ADVANCEMENTS IN PHYSICAL/CHEMICAL TREATMENT

Hallvard Ødegaard

CHALLENGES IN THE USE OF COAGULATION OF WASTEWATER

- MINIMISATION OF SLUDGE PRODUCTION
- MINIMISATION OF SPACE REQUIREMENT
  - Flocculation
  - Floc separation
- REMOVAL OF SOLUBLE (ORGANIC) MATTER
- PRODUCTION OF CARBON SOURCE IF NITROGEN REMOVAL IS TO BE ACHIEVED

DOWNSIDE OF TRADITIONAL PRIMARY PRECIPITATION

LARGE SLUDGE PRODUCTION

$$SP = SS_{in} - SS_{out} + K_{prec} * D$$

SP = sludge production (g SS/m^3)
K_{prec} = sludge production coeff. (g SS/g Me)(Fe~4, Al~6)
D = dose ofmetal coagulant (g Me/m^3)

EVALUATION OF SLUDGE PRODUCTION

$$SP = SS_{in} - SS_{out} + K_{prec.} * D$$

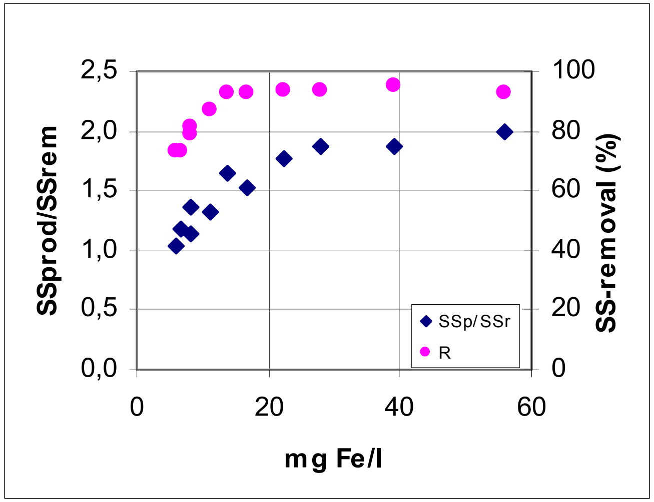
$$\frac{SP}{SS_{in} - SS_{out}} = \frac{SS_{prod}}{SS_{rem}} = 1 + \frac{K_{prec.}}{SS_{rem}} * D$$

When D $\longrightarrow$ 0

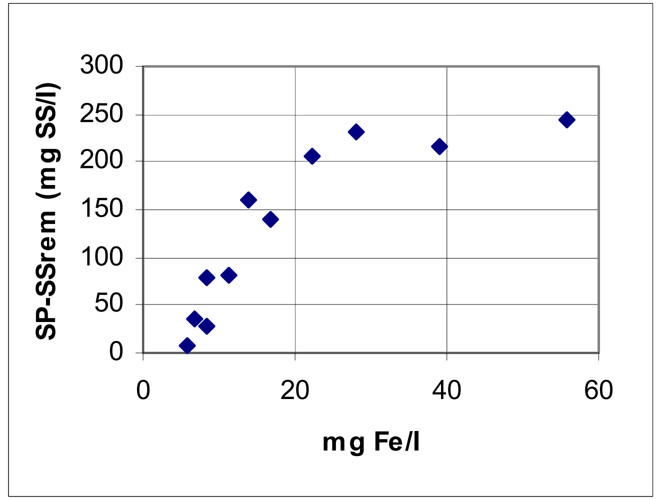
$$\frac{SS_{prod.}}{SS_{rem}} \longrightarrow 1$$

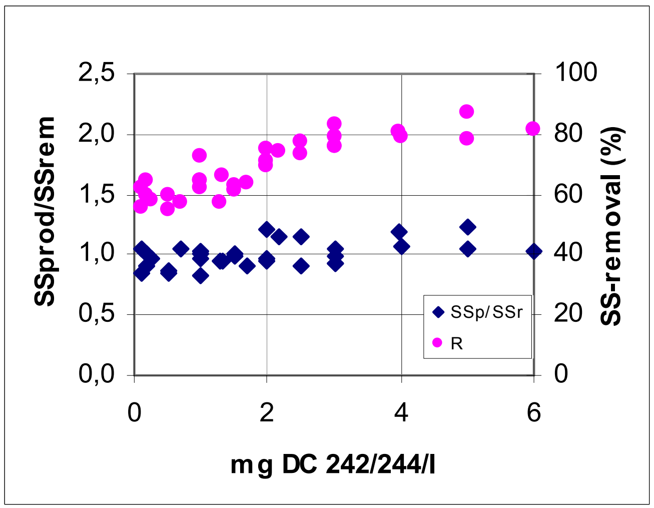
COMPARISON AT DIFFERENT DOSAGE SCENARIOS

a. $FeCl_3$ (high dose) only

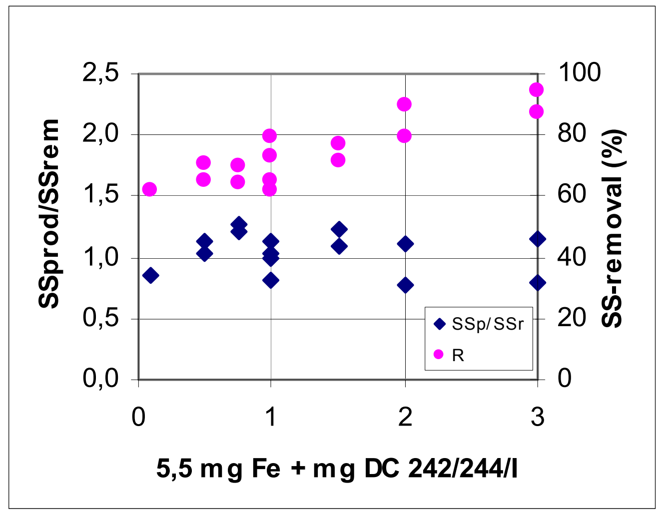


b. $FeCl_3$ (high dose) only





c. Cationic polymer only



d. $FeCl_3$ (low dose) + cationic polymer

FLOCCULATION - KEY FACTOR

a) Orthokinetic flocculation

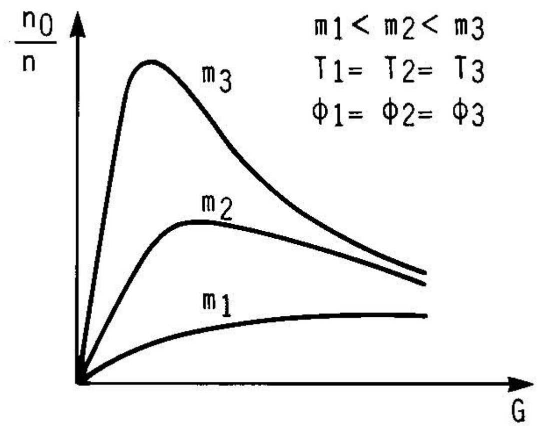
- * Turbulent velocity gradient (G) — $G = (W/\mu)^{1/2}$
- * Residence time (T) — $T = V/Q$
- * Residence time distribution (m) — m~number of reactors in series
- * Floc volume fraction — $\Phi = f(Me, dose)$

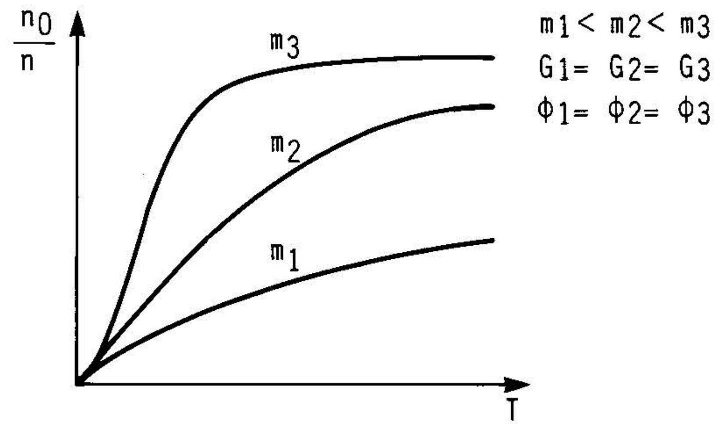
b) Chemical flocculation (polymeric flocculants) by anionic polymer addition

- * Polymer charge (anionic, cationic, non-ionic)
- * Polymer type (polyacrylamide, polyDadmac, polyamin)
- * Polymer dose
- * Polymer characteristic (MW, Charge density)

ORTHOKINETIC FLOCCULATION

Relationship between flocculation performance and flocculation variables





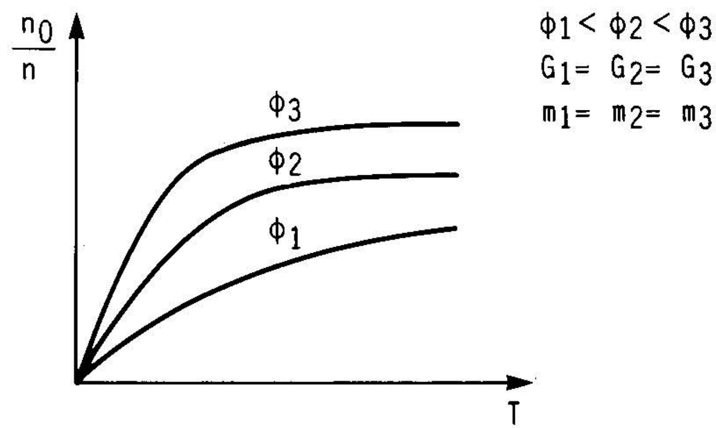
$\frac{n_0}{n}$ = Flokkuleringsgrad

G = Turbulent hastighetsgradient

T = Oppholdstid

m = Antall totalomrørte reaktorer i serie

φ = Fnokkvolum-fraksjon



CHEMICAL FLOCCULATION

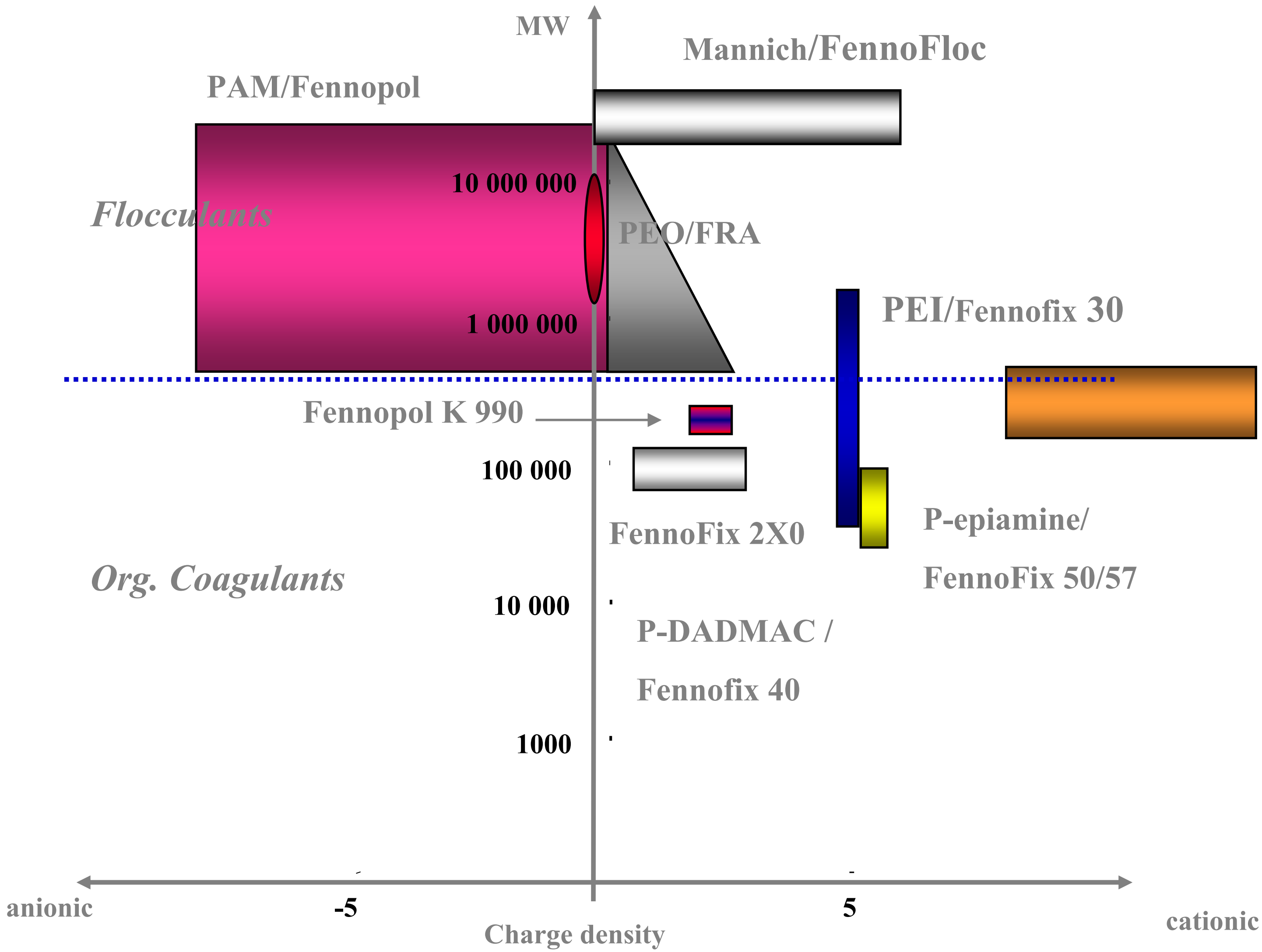
INFLUENCE OF ANIONIC POLYMER ADDITION ON CHEMICAL FLOC SETTLING RATE

1. Anionic polymer addition leads to larger flocs due to the bridging mechanism

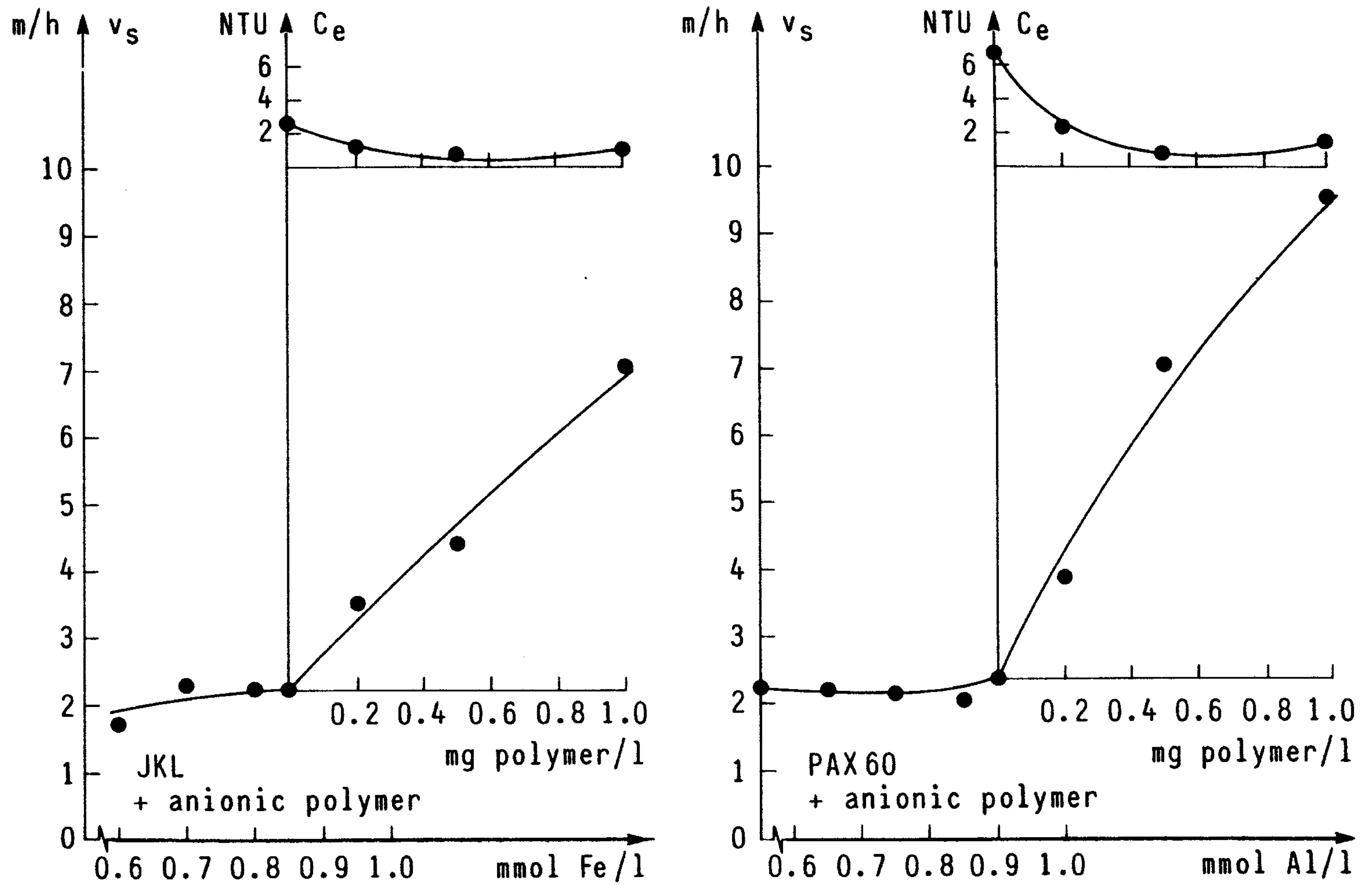
2. Low dosage needed (0,1 - 1,0 mg/l)

3. Polymer flocculant addition leads to higher acceptable turbulent velocity gradient and consequently to lower acceptable residence time

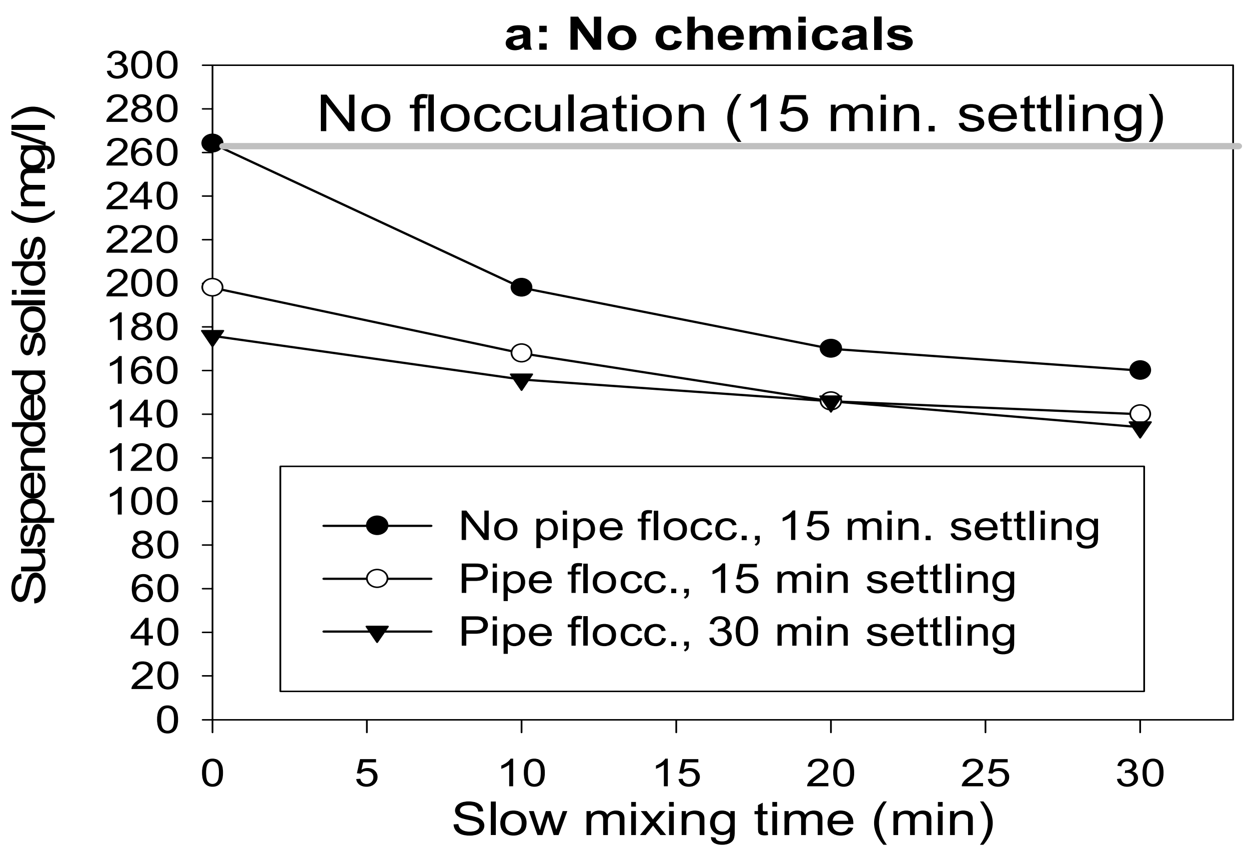
Organic flocculants and coagulants



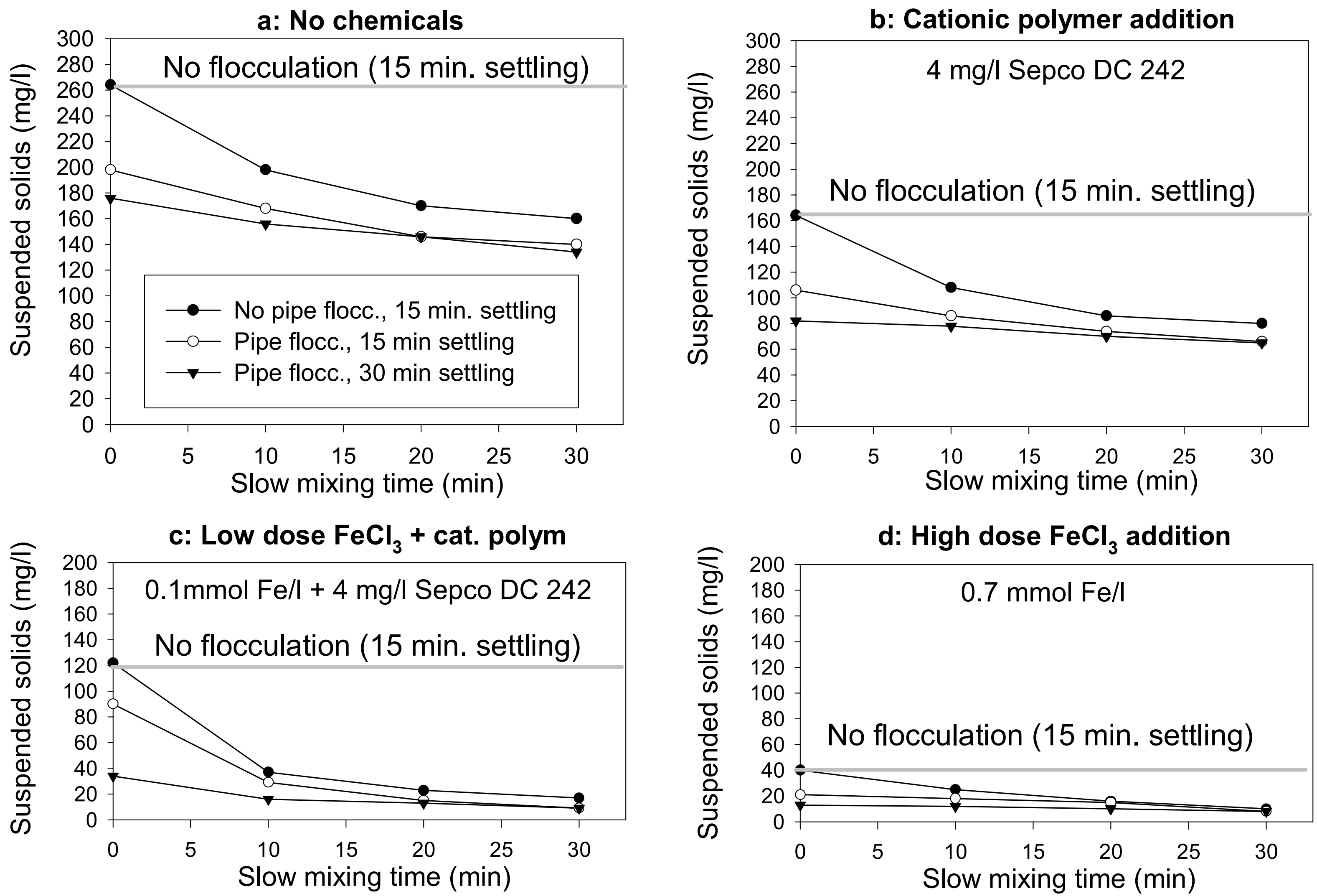
FLOC SETTLING RATE (v_s) VERSUS CHEMICAL DOSAGES
(C_e - turbidity of settled effluent)



