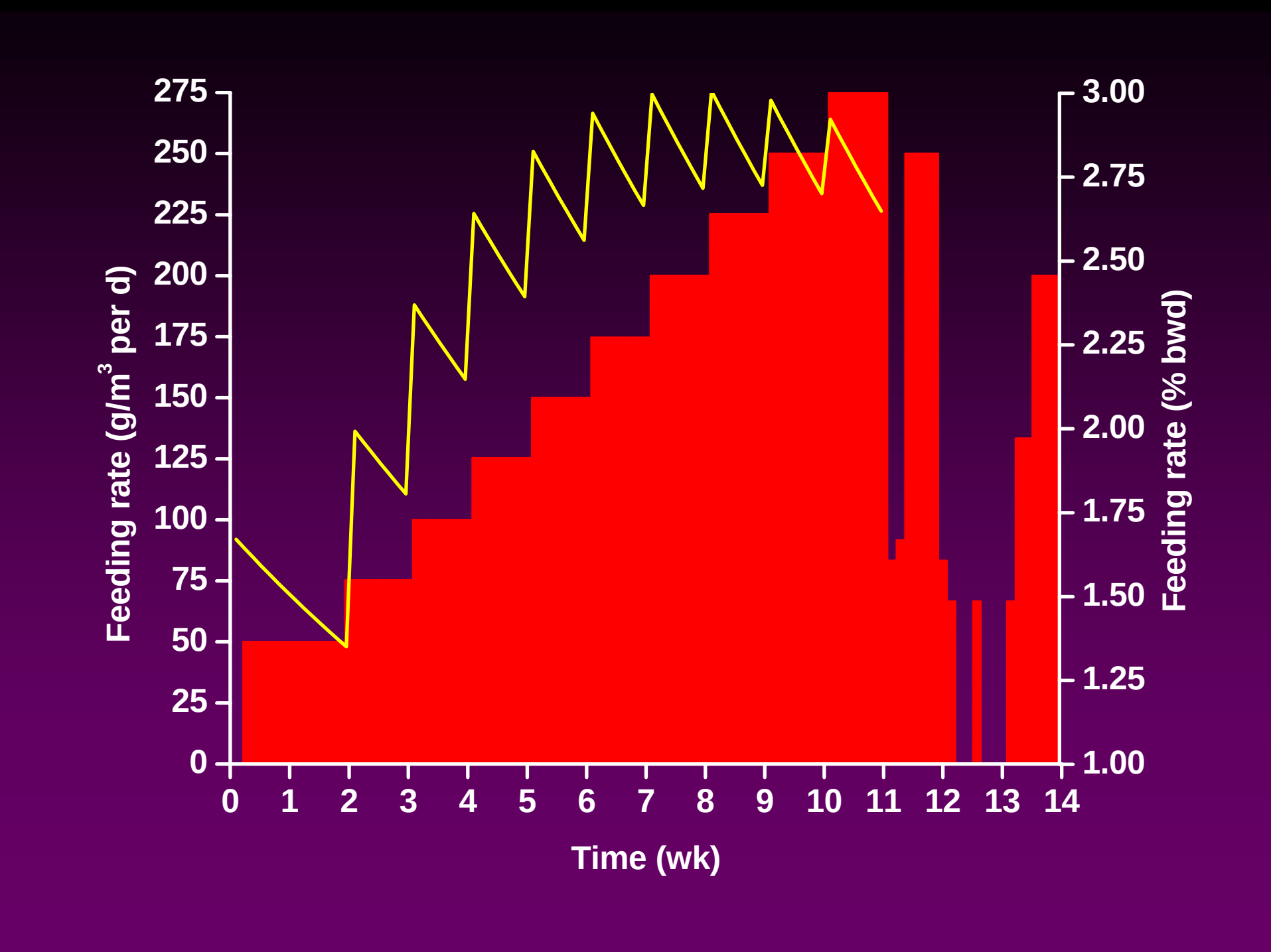
V = 80 L

Q = 3 L/min

HRT = 27 min

Experimental protocol:

- *tilapia (41 g) stocked at 3.0 kg/m^3*
- *fed 32%-protein feed 1 – 3x daily*
- *daily feeding rate increased weekly by 25 g/m^3*


Feeding rate (g/m3 per d)
275
250
225
200
175
150
125
100
75
50
25
0
Feeding rate (% bwd)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Time (wk)

Experimental protocol:

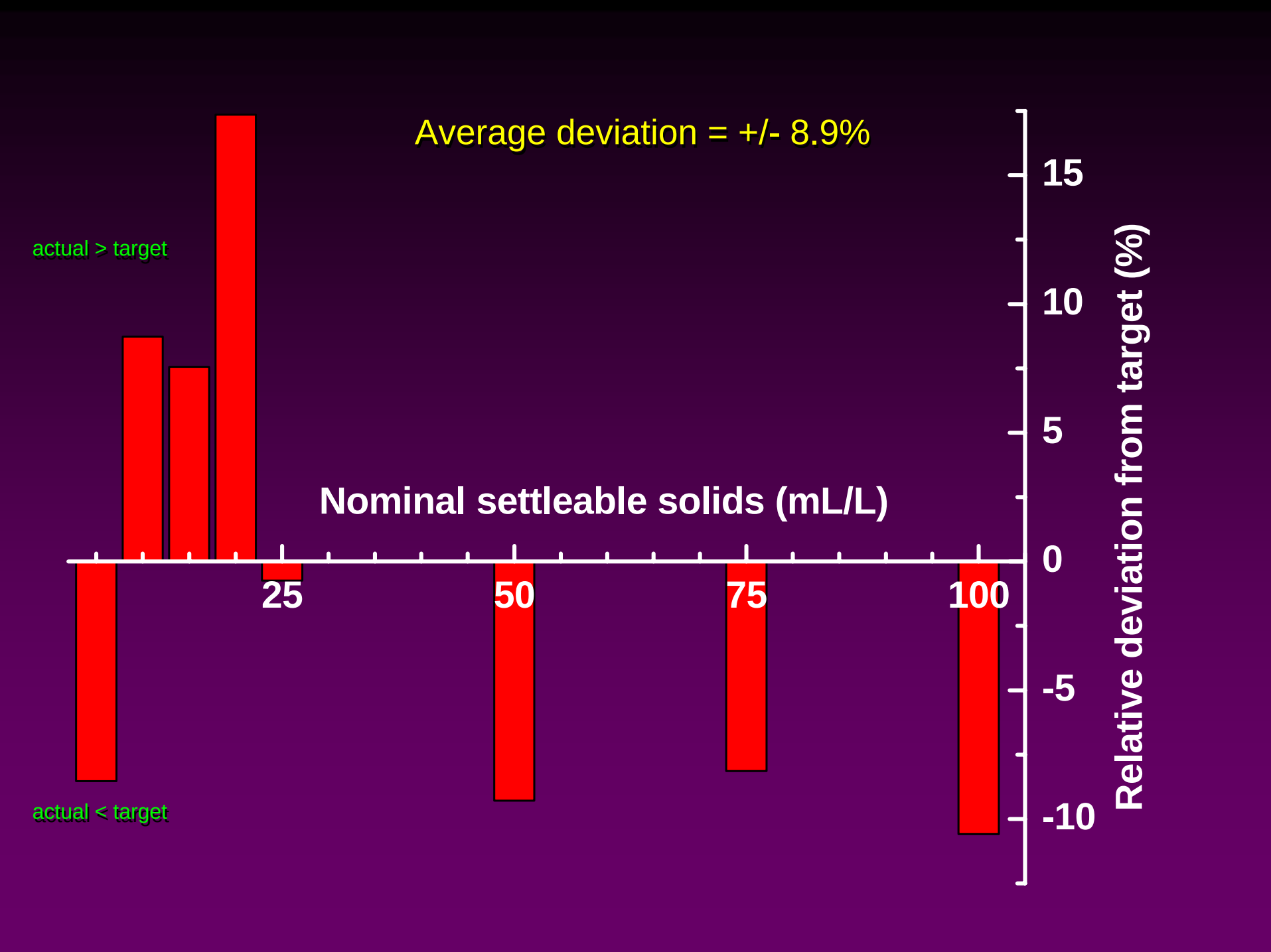
- *tilapia (41 g) stocked at 3.0 kg/m^3*
- *fed 32%-protein feed 1 – 3x daily*
- *daily feeding rate increased weekly by 25 g/m^3*
- *alkalinity maintained >100 mg/L w/ $NaHCO_3$*
- *water quality measured regularly*

