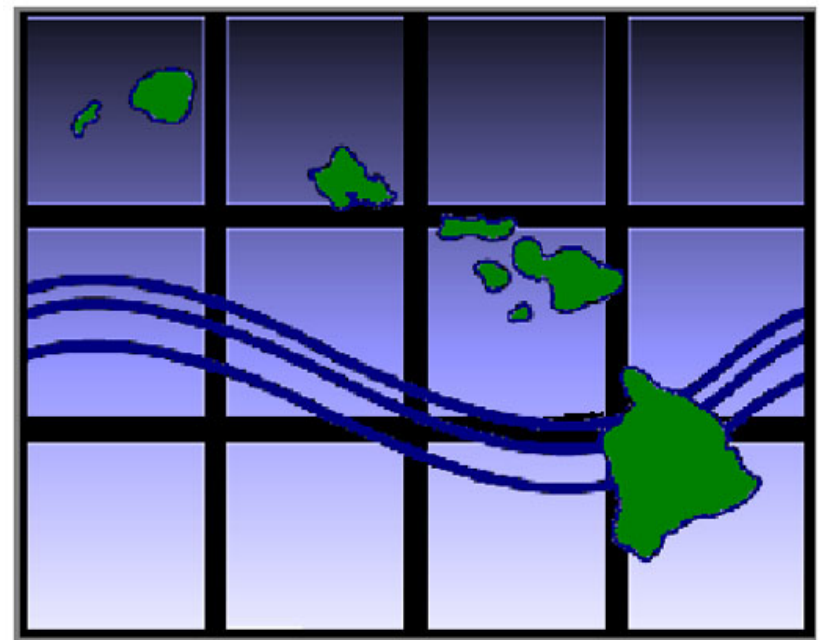


Putting the Misconceptions to Rest:

2010 HWEA Conference
Honolulu, HI

Brandy Nussbaum
I. Kruger, Inc



**HAWAII WATER ENVIRONMENT
ASSOCIATION • SINCE 1962**
P.O. Box 2422 • Honolulu, Hawai'i 96804
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KRÜGER



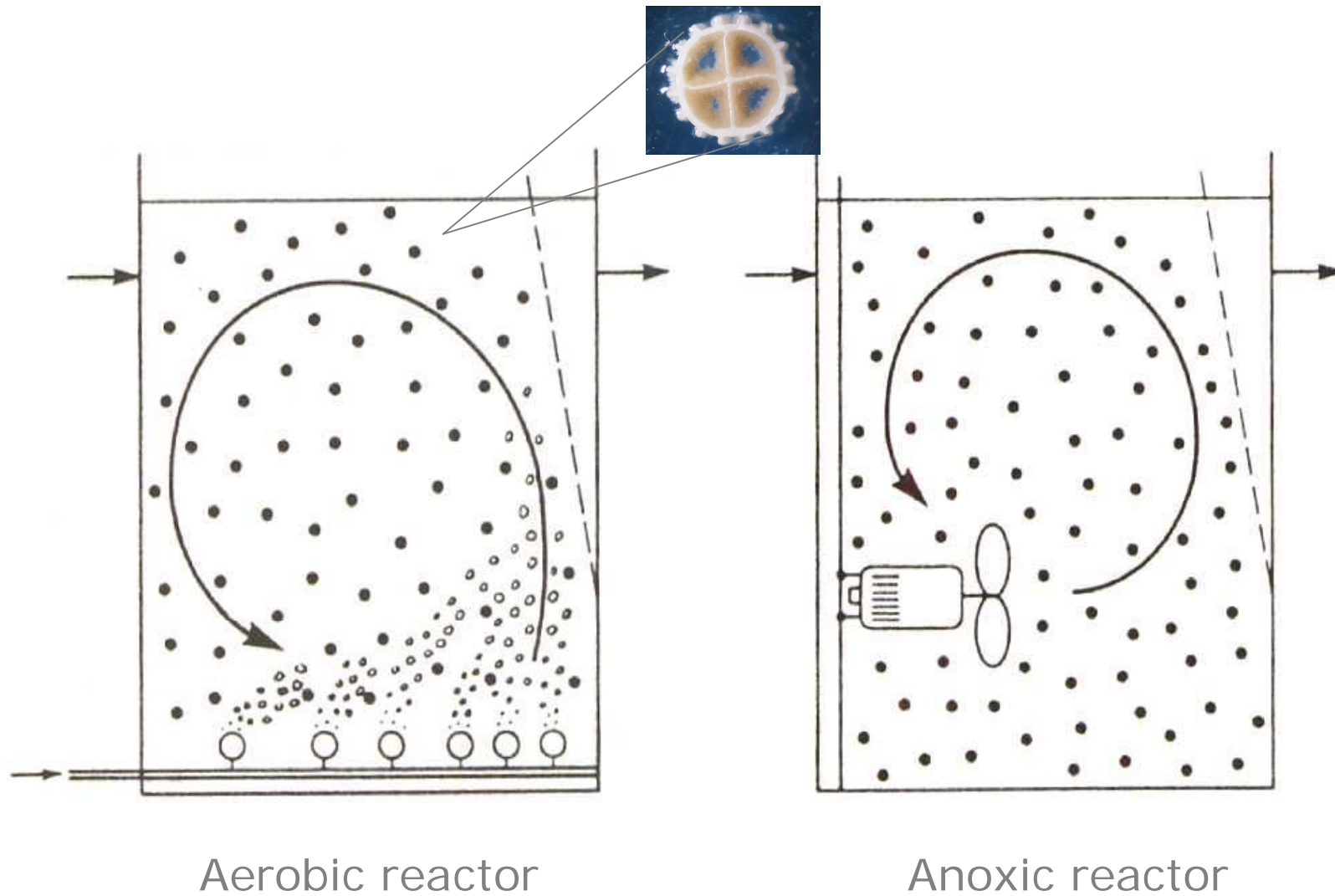
Clarification/Separation OPTIONS Following MBBR Treatment

Discussion Topics

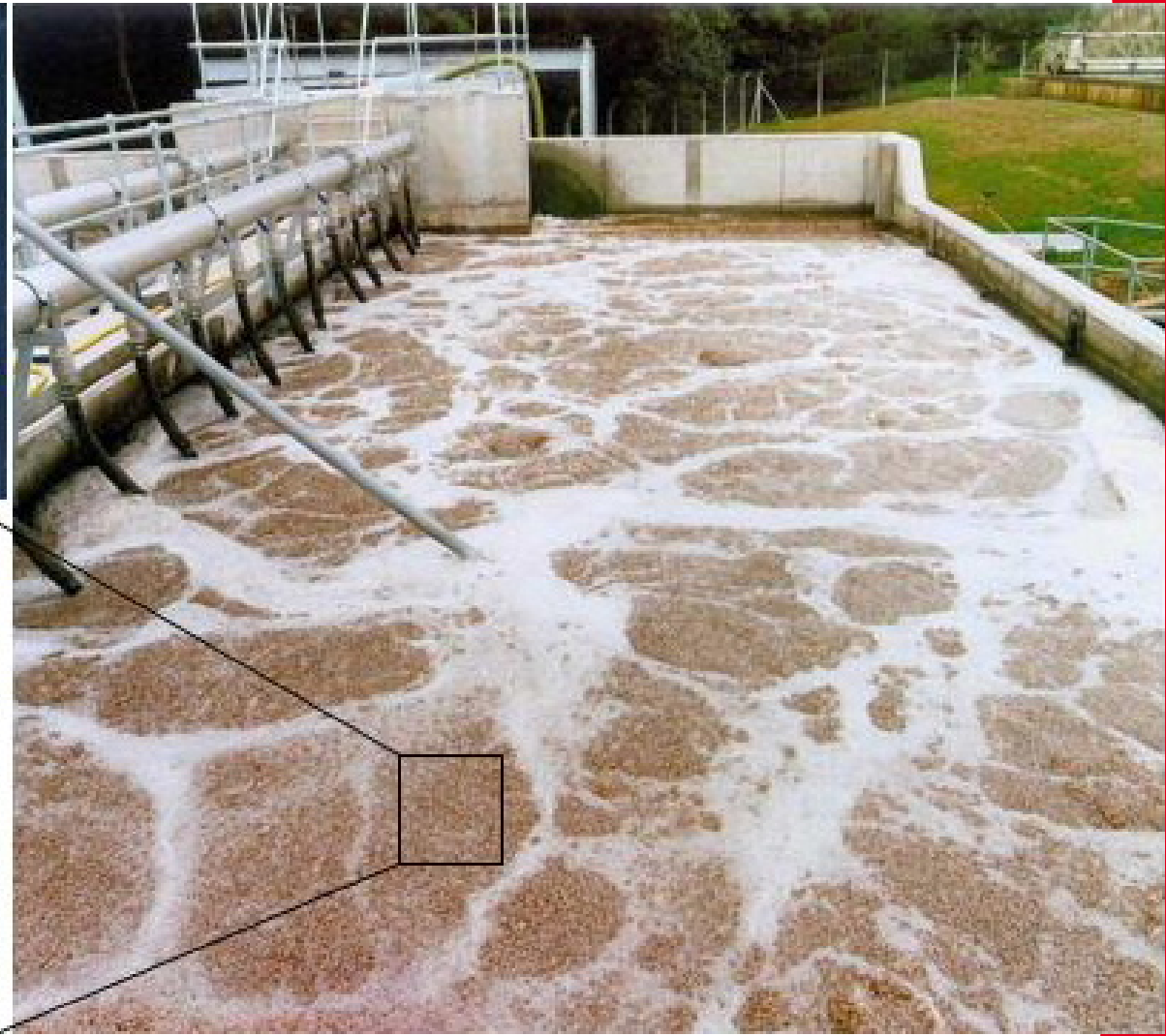
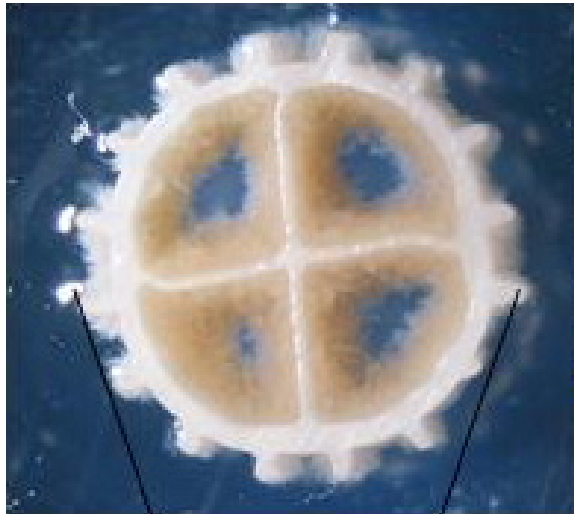
- What is MBBR
- Conventional Clarification
- High Rate Ballasted Clarification
- Dissolved Air Flotation
- Discfiltration
- Granular Media Filtration
- Membranes
- Summary



