NORDIC WATER

# DynaSand Oxy – DynaSand Deni

## Nitrogen reduction of municipal waste water

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# Nitrogen reduction

- Why is nitrogen treated in municipal waste water?
- In which forms are nitrogen present in municipal waste water?
- How to reduce nitrogen in municipal waste water?
  - -Nitrification in municipal waste water
  - - Denitrification in municipal waste water
- The operation principle of DynaSand for Nitrification & Denitrification of Municipal WWT
- Examples & experiences from municipal using DynaSand Oxy & DynaSand Deni for WWT

# Why is nitrogen treated in municipal waste water?

- Nitrogen is a elementary nutrient
- Often a limiting factor in marine environment

↓

Large biological production (Algea blooms )

↓

Large decomposion ($O_2$-shortage)

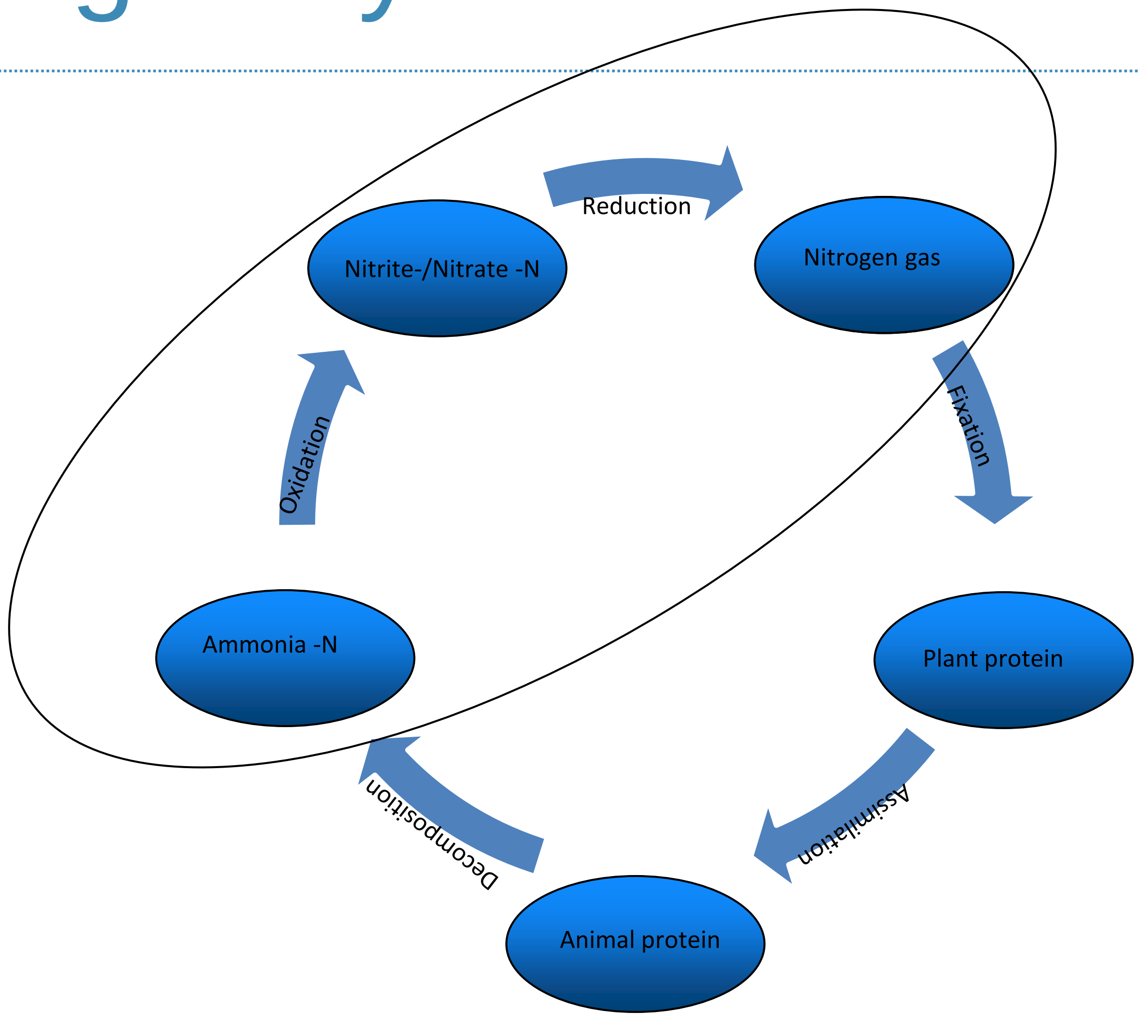
↓

Oxygen free coastal zone ($H_2S$-formation)

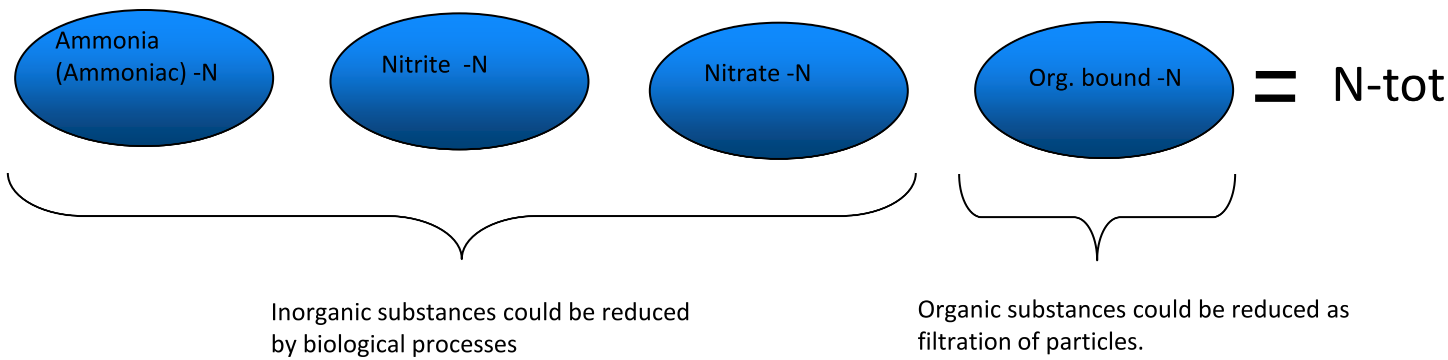
} Acc. to Nitrogen cycle

Thereof the necessity to limit the effluent of Nitrogen from industrial & municipal waste water

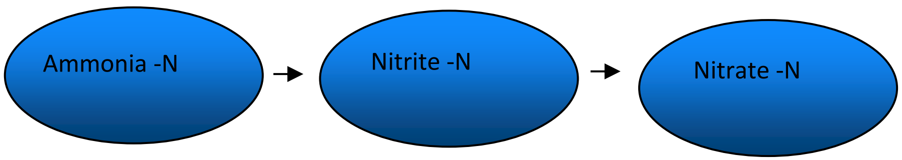
# Nitrogen cycle



# Nitrogen forms in municipal waste water



# Nitrification




$NH_4^+$ $NO_2^-$ $NO_3^-$

Is done in two steps of two types of bacteria groups:

Nitroso- bacterias: $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$

**Nitro- bacterias:** $2NO_2^- + 3O_2 \rightarrow 2NO_3^- + 2H_2O$

4,3 gram $O_2$ is consumed when 1 grams of $NH_4^+$ is oxidized to 1 gram $NO_3^-$

# Nitrification speed / reactivity

Expressed as:
Kg converted $NH_{4+}$ / m3 filter media, day

In municipal waste waters are the reactivity $NH_{4+}$ in the range of:
0,3 -1,2 kg/m3, day

In municipal waste waters are the reactivity BOD in the range of:
1 - 2 kg/m3, day

Reactivity = f [ Systemparameters , Equipment parameters]

# Reactivity

Reactivity = f [ Systemparameters , Equipmentparameters ]

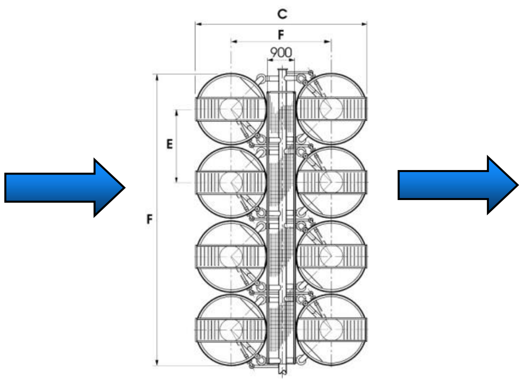
Systemparameters:

- Inlet flow (m3/h)
- Inlet concentrations (mg/l)
- Outlet concentrations (mg/l)
- Temperature ( *C )
- pH

Equipmentparameters:

- Type of processequipment (DynaSand)
- Surface loading rate (m/tim)
- Bed depth, (volume)
- Type of media
- Adjustments as: -Air (Oxygen)
  -Sand sinking speed
  -etc

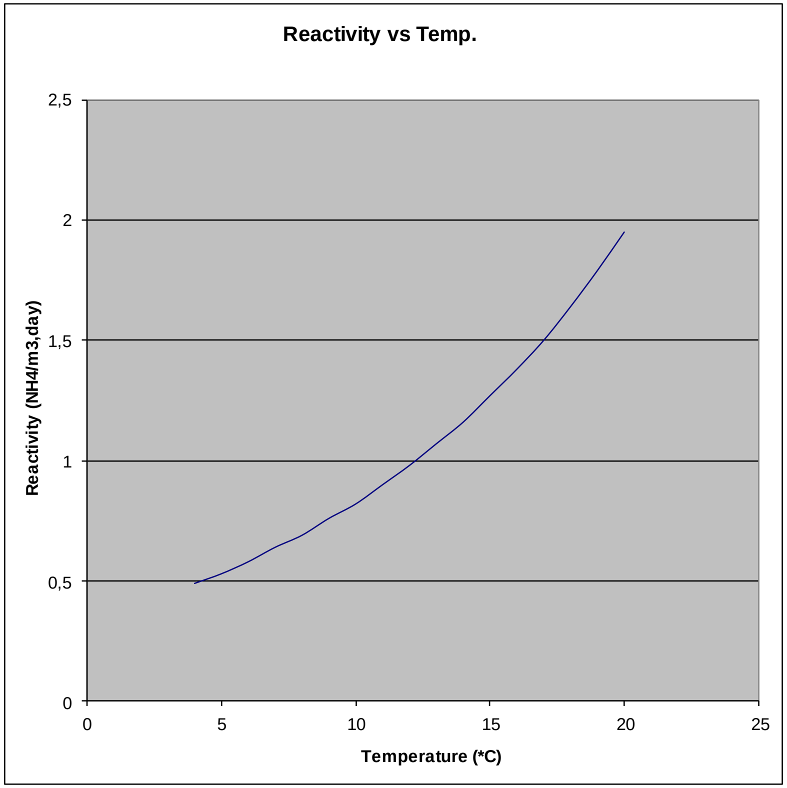
# Correlation between the system- & equipment parameters and the reactivity




Surface loading rate (m/tim)