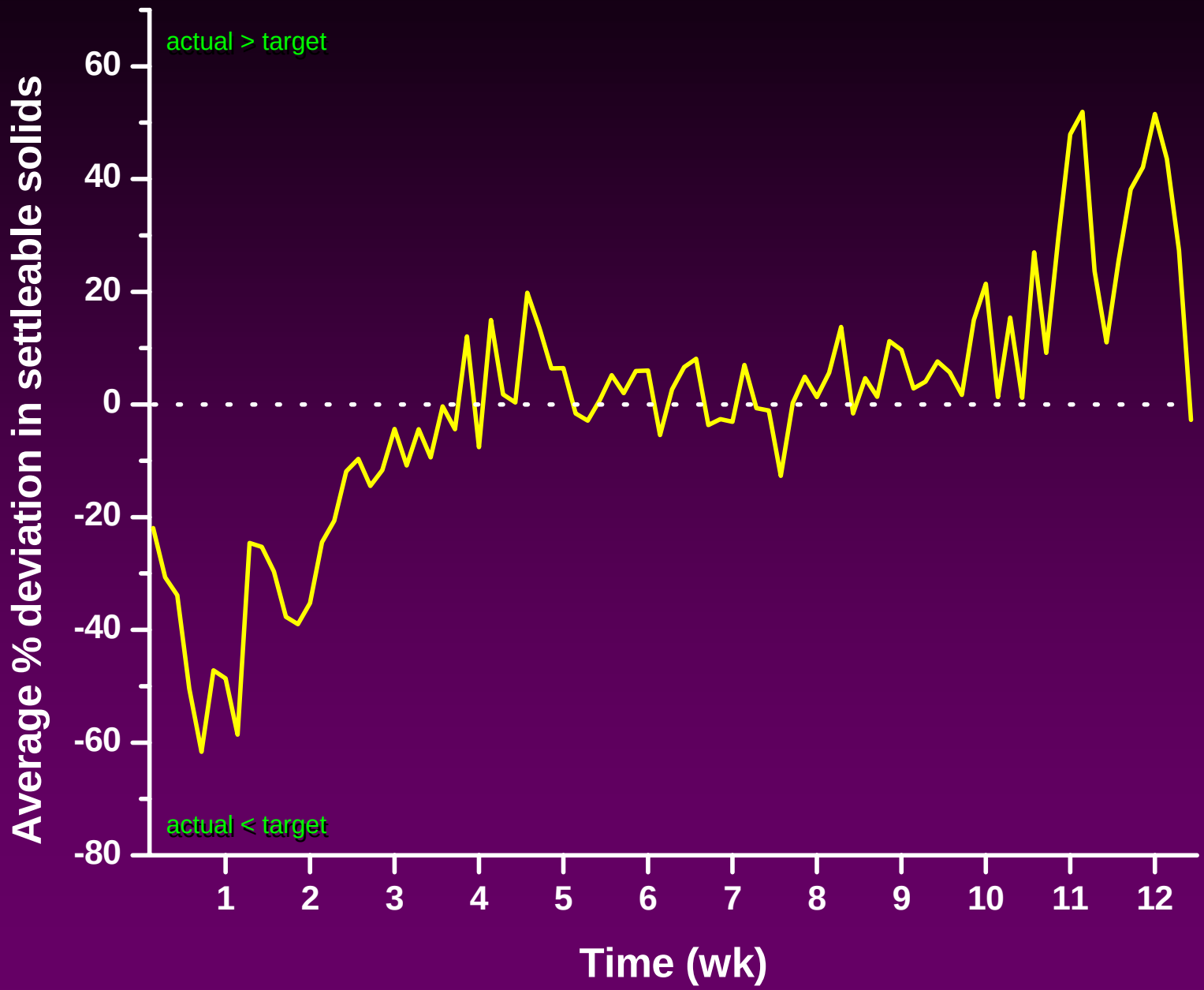
Water quality measurements:

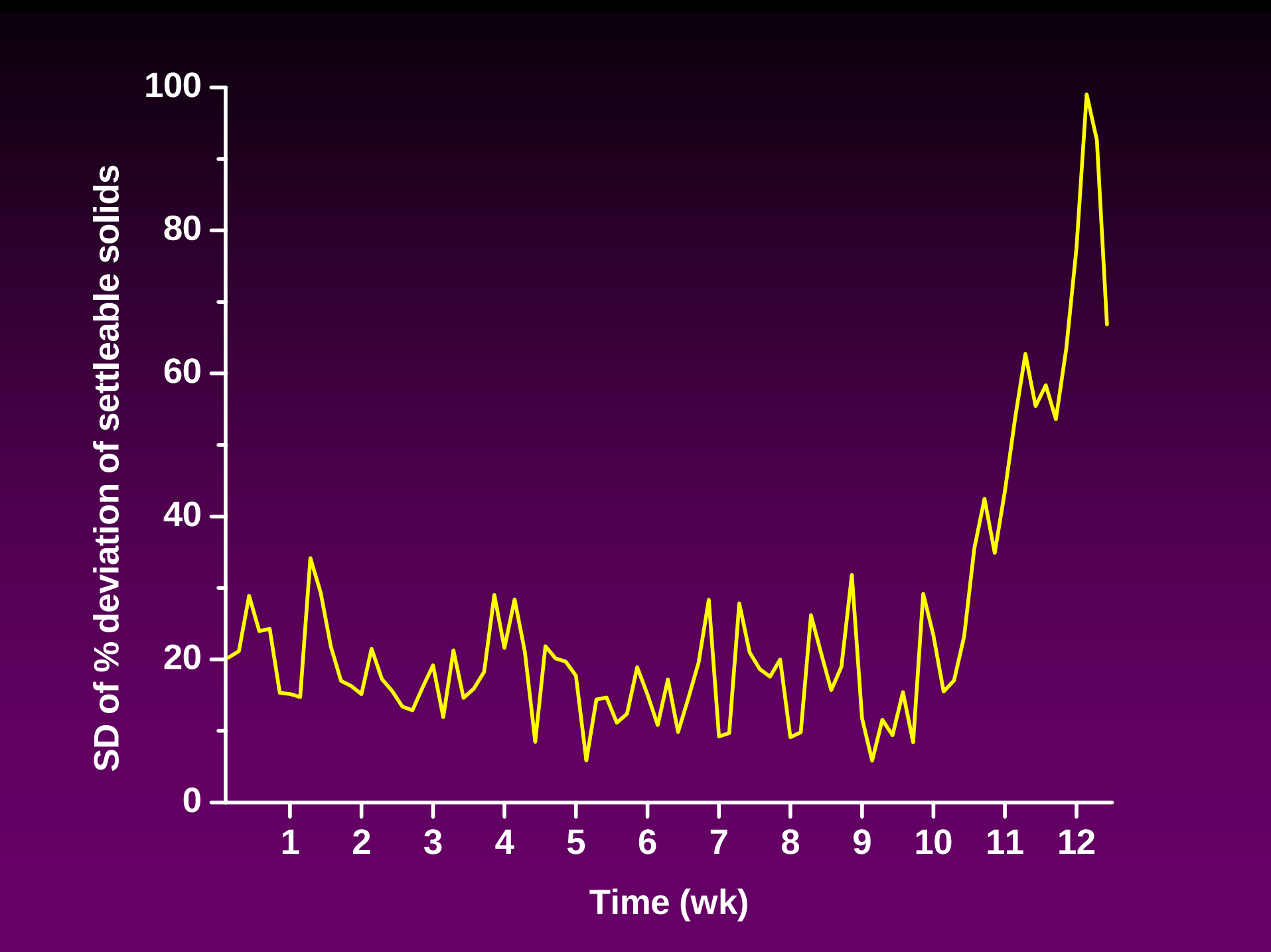
- Daily
  - settleable solids
  - water temperature
  - dissolved oxygen
- Periodically
  - NO_3
- Weekly
  - TSS
  - TAN, NO_2
  - carbon dioxide, alkalinity, pH
  - water respiration
- At termination
  - solids partition
  - COD
  - metals