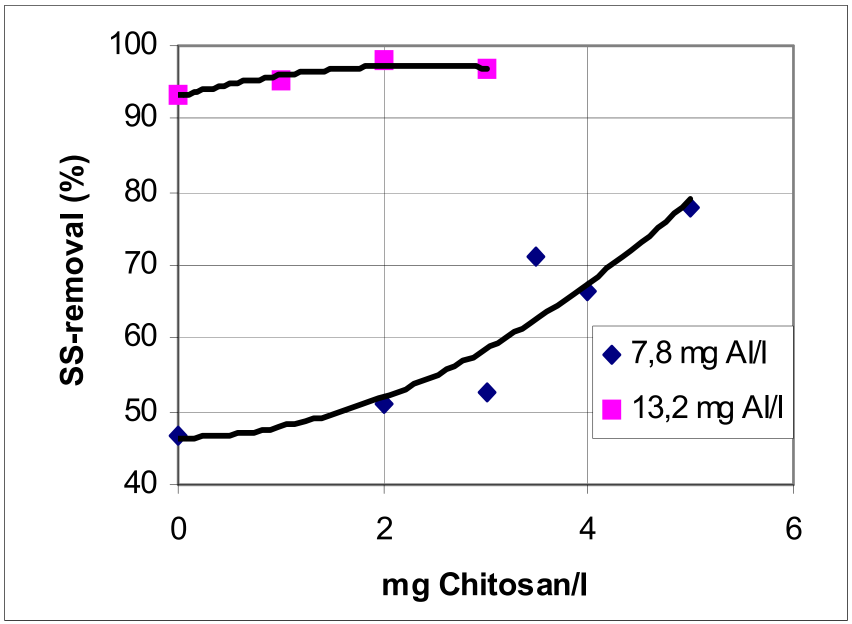
THE IMPORTANCE OF ORTHOKINETIC FLOCCULATION EVEN IN PRIMARY TREATMENT

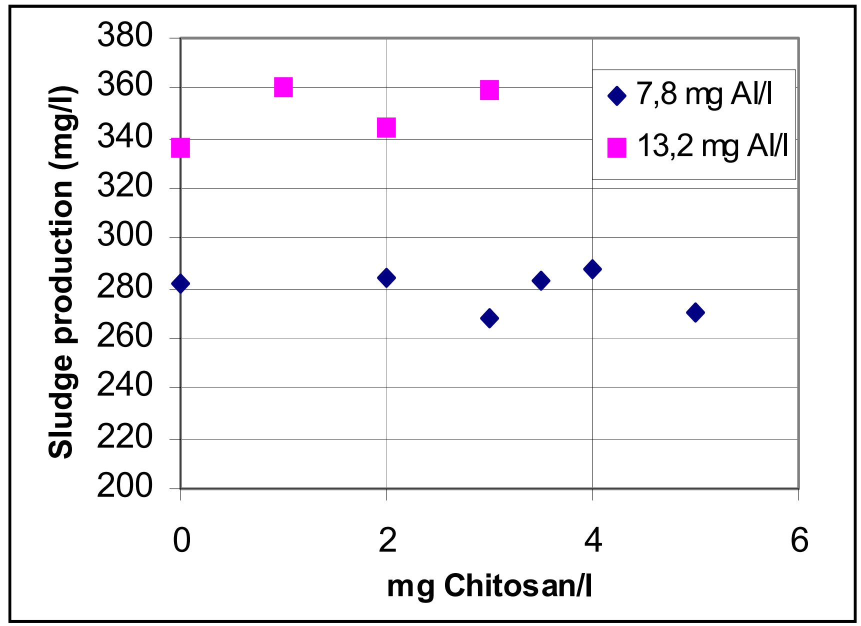


COMPARISON AT DIFFERENT DOSAGE SCENARIOS

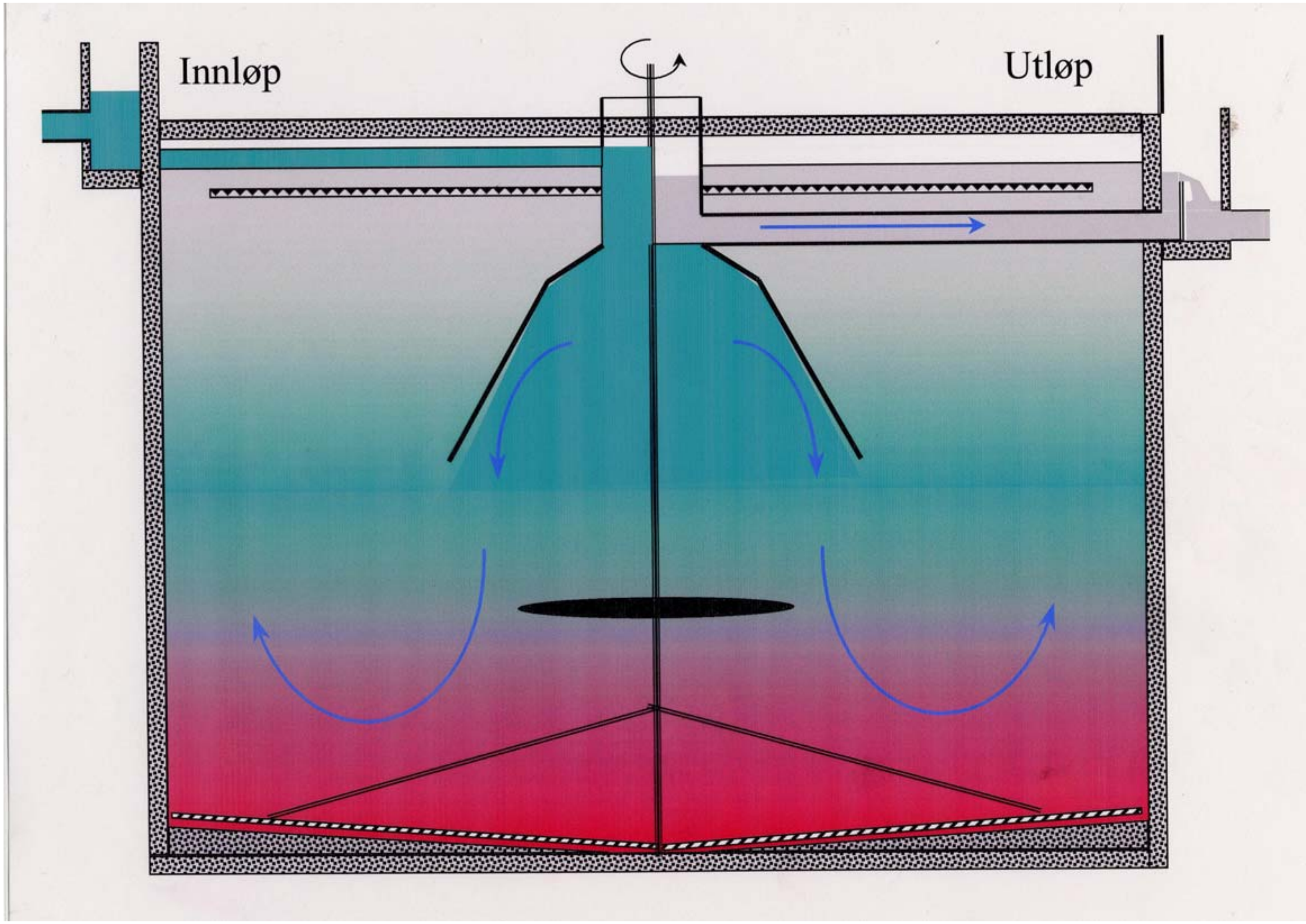


THE BIOPOLYMER CHITOSAN AS REPLACEMENT FOR METAL CATION IN PRIMARY COAGULATION

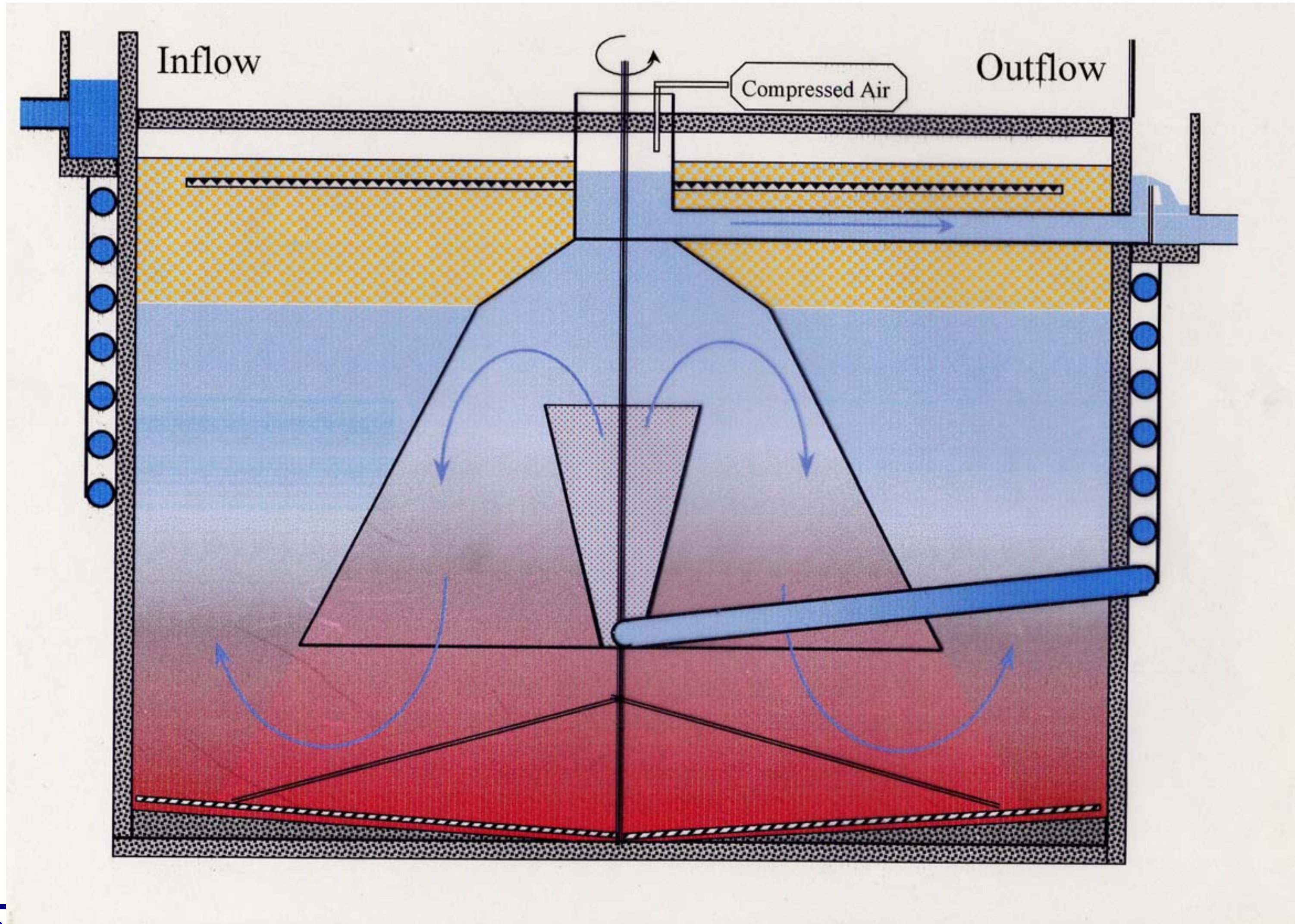


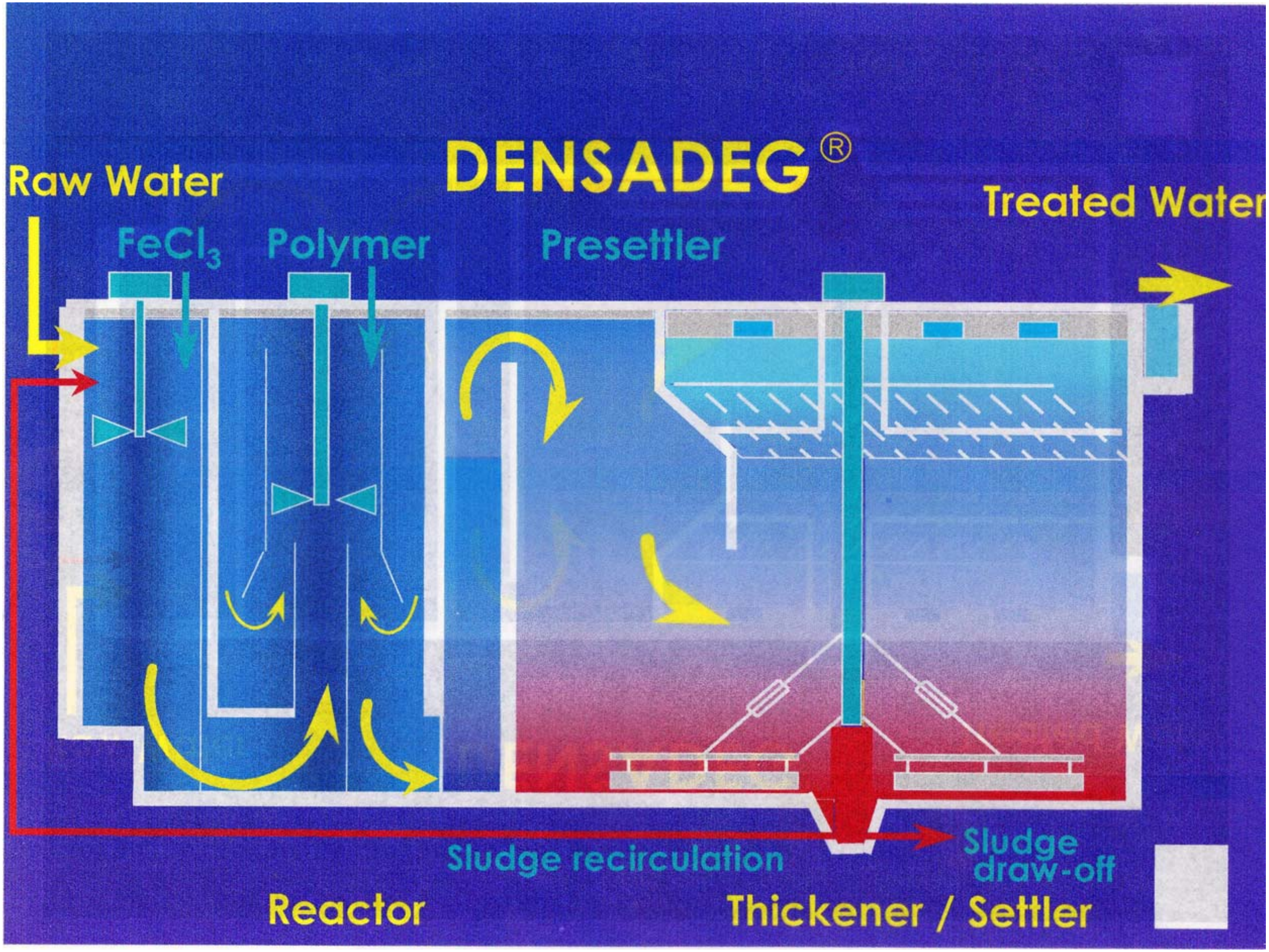


DEEP SETTLING TANK WITH INTERNAL FLOCCULATION

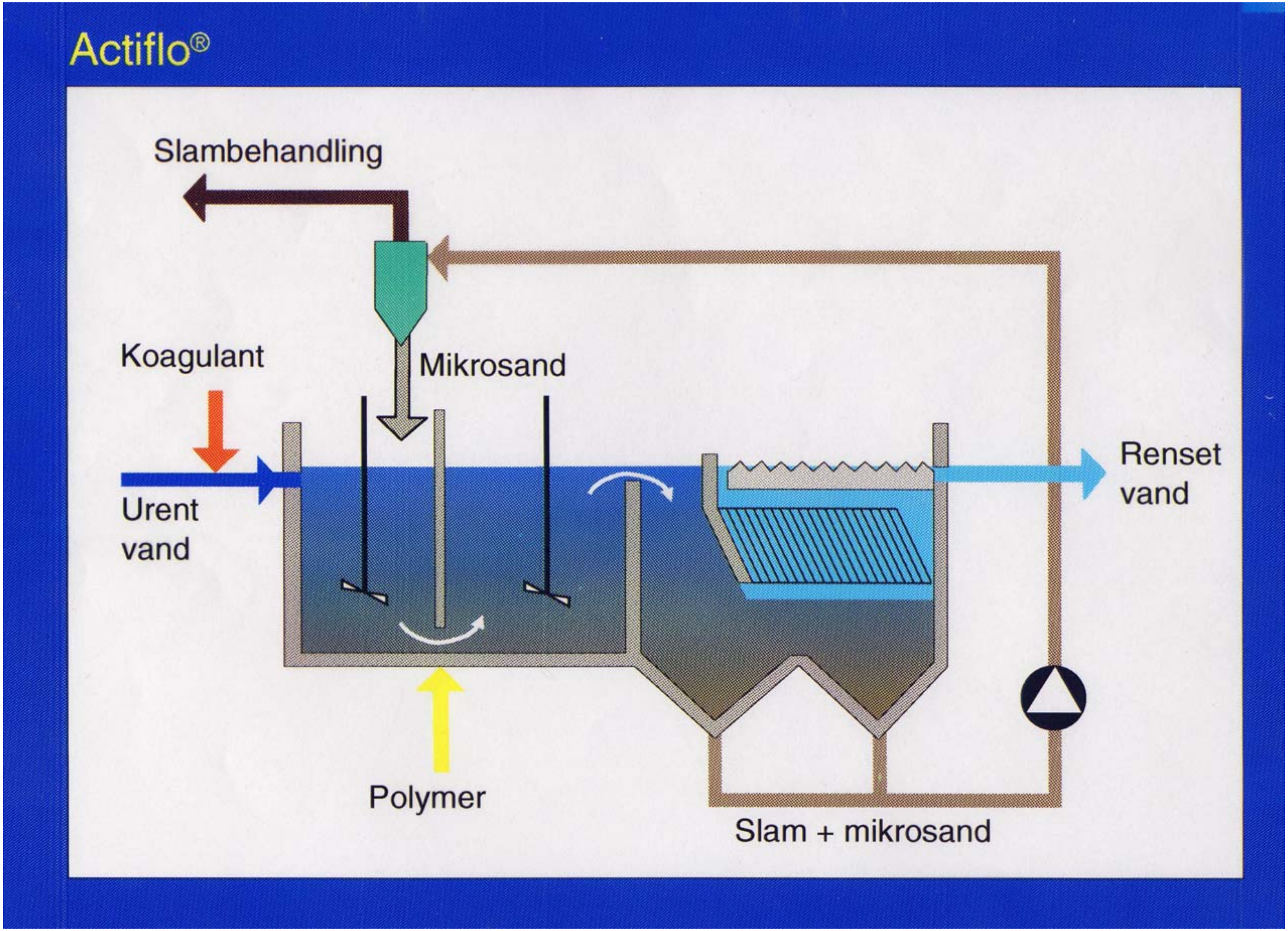


DEEP SETTLING TANK WITH PIPW FLOCCULATION AND COARSE FILTRATION/LAMELLA SEPARATION

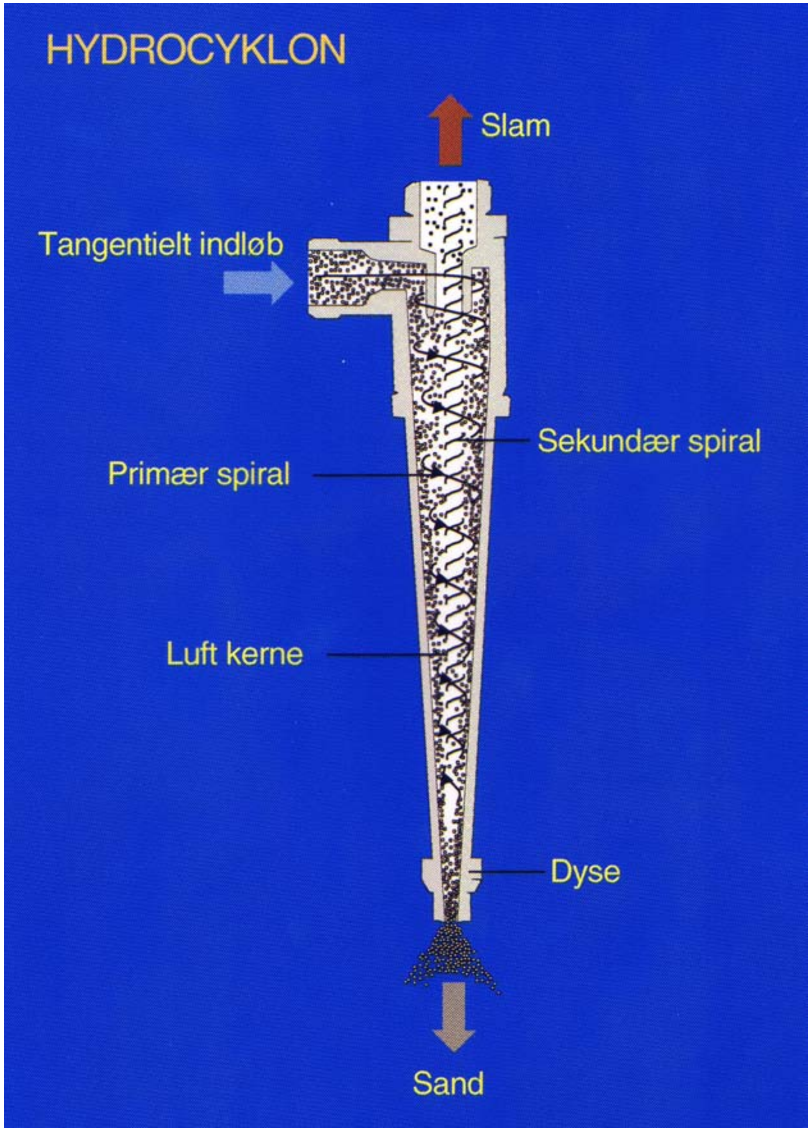




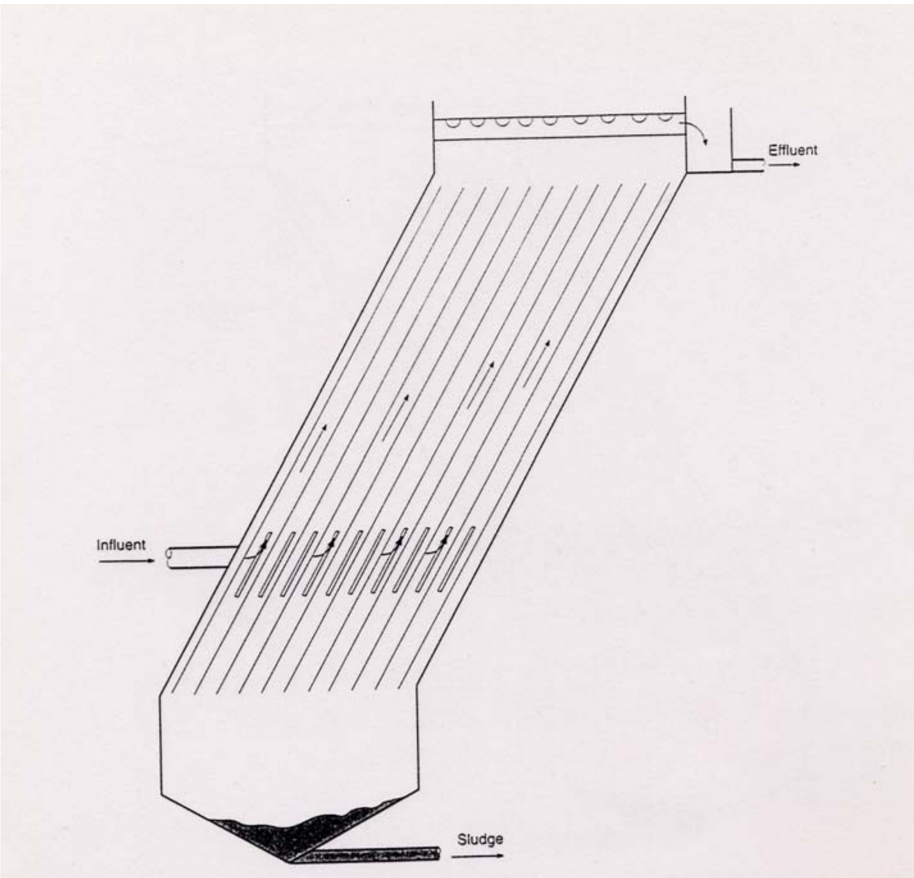
DENSADEG®
Raw Water
FeCl3
Polymer
Presettler
Treated Water
Sludge recirculation