The Principle of the Moving Bed Biofilm Reactor (MBBR) Technology

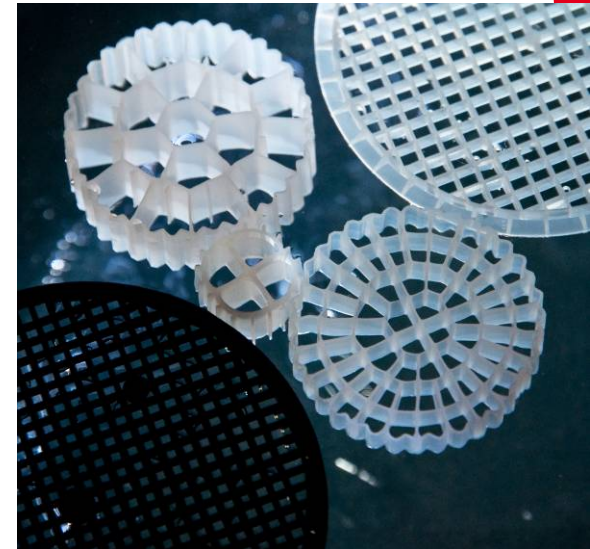


The Moving Bed Biofilm Reactor (MBBR) in Practice



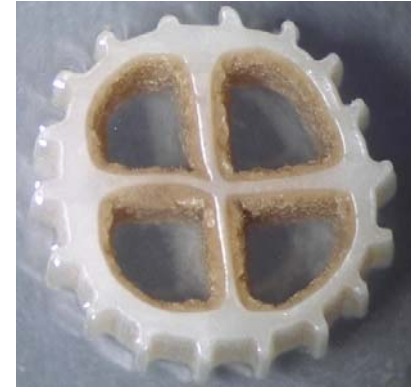
Components to the MBBR Aerobic System

- AnoxKaldnes Media
 - Media Retention Sieves
 - 304L Stainless Steel
 - Cylindrical Wedge Wire
 - Perforated Plate foam control sieves
- AnoxKaldnes Aeration Grid
 - 304L Stainless Steel
 - Medium Bubble
 - Maintenance Free – No replacement parts



Components to the Anoxic MBBR System

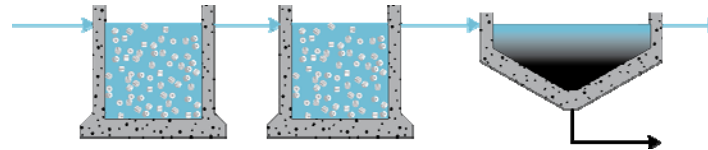
- AnoxKaldnes Media
- Media Retention Sieves
 - 304L Stainless Steel
 - Flat Panel Wedge Wire
- Slow-Speed Mixers
 - Submersible or Top entry
 - Can be speed controlled



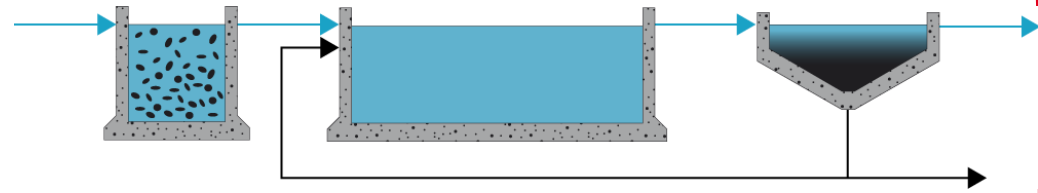
MBBR Solutions – Highly Flexible



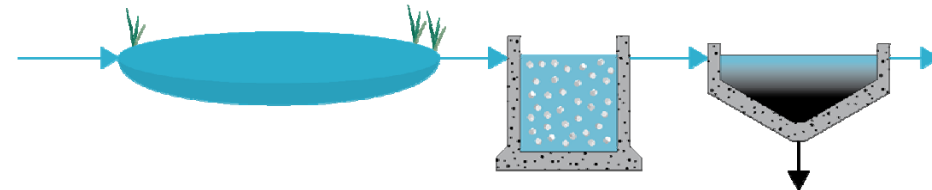
MBBR stand-alone



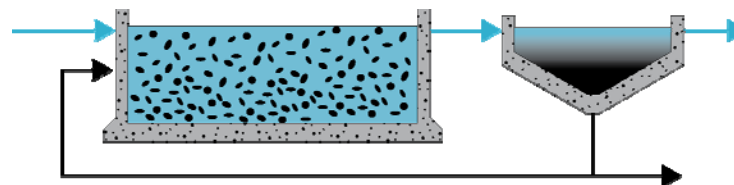
MBBR as pre-treatment (roughing, BAS™)



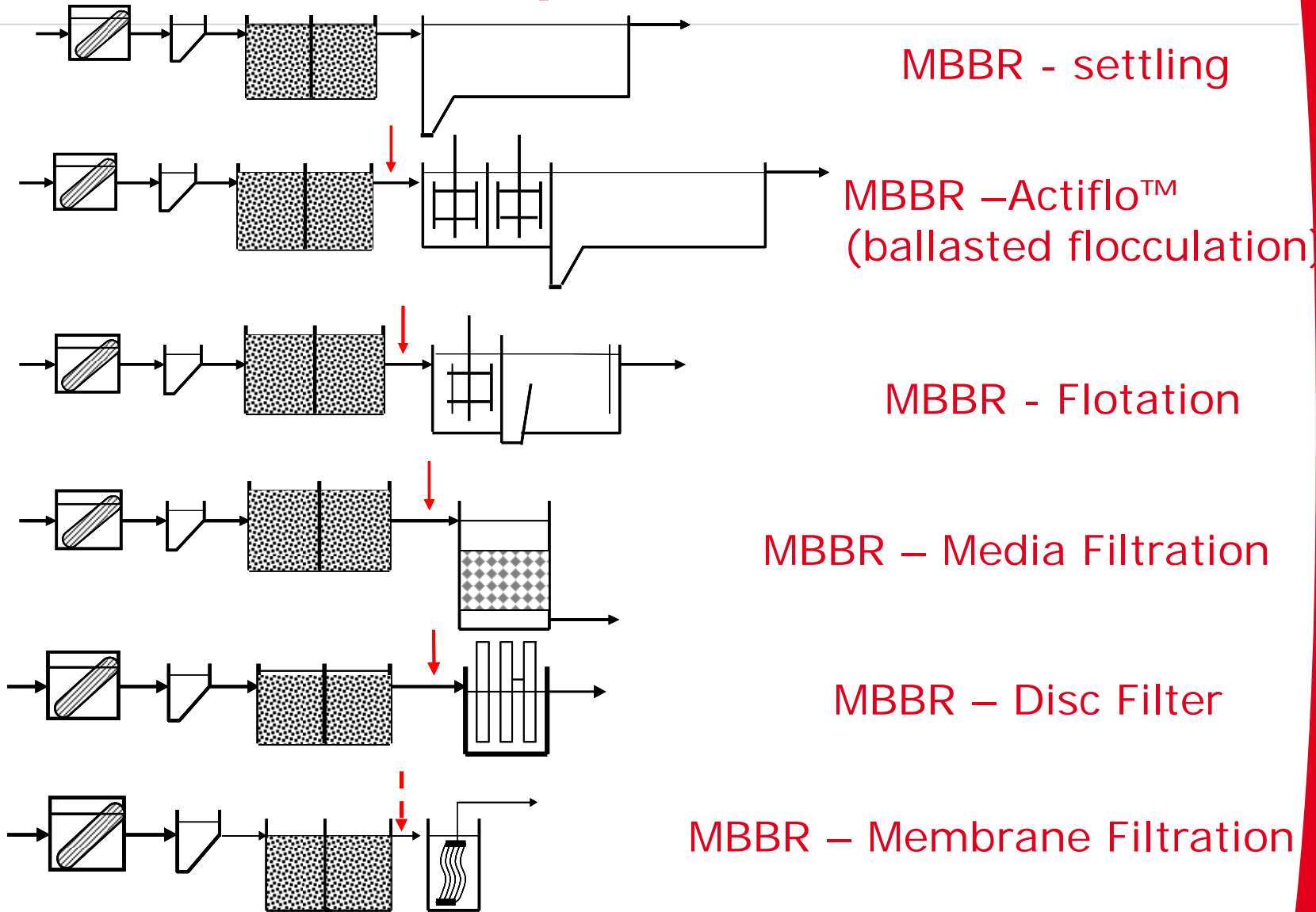
MBBR as tertiary treatment (polishing, LagoonGuard™)