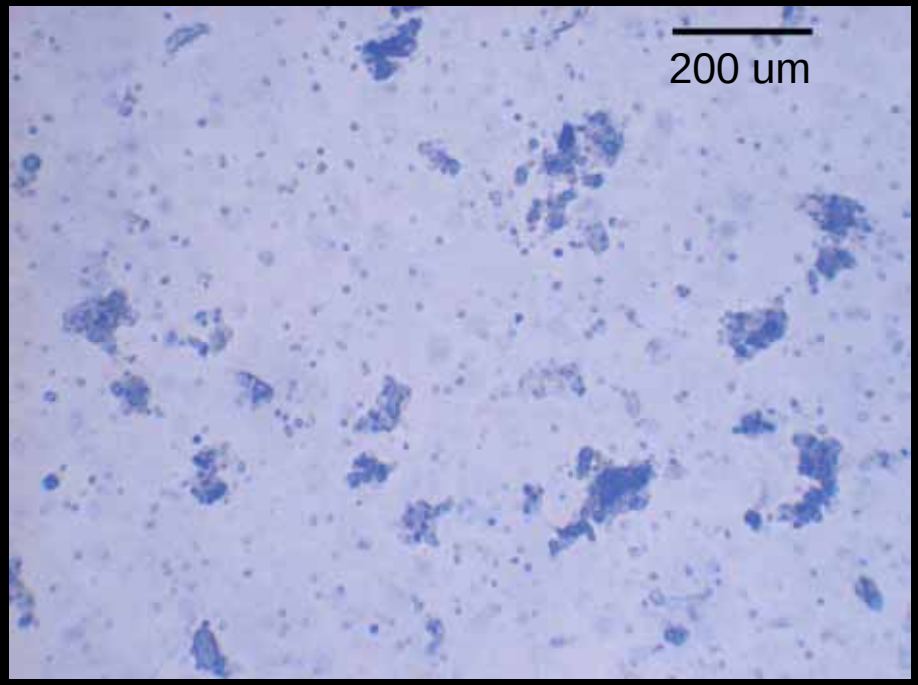
Overview:

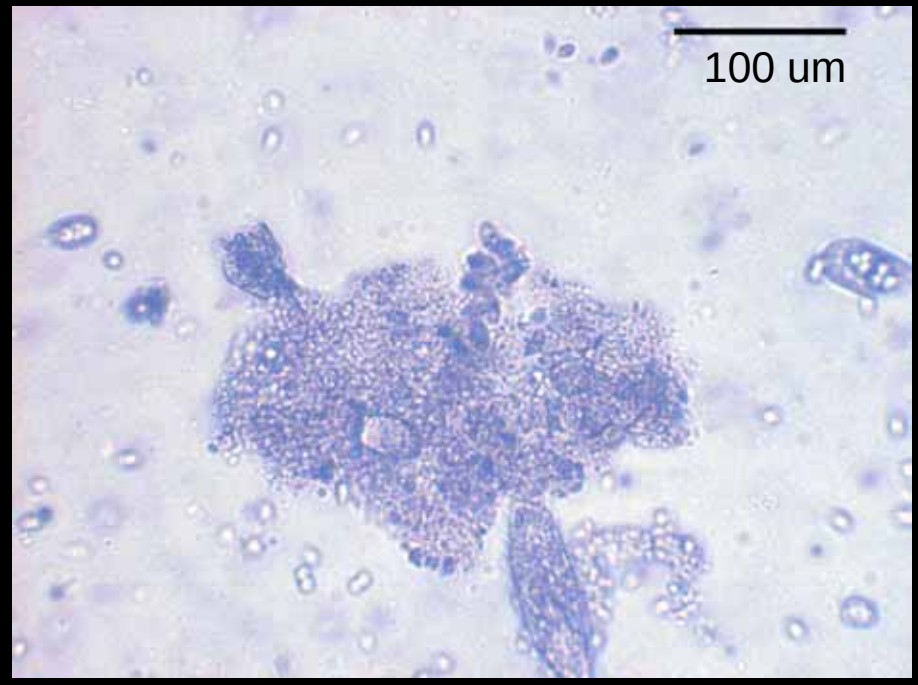
- *system configuration and operation*
- *experimental protocol*
- ***basic system performance data***


Average deviation = +/- 8.9%
actual > target
actual < target
Nominal settleable solids (mL/L)
25
50
75
100
15
10
5
0
-5
-10
Relative deviation from target (%)

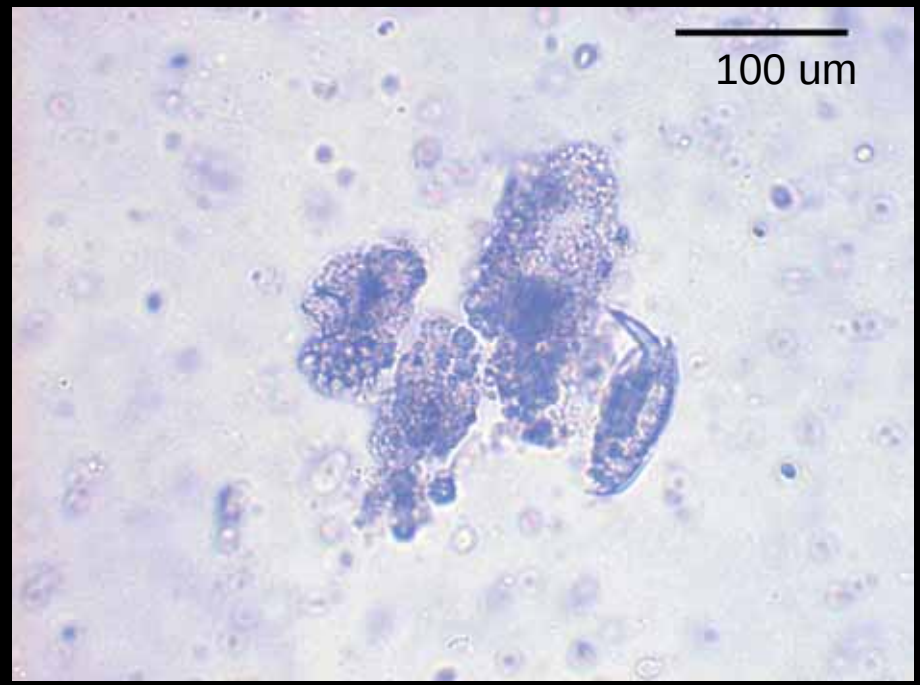

actual > target
actual < target
Average % deviation in settleable solids
60
40
20
0
-20
-40
-60
-80
1
2
3
4
5
6
7
8
9
10
11
12
Time (wk)