Sludge draw-off
Reactor
Thickener / Settler

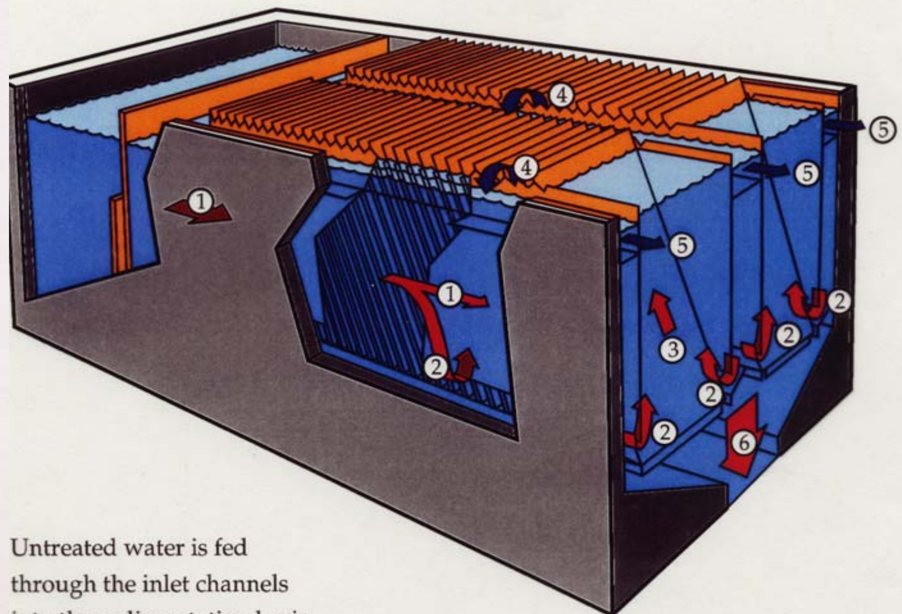

Actiflo®
Slambehandling
Koagulant
Mikrosand
Urent
vand
Renset
vand
Polymer
Slam + mikrosand

ACTIFLO MICROSAND SEPARATION



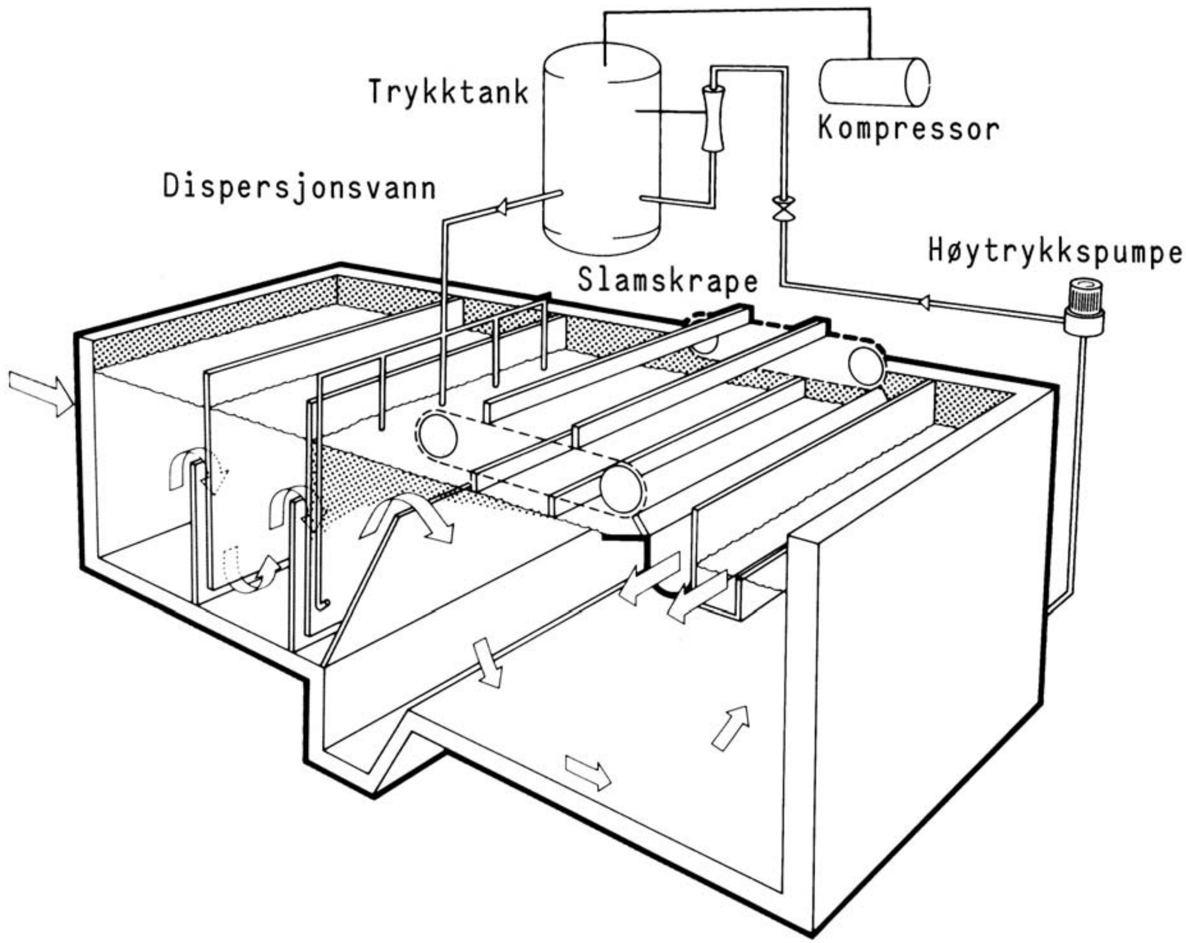
LAMELLA SETTLING





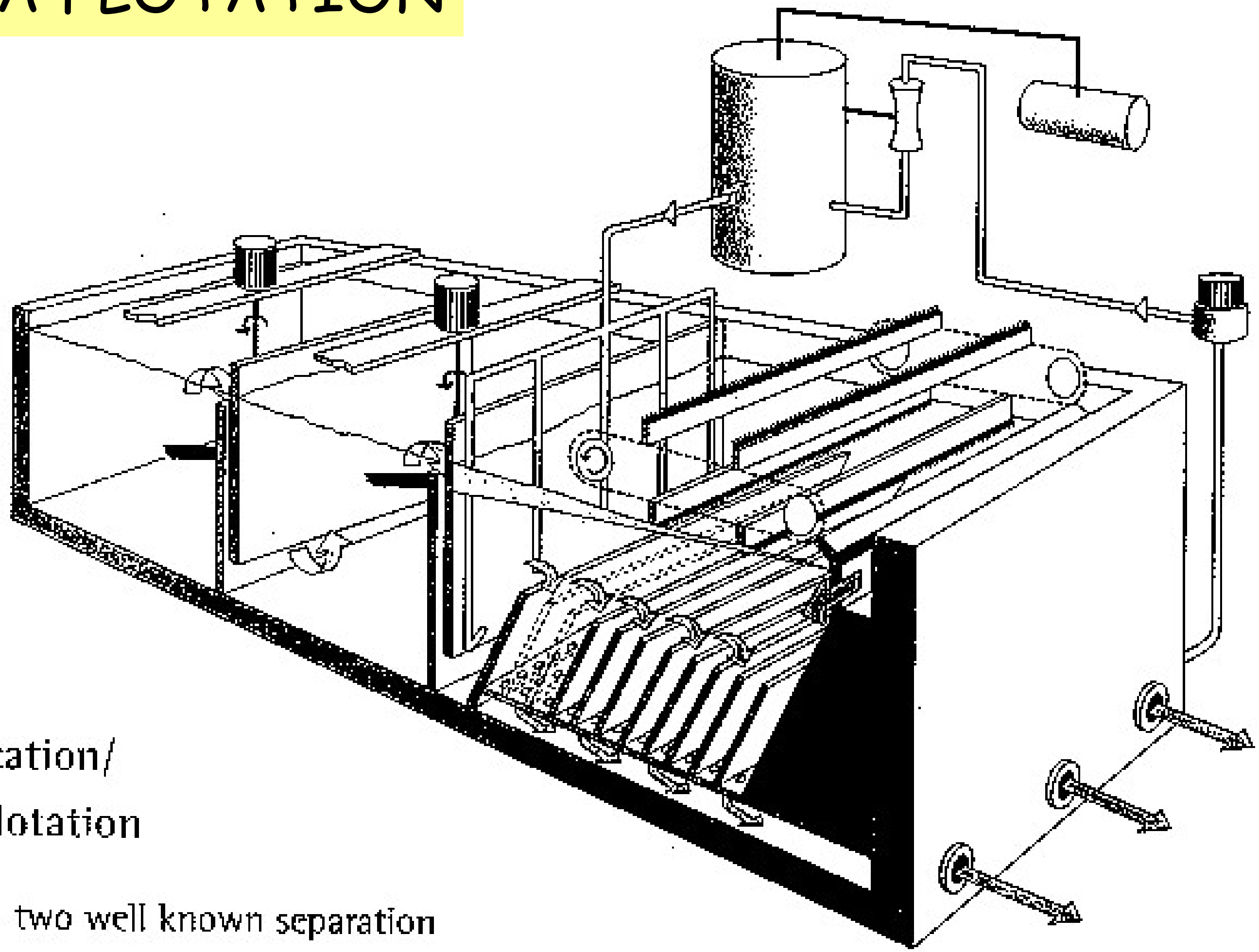
Untreated water is fed
through the inlet channels
into the sedimentation basin...

... flows in at the base of the lamellas...


Trykktank
Kompressor
Dispersjonsvann
Høytrykkspumpe
Slamskrape

FLOTATION

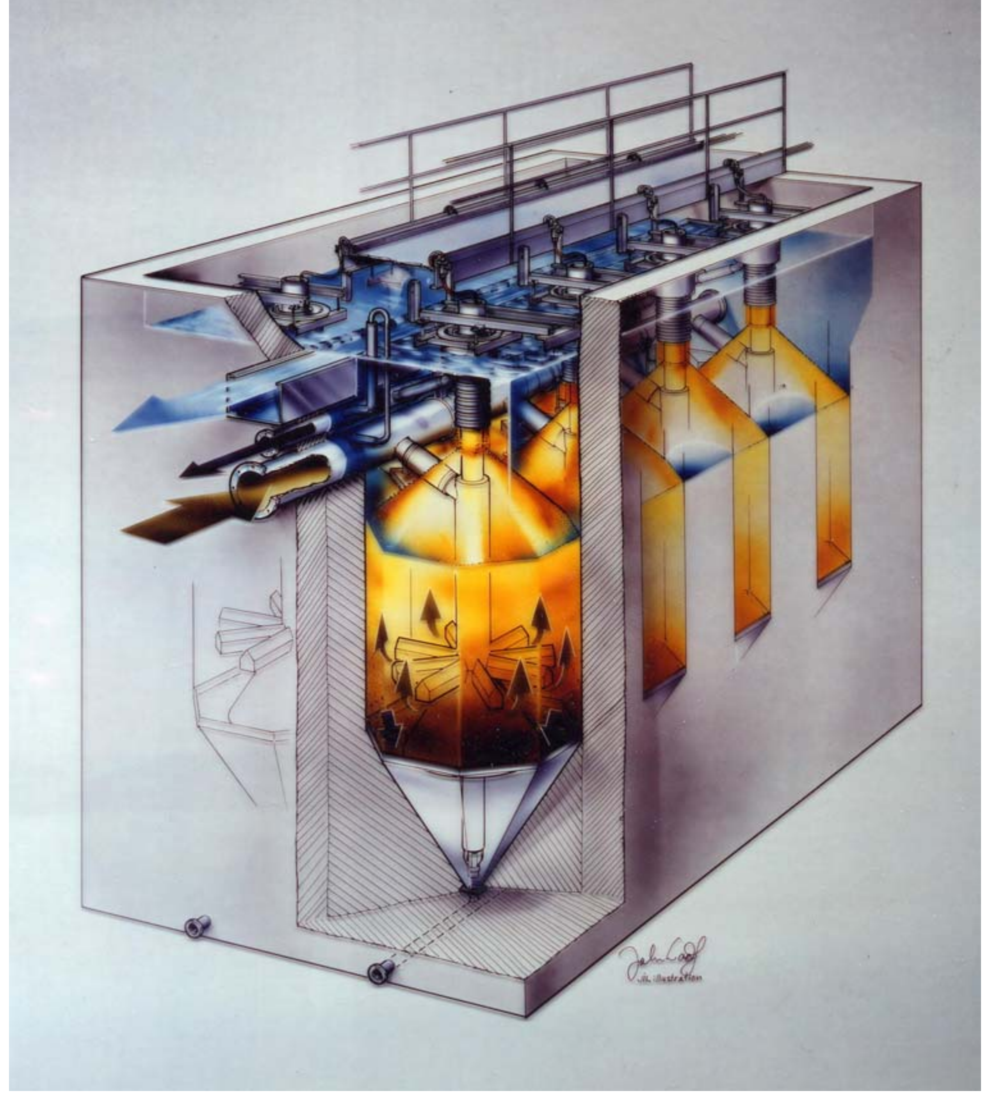
LAMELLA FLOTATION



Lamella Clarification/
Dissolved Air Flotation

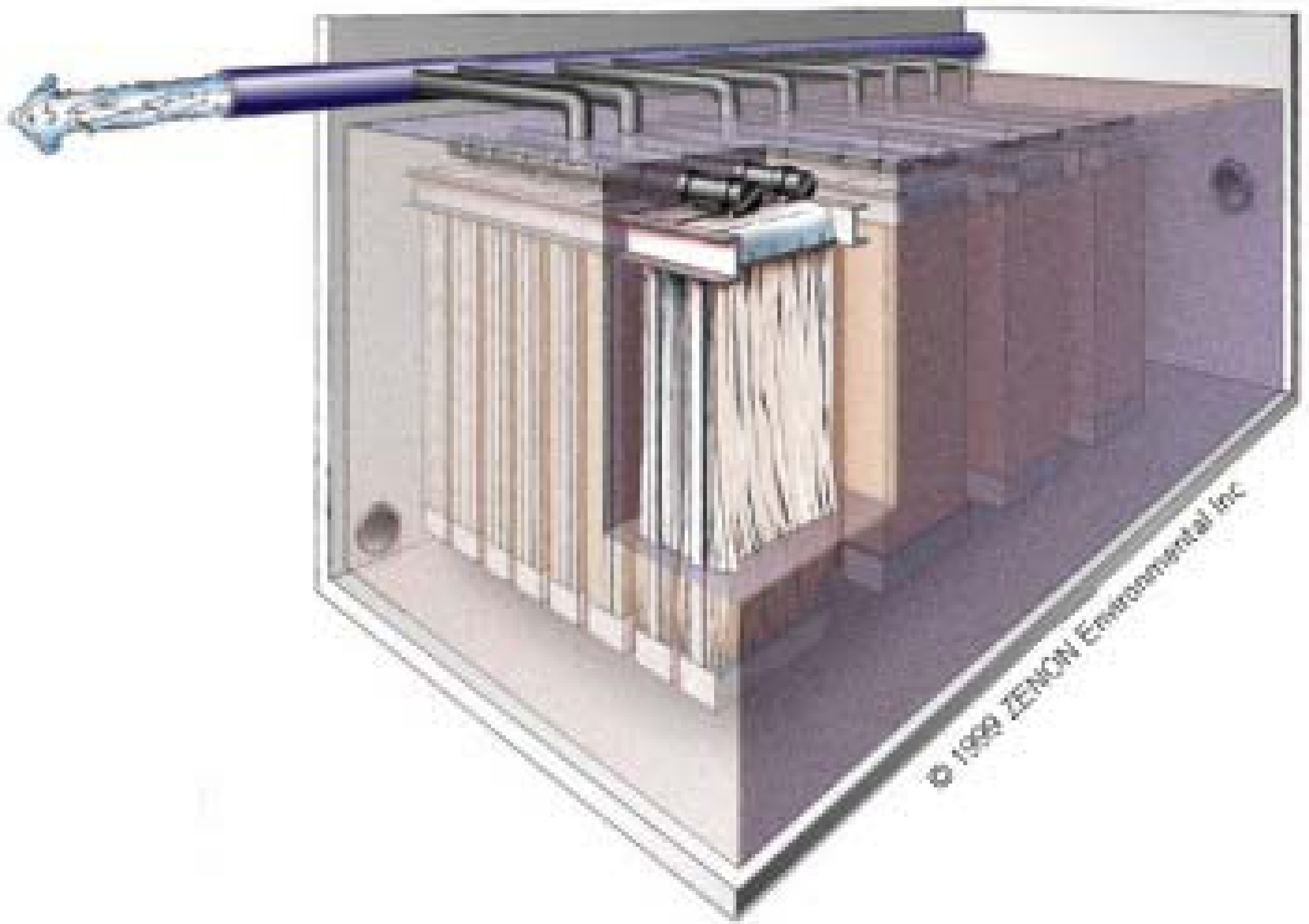
A synergy between two well known separation processes