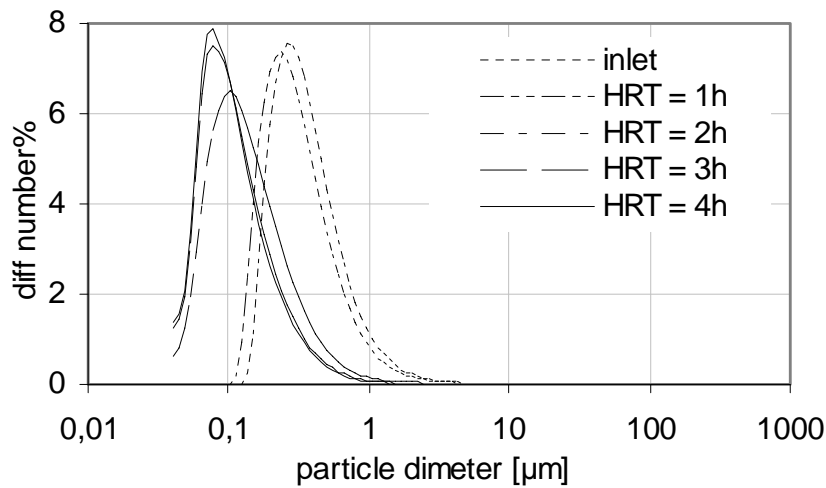
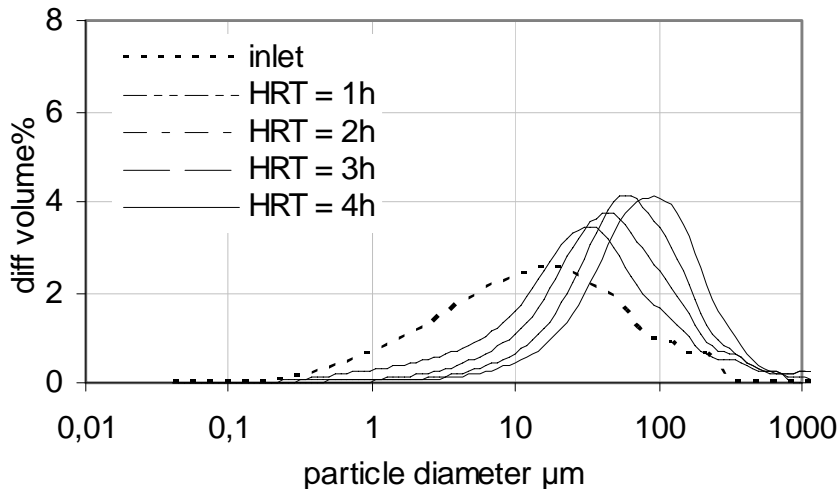
MBBR in activated sludge (HYBAS™/IFAS)



MBBR Biomass Separation Alternatives



Development of PSD's at various MBBR loadings (HRT's) (Åhl et al, 2006)

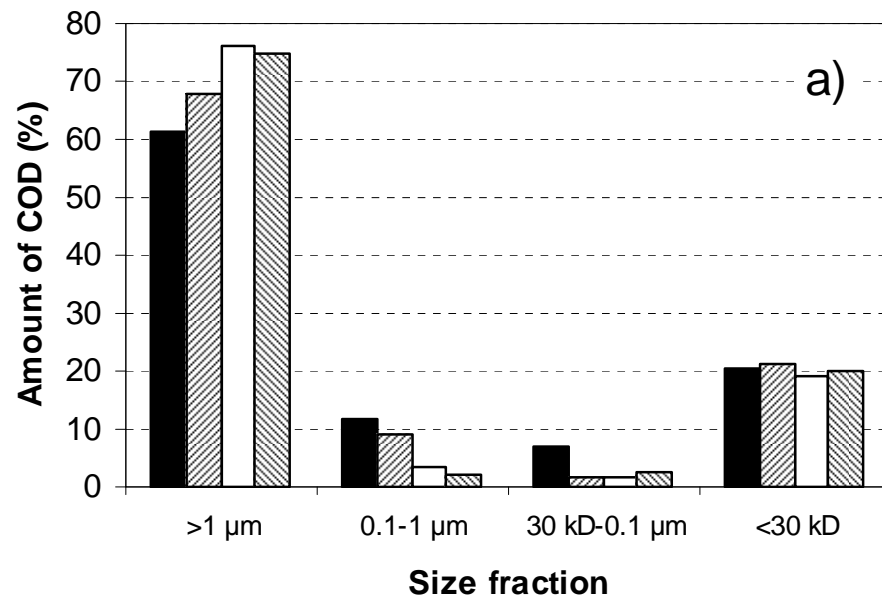


1. There is a shift towards a higher volume of larger particles with increasing HRT
2. There is at the same time, however, a relative increase in the number concentration of submicron particles with increasing HRT

Hypothesis :

- Flocculation is taking place
- Erosion of single bacteria or remains of dead cells happens
- Both are f/loading/HRT

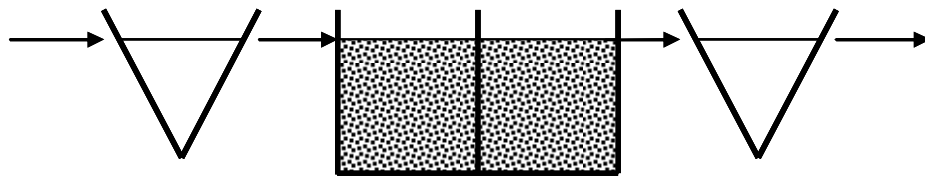
Relative amounts of COD in the different size fractions (Melin et al, 2005)



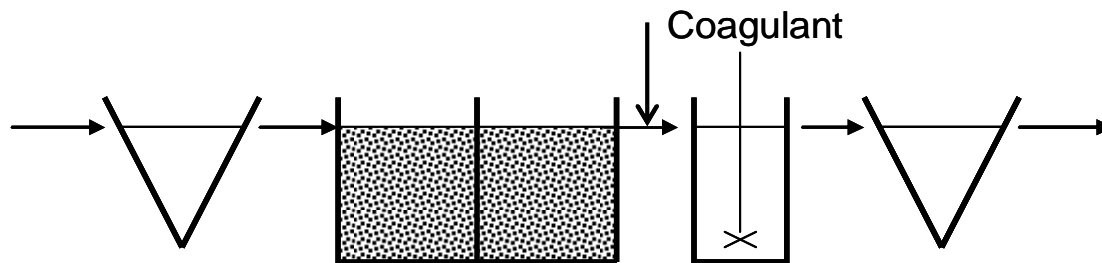
- Majority of COD in particles $> 1 \mu\text{m}$
- Increase in the suspended COD with increasing HRT
- Decrease in colloidal particles ($0,1 - 1 \mu\text{m}$) when HRT increase

■ HRT = 0.75 h ▨ HRT = 1 h □ HRT = 3 h ▩ HRT = 4 h

Conventional Settling after MBBR



Without
coagulation



With coagulation

- Metal salt (Al, Fe)
- Cationic polymer
- Low Al/Fe + cat. polymer
- High Al/Fe + anionic polymer