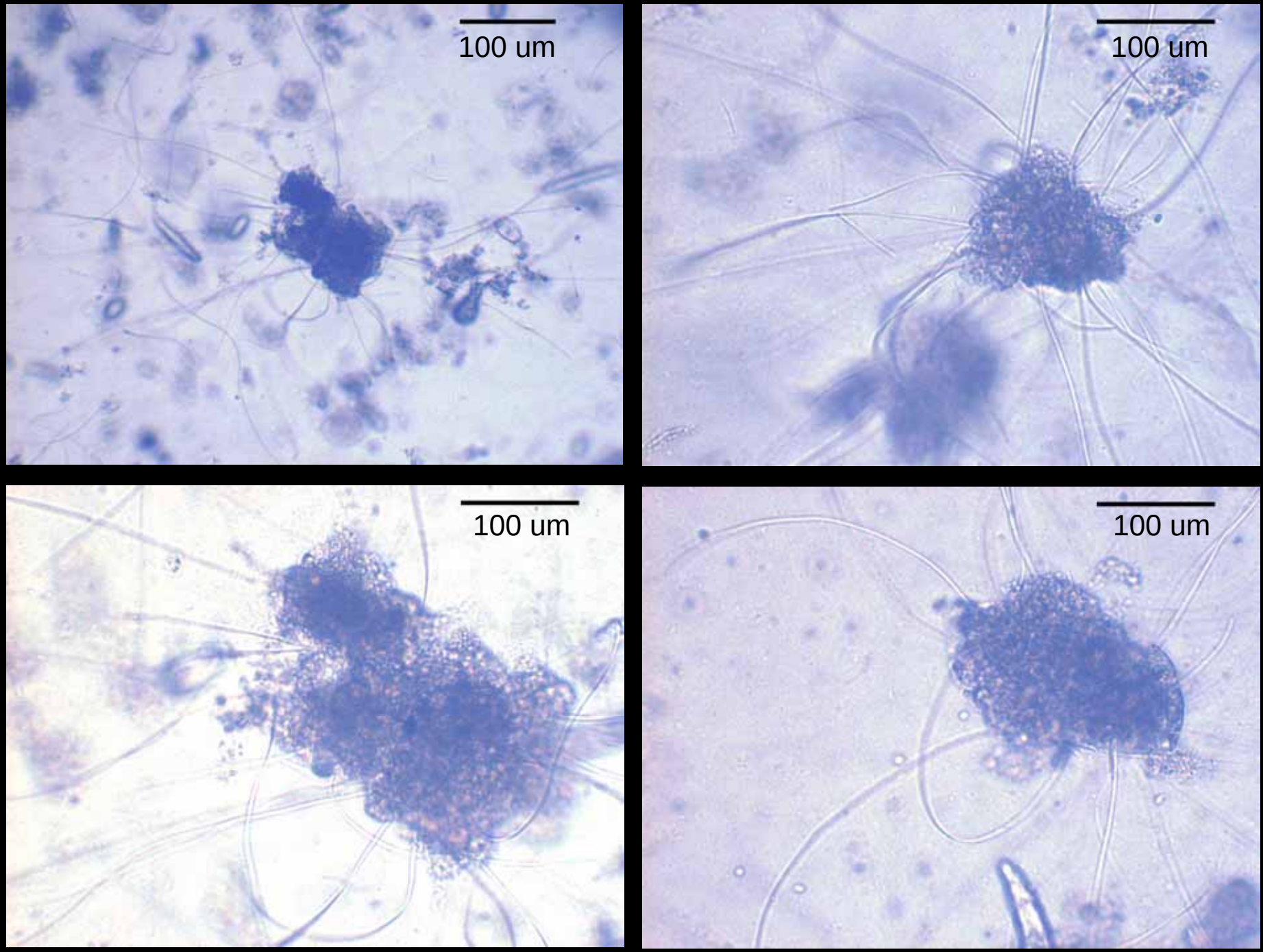

SD of % deviation of settleable solids
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
Time (wk)


200 um


100 um


200 um


100 um


100 um
100 um
100 um
100 um

Overview:

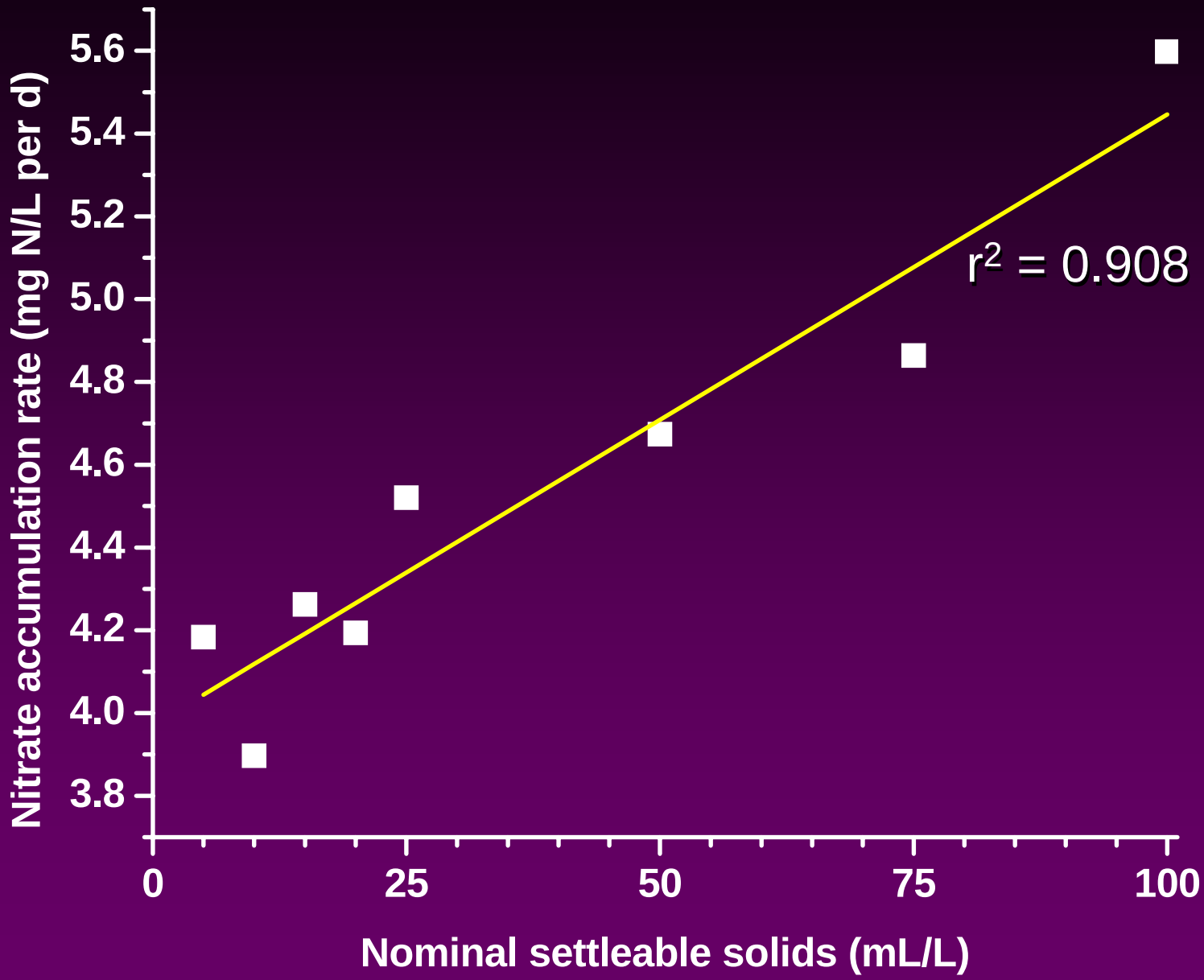
- system configuration and operation
- experimental protocol
- basic system performance data
- main effects on water quality
  - solids concentration
  - feed loading