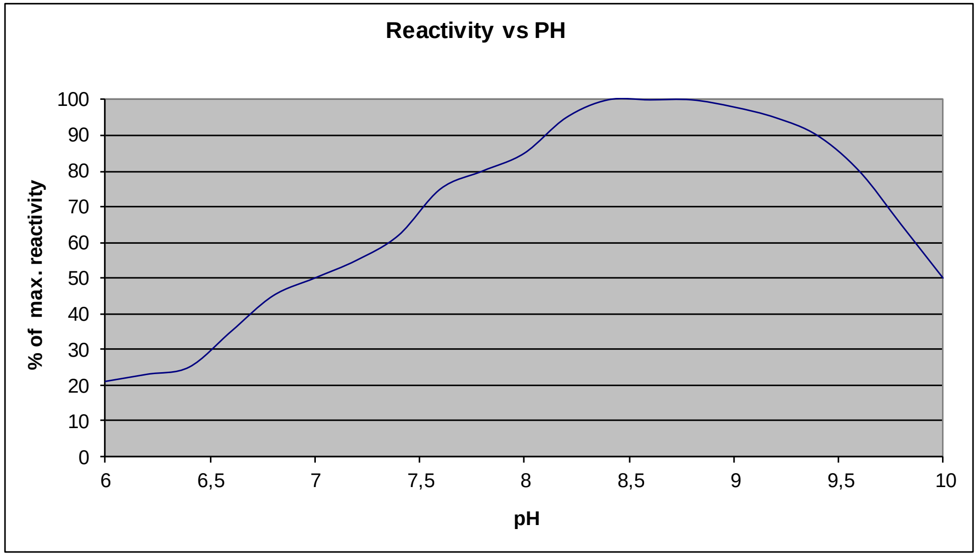
- Higher surface loading rate give a higher reactivity

# Correlation between the system- & equipment parameters and the reactivity




- Higher temperature give a higher reactivity

# Correlation between the system- & equipment parameters and the reactivity




- Normally gives a higher pH a higher reactivity

# Correlation between the system- & equipment parameters and the reactivity

Inlet concentrations of:

**BOD**

BOD / (COD) degraded of hetrotrophic bacterias which:
- Consume $O_2$
- Require filter media

**Until BOD is < 15-20 mg/l**

**$NH_4^+$**

High conc. of $NH_4^+$ gives a higher reactivity

**$O_2$**

Oxygen koncentration in the water should be kept > 3mg/l

**$HCO_3^-$**

Alcalinity decreases within the process → pH- decrease

**$PO_4^-$ -P**

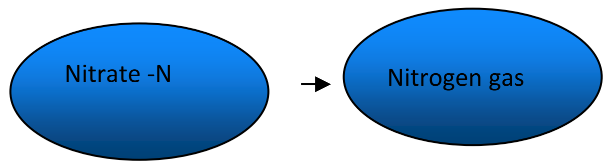
Halten bör överstiga > 0,3mg/l

# Correlation between the system- & equipment parameters and the reactivity

The outlet concentrations are a design parameter for the selection of the equipment parameters:

- Type of process equipment (DynaSand)
- Surface loading rate (m/h)
- Bed depth (volume)
- Type of media
- Adjustments
  - -Air (Oxygen)
  - -Sand sinking speed
  - -etc

# Denitrification




$NO_{3-}$ $N_2$

Denitrification bacterias prefer using $O_2$ as energy instead of $NO_{3-}$ :
-that´s why the $O_2$ concentration have to be very low

$$NO_{3-} \quad + \quad H_{+} \quad + \quad \text{Org. Subs.} \quad \longrightarrow \quad N_2 \quad + \quad HCO_{3-}$$

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# Denitrification speed / reactivity

Expressed as:
Kg converted $NO_{3-}$ / m3 filter media, day

In municipal waste waters are the reactivity in $NO_{3-}$ the range of:
0,5 -2 kg/m3, day

Reactivity = f [ Systemparameters , Equipment parameters]

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# Reactivity

Reactivity = f [ Systemparameters , Equipment parameters]

Systemparameters:

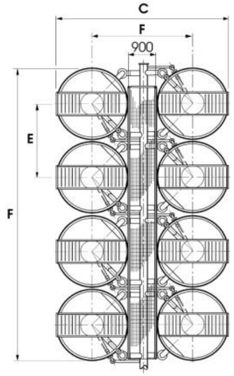
- Inlet flow (m3/h)
- Inlet concentrations (mg/l)
- Outlet concentrations (mg/l)
- Temperature ( *C )
- pH
- Type of carbon source

Equipment parameters:

- Type of process equipment (DynaSand)
- Surface loading rate (m/h)
- Bed depth, (volume)
- Type of media
- Adjustments -Sand sinking speed.
  -etc

# Correlation between the system- & equipment parameters and the reactivity

Inlet flow (m3/h)




Surface loading rate (m/h)

- Higher surface loading rate gives a higher reactivity

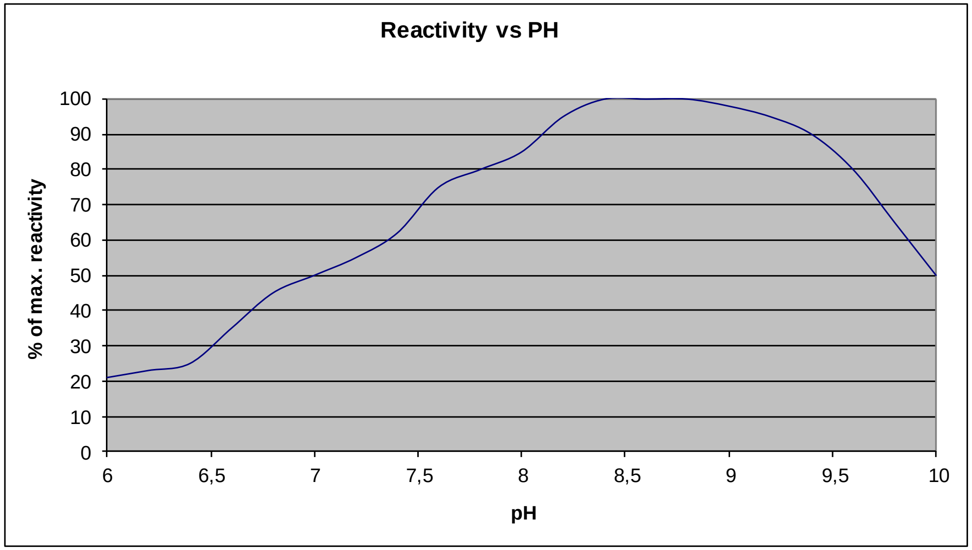
↓

- But the outlet SS is often a limiting factor

↓

- Often relatively low surface loading rate (8-12 m/h)

# Correlation between the system- & equipment parameters and the reactivity




- Normally a higher pH gives a higher reactivity also for denitrification

# Correlation between the system- & equipment parameters and the reactivity

Inlet concentrations of:

$NO_3^-$ — High concentrations of $NO_3^-$ give a higher reactivity

$O_2$ — Oxygen concentrations should be kept < 3mg/l

$HCO_3^-$ — Alcalinity will increase within the process → pH-increase

$PO_4^-$-P

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# Correlation between the system- & equipment parameters and the reactivity

## Inlet concentrations of:

Org. Material
BOD

Natural Organic Material (NOM) in the inlet water could be used:
- Which lead to a saving in the external carbon source

External
carbon source

External carbon source in addition to NOM increase the reactivity
Common external carbon sources are: Metanol, Etanol etc
-The reactivity between them varies

→

- But they cost quite a bit!
- Could lead to higher COD in outlet

$O_2$

To reduce 1 gram of $NO_3^-$ approx , 3 gram of carbon source is required

For every mg/l $O_2$ in the inlet 1,2 mg/l extra carbon source is required

$HCO_3^-$

# Correlation between the system- & equipment parameters and the reactivity

The outlet concentrations are a design parameter for the selection of the equipment parameters:

- Type of process equipment (DynaSand)
- Surface loading rate (m/h)
- Bed depth, (volume)
- Type of media
- Adjustments -Sand sinking speed.
  -Oxygen in inlet, etc
- Carbon souce

# DynaSand-filter history

The first DynaSand filter is tested at municipal waste water in august 1978:

The first DynaSand filter is installed at surface treatment  industry in 1979:

The first intensive pilot tests with nitrogen reduction were performed at Louddens WWTP in Sweden 1985:

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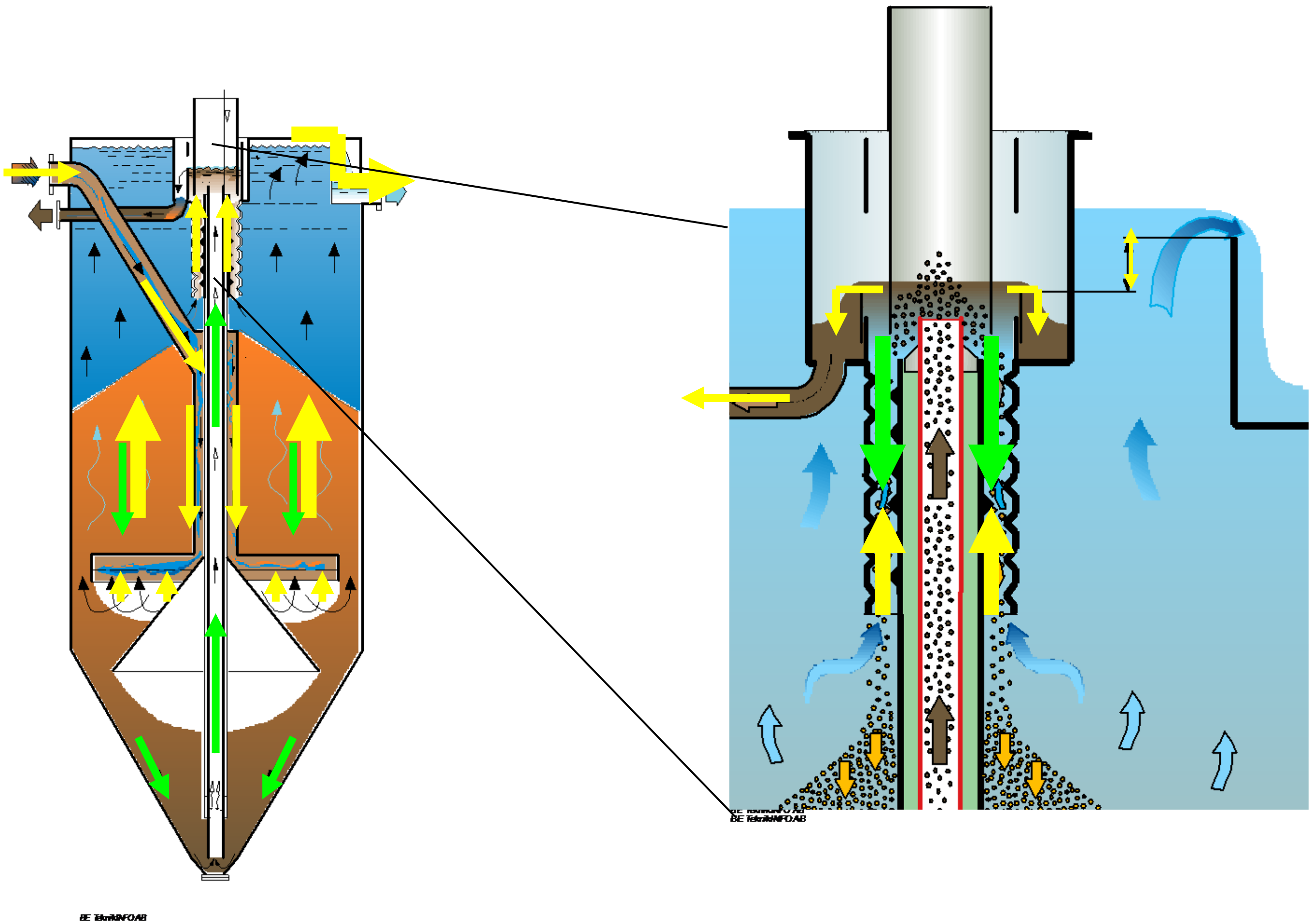
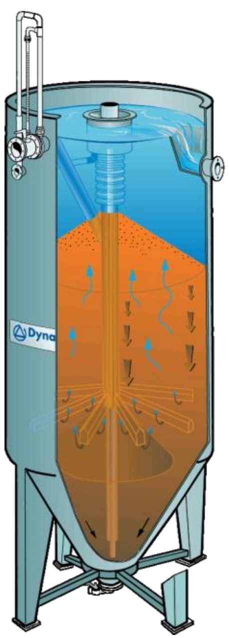
# Flow of water and sand