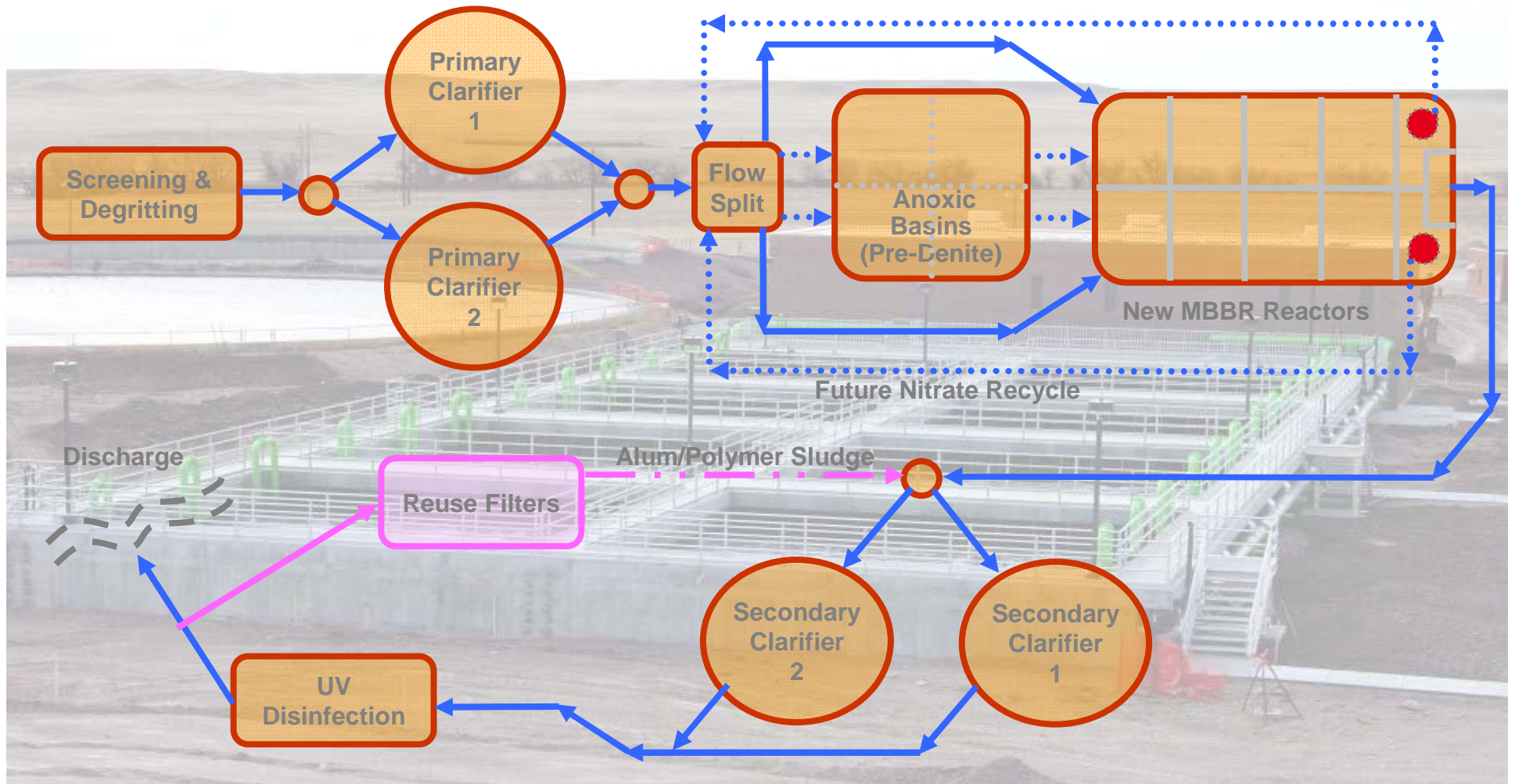
Cheyenne – Crow Creek WWTP



THE CROW CREEK WATER RECLAMATION FACILITY



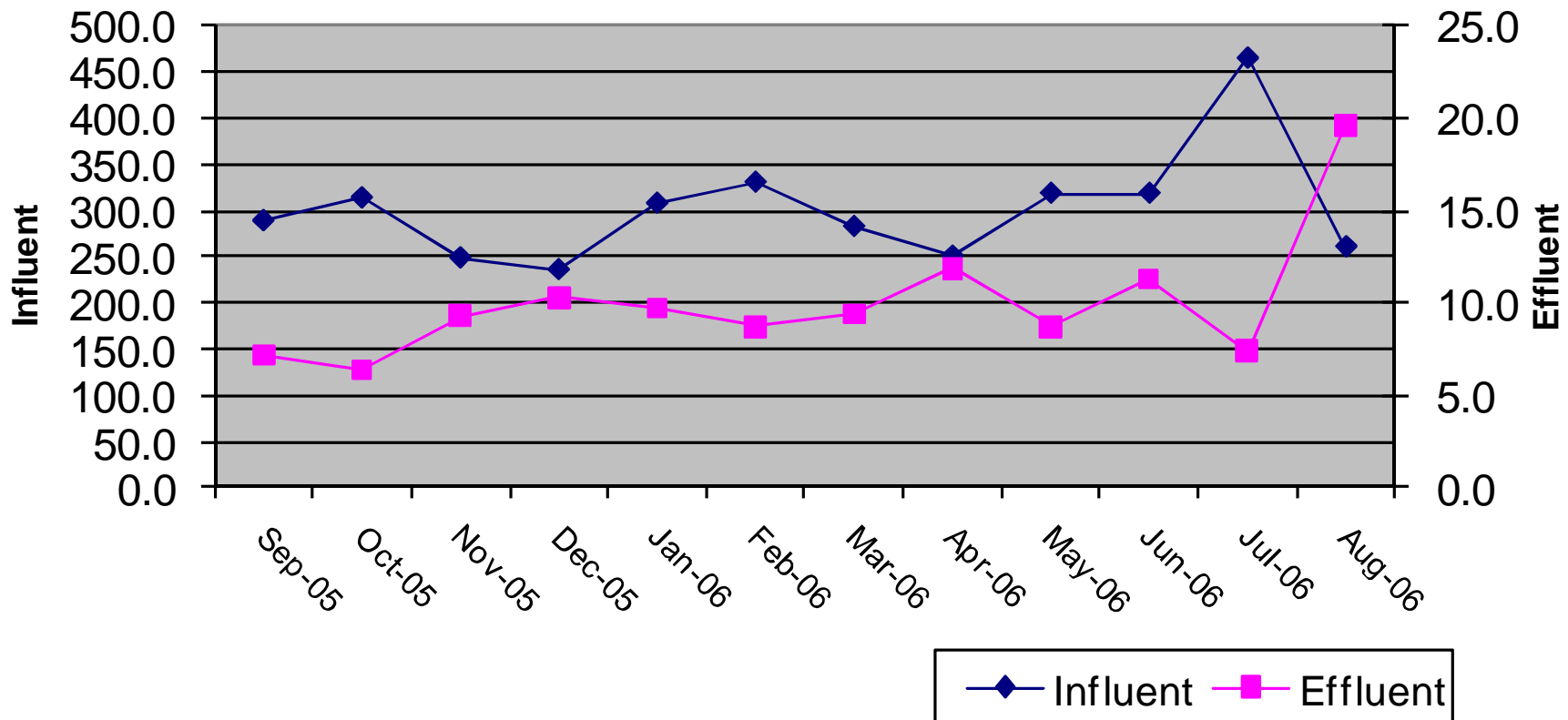
New Treatment Process



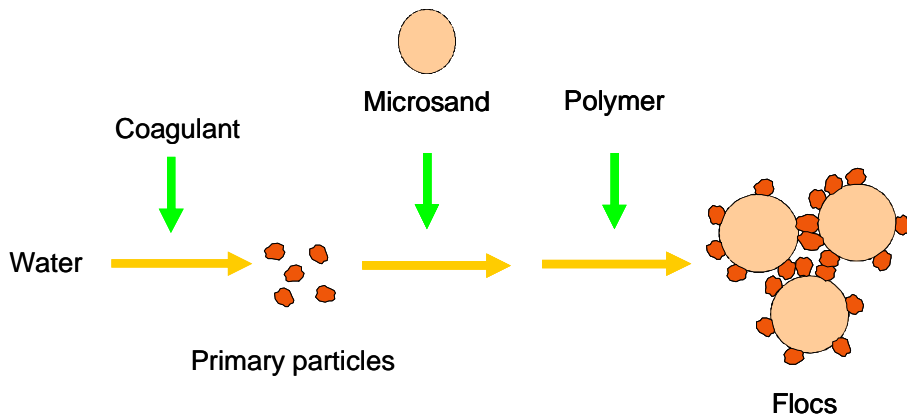
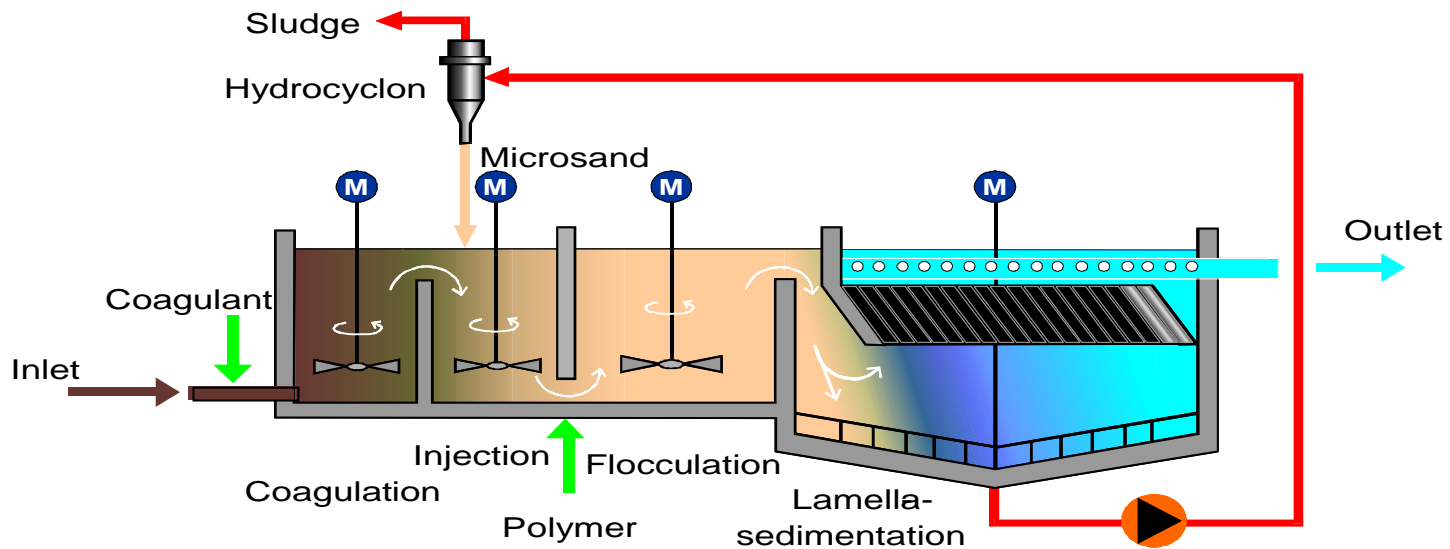
PERFORMANCE DATA



**Cheyenne BOPU Crow Creek WRF
TSS Removal - 30 Day Average**



Actiflo[®] Microsand Ballasted Clarification



South Adams WWTP MBBR-ACTIFLO[®] Pilot



| Process | Rise rate ³ | Influent characteristics | | Coagulants and dose | Effluent characteristics | | |
|--|--|--------------------------|---------|---|--------------------------|-------|-------------------|
| | | mg SS/l | Turb | FeCl ₃ or Al _s (SO ₄) ₃ + anionic polymer ¹ | mg SS/l | Turb. | mg P/l |
| MBBR + ACTIFLO [®] | 55 – 85 m/h most tests at 65 m/h ⁴ | 110-150 | 130-160 | 12.4 mg Fe/l + 0,8 mg/l | 3 | < 2 | |