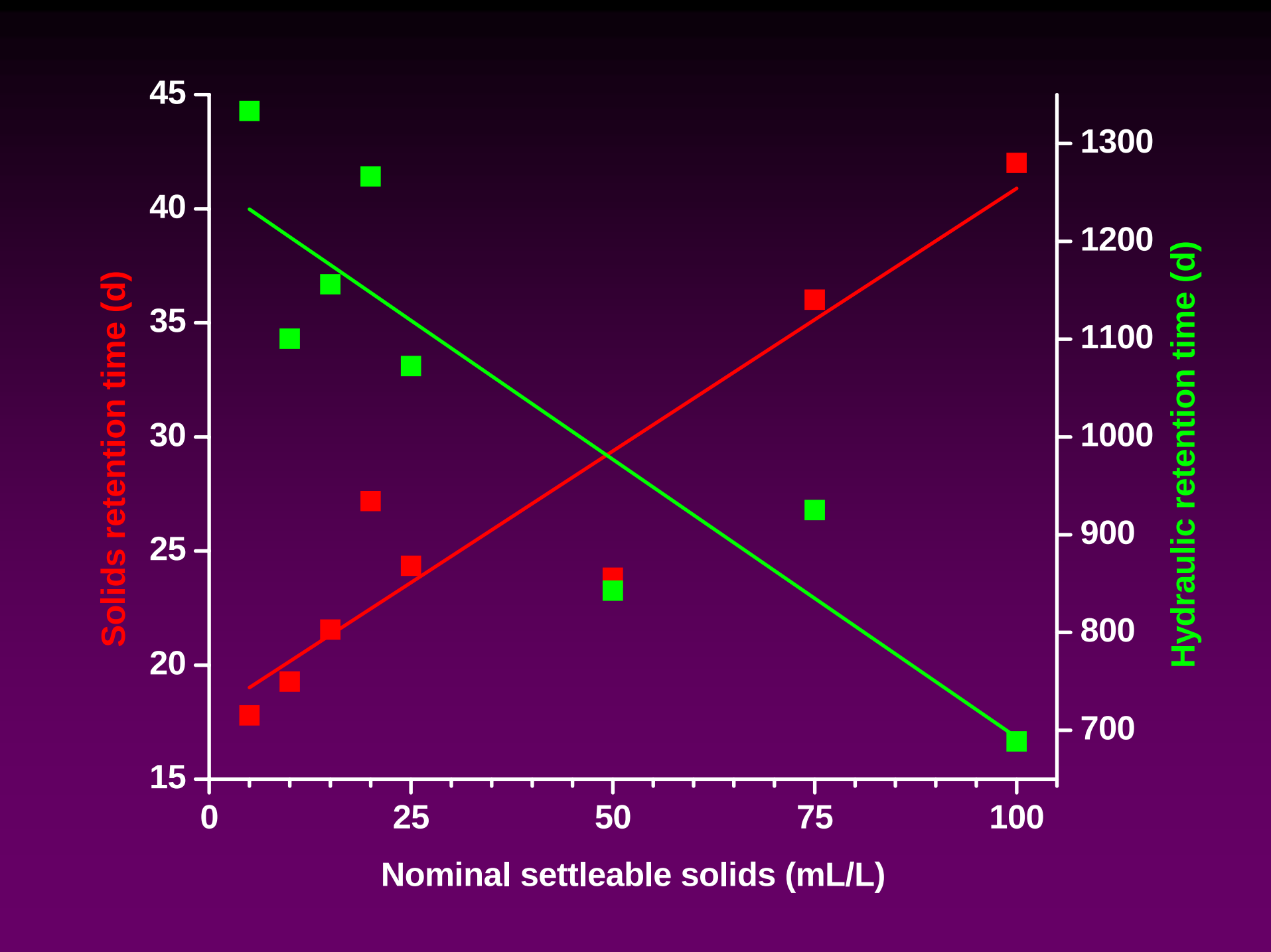
Two main effects:

- ***settleable solids concentration***
  - ***"fixed" by design, but fluctuated in reality***
  - ***variable degree of control through time***
- ***loading (feeding) rate***

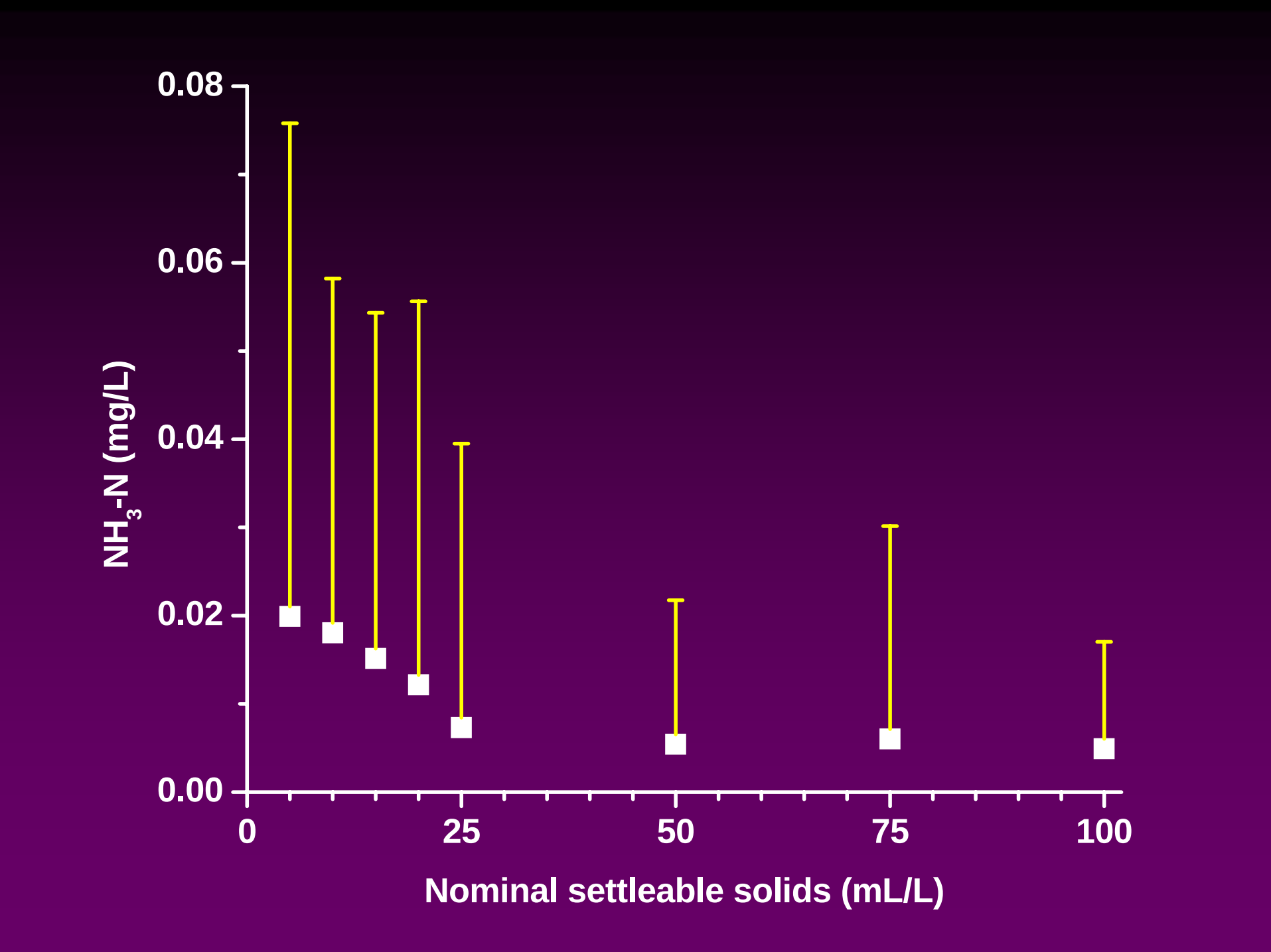
General trends with solids:

- **Positive relationship**
  - nitrate accumulation (nitrification) rate
  - water respiration rate
  - carbon dioxide
- **Negative relationship**
  - pH
  - DO
  - NH_3
- **No trend**
  - TAN
  - NO_2


Nitrate accumulation rate (mg N/L per d)
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
0
25
50
75
100
Nominal settleable solids (mL/L)
r2 = 0.908

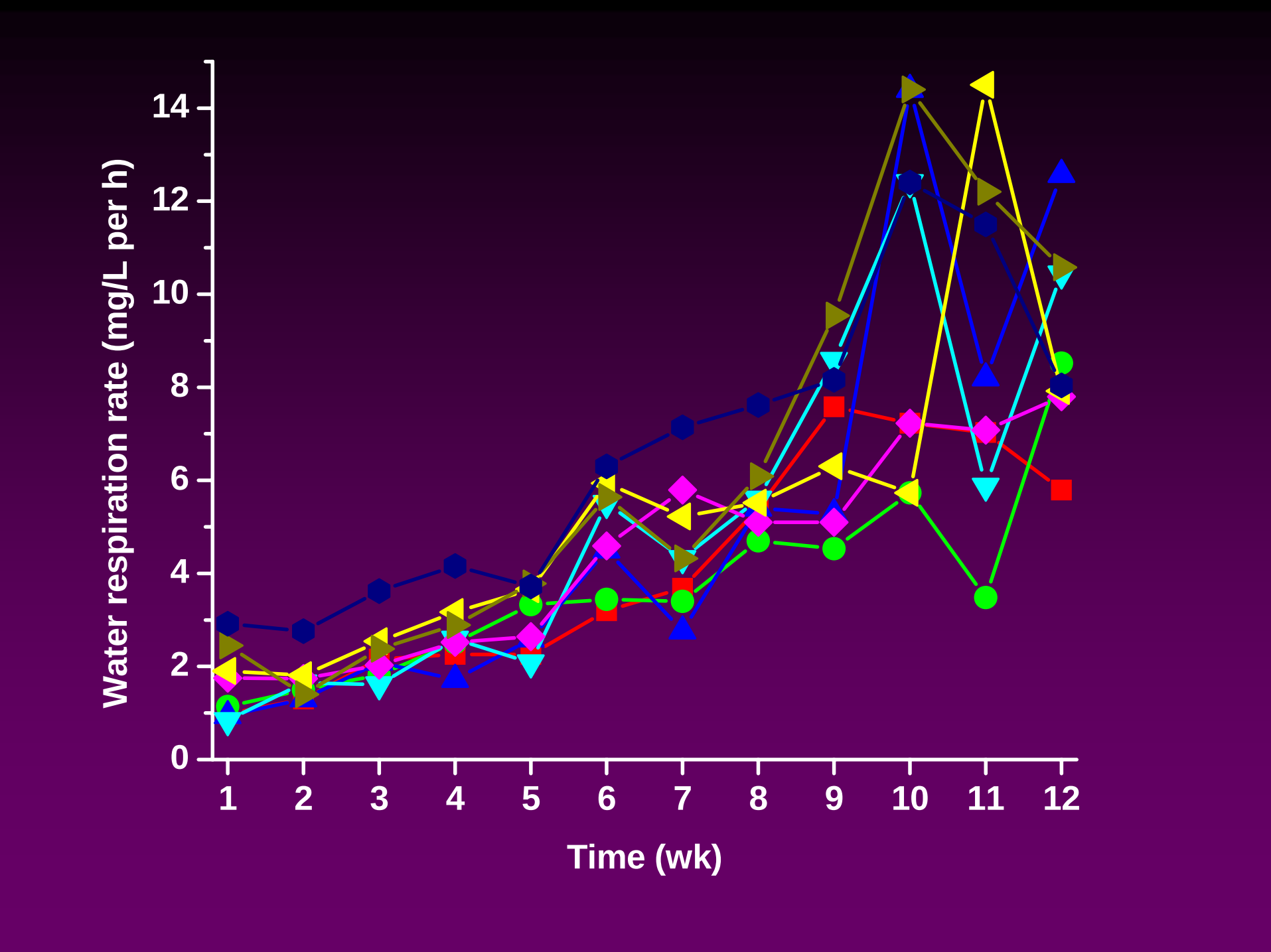

Solids retention time (d)
Hydraulic retention time (d)
Nominal settleable solids (mL/L)
45
40
35
30
25
20
15
1300
1200
1100
1000
900
800
700
0
25
50
75
100

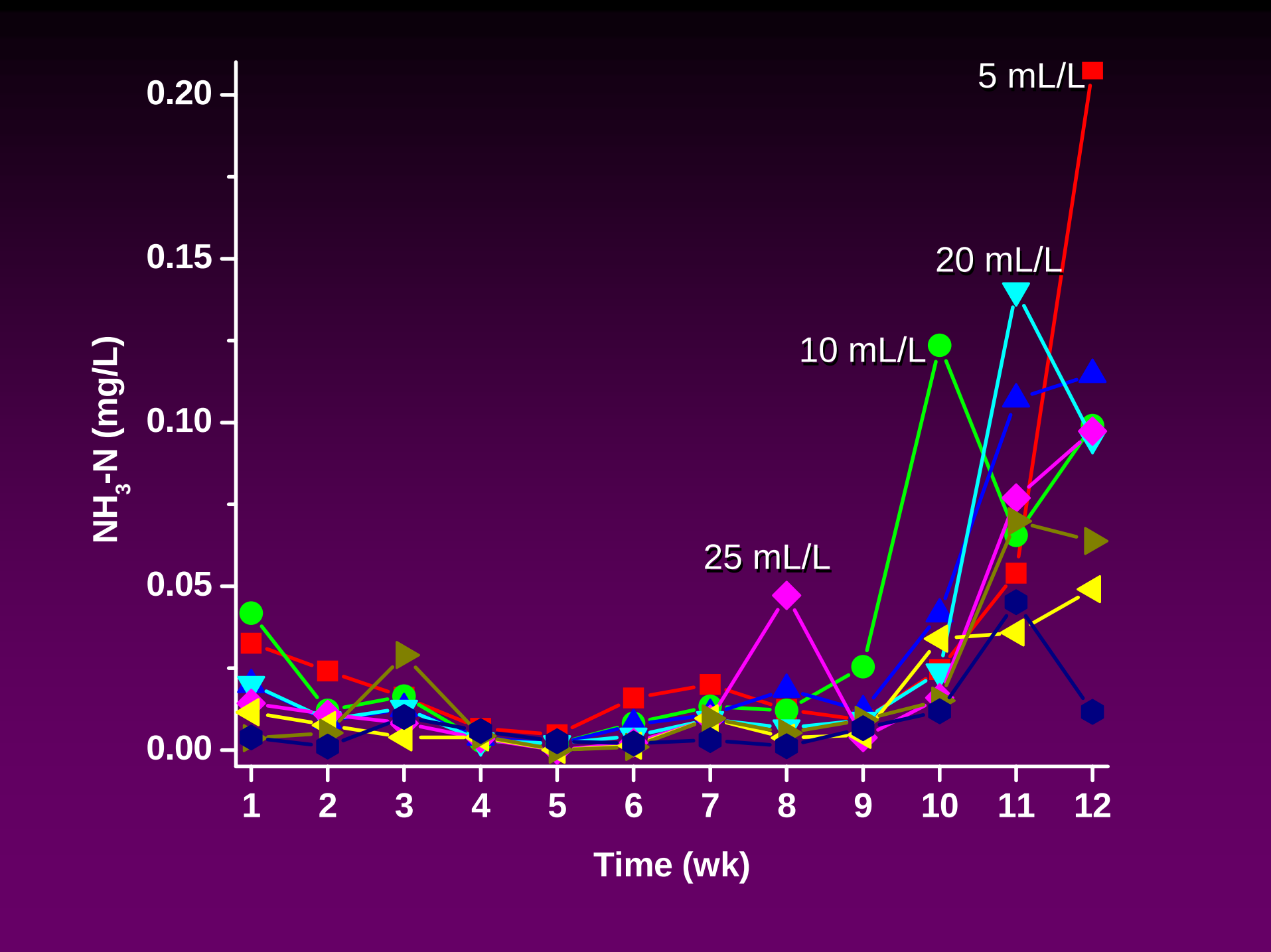
Treatment goal	SRT range (d)
removal of soluble BOD in wastewater	1 – 2
develop flocculent biomass for treating domestic wastewater	3 – 5
provide complete nitrification	3 – 18
this study	17 – 42
stabilization of activated sludge	20 – 40