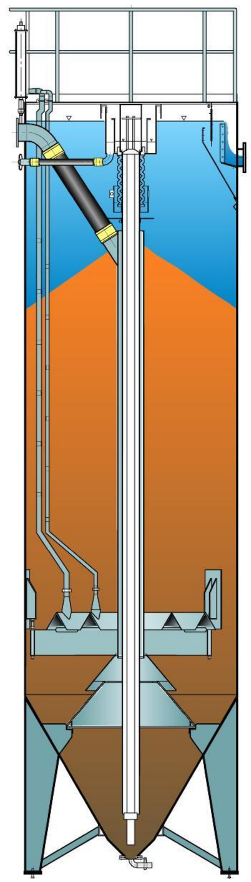
# DynaSand vs DynaSand Oxy and Deni

Filter bed height is higher

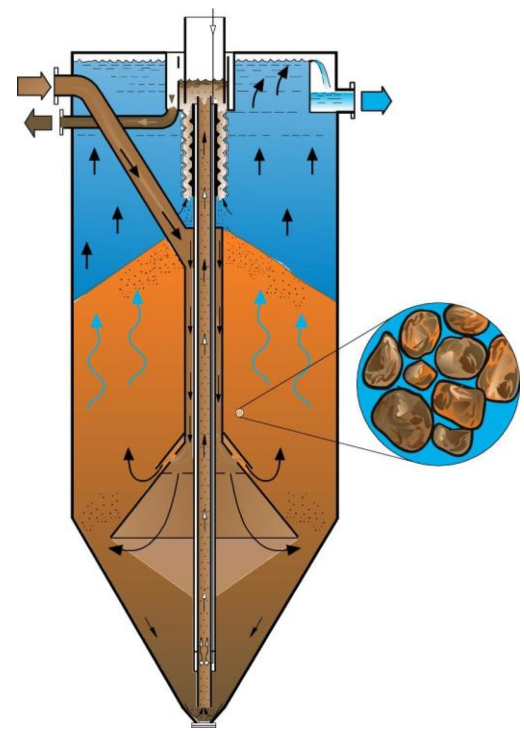
Filter material –Basalt/Sand



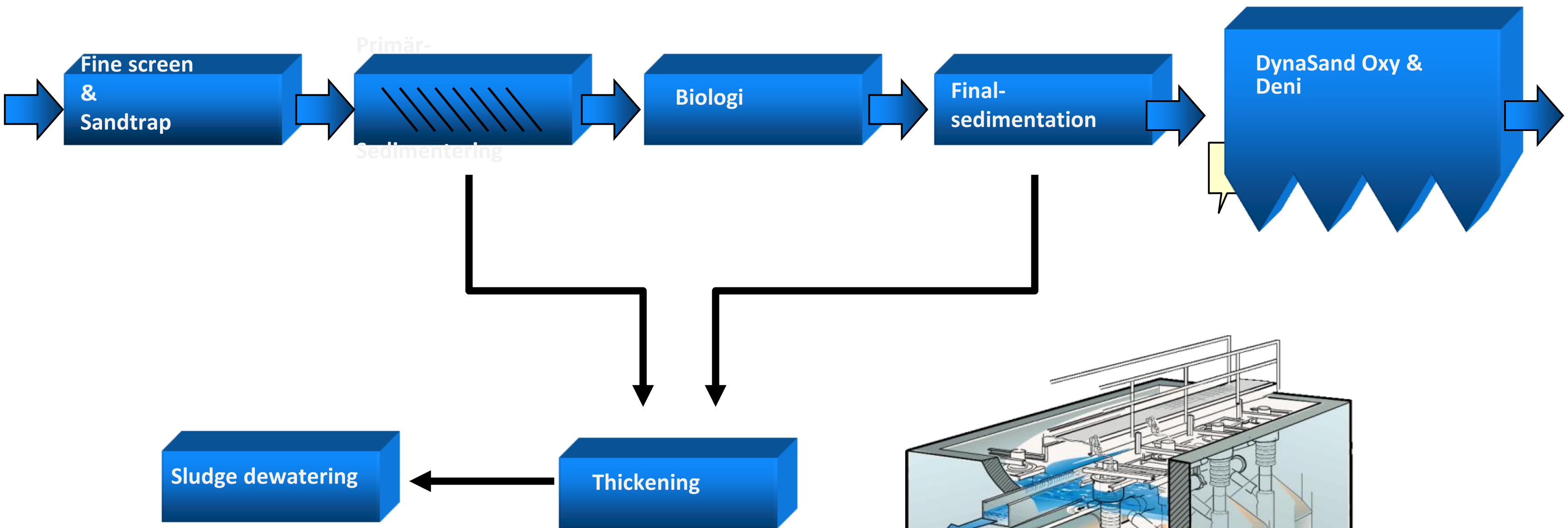
DynaSand

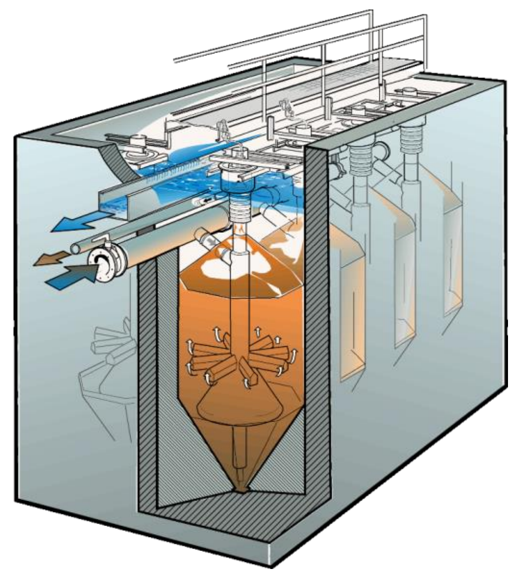


DynaSand Oxy & Deni

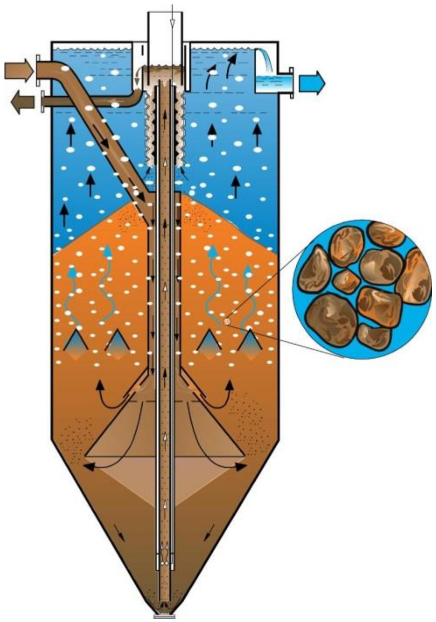


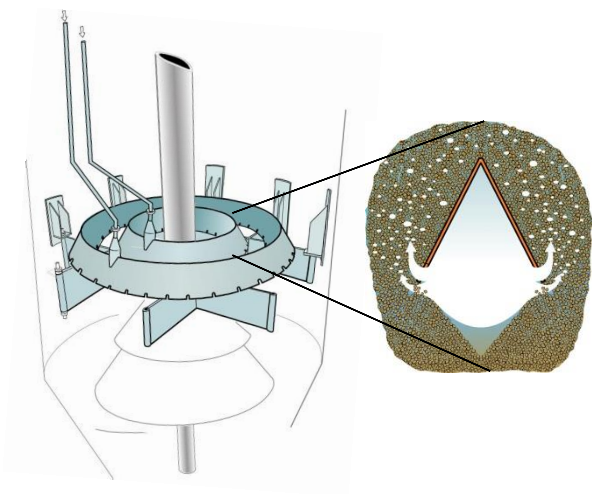
# Where on a WWTP should DynaSand Oxy och Deni be installed?