| | | | | 7.6 mg Al/l + 0,6 mg/l | ≤5 | < 2 | 0.12 ² |
| | | | | 6.2 mg Fe/l + 0,6 mg/l | 5 | | |
| | | | | 2.1 mg Fe/l + 0,45 mg/l | 10 | | |
| MBBR + Settling + ACTIFLO [®] | 120 m/h | 3,5–4,5 | 10 - 25 | 13.2 mg Fe/l + 0,5 mg/l | | 1.4 | <0,1 |
| | 100 m/h | | | 6.0 mg Al/l + 0,6 mg/l | < 2 | ≥0.3 | |
| MBBR + Settling + ACTIFLO [®] Turbo | 90 m/h | 3,5–4,5 | 10 - 25 | 13.2 mg Fe/l + 0,5 mg/l | | < 1 | <0.1 |
| | 115 m/h | | | 9.6 mg Fe/l + 0,5 mg/l | | 1.2 | <0.1 |
| | 115 m/h | | | 9.1 mg Al/l + 0,6 mg/l | | 1.4 | 0.1 |

¹Anionic polymer M155

²Lowest value achieved - at high Al dose (14.4 mg Al/l)

³Rise rate, hydraulic surface load (m³/m² · h) calculated on the settler foot-print area

Summary of Pilot Results, Quebec, Can

(John Meunier, VWS, Can)



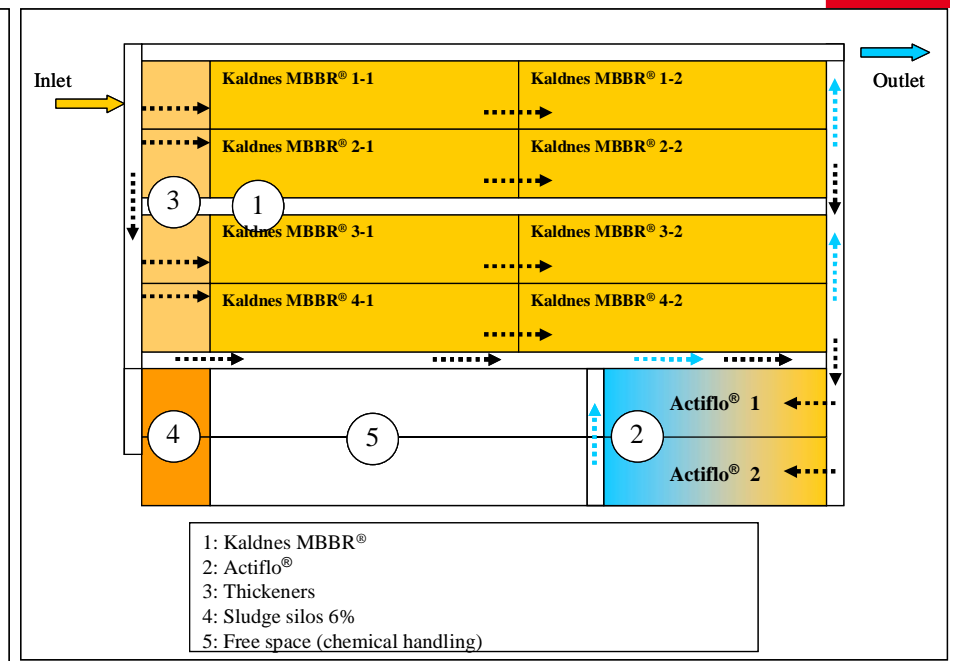
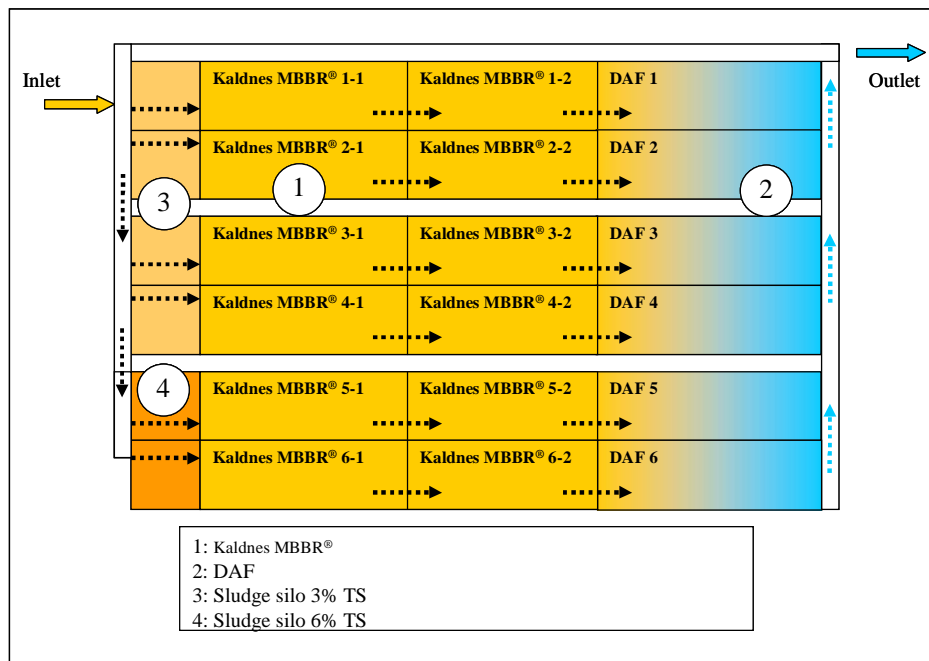
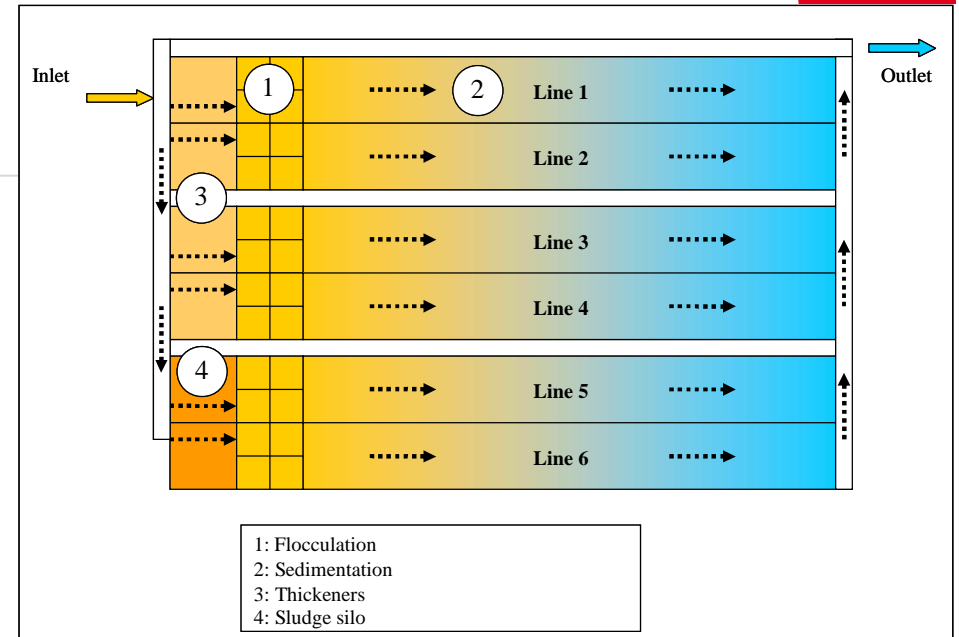
Actiflo following MBBR