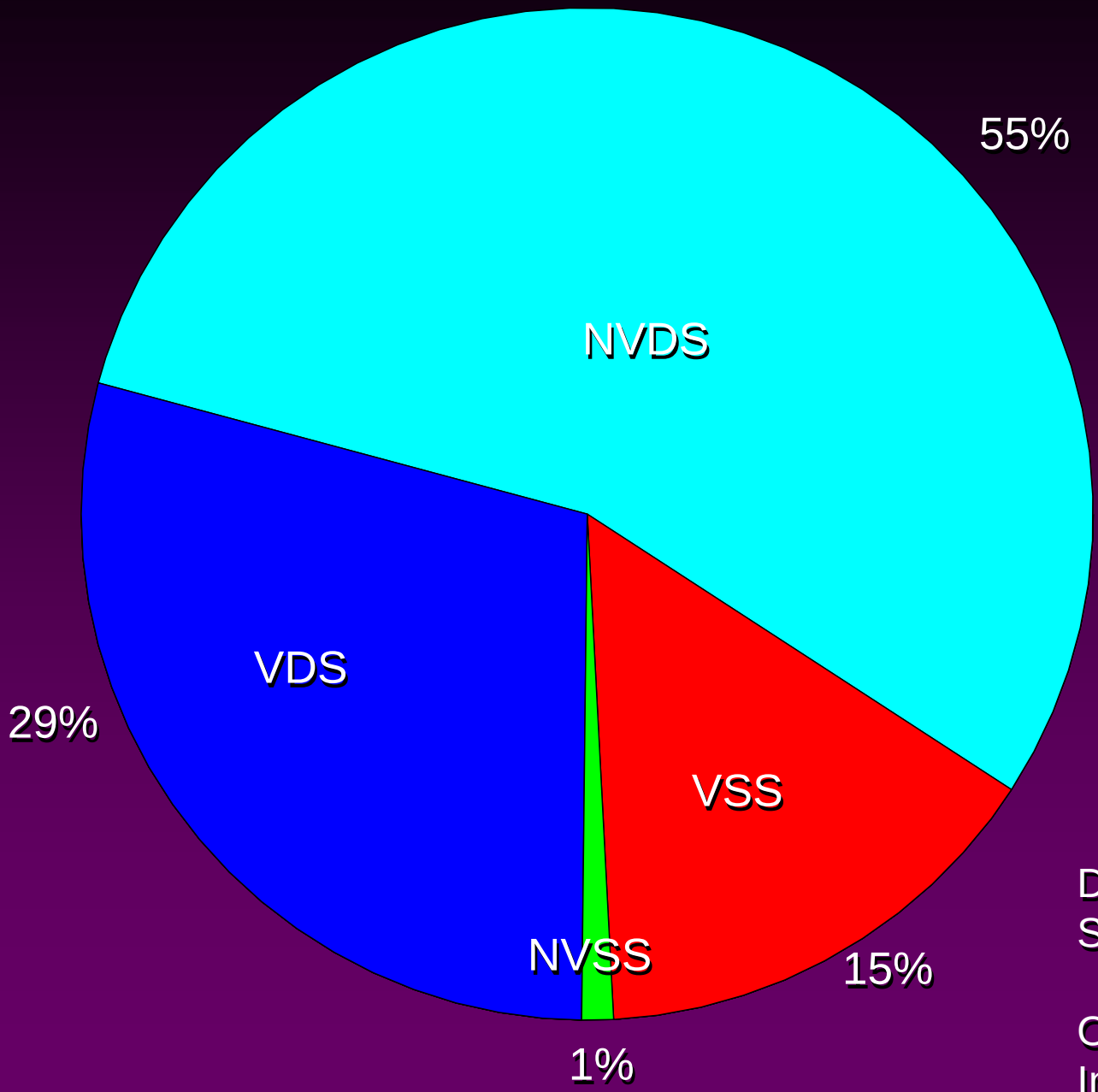

0.08
0.06
0.04
0.02
0.00
NH3-N (mg/L)
0
25
50
75
100
Nominal settleable solids (mL/L)

General trends with loading:

- Positive relationship
  - water respiration rate
  - carbon dioxide
  - TAN
  - NH_3
  - NO_2


Water respiration rate (mg/L per h)
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
Time (wk)


0.20
0.15
0.10
0.05
0.00
NH3-N (mg/L)
1
2
3
4
5
6
7
8
9
10
11
12
Time (wk)
5 mL/L
20 mL/L
10 mL/L
25 mL/L



Dissolved	84%
Suspended	16%
Organic	44%
Inorganic	56%

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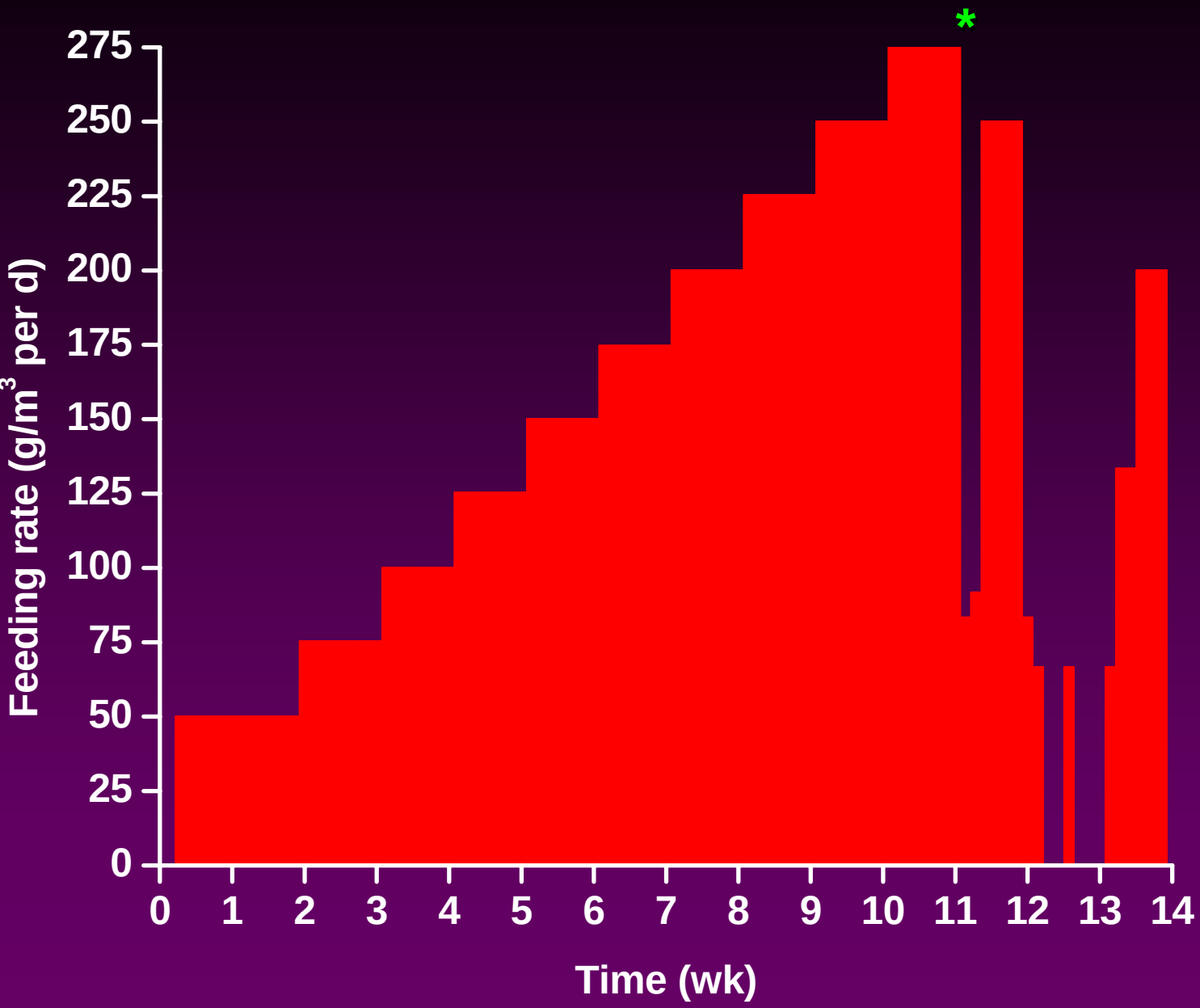
  - solids concentration
  - feed loading
- fish performance data