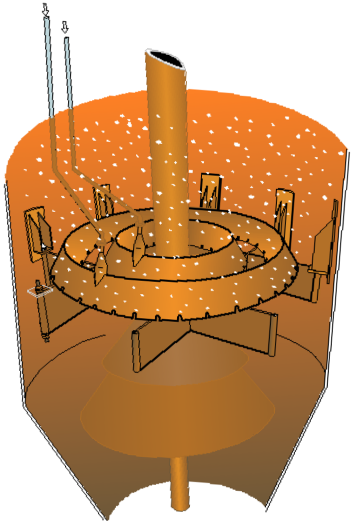


# DynaSand Oxy – for nitrification & BOD-reduction



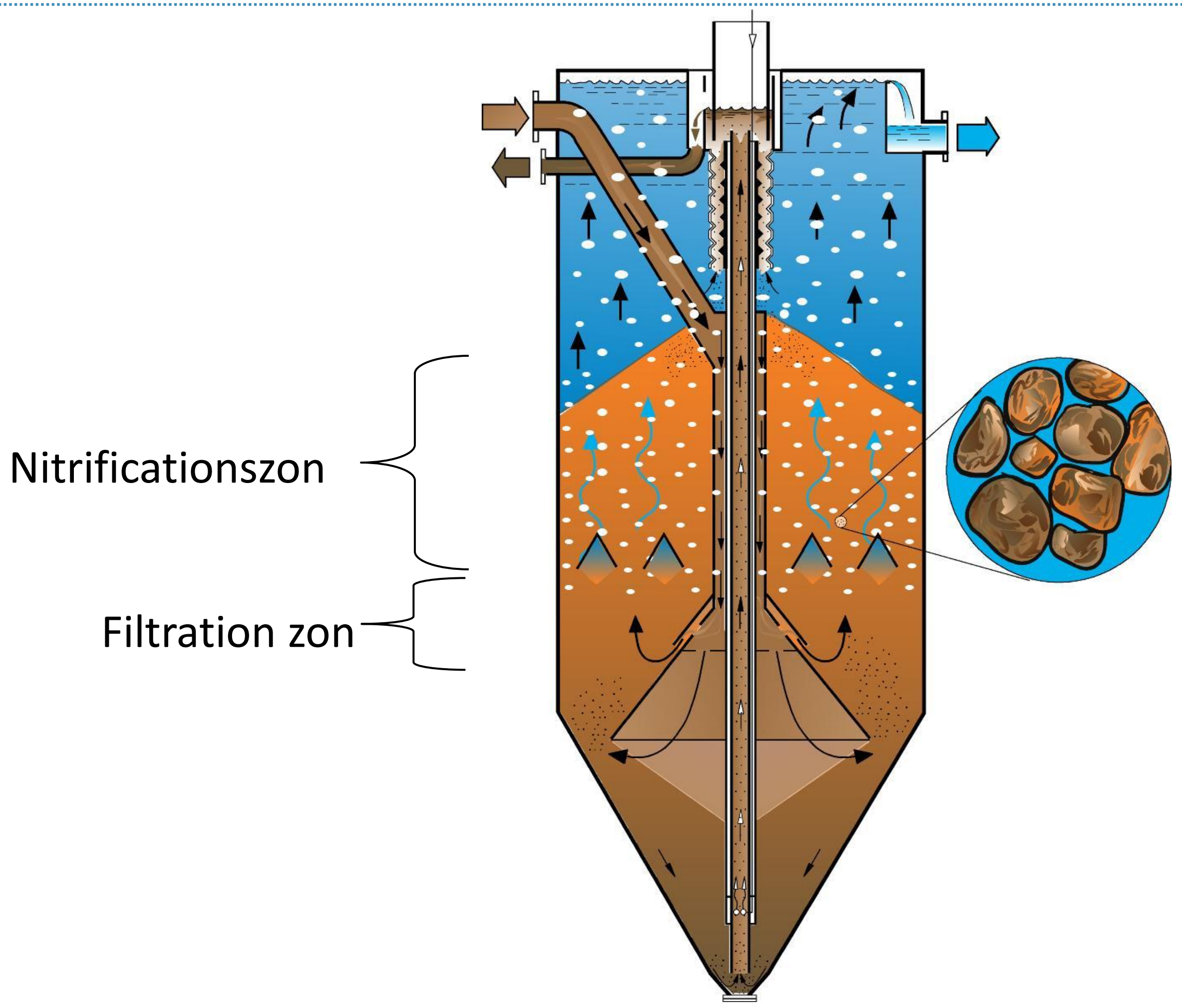




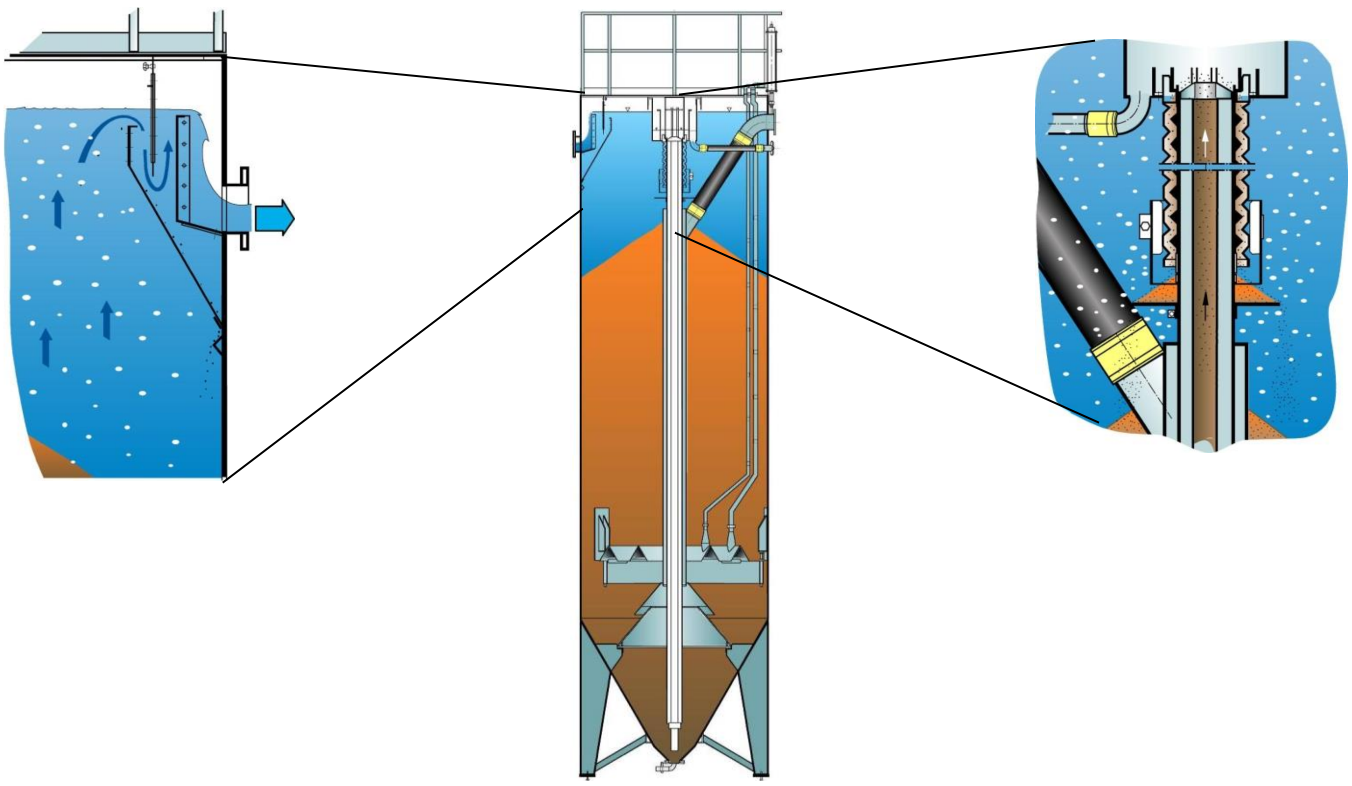
Air Supply:

- Air lift pump
  - 1,6-5 bar
  - On/Off regulation
- Process air
  - 1-2 bar
  - On, On/Off regulation

# DynaSand Oxy – for nitrification & BOD-reduction



# DynaSand Oxy – för nitrification & BOD-reduction



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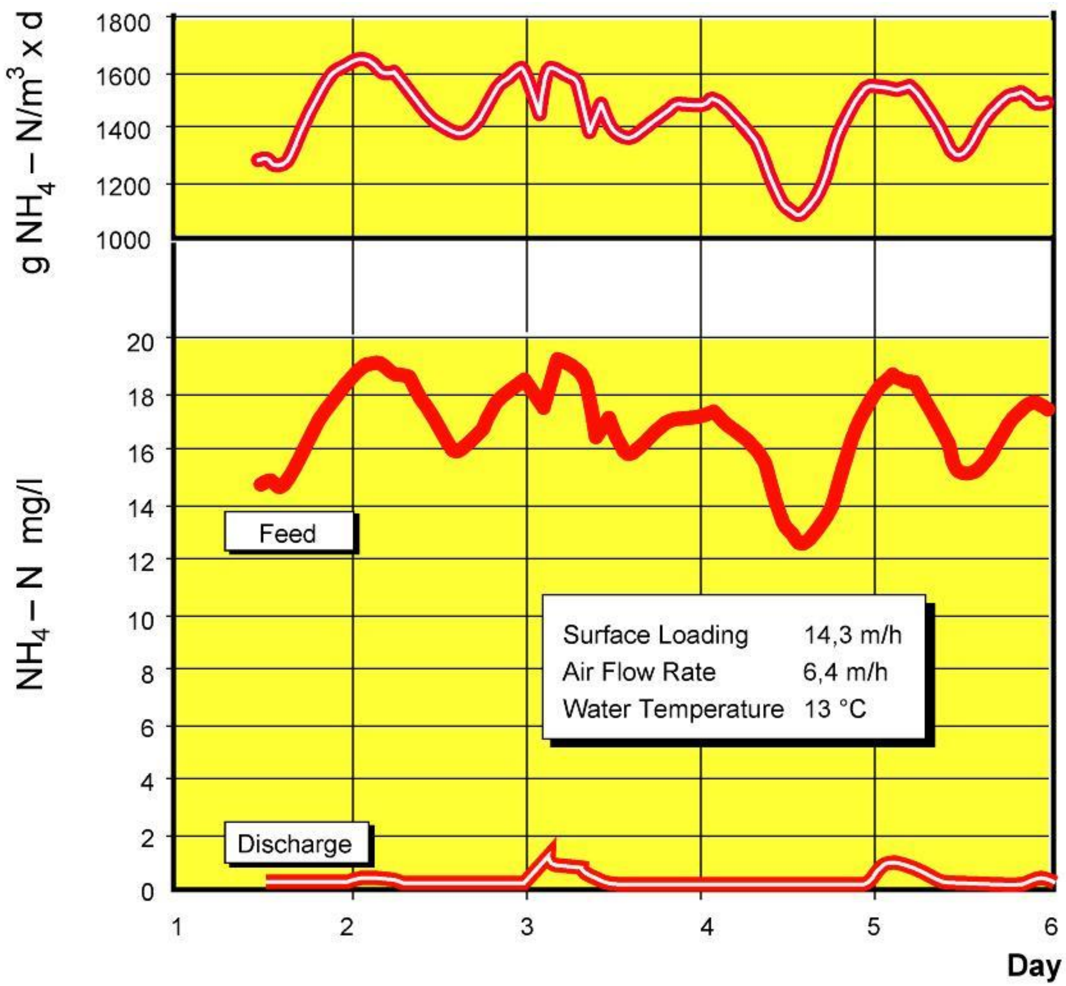
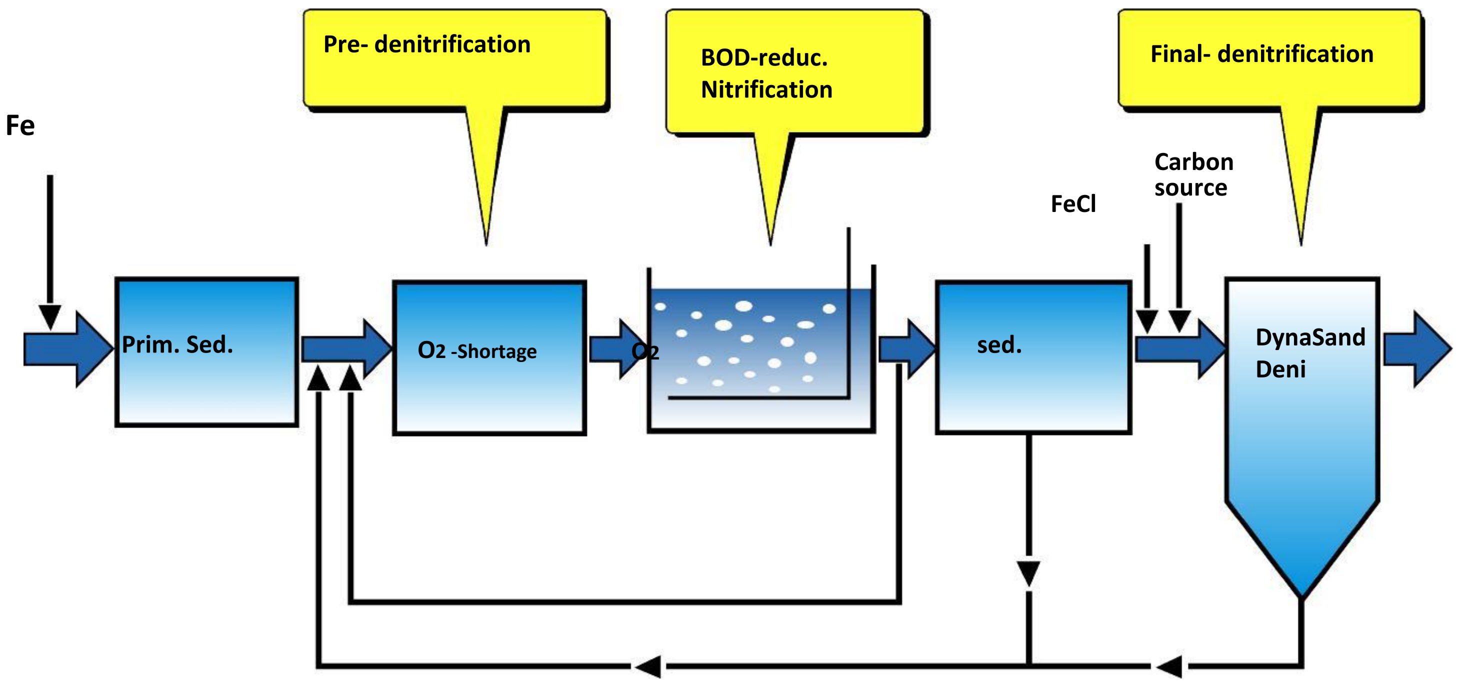
# DynaSand Oxy – for nitrification & BOD-reduction