- MBBR load : 4 – 25 g BOD₅/m²d
- Actiflo rise rate: 40 – 120 m/h
- FeCl₃-dose : 30 – 115 µL/L
- Polymer dose : 0.5 - 1.2 mg/l

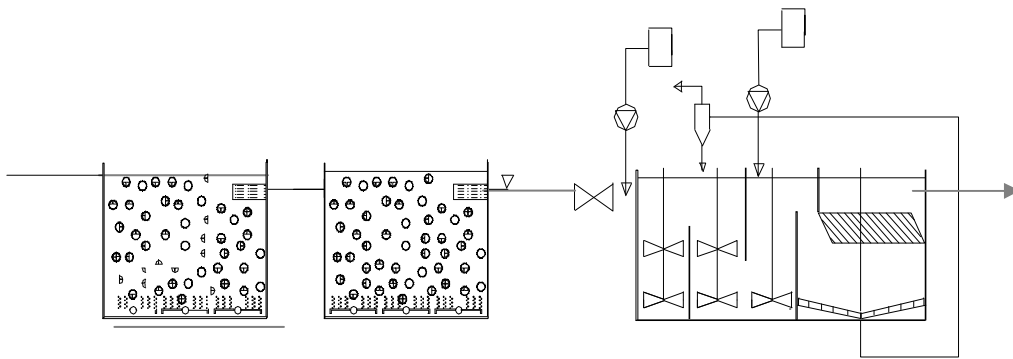
| Parameter | units | Influent | Effluent | % removal |
|-----------|--------|-----------|-----------|-----------|
| Total P | (mg/L) | 1 - 5 | 0.2 -0.7 | |
| Turbidity | NTU | 58 - 154 | 2.5 - 6.8 | |
| TSS | (mg/L) | 94 - 196 | 13 - 24 | 86 - 88 |
| COD | (mg/L) | 176 - 361 | 31 - 58 | 82 -84 |
| BOD | (mg/L) | 53 - 155 | 5 - 11 | 91 -93 |
| pH | | --- | 7.1 - 7.5 | |

Example Drammen WWTP

Upgrading a chemically enhanced primary plant to become a secondary plant by the use of MBBR and ACTIFLO®



Two MBBR – ACTIFLO in Bergen Under Construction



Bergen WWTP design:

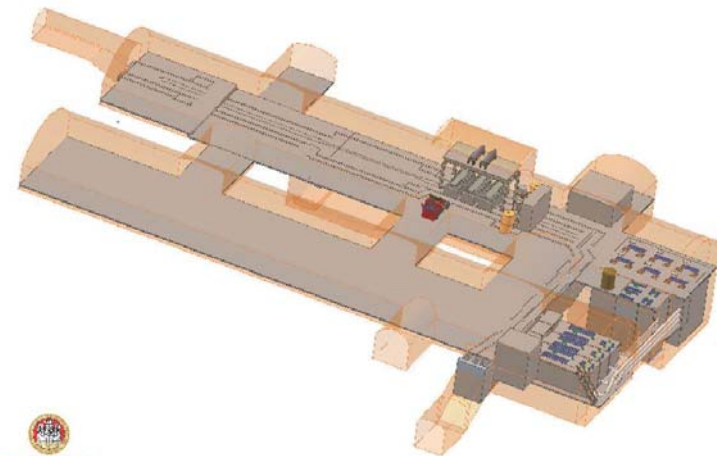
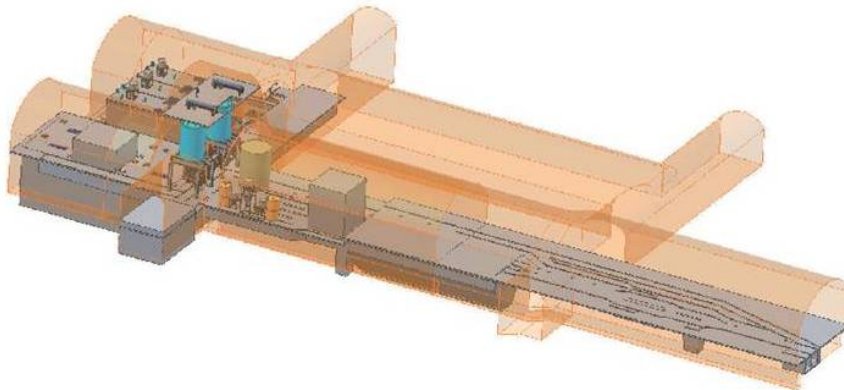
- $r_{\text{BOD}} = 11,5 \text{ g BOD}_5/\text{m}^2\text{d}$
- $v_f = 60 \text{ m/h}$
(rise rate in settling zone)