THE DYNASAND FILTER

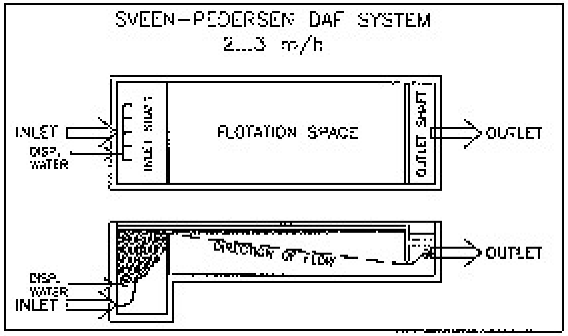


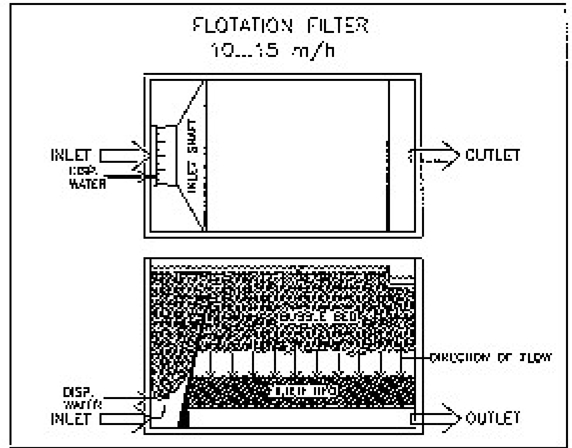
Prof. Hallvard Ødegaard

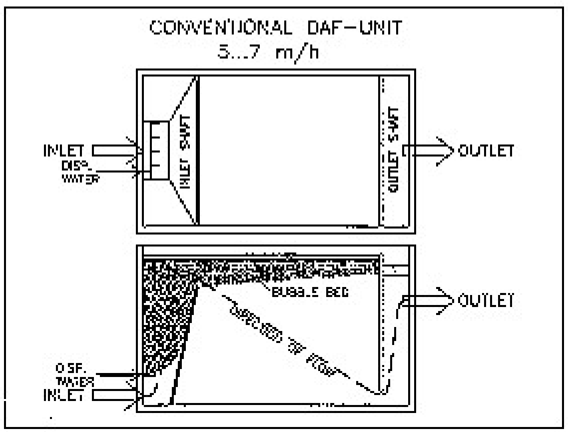
ZENON ULTRAFILTRATION

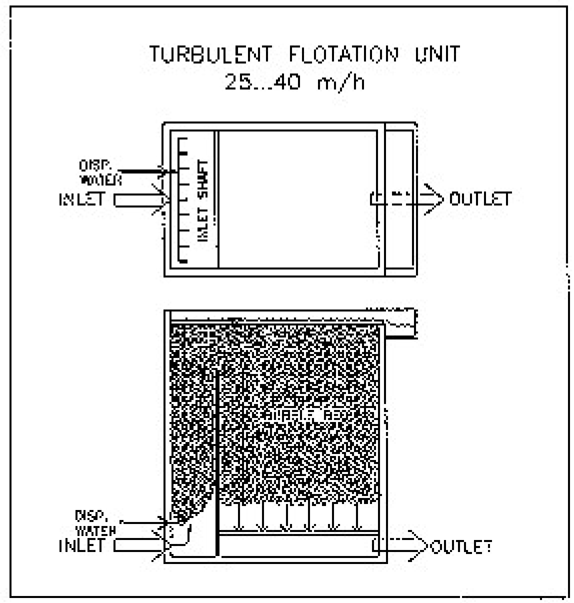


DEVELOPMENT OF FLOTATION









ADVANTAGES AND DISADVANTAGES OF FLOTATION IN COMPARISON WITH SEDIMENTATION

ADVANTAGES

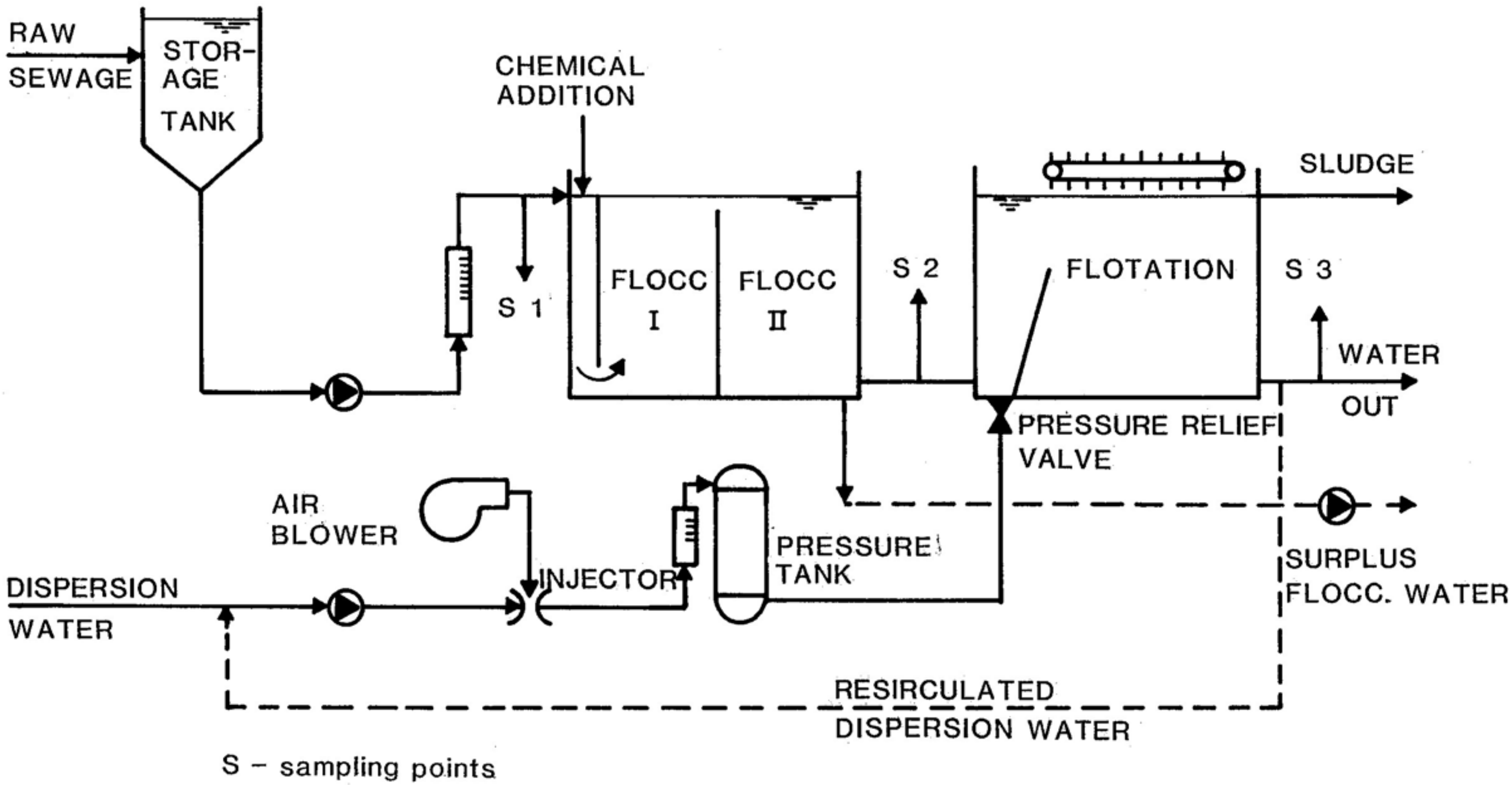
- Less space required, v_f = 5-15 m/h against 1-2 m/h
- Better separation efficiency
- Higher sludge concentration

DISADVANTAGES

- Higher costs ?
- Less known technology
- More skilled operators needed ?

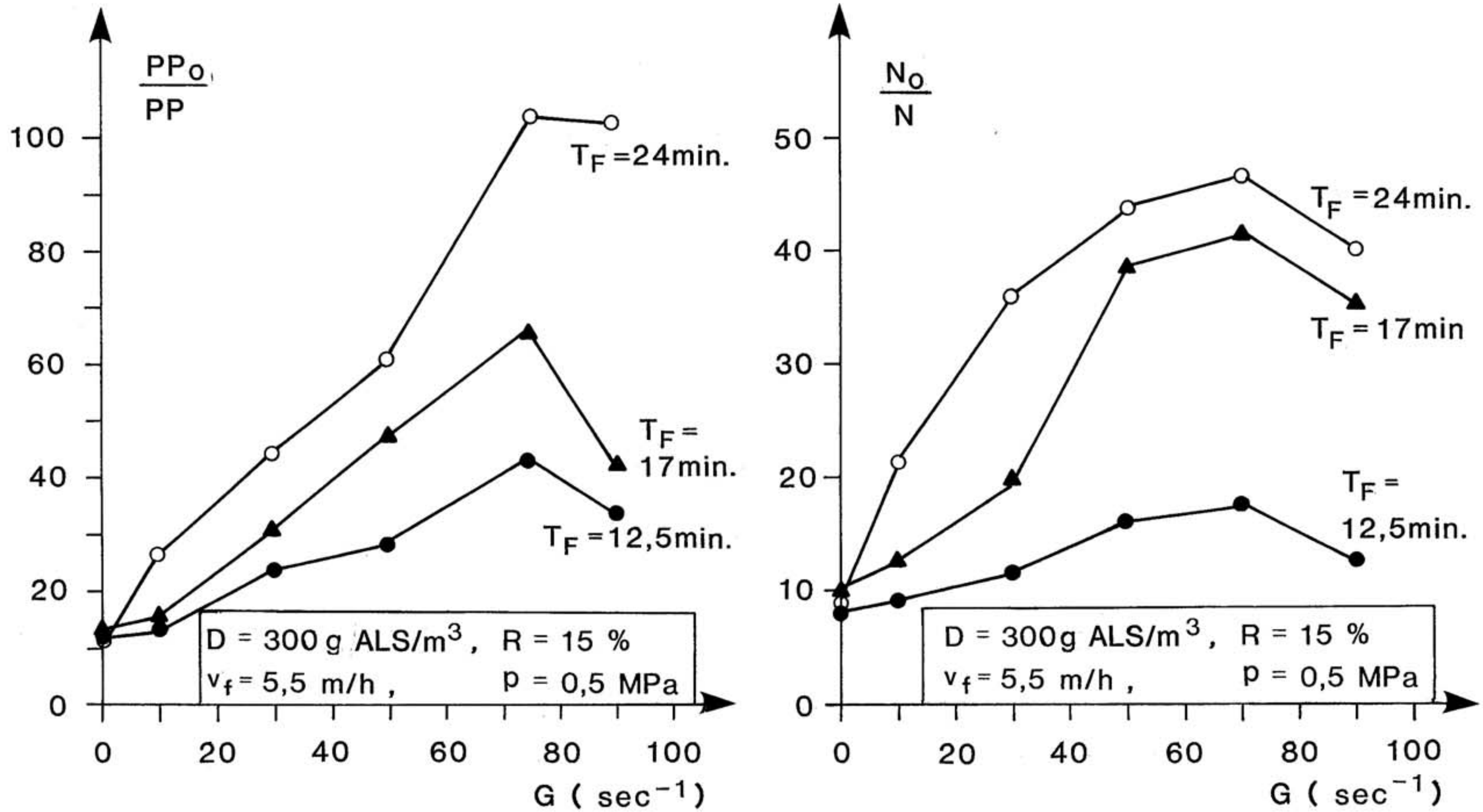
FLOCCULATION/FLOTATION EXPERIMENTS

Ødegaard(1995) Wat.Sci.Tech. Vol. 31, No 3.-4. Pp 73-82



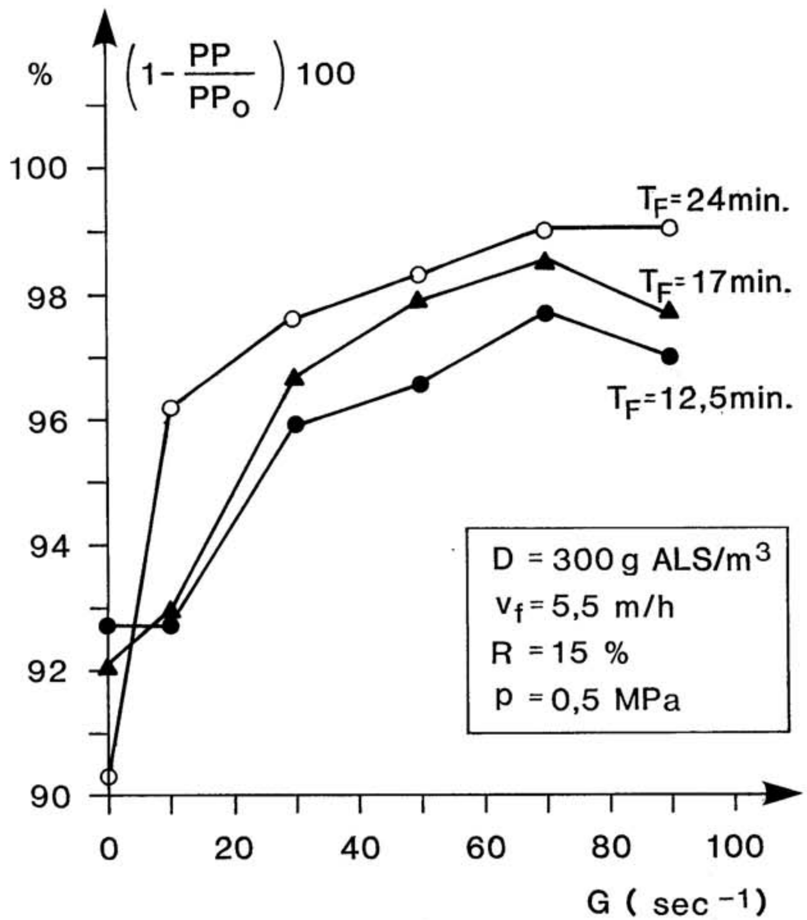
FLOW SHEET – EXPERIMENTAL SETUP

FLOCCULATION /FLOTATION EFFICIENCY VS G-VALUE AT VARIOUS RESIDENCE TIMES (T)

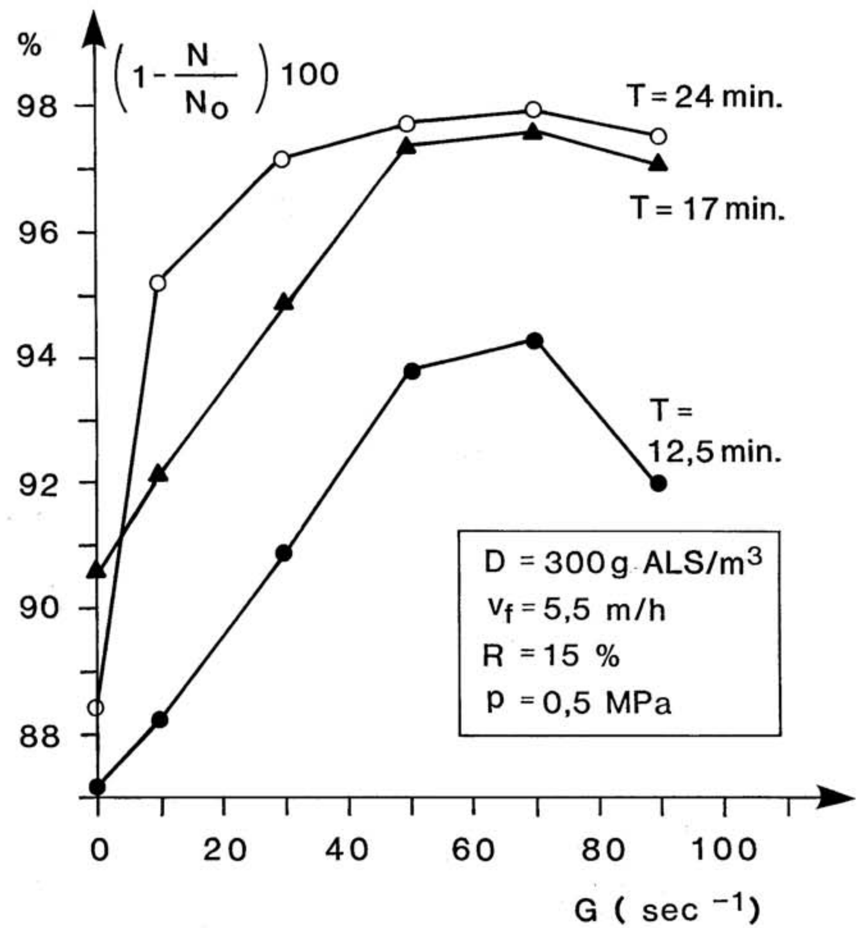


REMOVAL (%) VERSUS G AT VARIOUS T

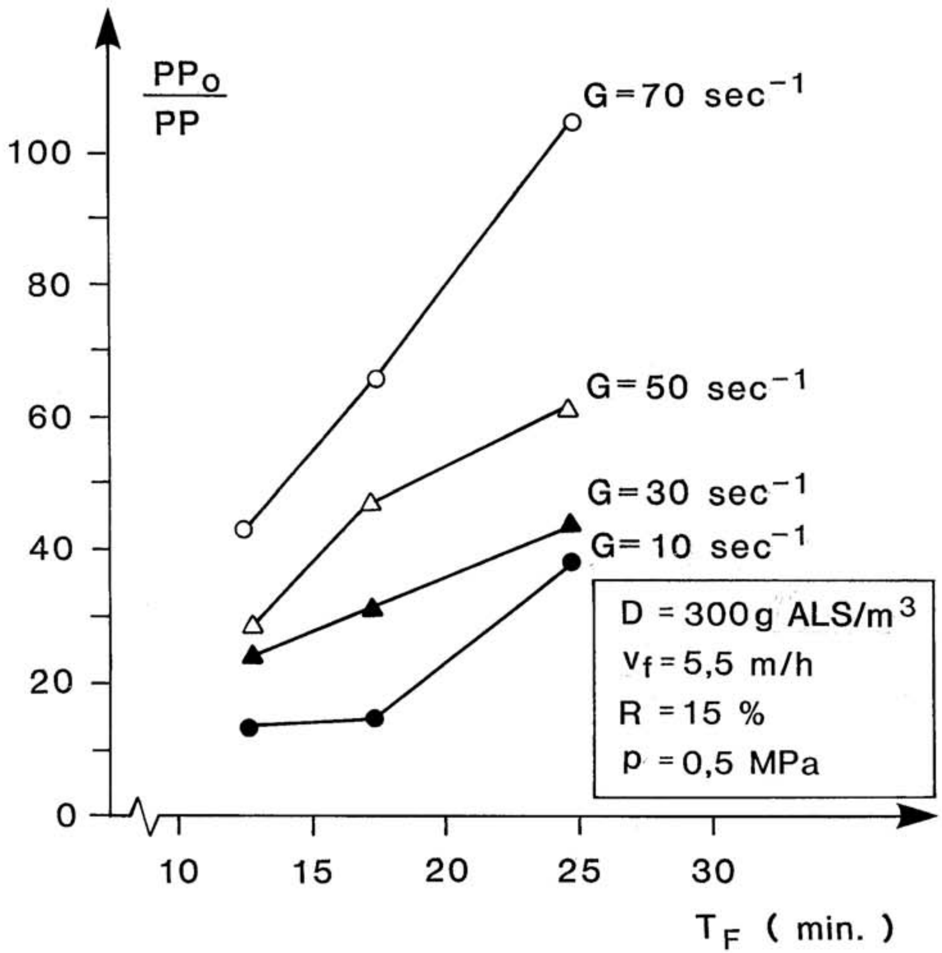
PP – particulate phosphate

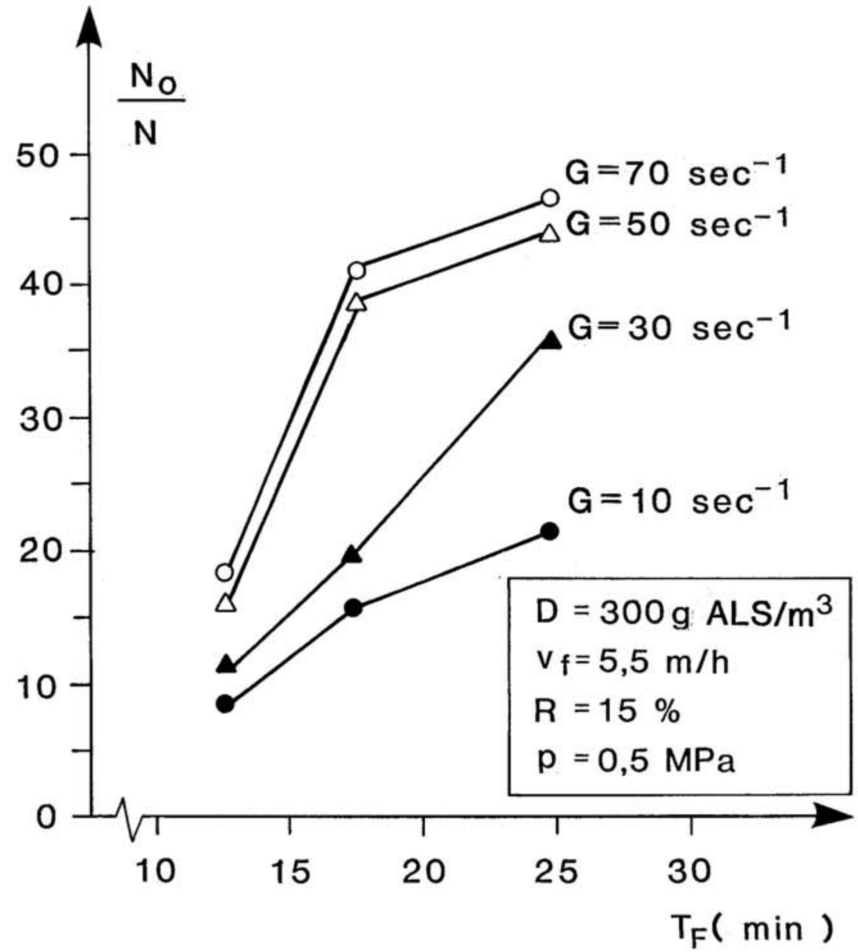


N - turbidity



FLOCCULATION/FLOTATION EFFICIENCY VERSUS T AT VARIOUS G





FLOCCULATION AHEAD OF FLOTATION

Ødegaard, Wat.Sci.Tech. Vol 31, No3-4, 1995

1. The theor.mean residence time at design flow should be 25 - 30 min.

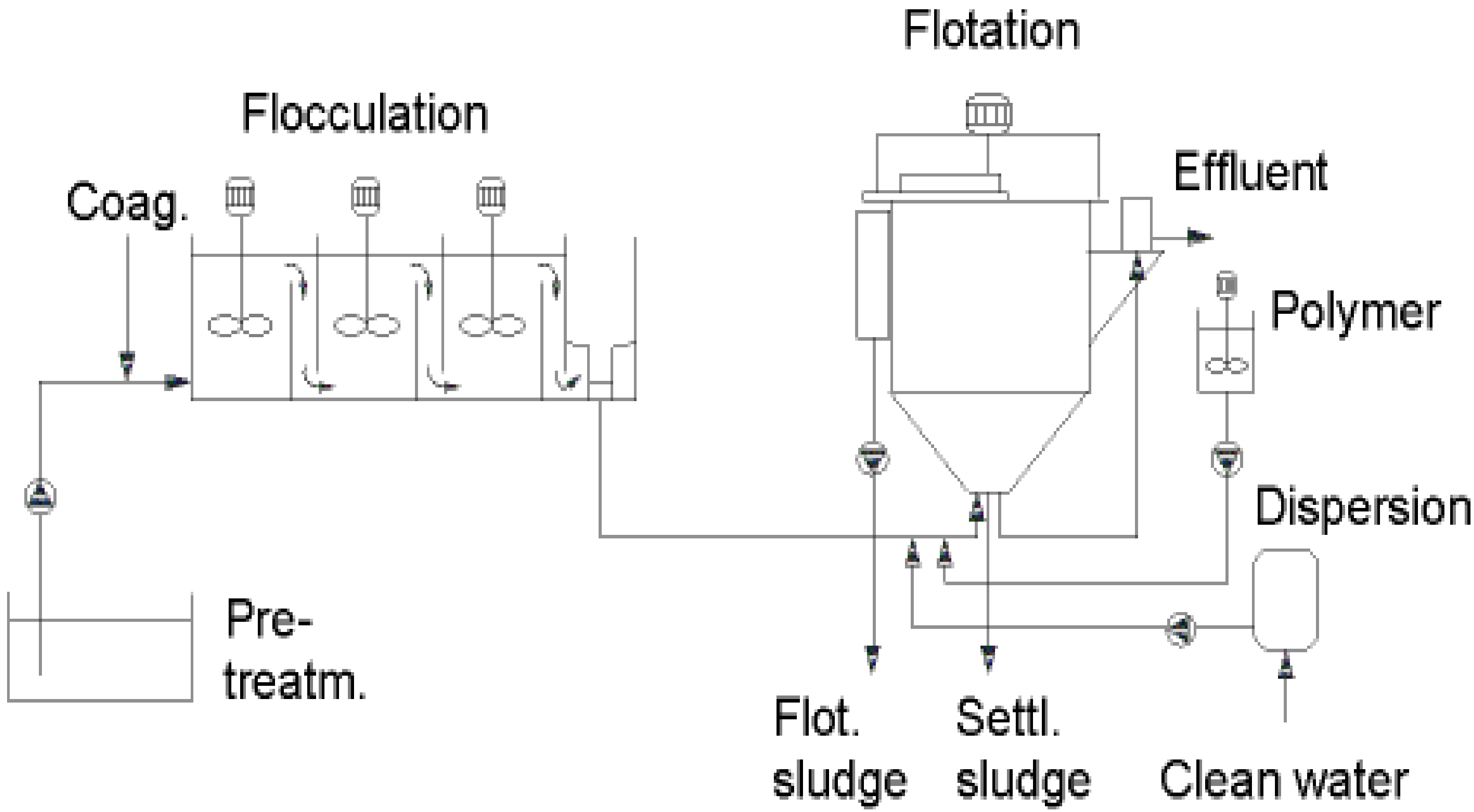
2. The flocculator should be designed to give a residence time distribution as plug flow like as possible. If stirred tanks are used, the flocculator should be divided into at least two chambers

3. The G-value should be the same in each of the flocculator chambers and in the order of 60 - 80 sec^{-1}.

4. The flotation unit should be designed for a hydraulic surface load of 5 - 6 $m^3/m^2 \cdot h$ at design flow allowing for variations up to 10 $m^3/m^2 \cdot h$ at maximum design flow. If the variation in the flow is small, a load of 8 $m^3/m^2 \cdot h$ could be recommended at design flow.