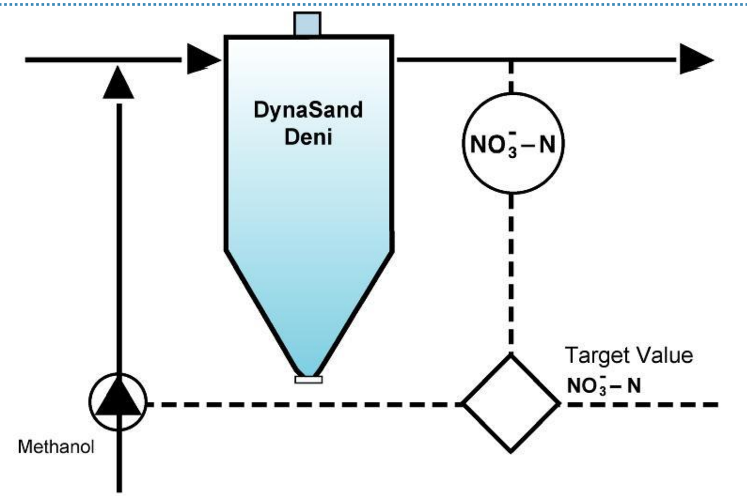
Typical values
-Nitrification

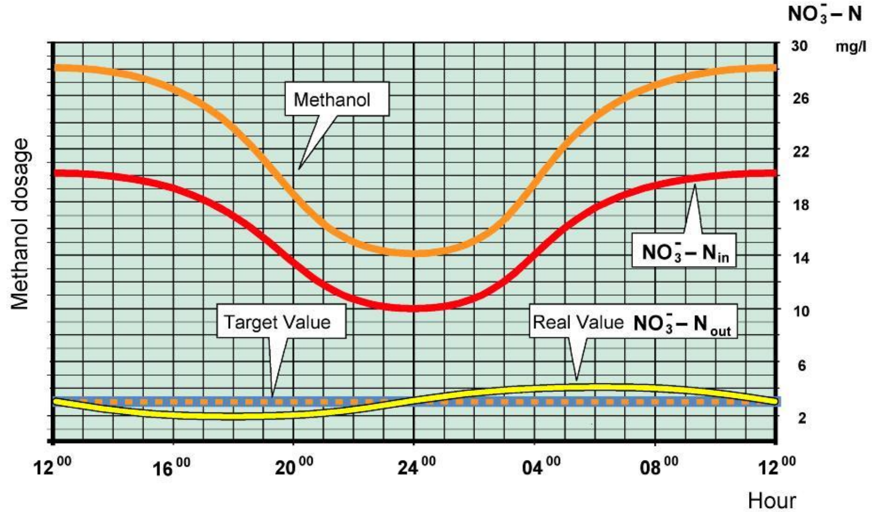


# DynaSand Deni – denitrification & koagulation for phosphorus reduction



# Control of dosage of external carbon source



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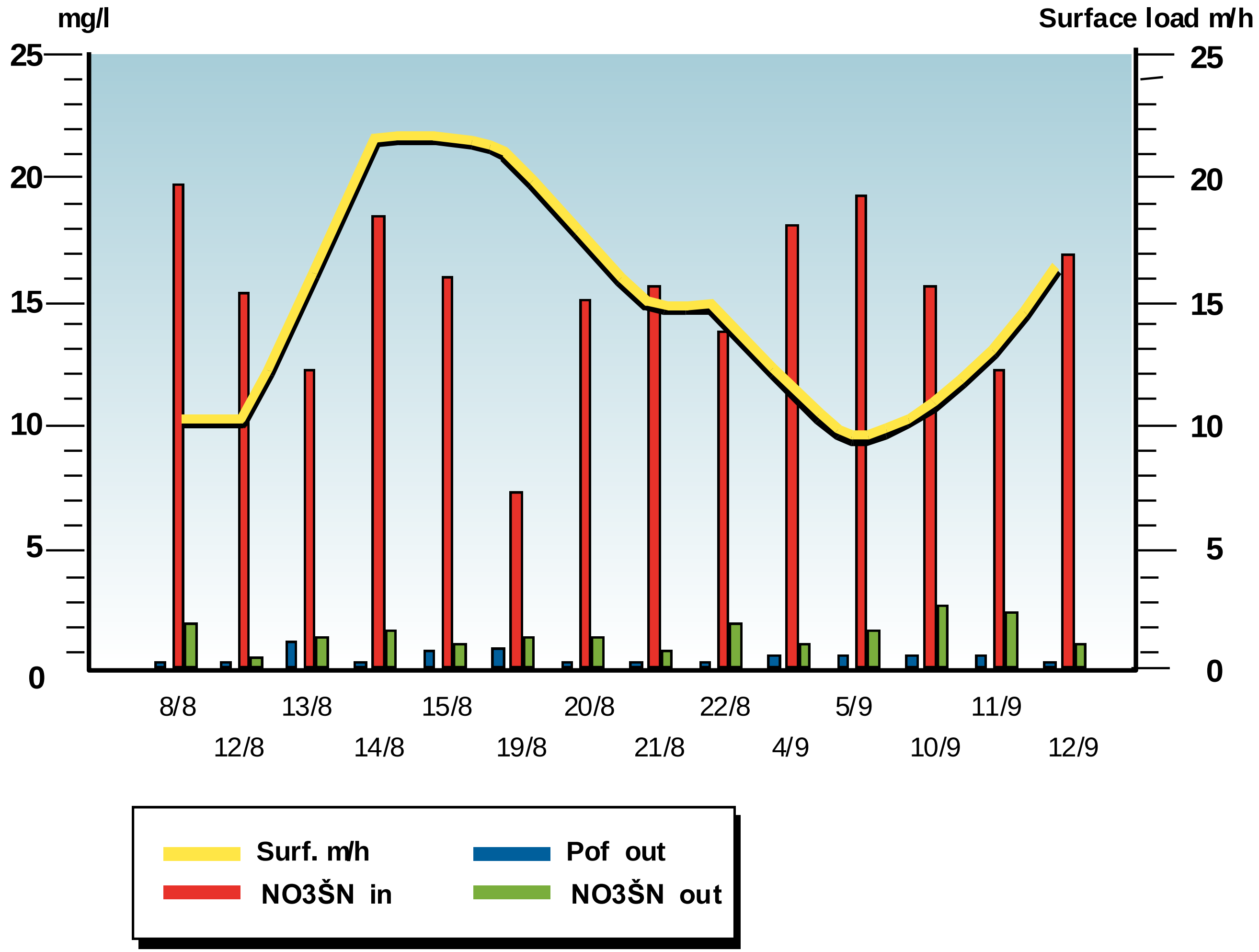
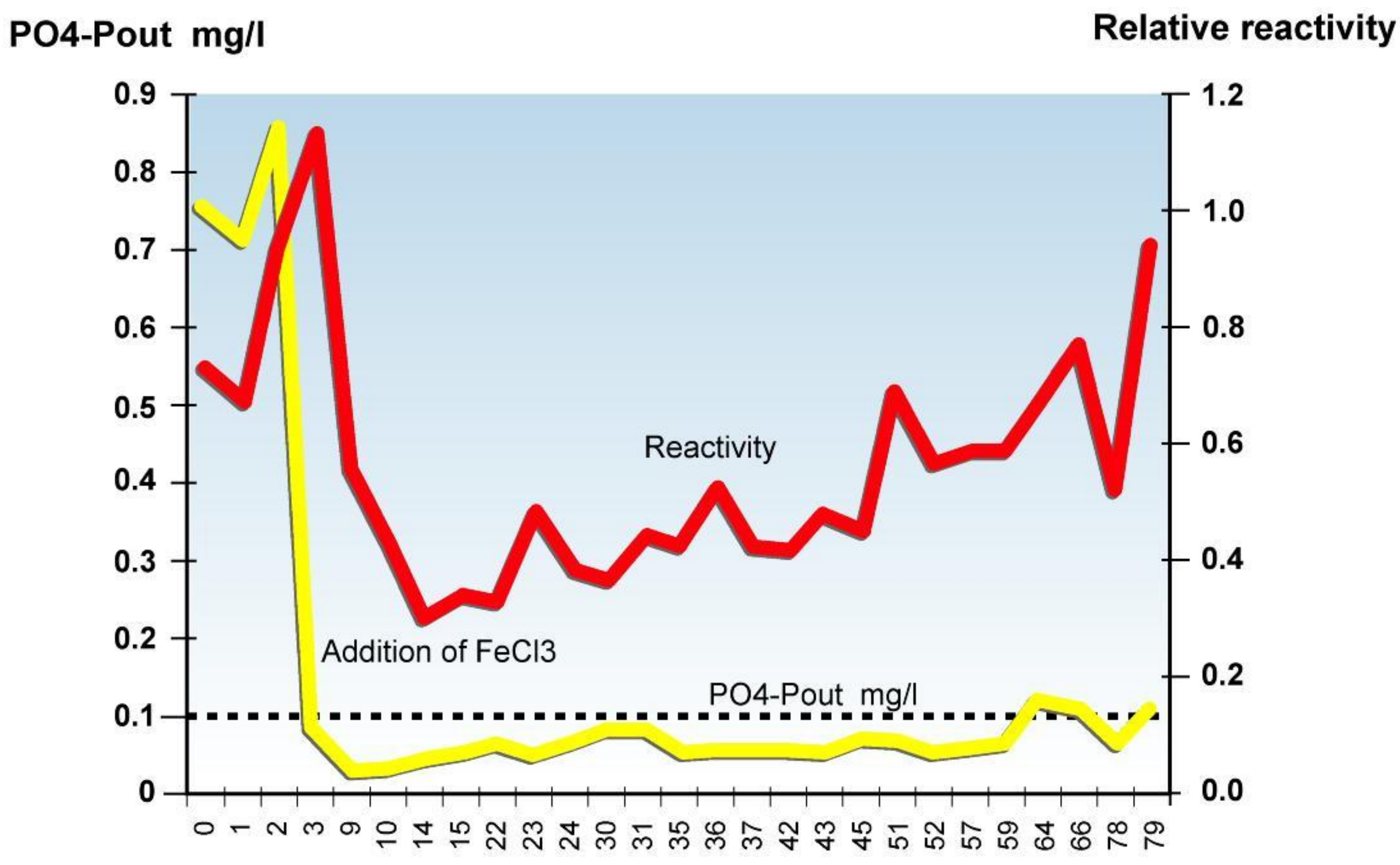
# Denitrification & Phosphorous reduction