M3 Hølen

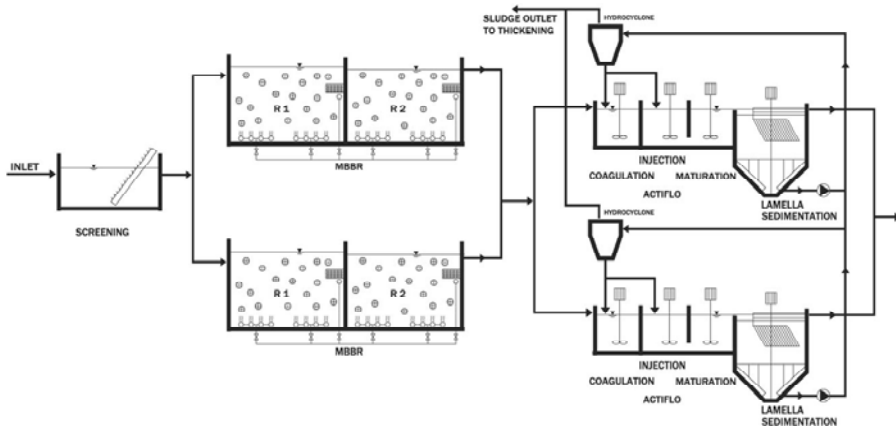
KRÜGER KALDNES

M5 Ytre Sandviken

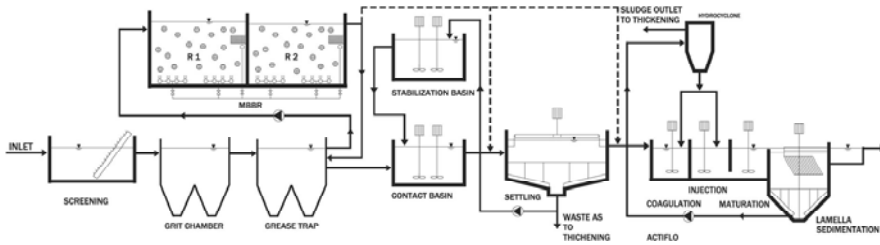
KRÜGER KALDNES



Handeland, Skreia MBBR/Actiflo® Plants

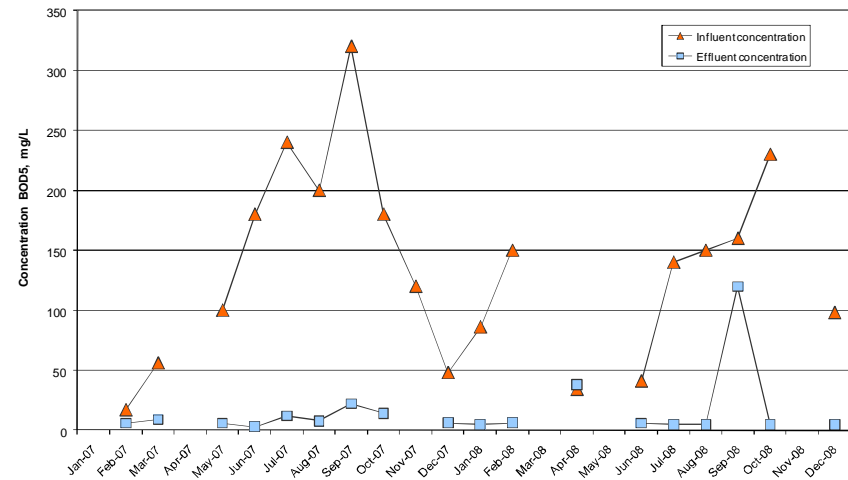


a. Handeland WWTP

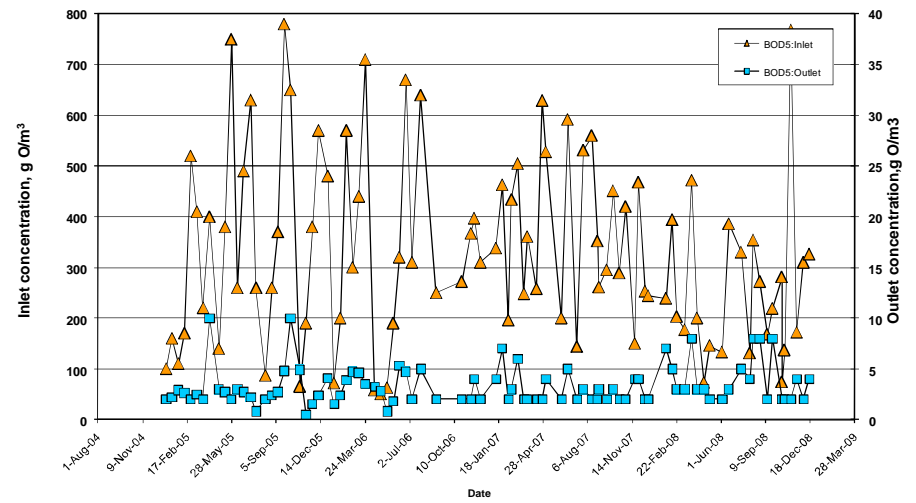


b. Skreia WWTP

BOD₅ results Handeland WWTP 2007-2008



BOD₅ results Skreia WWTP 2005-2008



MBBR-Flotation (DAF)

Historically a very popular option for compact MBBR separation in Scandinavia

Data below from the Johnstown, CO LagoonGaurd MBBR-DAF Installation

| Parameter | DAF influent Range | Average | DAF Effluent Range | Average |
|-----------------------|---------------------------|----------------|---------------------------|----------------|
| Turbidity, NTU | 18-80 | 40 | 2-28 | 15 |
| BOD mg/l | 24-35 | 27 | 3-13 | 10 |
| TSS mg/l | 19-62 | 35 | 8-25 | 11 |



Typical design values for DAF following MBBR (Ødegaard et al, 2009)



| Tank depth | Surface overflow rate (m ² /m ³ ·h) | |
|------------|---|--------------------------------------|
| | At design flow, Q_{dim} | At maximum design flow, Q_{maxdim} |
| 2 – 3 m | 5 | 10 |

Dispersion pressure : 400 – 600 kPa (4-6 bar)

Air saturation: 80 - 90 %

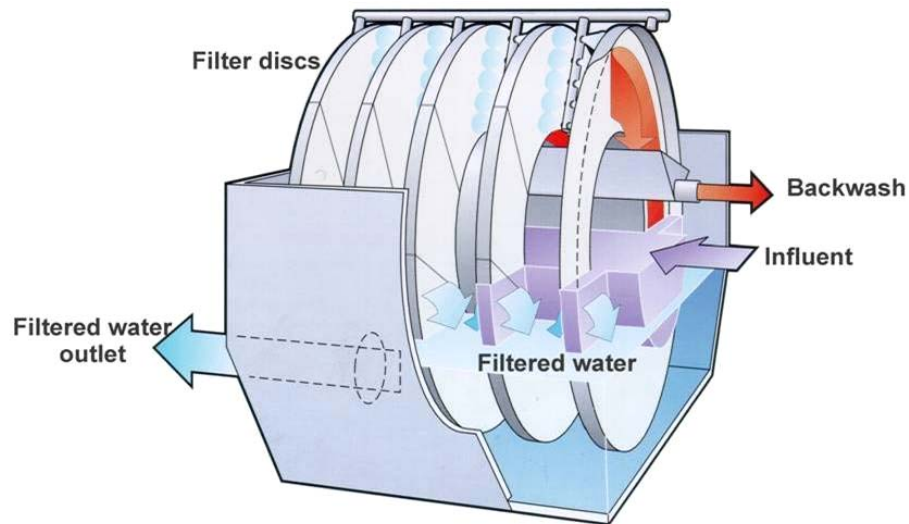
Dispersion water flow (% of Q_{maxdim}) : 10 - 25 %
(depending on SS_{in} and air saturation)

Average Results from three Scandinavian Plants using DAF after MBBR



| Parameter | Nordre Follo WWTP | | | Gardermoen WWTP | | | Sjölunda WWTP | | |
|--|-------------------|------|----|-----------------|------|----|---------------|------|----|
| Design values | | | | | | | | | |
| Design flow (m ³ /h) | 750 | | | 920 | | | 7920 | | |
| Max. flow (m ³ /h) | 1125 | | | 1300 | | | 15840 | | |
| Temp. (°C) | 6-14 | | | 4-14 | | | 8-20 | | |
| Plant size | | | | | | | | | |
| Tot. MBBR vol. (m ³) | 3710 | | | 5790 | | | 6230 | | |
| Flocculation vol. (m ³) | 230 | | | 180 | | | 3960 | | |
| Flotation area (m ²) | 150 | | | 215 | | | 2000 | | |
| Year documented | 2008 | | | 2009 | | | 2009 | | |
| Average in-out conc. and treatment efficiency | In | Out | % | In | Out | % | In | Out | % |
| SS (mg/l) | - | - | - | - | - | - | 282 | 12 | 96 |
| BOD (mg/l) | 123 | 3.8 | 97 | 274 | 2.2 | 99 | 231 | 10 | 96 |
| COD (mg/l) | 453 | 49 | 89 | 725 | 33 | 95 | 559 | 62 | 89 |
| Tot N (mg/l) | 32 | 6.5 | 80 | 62 | 8.7 | 85 | 41 | 10 | 76 |
| Tot P (mg/l) | 4.2 | 0.14 | 97 | 8.8 | 0.11 | 99 | 5.3 | 0.30 | 94 |

MBBR - Microscreening



The Hydrotech Disc Filter

- Directly after MBBR or for polishing
- Sieve openings: 10 – 100 μm
- Operational head-loss: 10"
- Backwash during operation

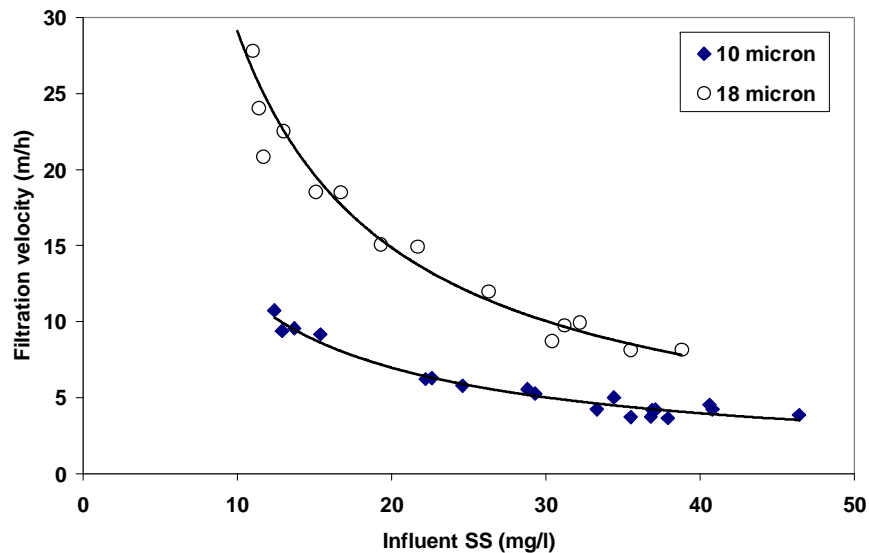


Disc Filter plant after post DN MBBR at Rya WWTP, Gothenburg, Sweden



Results from the Rya WWTP Discfilter (Mattson et al, 2009)