5. The amount of pressurized water should be 10-20 % of design flow when the pressure is 0.5 MPa.

THE MUSLINGEN FLOTATION PLANT





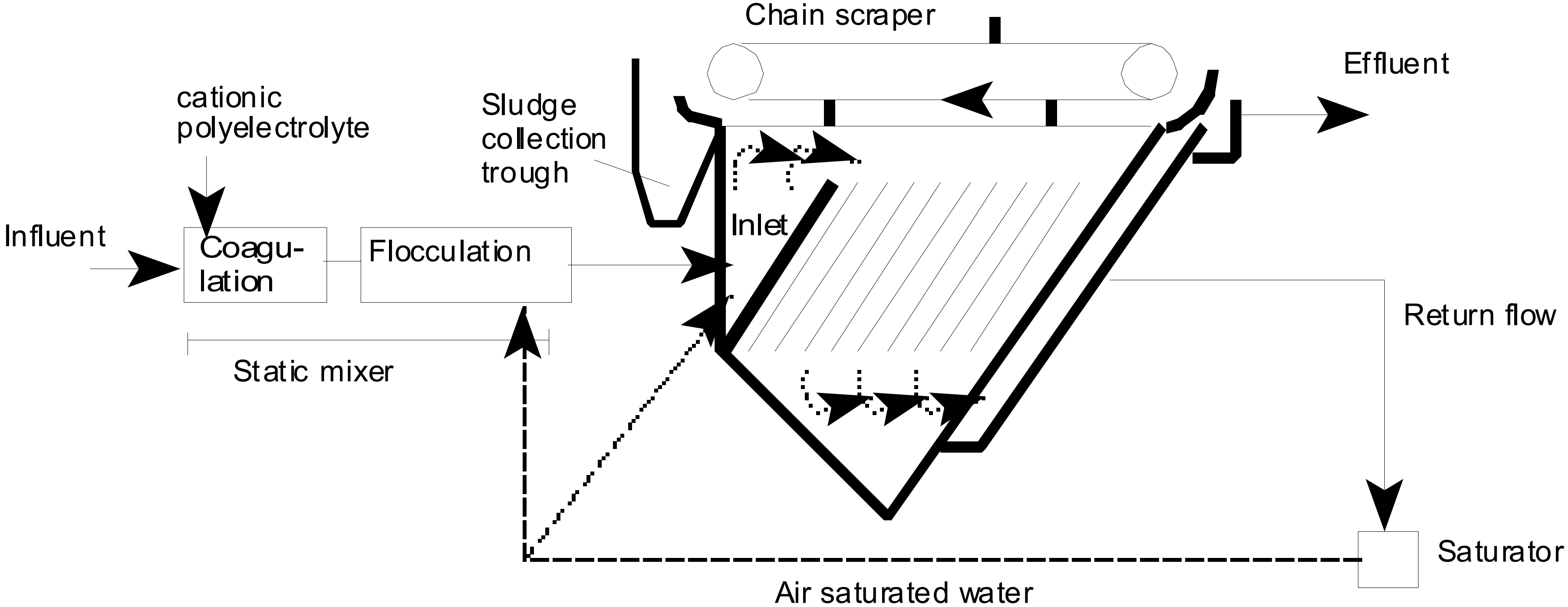
TREATMENT RESULTS MUSLINGEN

Plant	Overflow rate (m/h)	Tot P In (mg/l)	Tot P Out (mg/l)	Tot P %
A	1.9 (4,0)	5,9 (9,3)	0.12 (0,42)	98.0
B	4.2 (8.7)	4,6 (7,3)	0.21 (0.59)	95.4
C	1.9 (6.9)	4.4 (7.6)	0.10 (0.34)	97.7
D	4.6 (7.3)	4.6 (7.3)	0.38 (1.63)	91.7
E	4.4 (6.6)	1.9 (2,7)	0.06 (0.07)	96.8

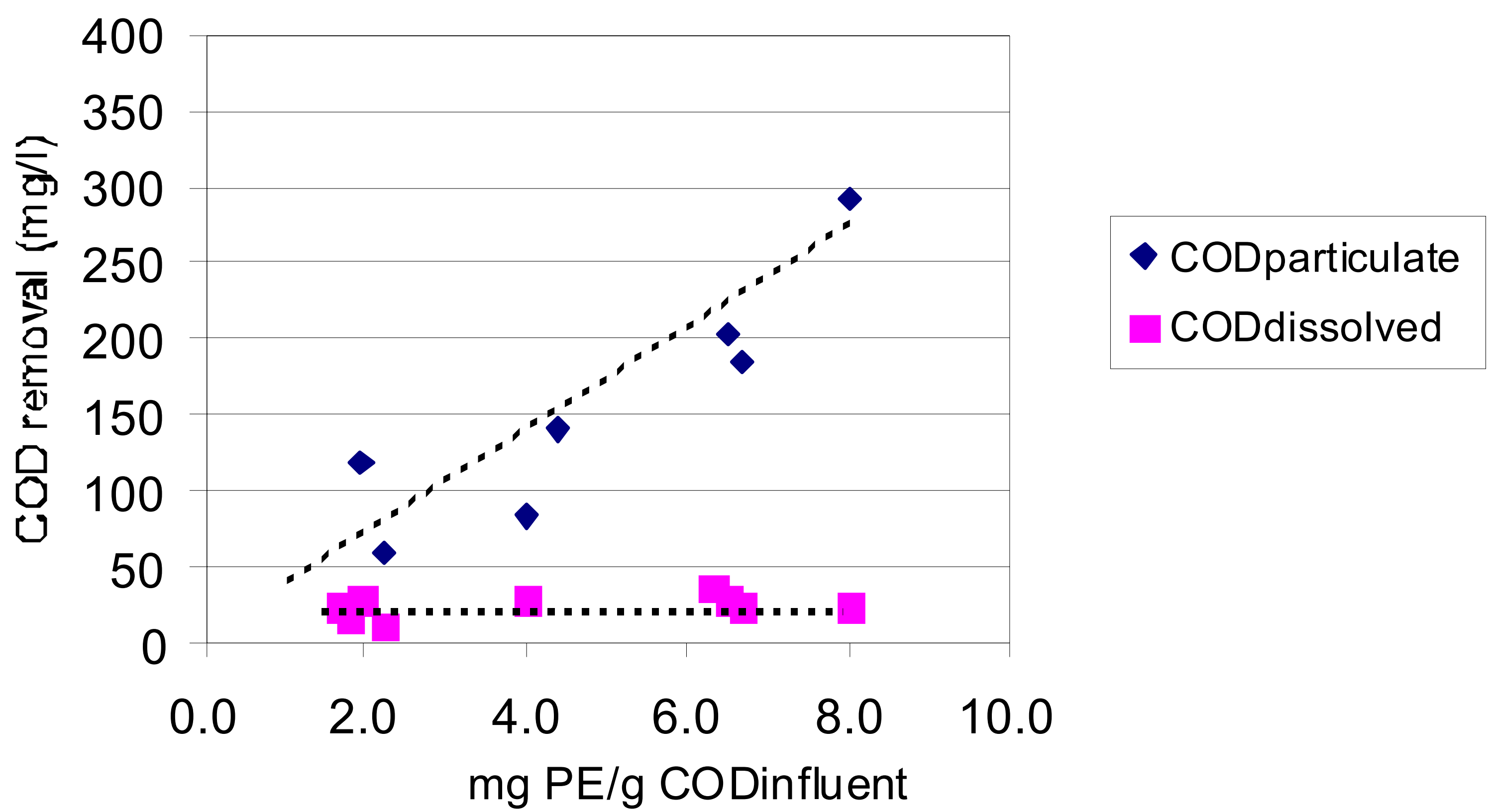
Plant	Overflow rate (m/h)	COD *(TOC)* In (mg/l)	COD *(TOC)* Out (mg/l)	COD *(TOC)* %
A	1.9 (4,0)	337 (710)	62 (120)	81.6
B	4.2 (8.7)	*109 (190)*	*8.9 (15.3)*	*91.8*
C	1.9 (6.9)	343 (643)	97 (151)	71.7
D	4.6 (7.3)	*93 (180)*	*28 (58)*	*69.9*
E	4.4 (6.6)	119 (167)	30 (30)	74.8

Dutch experiments (Mels et al, 2000)

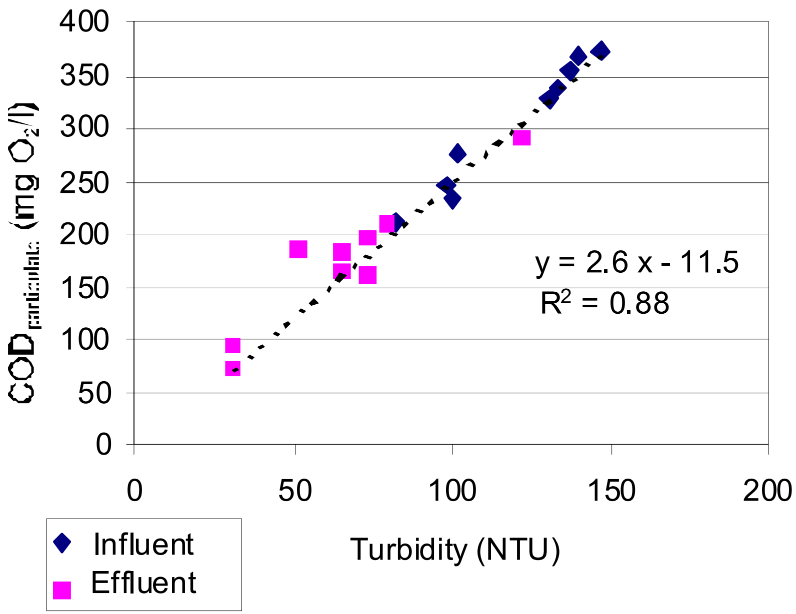
Pilot system

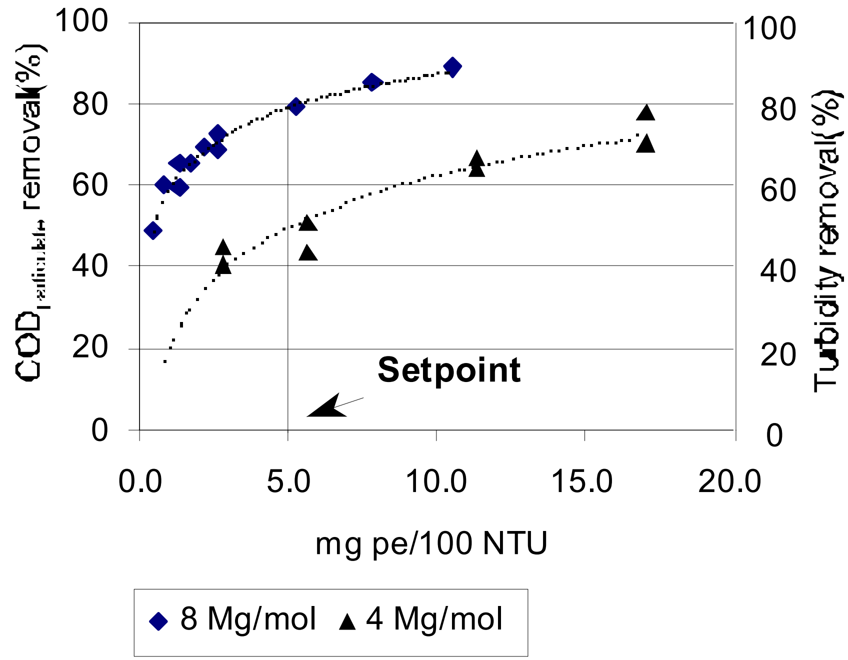


DAF Pilot results: COD removal



Discussion: Determining flocculation/flotation efficiency with turbidity measurements



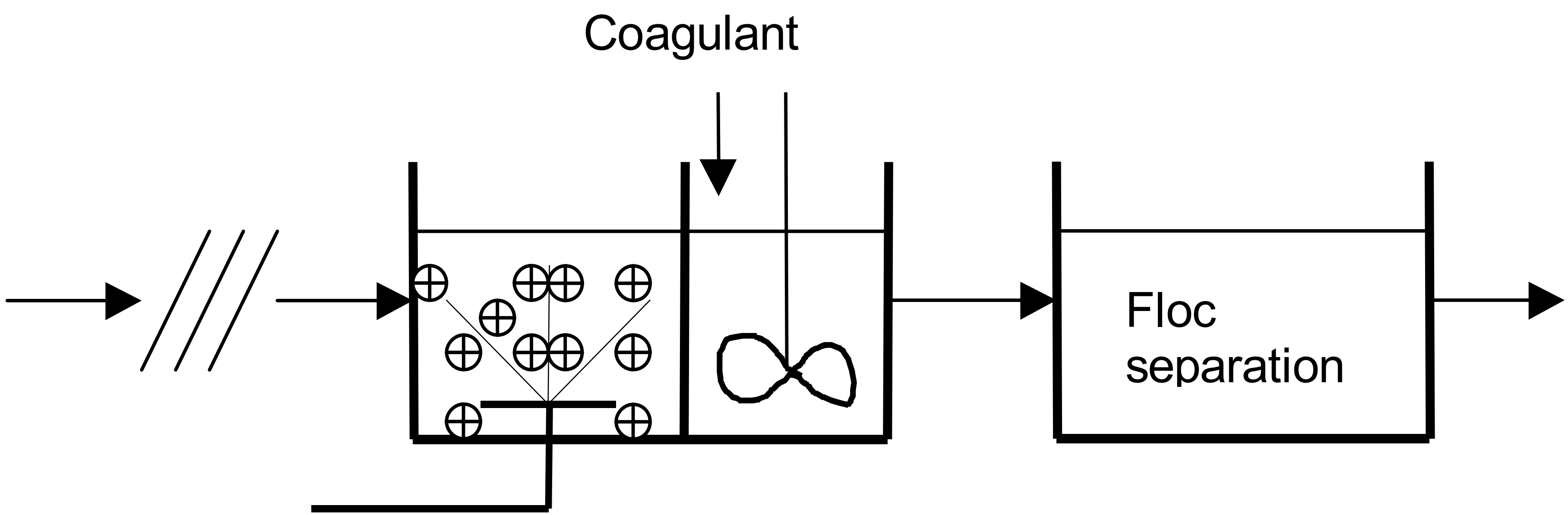


Linear relation turbidity and particulate COD

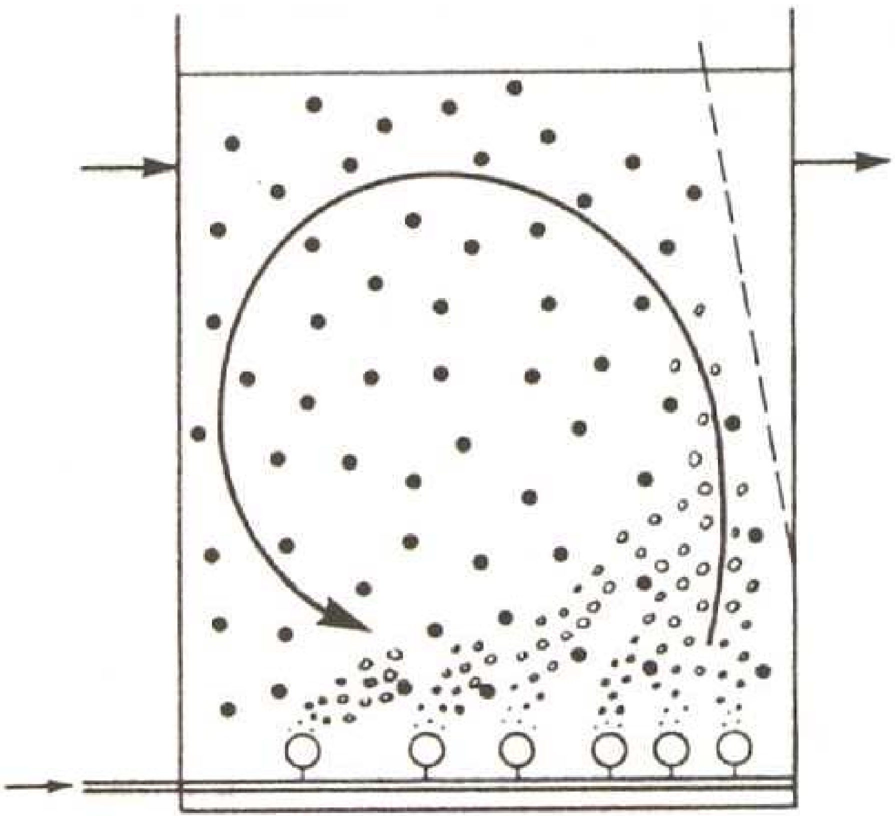
Evaluation of two PE's by plotting particulate COD as a function of PE-$NTU_{influent}$-ratio

PROPOSED SECONDARY TREATMENT PROCESS

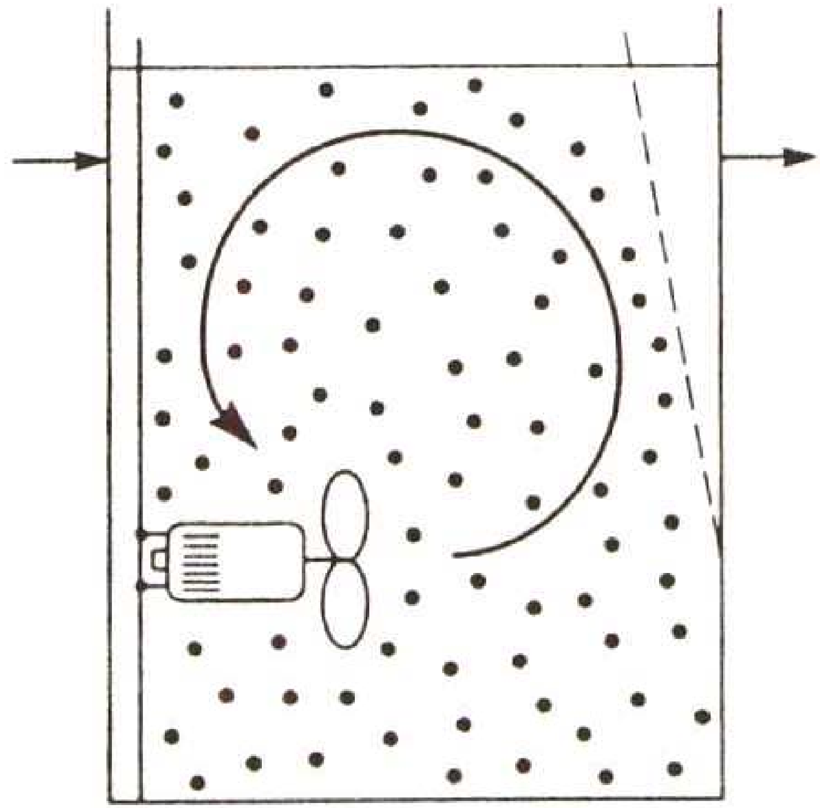
- Particulate organic matter is coagulated and separated as in a conventional chemical plant
- Easily biodegradable matter is removed in a highly loaded biofilm reactor at such a high load that only easily biodegradable organic matter is degraded (no hydrolysis)
- Good biomass separation of incoming particles as well as produced biomass