# Denitrification & phosphorus reduction



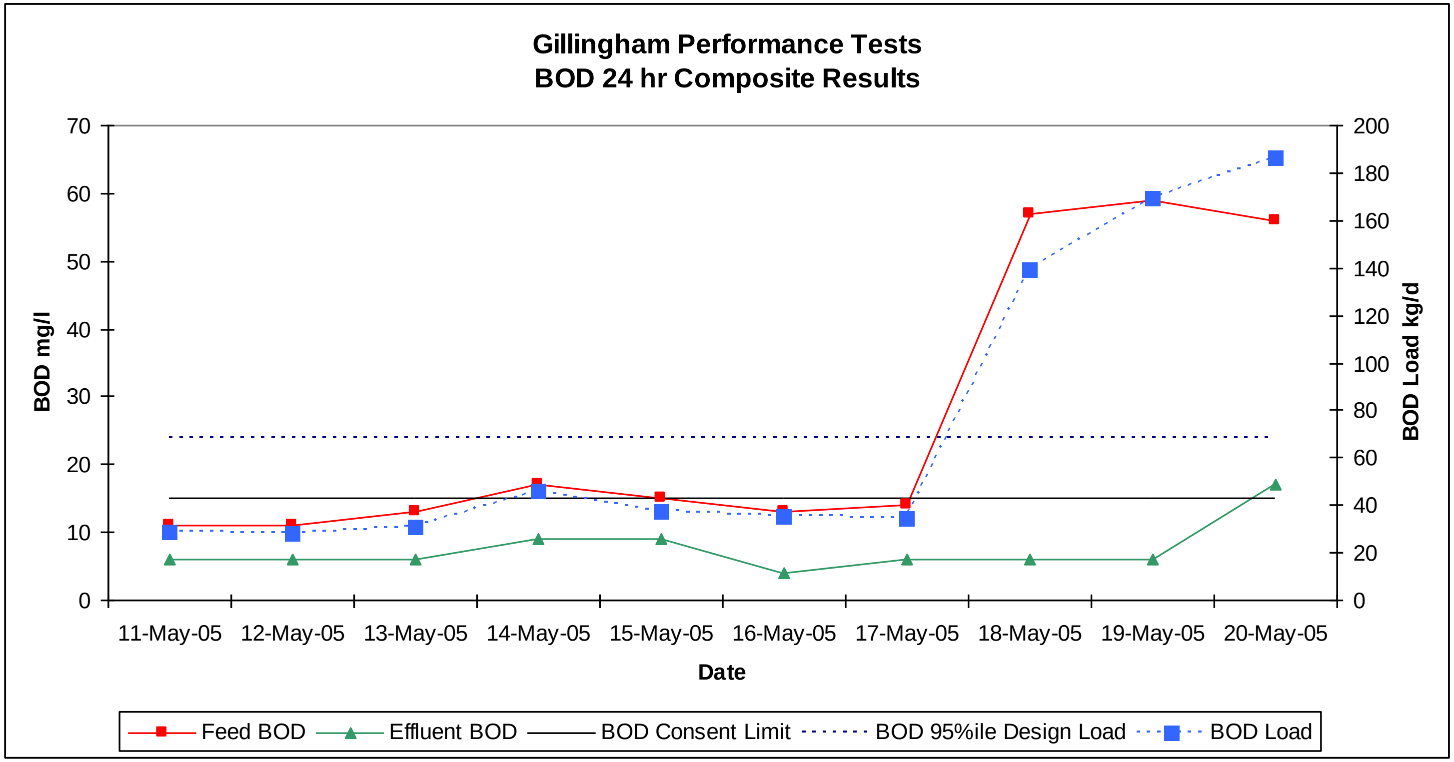
# Case Story - Gillingham

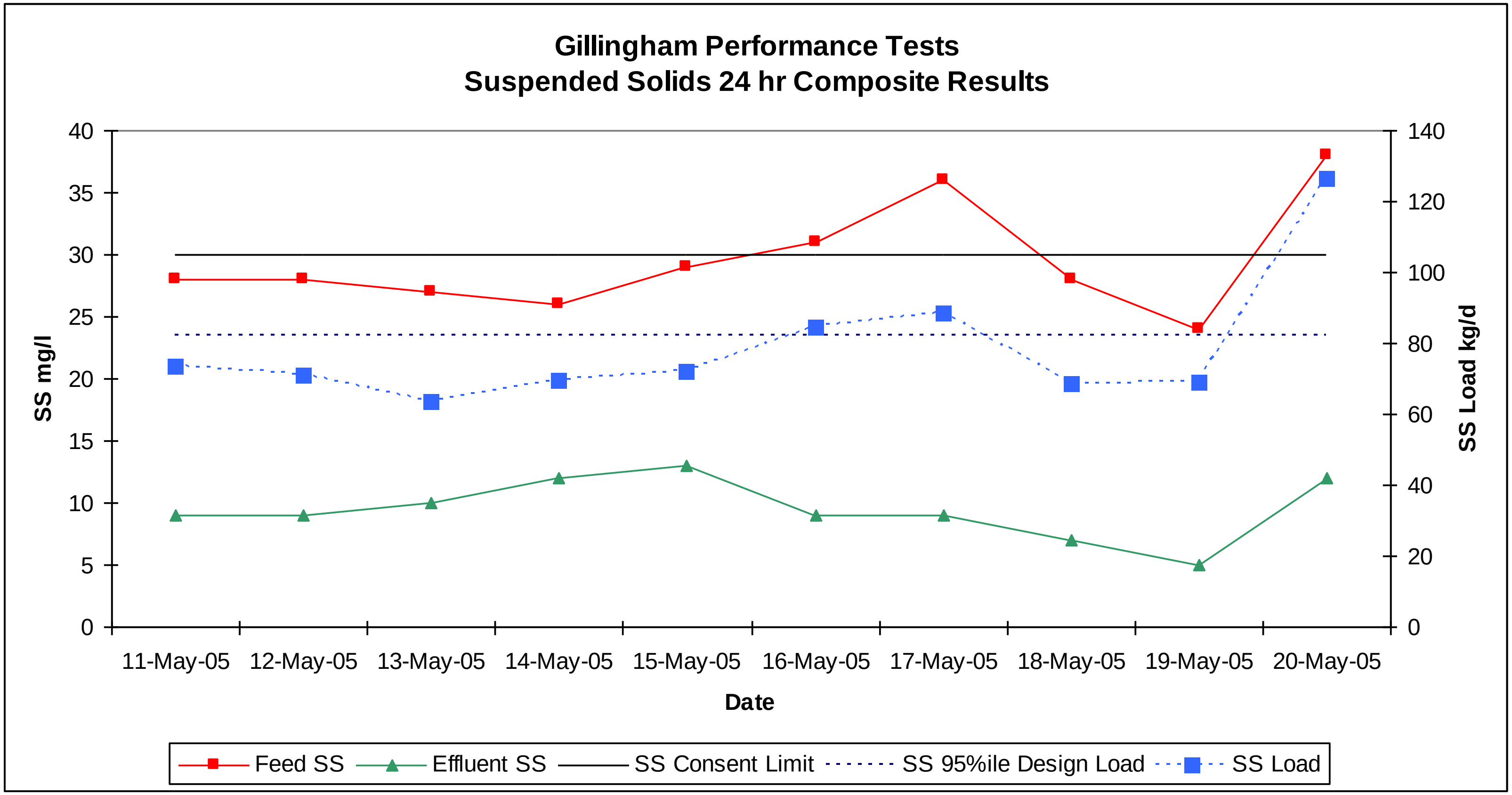
- Designflow 76 l/s (273 m3/h), Average flow: 32 l/s (115 m3/h)
- Inlet conc:  25:30:17 95%ile (BOD:TSS:Amm)
- Outlet demand:  15:30:8 95%ile (BOD:TSS:Amm)
- Should be able to treat average flow when one filter is out of operation
- Should be able to meet outlet demand down to 5ºC
- Nordic water design:  – 4 st DS5000 Oxy 5.0

# Case Story - Gillingham

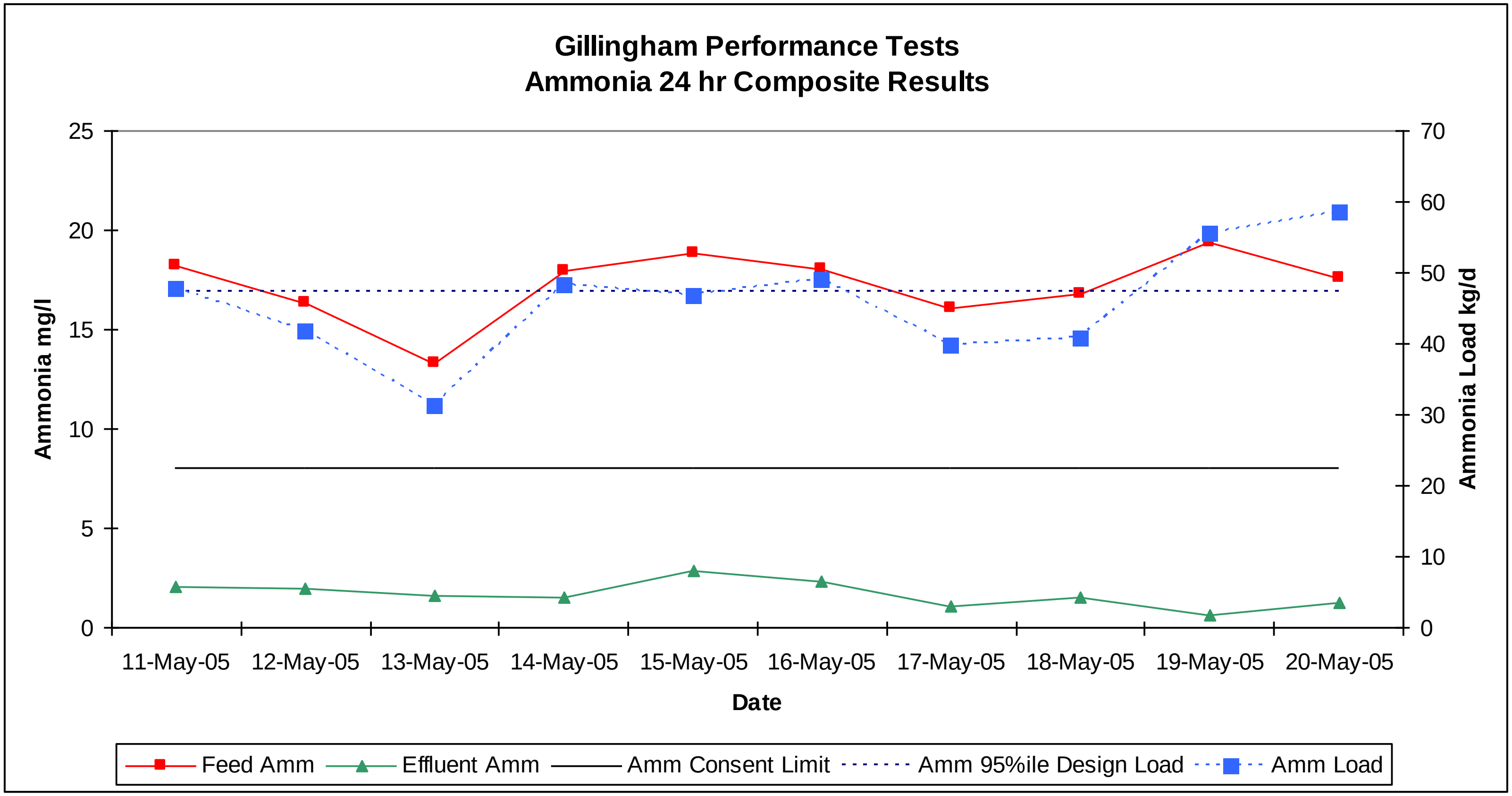
**Preformance test should be made and following tests were preformed:**