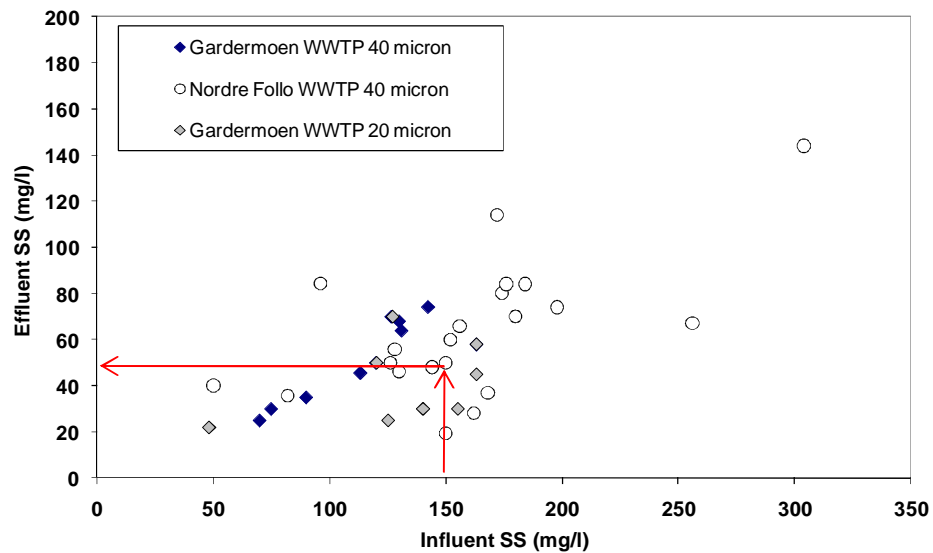
| Mesh pore size, μm | Feed, mg SS/l | | Effluent, mg SS/l | | Capacity, $\text{m}^3/\text{m}^2_{\text{filter}} \cdot \text{h}$ | | Number of Samples |
|-------------------------------|---------------|---------|-------------------|---------|--|---------|-------------------|
| | Average | St.dev. | Average | St.dev. | Average | St.dev. | |
| 18 | 27.5 | 14.5 | 5.0 | 1.8 | 13.7 | 7.2 | 37 |
| 10 | 30.5 | 10.8 | 3.5 | 1.3 | 4.8 | 2.2 | 22 |



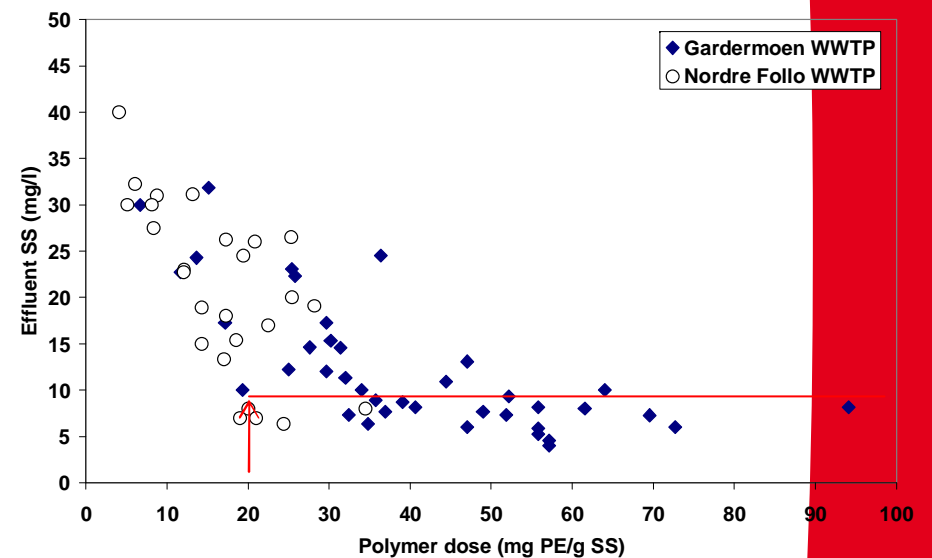
Filtration rate
(based on total filter mesh area)
versus influent SS
(Persson et al. 2006)



Discfilter With Chemical Dosing



Effluent SS versus influent SS without any pre-coagulation/flocculation

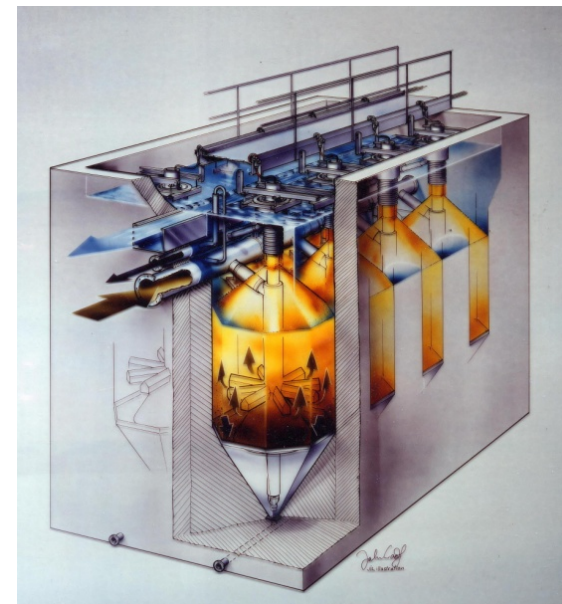


Effluent SS as a function of polymer dosing.

Sand filtration after MBBR

Various uses:

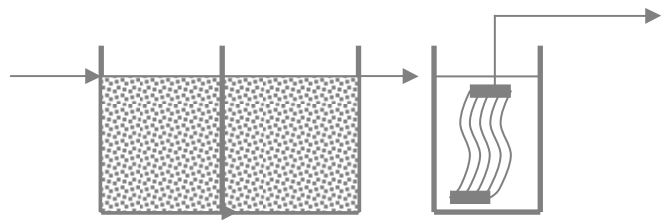
- As polishing step
- Directly after nitrifying or denitrifying MBBR
 - Ex.: Klagshamn WWTP
 - 8,2 m/h at Q_{\max}
 - Effluent : < 5 mg SS/l, 0,2 mg P/l
- Directly after high-rate (secondary treatment) MBBR-
Cheyenne Crow Creek



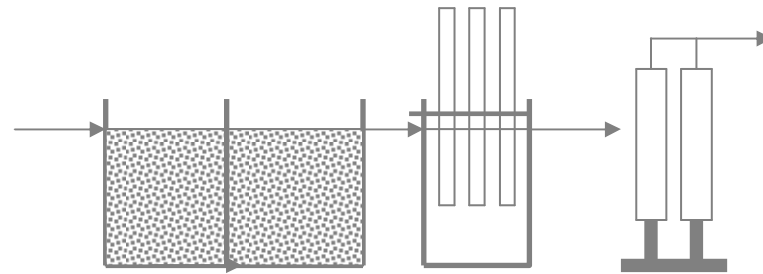
Membrane filtration after MBBR



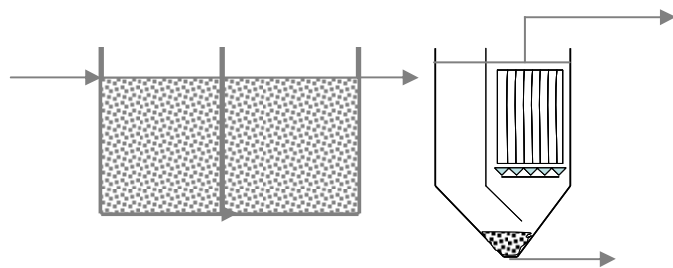
Different strategies tested



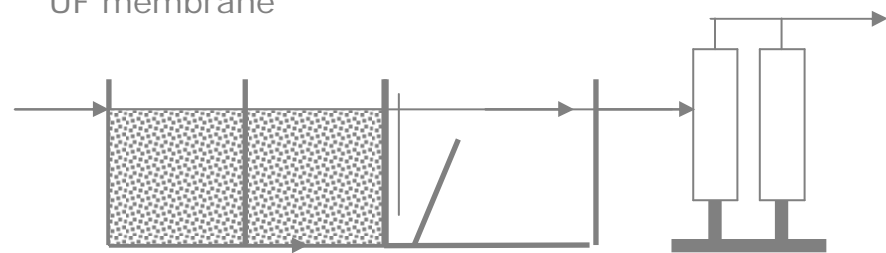
a.
MBBR – submerged hollow fiber UF
membrane (i.e. Zenon ZeeWeed)



b.
MBBR – Discfilter – Contained hollow fiber
UF membrane



c.
MBBR – submerged membrane
in reactor with settling zone



d.
MBBR – DAF – Contained hollow fiber UF
membrane

Conclusions

1. Particle size distribution (PSD) of biomass leaving MBBR:
 - a. Large mass fraction of relatively large particles (30 – 300 μm), but a high number of small particles (0.1 – 1 μm). The easiest way to deal with the latter is by coagulation ahead of the separation reactor
 - b. The PSD is shifted towards larger particles when the organic area load is decreasing (HRT is increasing). Hence the higher the area load, the better is the effect of pre-coagulation
2. All of the commonly used separation methods may be used.
 - a. MBBR allows the use of a variety of separation methods providing greater flexibility than the AS processes miss
 - b. DAF is well proven
 - c. Microsand ballasted lamella settling (Actiflo) is of increasing interest and results in an extremely compact plant
 - d. A very compact solution is also achieved with the use of Discfilter

Final Thoughts