THE PRINCIPLE OF THE MOVING BED REACTOR



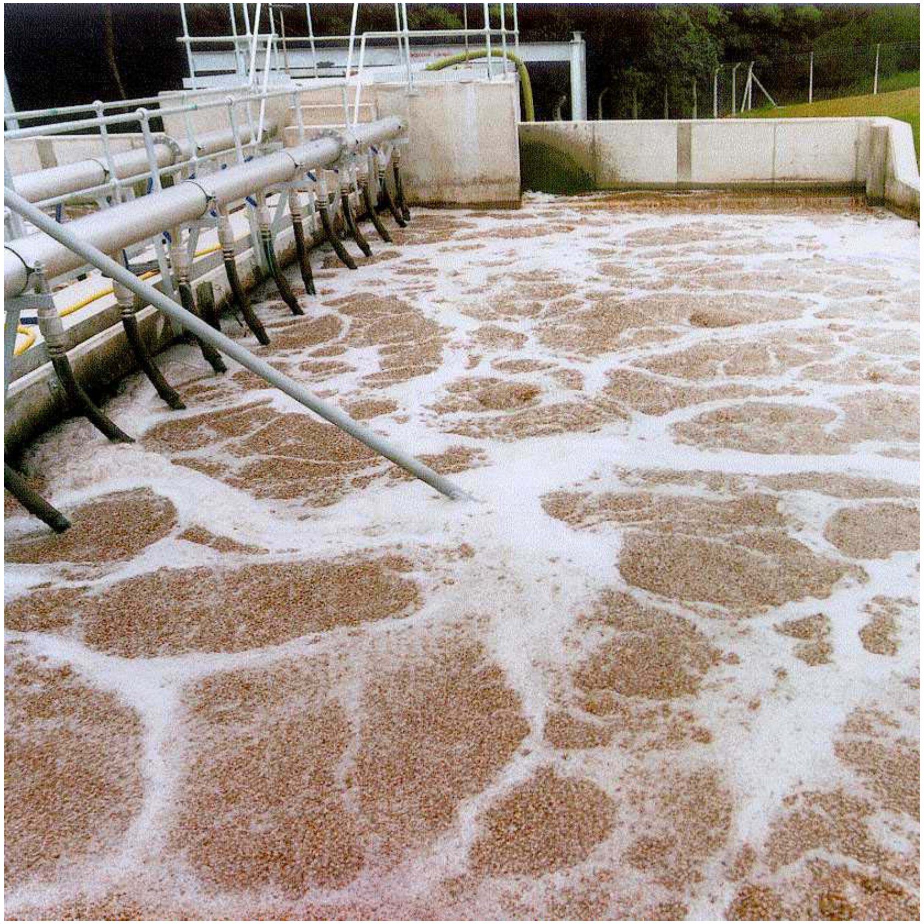
Aerobic reactor



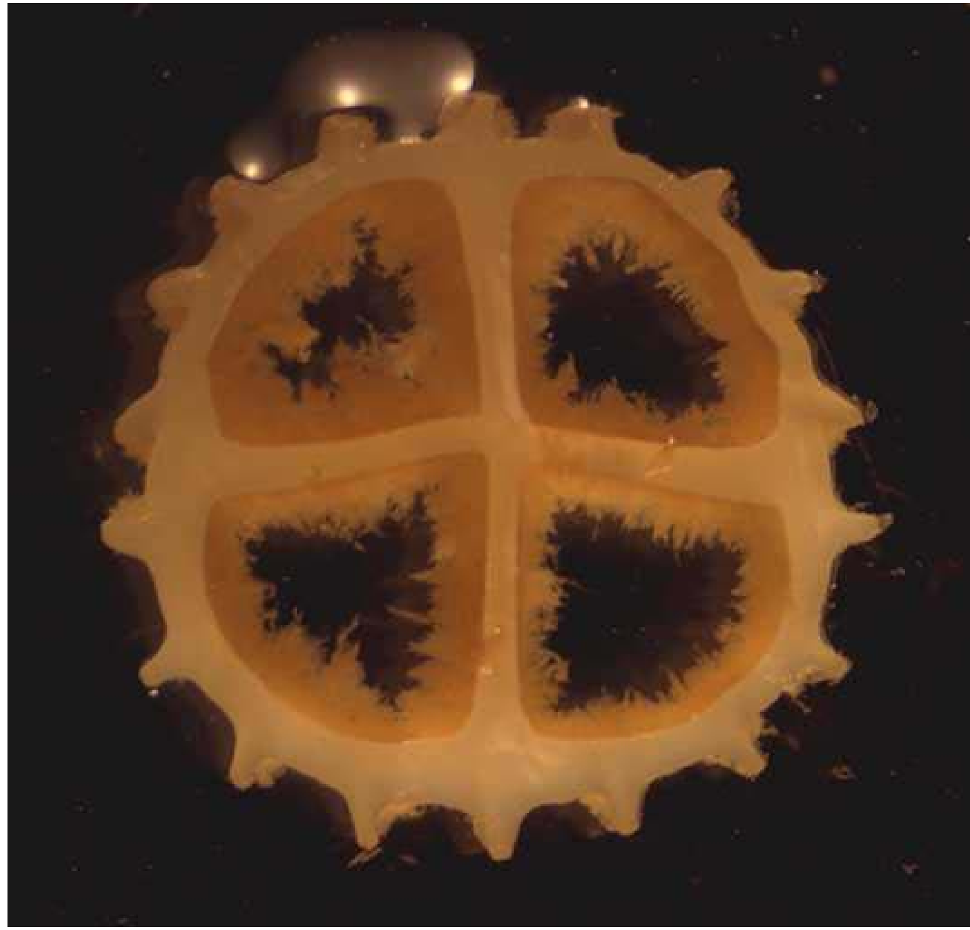
Anaerobic/anoxic reactor

THE KALDNES MOVING BED BIOFILM PROCESS

Aerated tank for nitrification



Carrier under water



CHARACTERISTICS OF THE BIOFILM CARRIERS

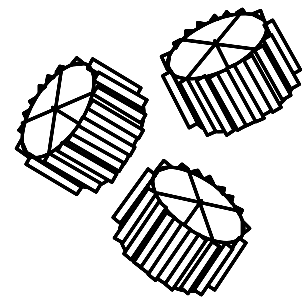
Biofilm carrier :

Material : Polyethylene (density 0,95 g/cm^3)

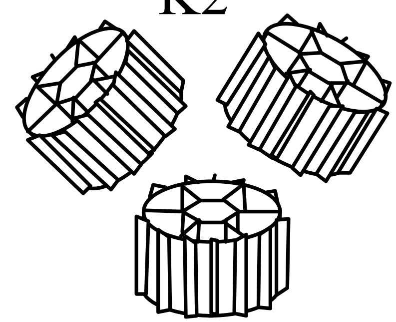
Size : K1 - Diam./Length = 10mm/7mm

K2 - Diam./Length = 15mm/15mm

K1



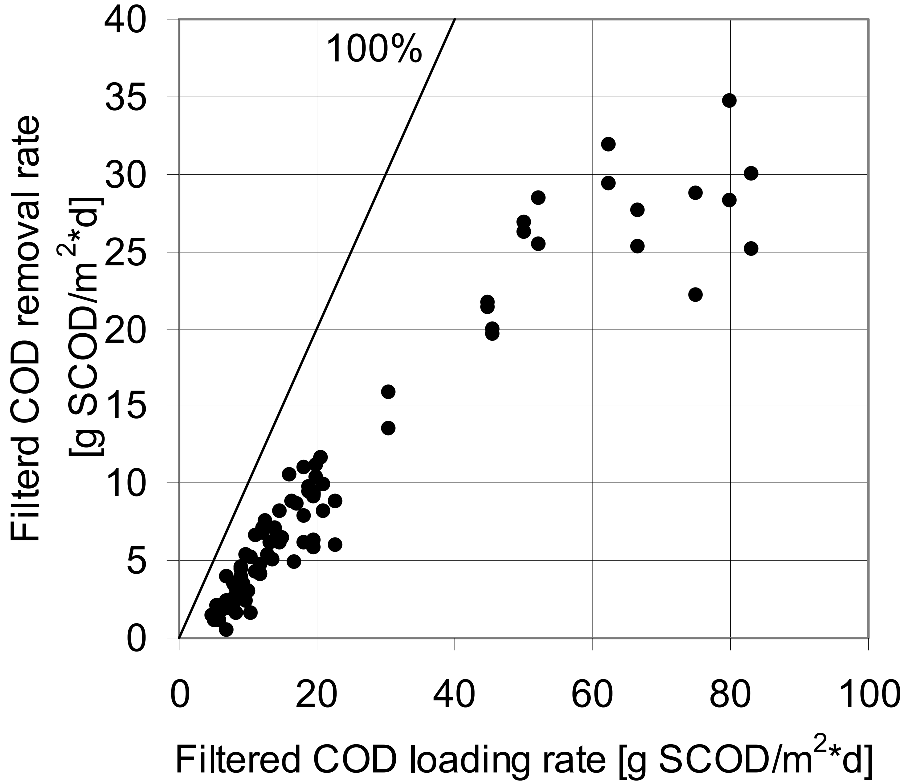
K2



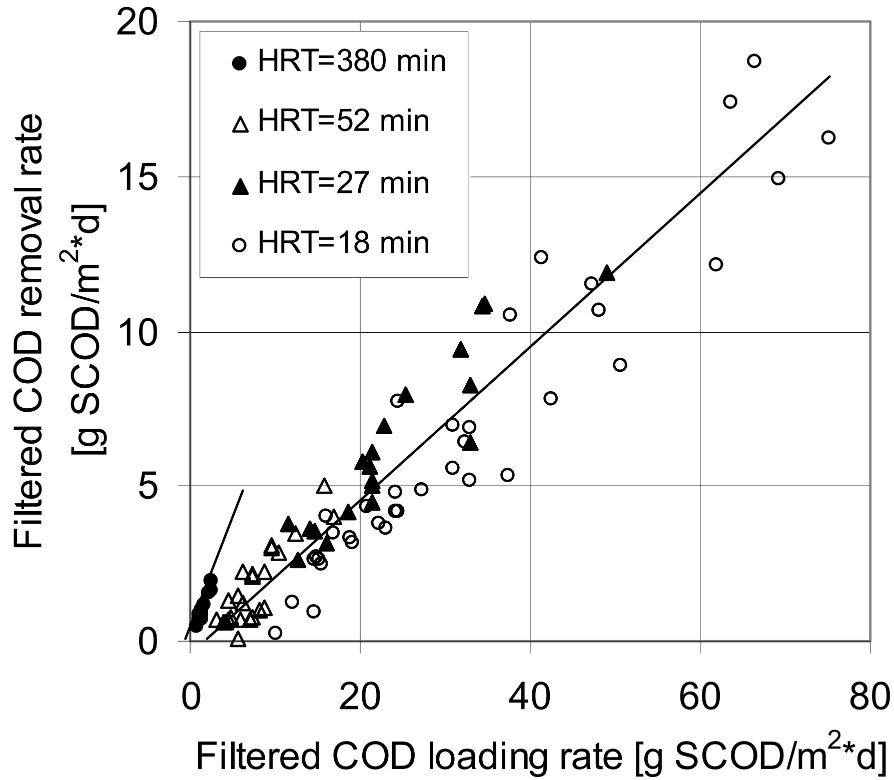
Surface area	K1	K2
Per carrier (mm^2)		
Total	670	2300
Effective for biofilm growth	490	1530
Specific area (m^2/m^3)		
Total at 70 % carrier filling	490	330
Effective for biofilm growth	350	220