- 10 day preformence test during Qdim
- Ammonia peak at max.flow (FFT)
- Ammonia peak at min. flow (DWF)
- Hydaulic test at max. flow with one filter out of operation


Gillingham Performance Tests
BOD 24 hr Composite Results
BOD mg/l
BOD Load kg/d
Date
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
200
11-May-05
12-May-05
13-May-05
14-May-05
15-May-05
16-May-05
17-May-05
18-May-05
19-May-05
20-May-05
Feed BOD
Effluent BOD
BOD Consent Limit
BOD 95%ile Design Load
BOD Load



Gillingham Performance Tests
Suspended Solids 24 hr Composite Results
SS mg/l
SS Load kg/d
Date
11-May-05
12-May-05
13-May-05
14-May-05
15-May-05
16-May-05
17-May-05
18-May-05
19-May-05
20-May-05
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120
140
Feed SS
Effluent SS
SS Consent Limit
SS 95%ile Design Load
SS Load

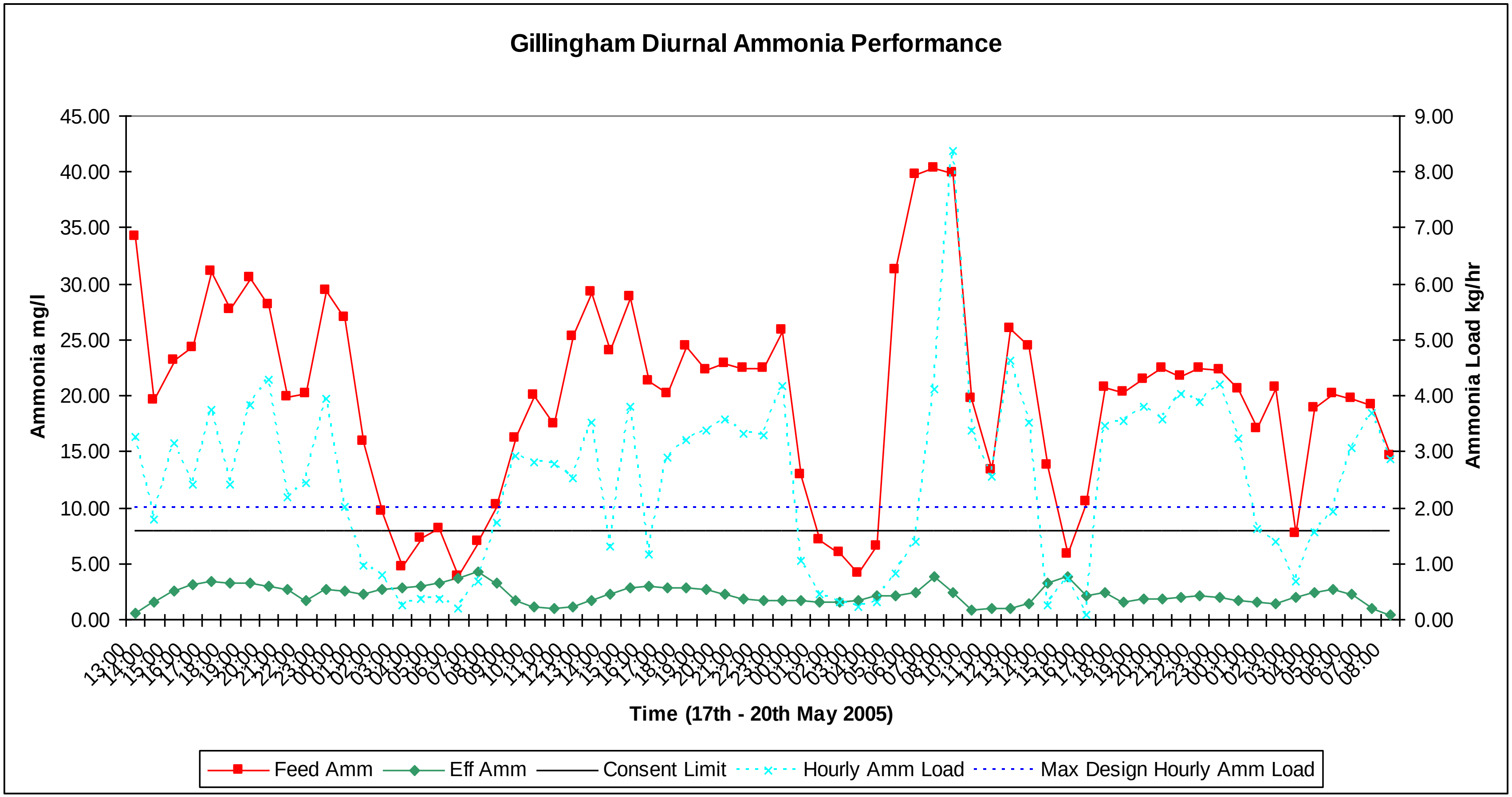

Gillingham Performance Tests
Ammonia 24 hr Composite Results
Ammonia mg/l
Ammonia Load kg/d
25
20
15
10
5
0
70
60
50
40
30
20
10
0
11-May-05
12-May-05
13-May-05
14-May-05
15-May-05
16-May-05
17-May-05
18-May-05
19-May-05
20-May-05
Date
Feed Amm
Effluent Amm
Amm Consent Limit
Amm 95%ile Design Load
Amm Load

# 10 day performance test

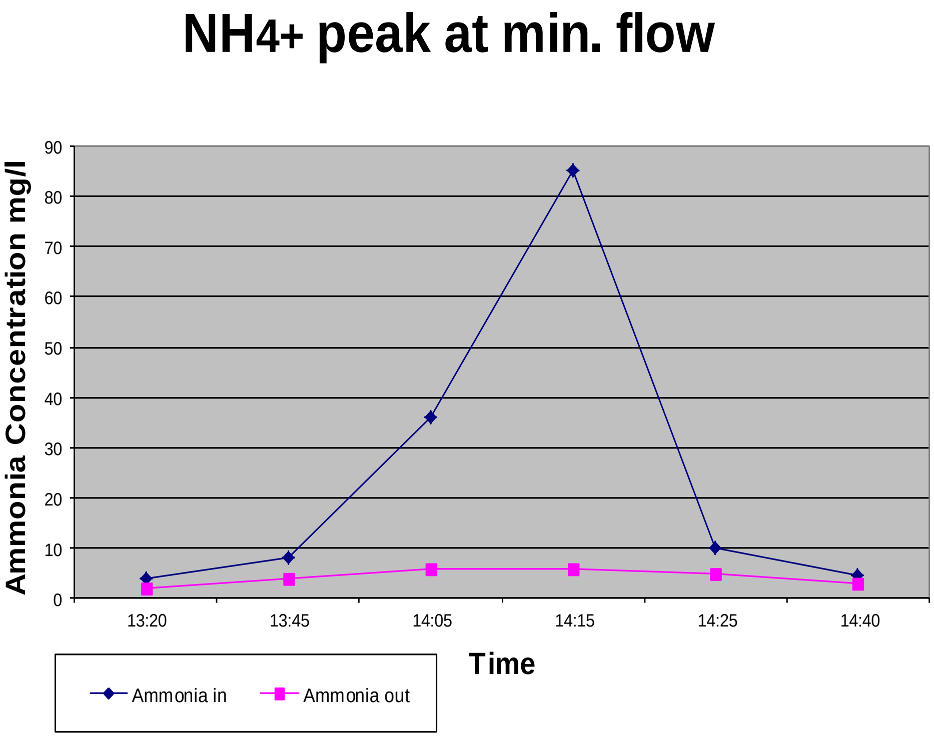
## Result – average values

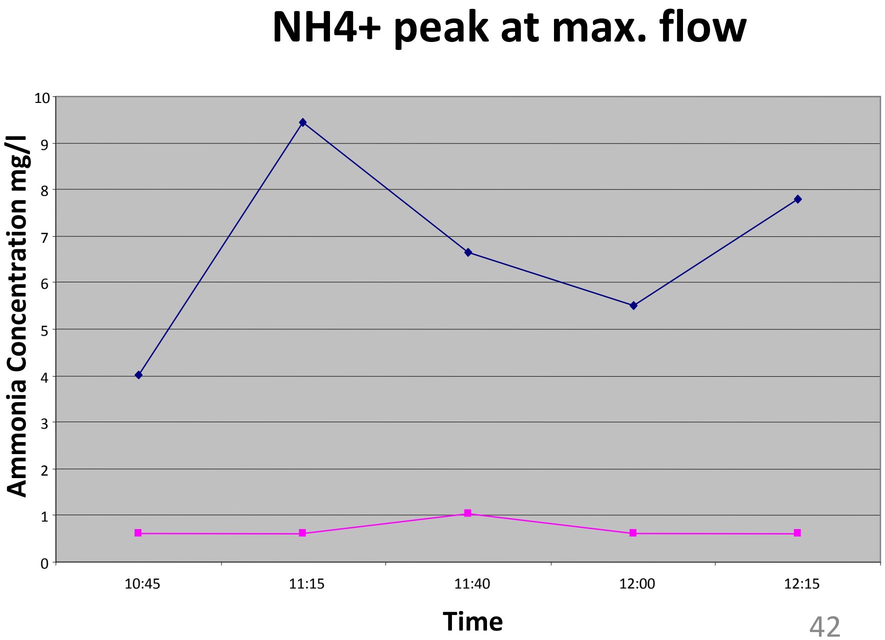
| | BOD mg/l | SS mg/l | NH4+ mg/l |
|---|---|---|---|
| Design 95%ile | 25 | 30 | 17 |
| Inlet average: | 26.6 | 29.5 | 17.2 |
| Outlet average: | 7.5 | 9.5 | 1.69 |
| Outlet demand: | 15 | 30 | 8 |

# Daily variations $NH_{4+}$



# $NH_{4+}$ peak


NH4+ peak at min. flow
Ammonia Concentration mg/l
90
80
70
60
50
40
30
20
10
0
13:20
13:45
14:05
14:15
14:25
14:40
Time
Ammonia in
Ammonia out


NH4+ peak at max. flow
Ammonia Concentration mg/l
10
9
8
7
6
5
4
3
2
1
0
10:45
11:15
11:40
12:00
12:15
Time