	Average	CV (%)
initial wt (g)	41	2.4
final wt (g)	141	9.2
growth (g/d)	1.03	12.6
specific growth (%/d)	1.27	7.1
FCR	1.83	12.0
survival (%)	94.7 *	4.9
final density (kg/m^3)	9.8	9.2


*
275
250
225
200
175
150
125
100
75
50
25
0
Feeding rate (g/m3 per d)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Time (wk)

After 11 weeks:

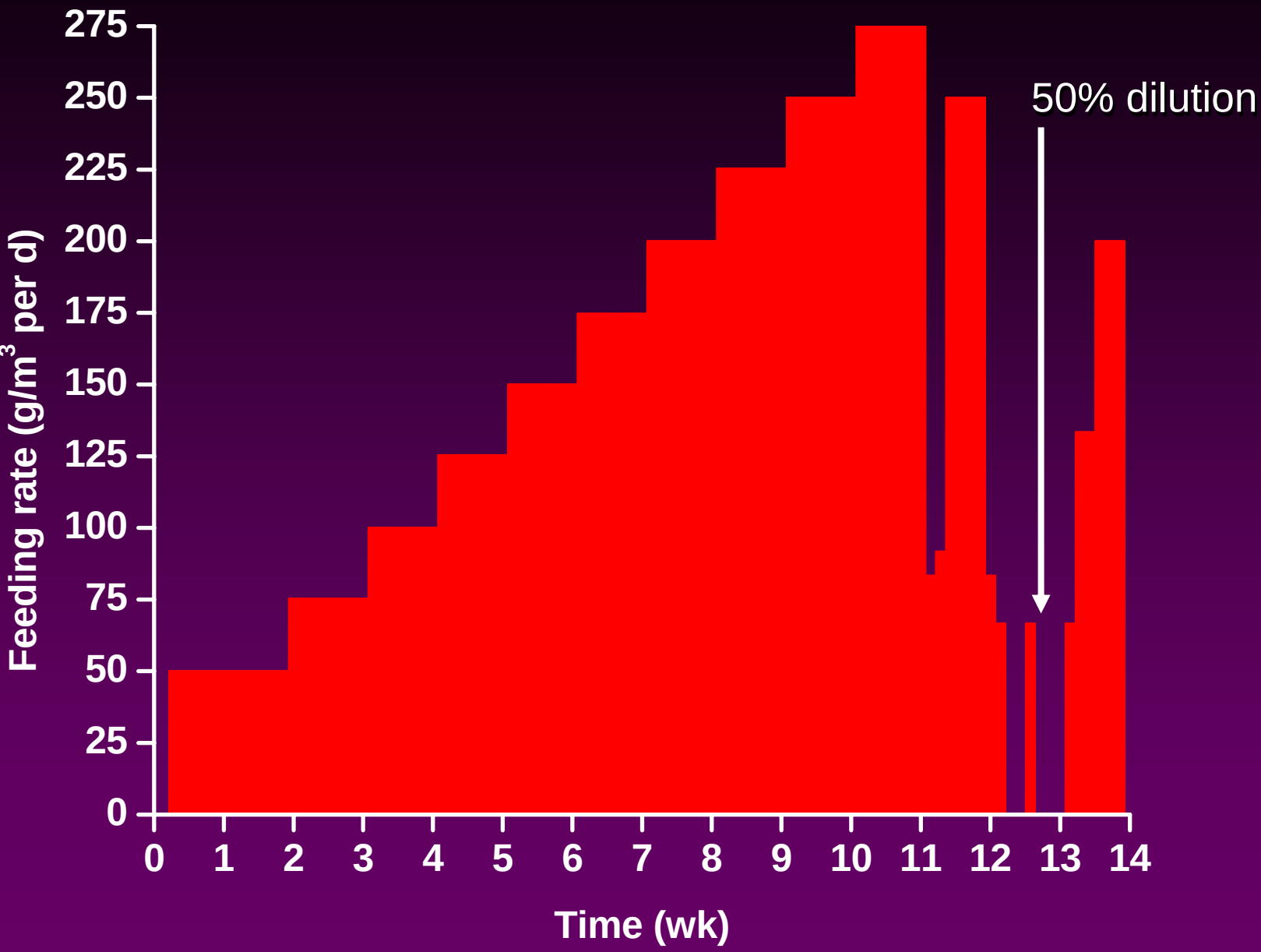
- *Fish*
  - *stopped eating*
  - *apparent signs of respiratory distress*
  - *all fish in one tank died (15 mL/L)*
  - *affected fish in all tanks*
- *Conditions*
  - *feeding rate: 275 g/m^3 per d*
  - *cumulative feed: 12 kg/m^3*
  - *cumulative feed burden: 130 kg/m^3*

After 11 weeks:

- *Our response*
  - *reduced then ceased feeding*
  - *measured serum osmolality*
  - *measured hematocrit*
  - *measured metal concentrations*
  - *exchanged 50% of tank volume*

Potential hypotheses for fish stress:

- *metal toxicity related to low [Ca^{2+}]*
  - *Ca^{2+}: 1 – 5 mg/L (Ca hardness = 12.5 mg/L)*
  - *synergistic or collective effect among metals*
- *nitrate toxicity*
  - *chronic exposure*
  - *~400 mg/L as N*
- *unknown factor associated with DOM*
  - *COD: 300 – 500 mg/L*
  - *VDS: ~1000 mg/L*


275
250
225
200
175
150
125
100
75
50
25
0
Feeding rate (g/m3 per d)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Time (wk)
50% dilution

Conclusions:

- *system functional across a wide range of solids concentrations (200 – 1000 mg/L)*
  - *“best”: 300 – 500 mg/L TSS, 25 – 50 mL/L*

Conclusions:

- *system functional across a wide range of solids concentrations (200 – 1000 mg/L)*
- *system "collapse" at 275 g/m^3 per d*
  - *sustainable max. rate ~200 g/m^3 per d*

Conclusions:

- *system functional across a wide range of solids concentrations (200 – 1000 mg/L)*
- *system "collapse" at 275 g/m^3 per d*
- ***process instability***
  - *difficult to control solids concentration when foam develops (pin floc)*
  - *need foam fractionators*

Conclusions:

- system functional across a wide range of solids concentrations (200 – 1000 mg/L)
- system “collapse” at 275 g/m^3 per d
- process instability
- no improvement in fish performance with solids concentration