SOLUBLE COD REMOVAL RATE VERSUS SOLUBLE COD LOADING RATE

Period 1 and 2



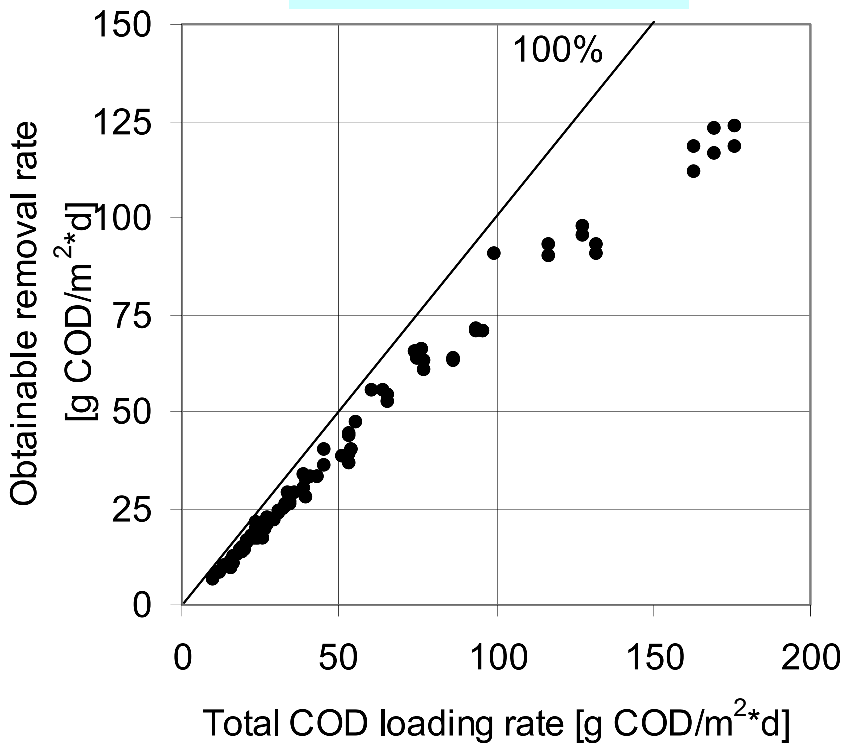
Period 3



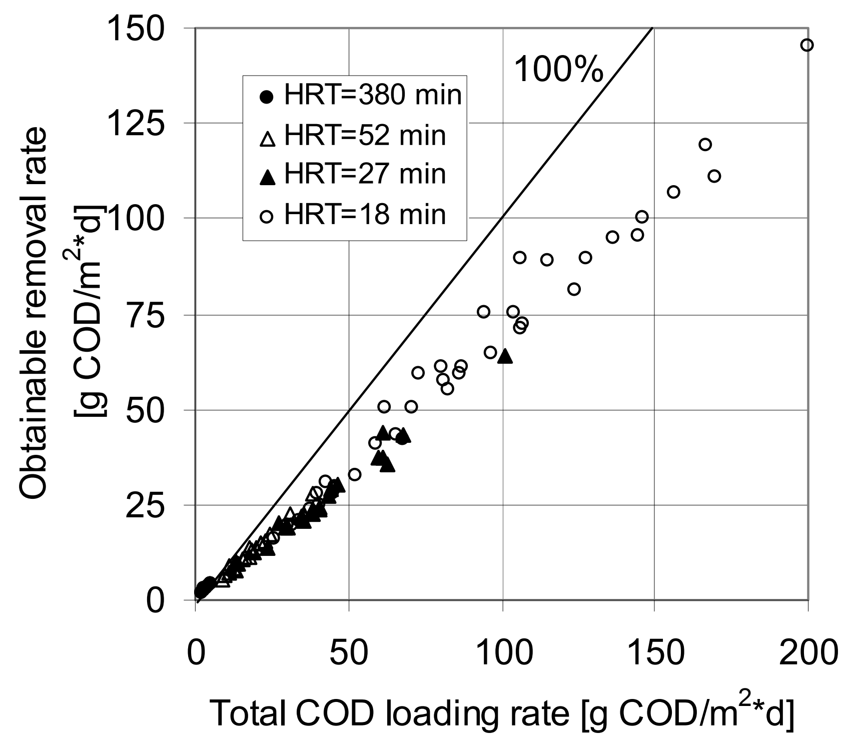
"OBTAINABLE" COD REMOVAL RATE VERSUS TOTAL COD LOADING RATE

"Obtainable" COD removal rate : $(COD_{influent} - SCOD_{effluent}) * Q/A$

Period 1 and 2

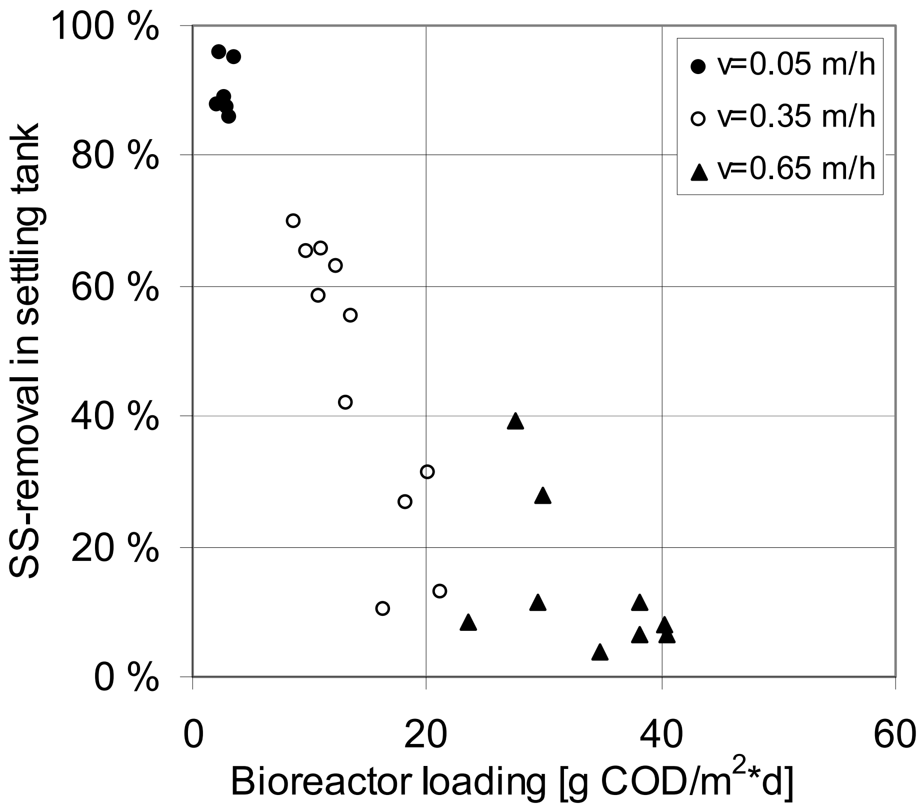


Period 3



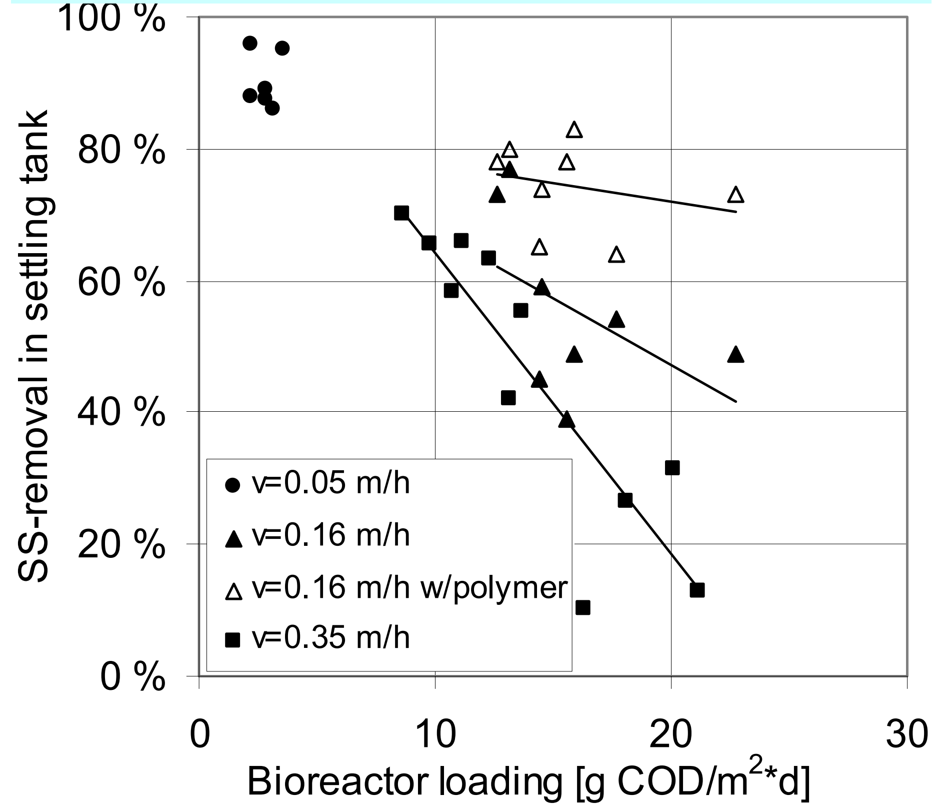
RESULTS SETTLING EXPERIMENTS

Influence of organic loading rate in bioreactor on settleability

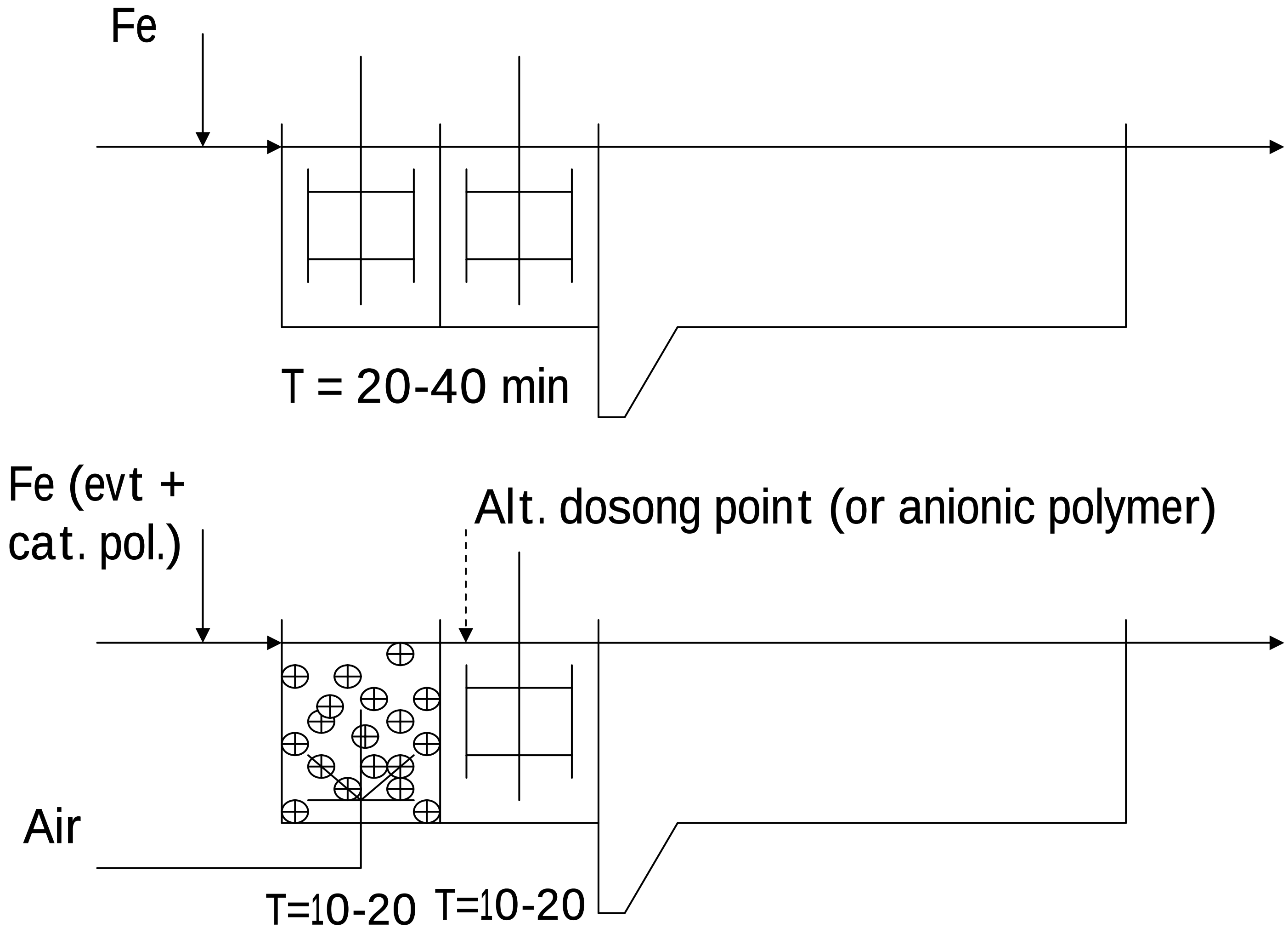


Influence of polymer addition on settleability

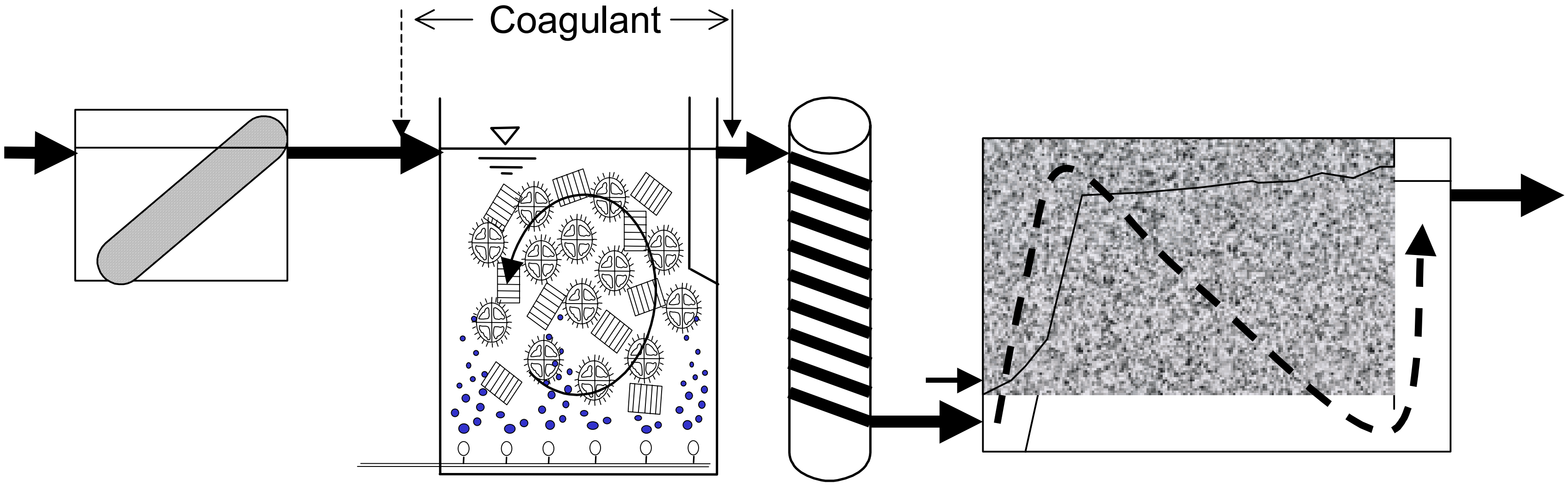
Medium charge, high MW cationic polymer



RETROFITTING EXISTING PRIMARY PRECIPITATION PLANTS BY THE HIGH RATE MOVING BED PROCESS

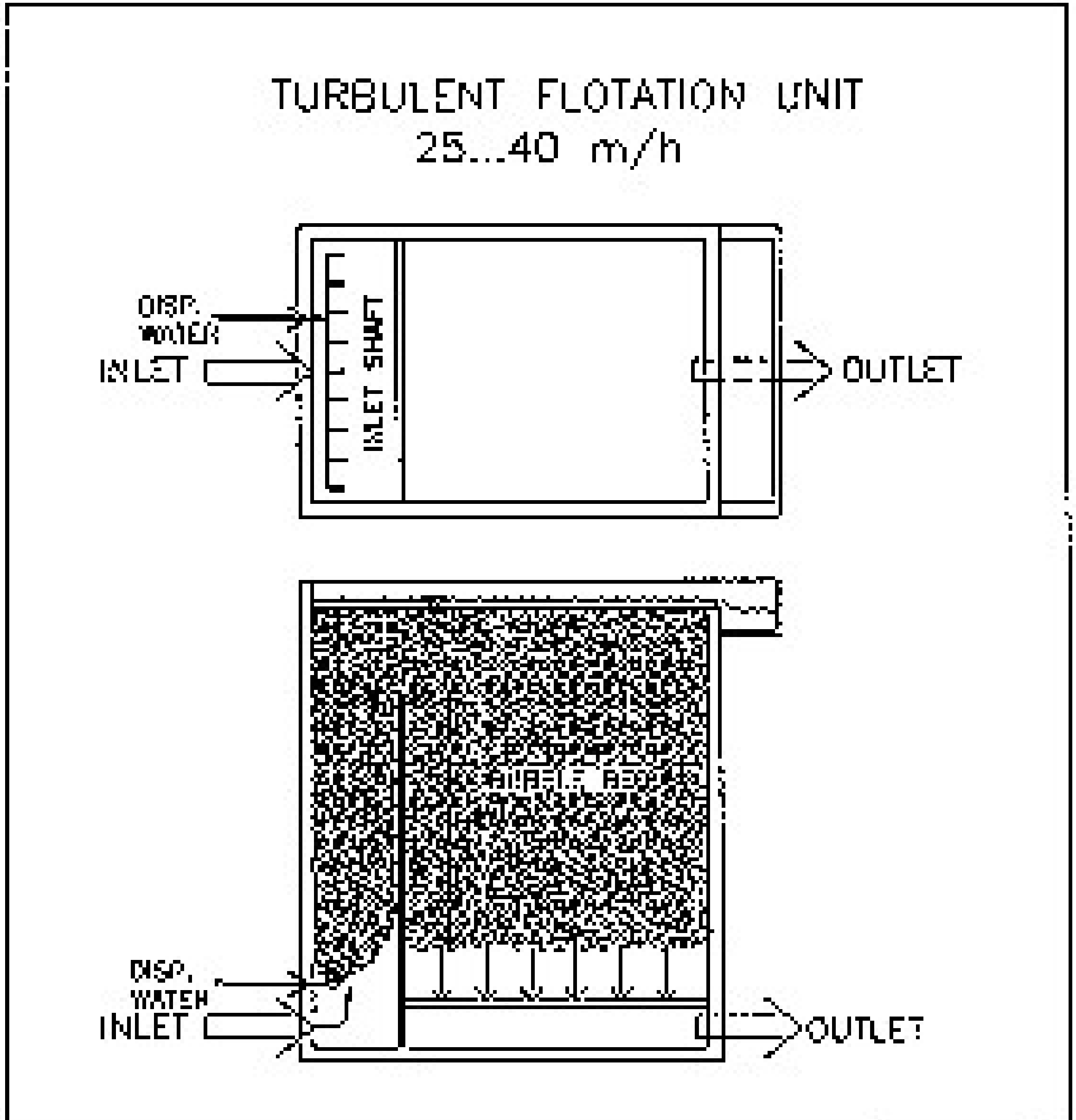


THE HIGH RATE PROCESS IN A NEW PLANT (total residence time < 1 time)



Pre treatment	MBBR	Flocculation	Flotation
fine sieve	HRT: ~30 min	HRT: 10 - 15 min	HRT: 15 - 30 min

TURBULENT FLOTATION



QUESTIONS TO BE ANSWERED

ON COAGULATION/FLOCCULATION

- Where to dose the coagulant?
- What coagulant?
- How much coagulant?

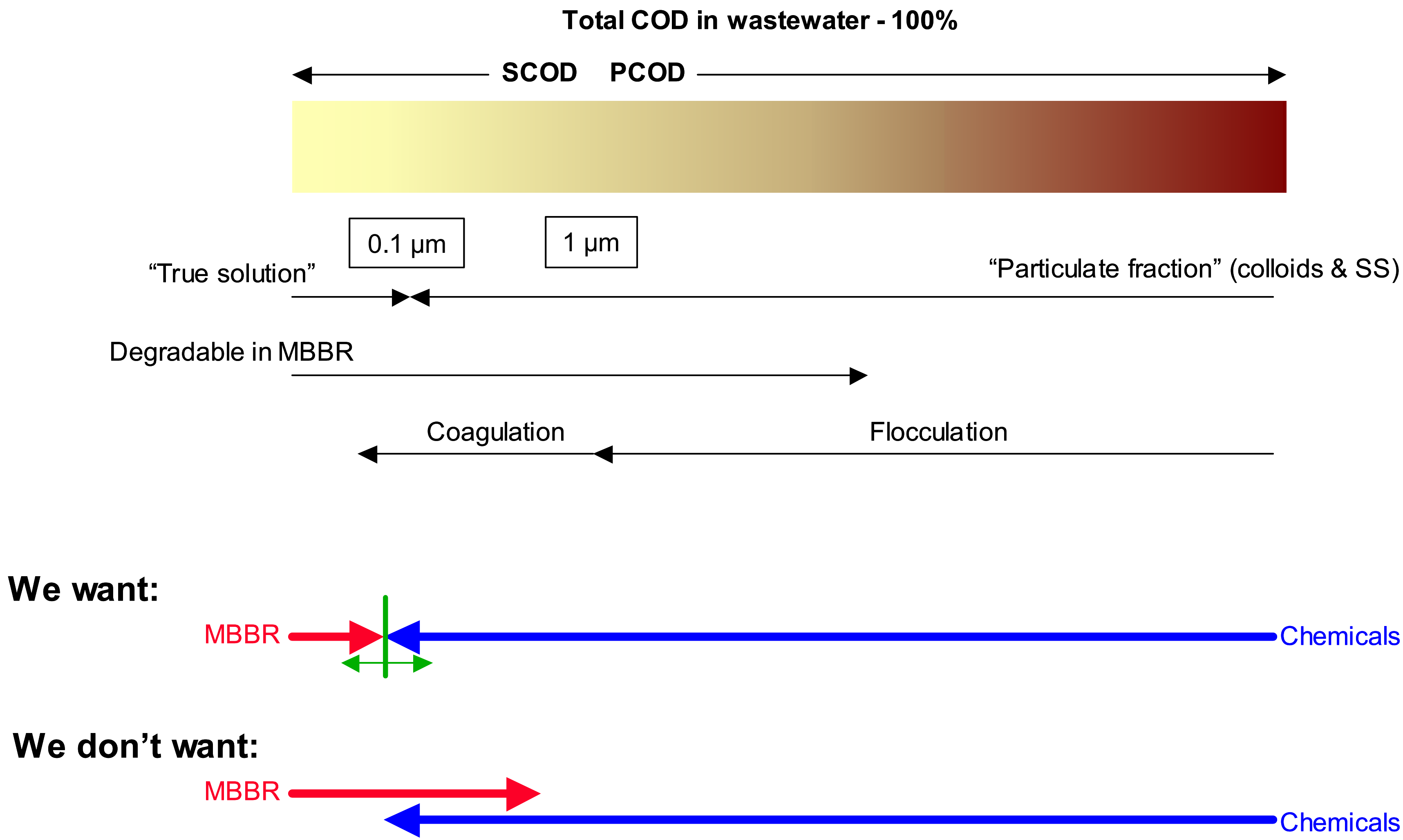
ON THE BIOREACTOR

- What happens to the soluble COD?
- What happens to the particulate COD?
- How to design the MBBR

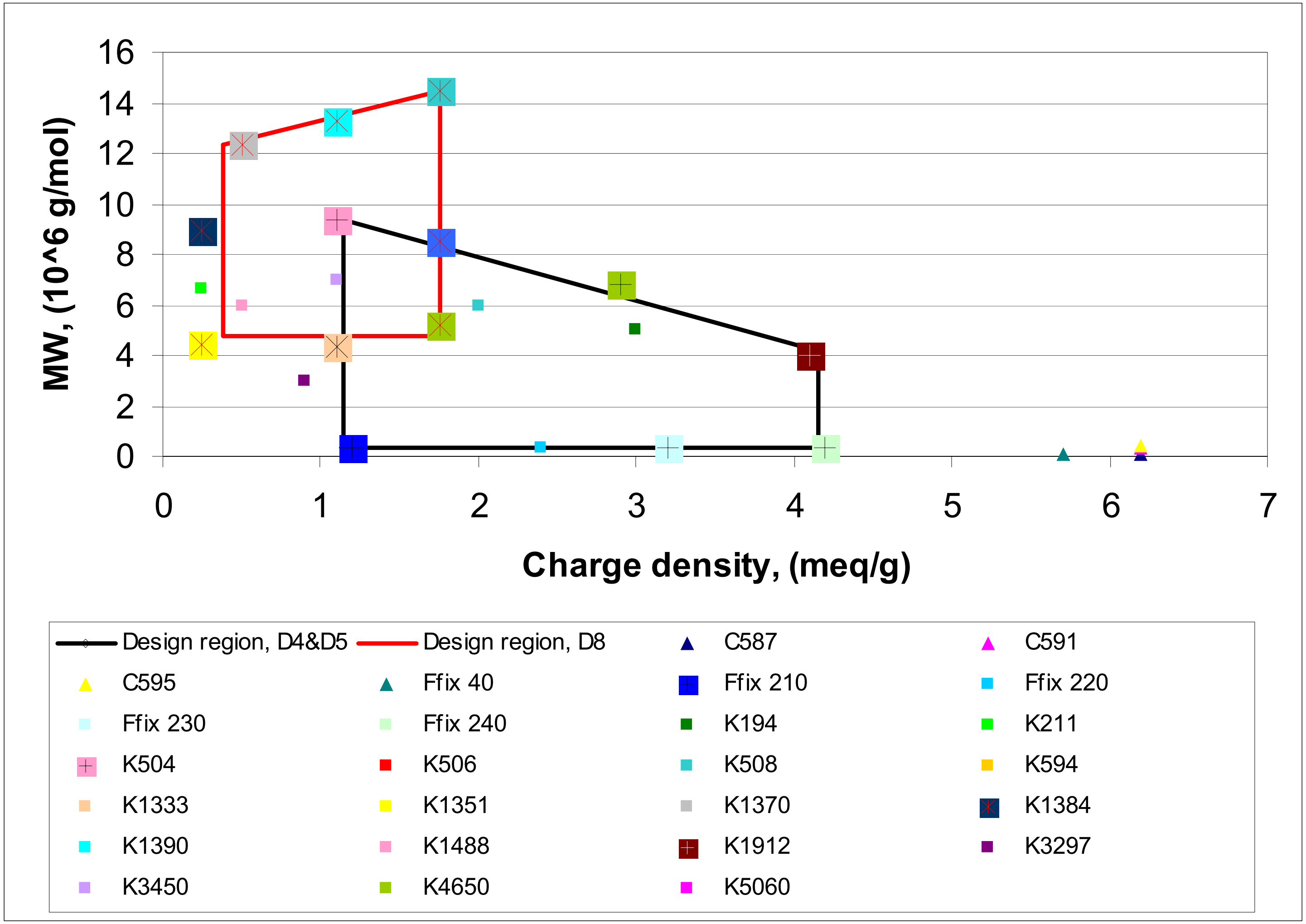
ON THE FLOTATION REACTOR

- Performance of turbulent flotation
- Design of turbulent flotation

COD DEGRADATION/TRANSFORMATION

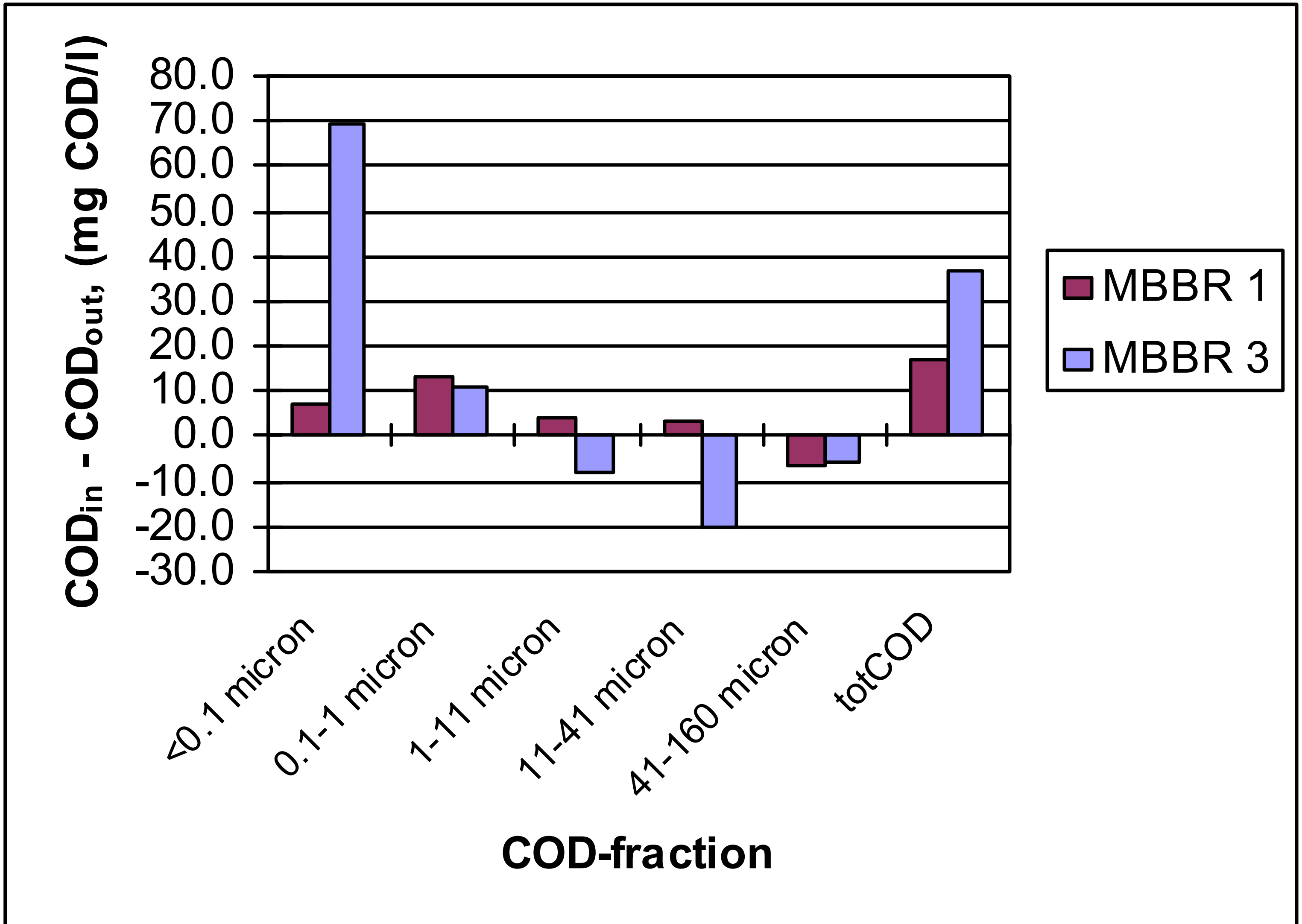


POLYMERS INVESTIGATED

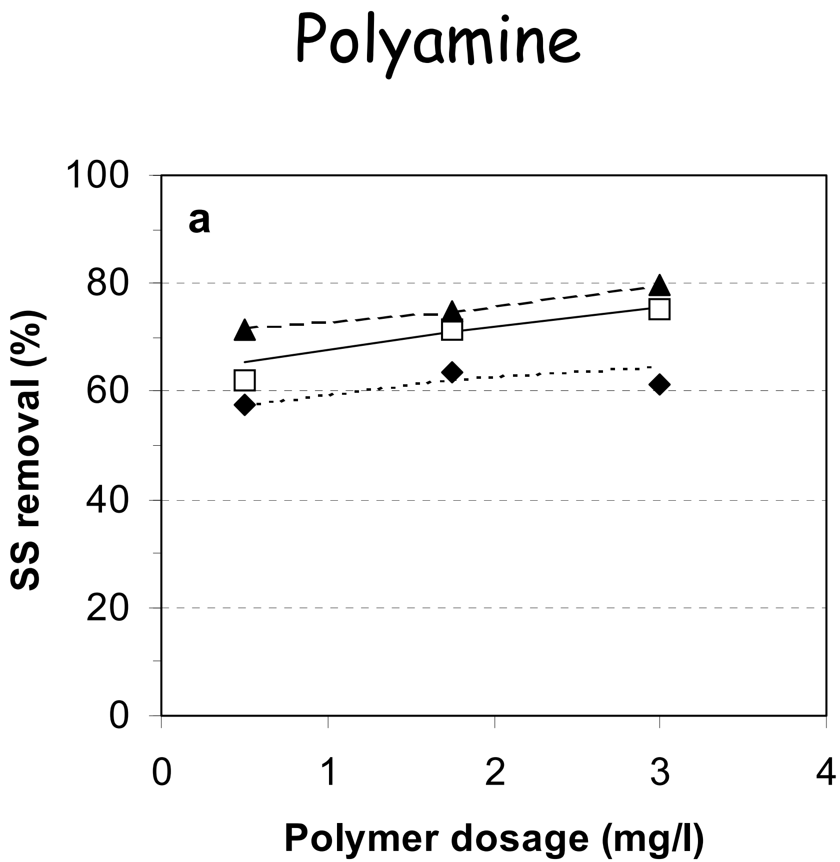


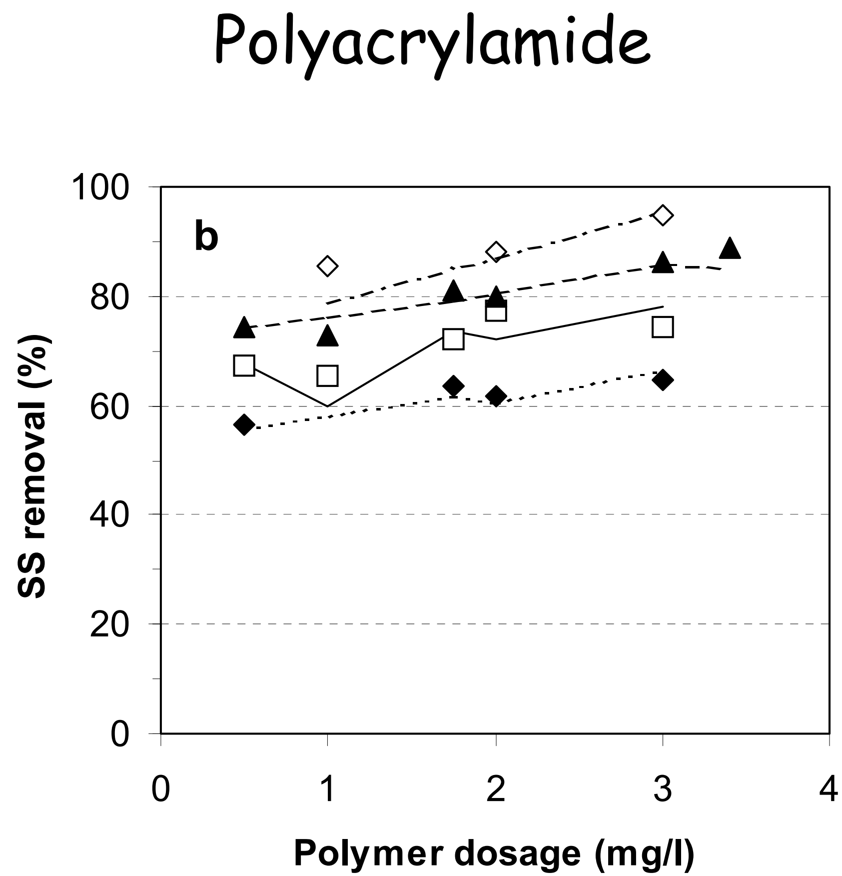
Net change in COD fractions through the MBBR