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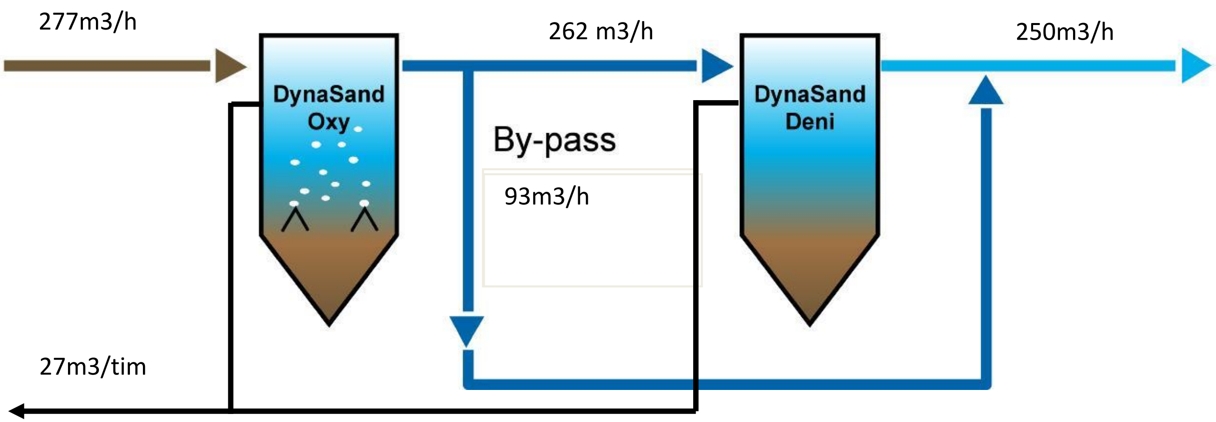
# Razeburg, Germany

- In operation since Dec -96
- Nitrification 3xDS5000Oxy 5.0
- Denitrification 4 x DS 5000 Deni 3.0
- Qmax : 250 m3/h
- Qmedel : 200 m3/h

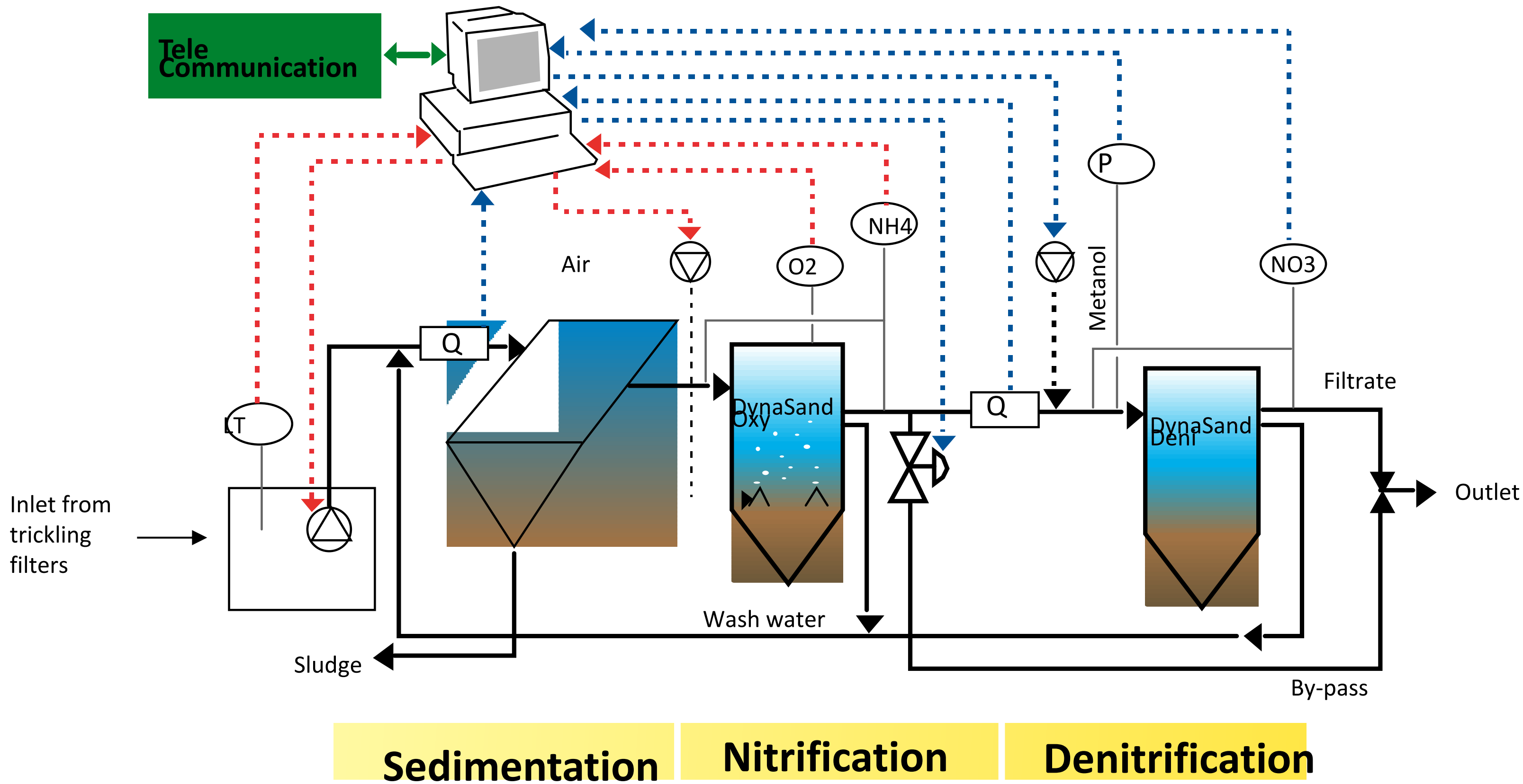


# Ratzeburg, Germany

- Nitrification
  - Filterarea 15 $m^2$
  - Filterbäd height 5 m
  - Bedmaterial
    - Basalt 1,4 - 2,5 mm
    - Sand sinking speed 8 mm/min
  - Wash water amount 15 $m^3/h$
  - Air requirment 200 $Nm^3/h$
  - $O_2$ - control 4 mg/l

- Denitrification (by-pass)
  - Filterarea 20 $m^2$
  - Filterbäd height 3 m
  - Bedmaterial
    - Basalt 1,0 - 1,6 mm
    - Sand sinking speed 8 mm/min
  - Wash water amount 12 $m^3/h$
    - Sandwasher type DST 30
  - External carbon source
    - Methanol
    - Nitrate control

# Ratzeburg, Germany



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# Ratzeburg, Germany

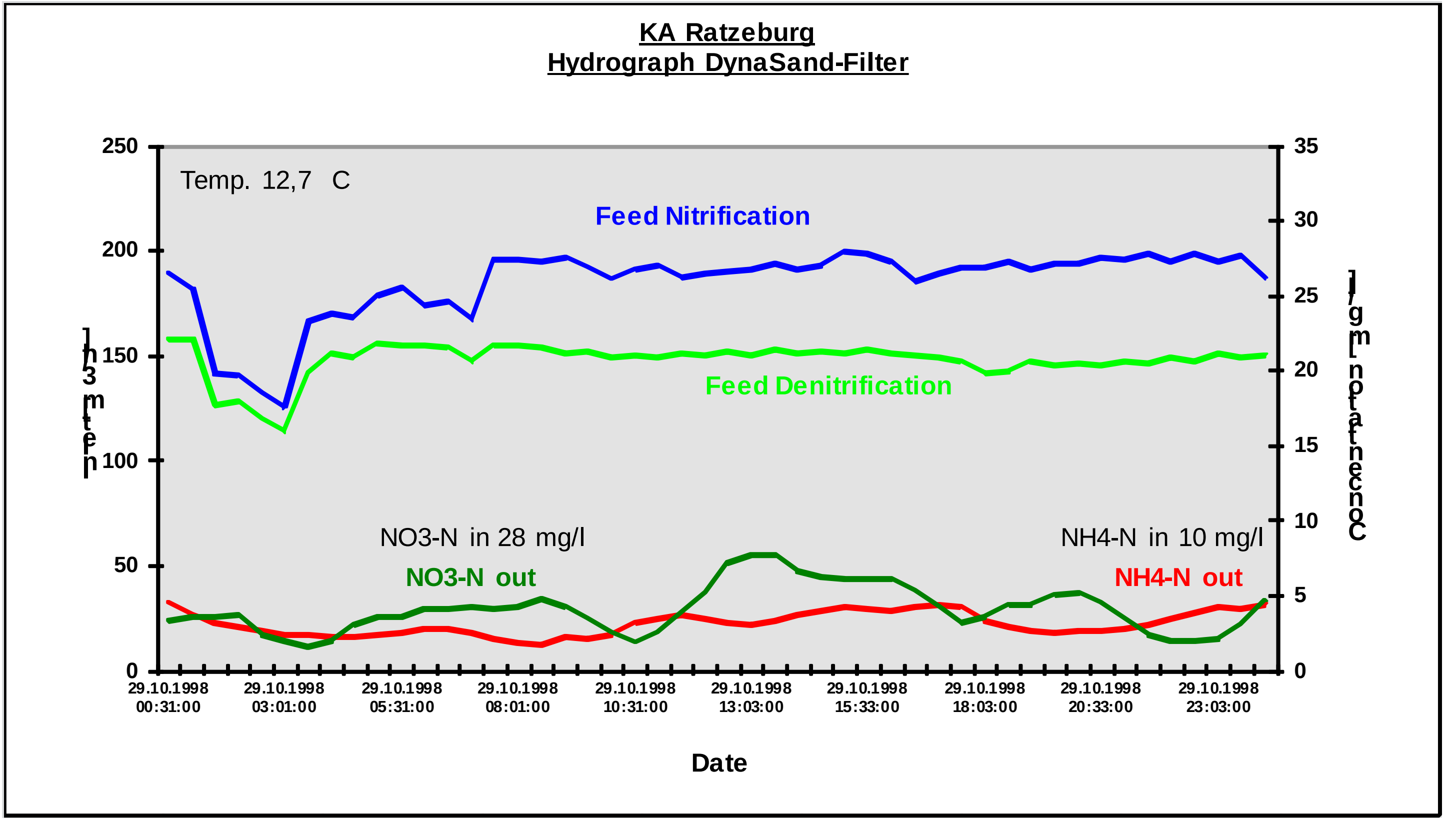
## Inlet values:

| | Design: | In operation: |
|---|---|---|
| – SS | 100 mg/l | 150 mg/l |
| – COD | 100 mg/l | 150 mg/l |
| – $BOB_5$ | 50 mg/l | 50 mg/l |
| – $NH_4$-N | 12 mg/l | 20 mg/l |
| – $NO_3$-N | 28 mg/l | 37 mg/l |
| – $N_{TOT}$ | 41 mg/l | |
| – $P_{TOT}$ | 1 mg/l | |

## Outlet values:

| | Design: | In operation: |
|---|---|---|
| – SS | 20 mg/l | 15 mg/l |
| – COD | 80 mg/l | 80 mg/l |
| – $BOB_5$ | 16 mg/l | 16 mg/l |
| – $NH_4$-N | 5 mg/l | 2 mg/l |
| – $NO_3$-N | 15 mg/l | 10 mg/l |
| – $N_{TOT}$ | 20 mg/l | |
| – $P_{TOT}$ | 1 mg/l | |

# Ratzeburg, Germany



# Thanks!

Nordic Water Products AB
www.nordicwater.com