Positive value: net removal, negative value: net production

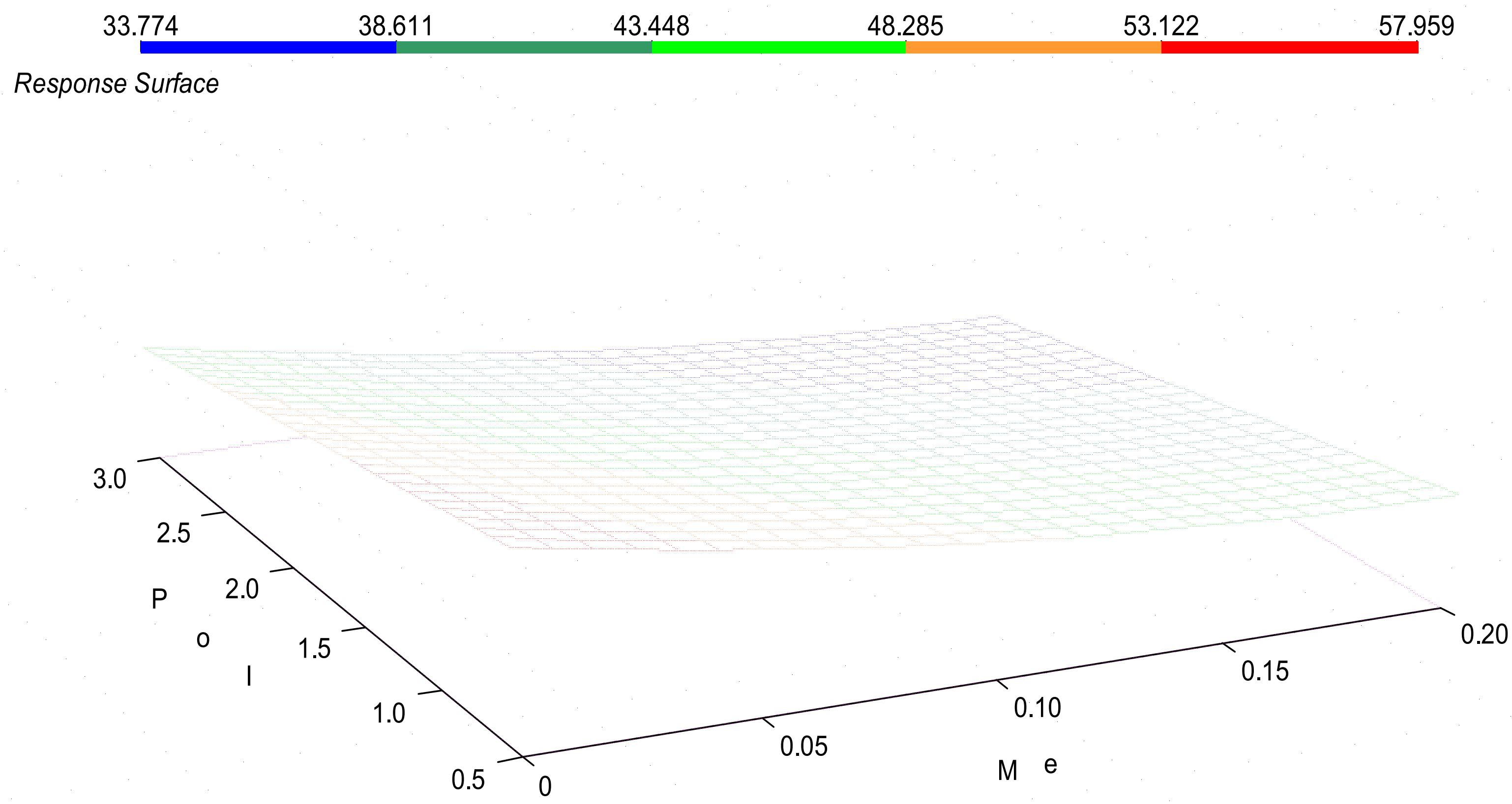


EFFECT OF POLYMER AND IRON DOSAGE ON SS REMOVAL





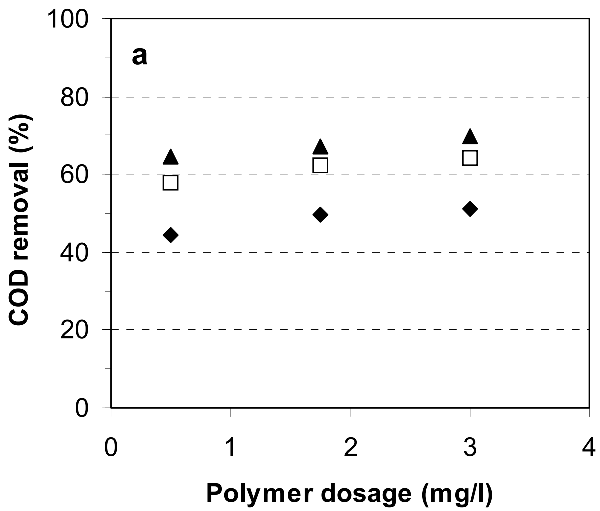
DETERMINATION OF OPTIMAL Fe/Polymer-DOSE

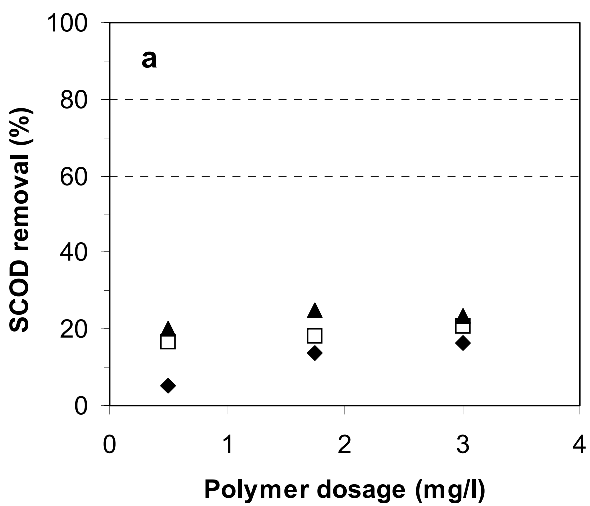


PAM01_pls1_MIS_…, PC: 2, Y-var: SSe, (X-var = value): CD = 2.1939, MW = 4.6231, SCODi = 67.6315, pHi = 7.7063

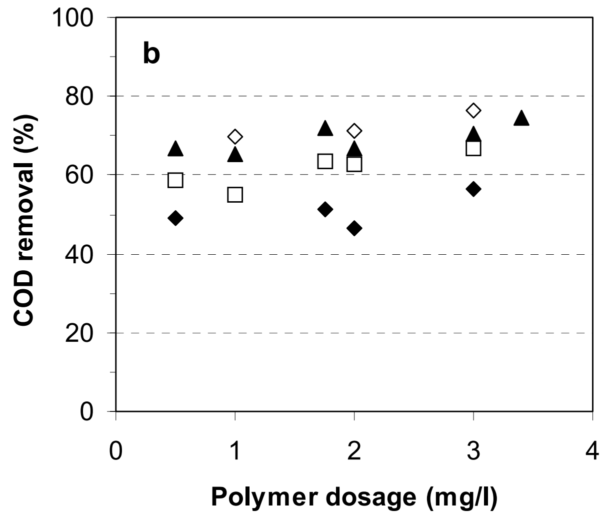
EFFECT OF POLYMER AND IRON DOSAGE ON COD REMOVAL

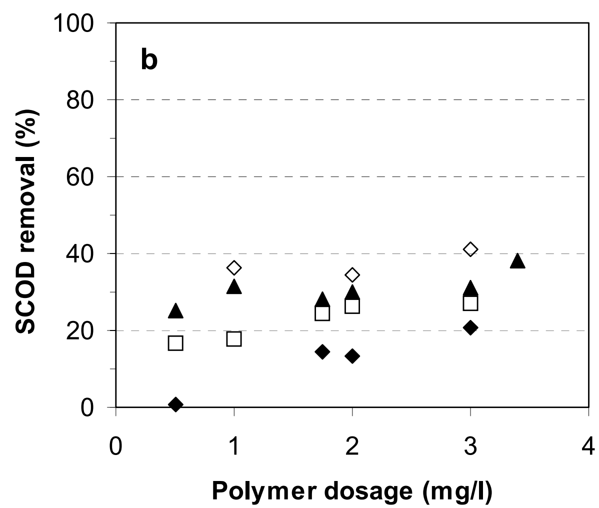
Polyamine



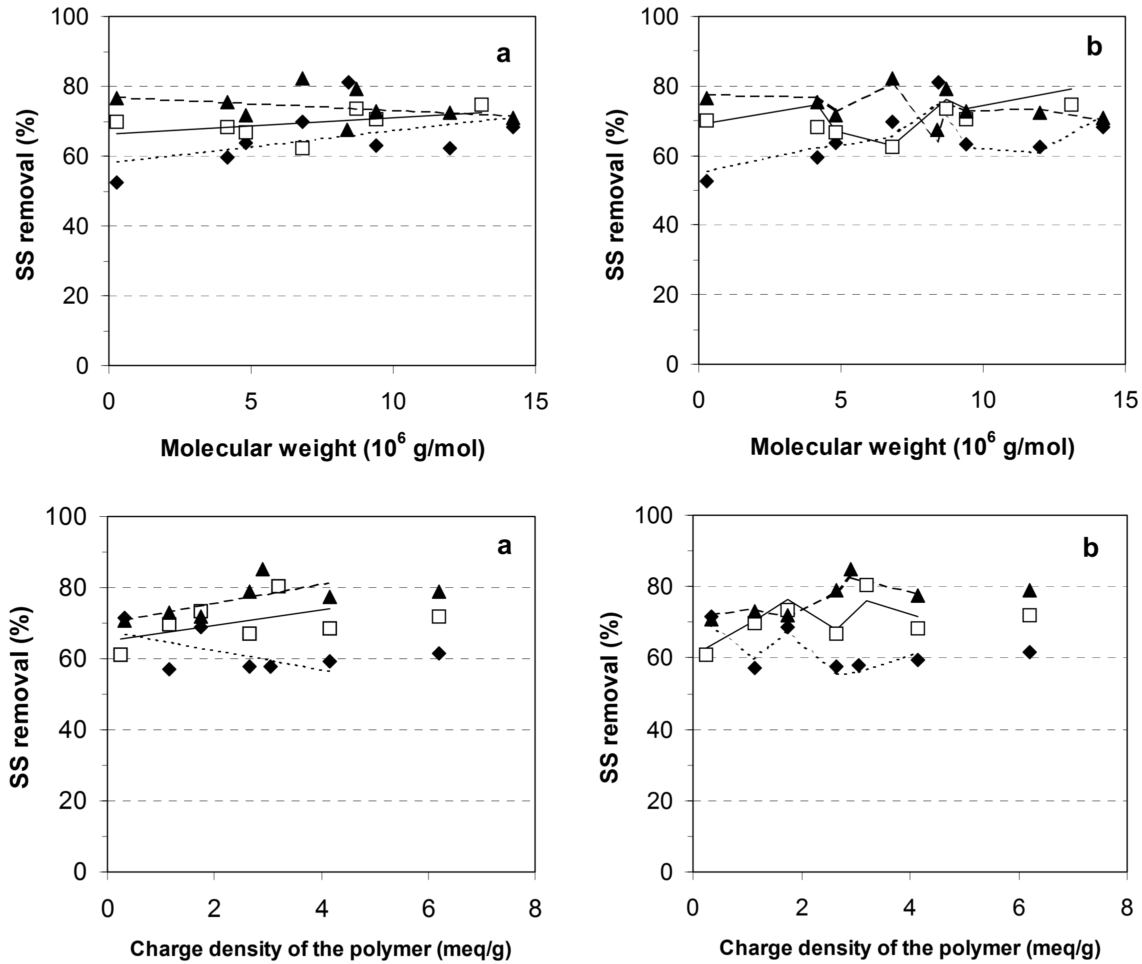


Polyacrylamide





EFFECT OF POLYMER PROPERTIES



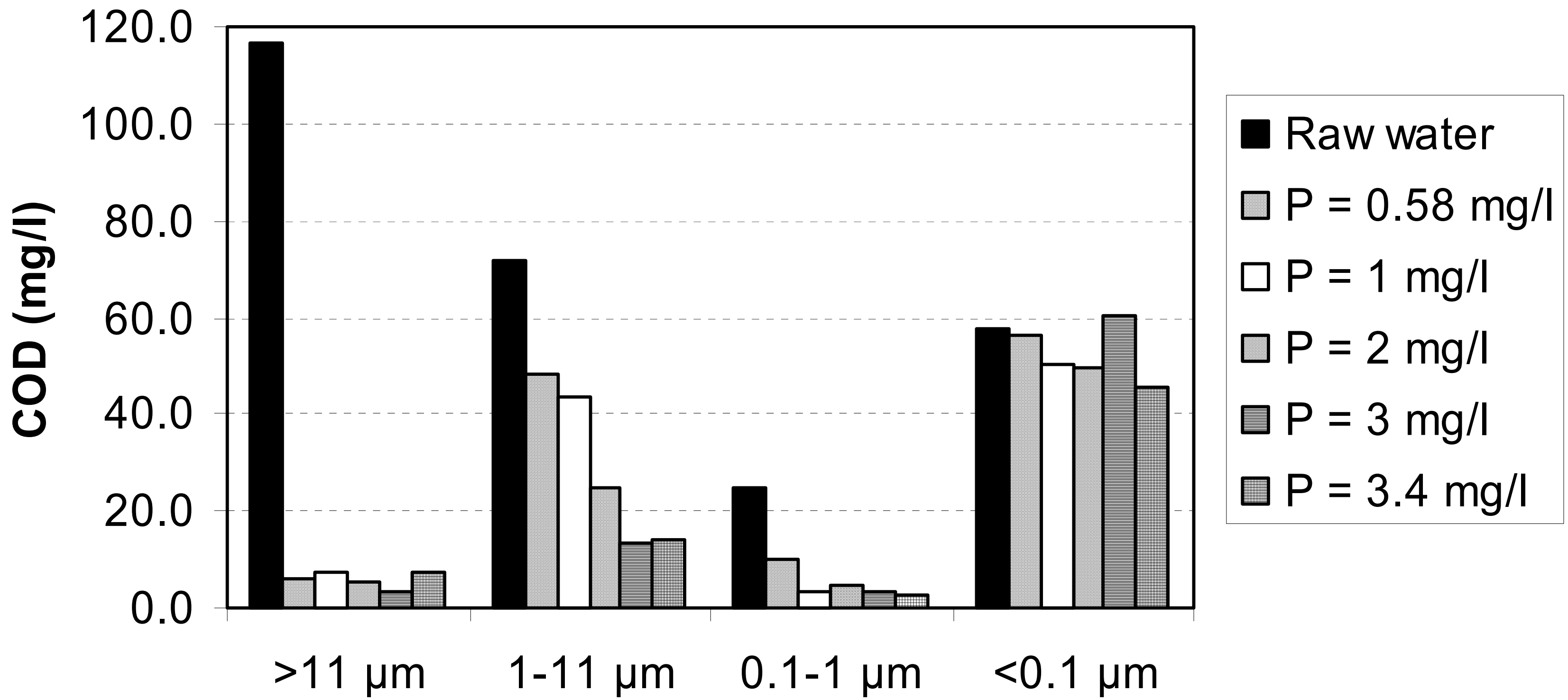
Molecular weigth

Charge density

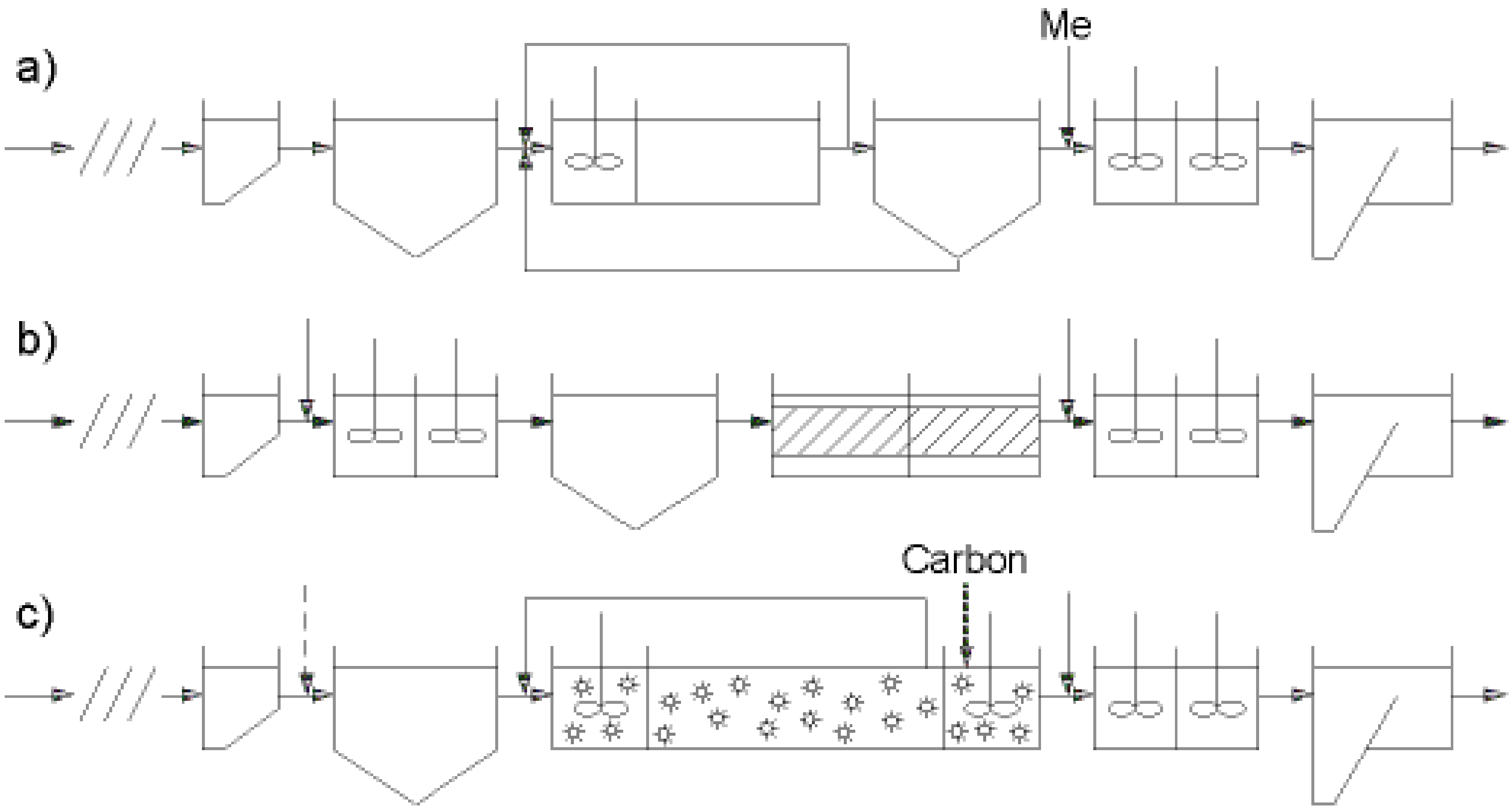
Results

Model predictions

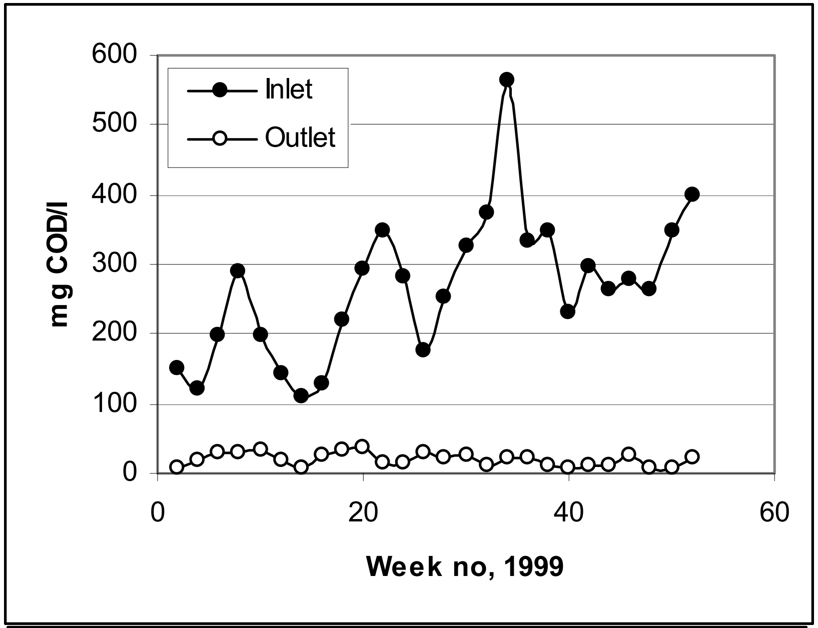
PARTICULATE COD FRACTIONS IN RAW WATER AND FLOTATED WATER WITH DIFFERENT POLYDADMAC DOSAGES AND 0.2 MMOL FE/L IRON.

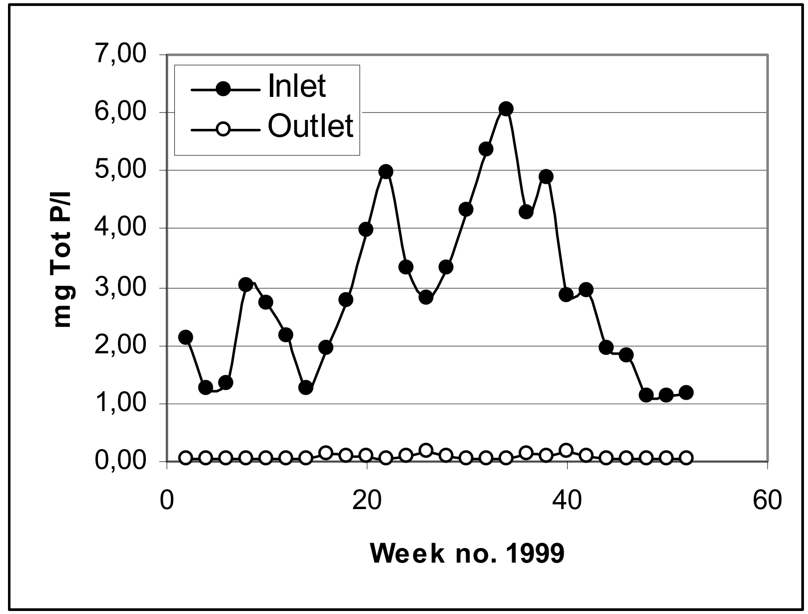


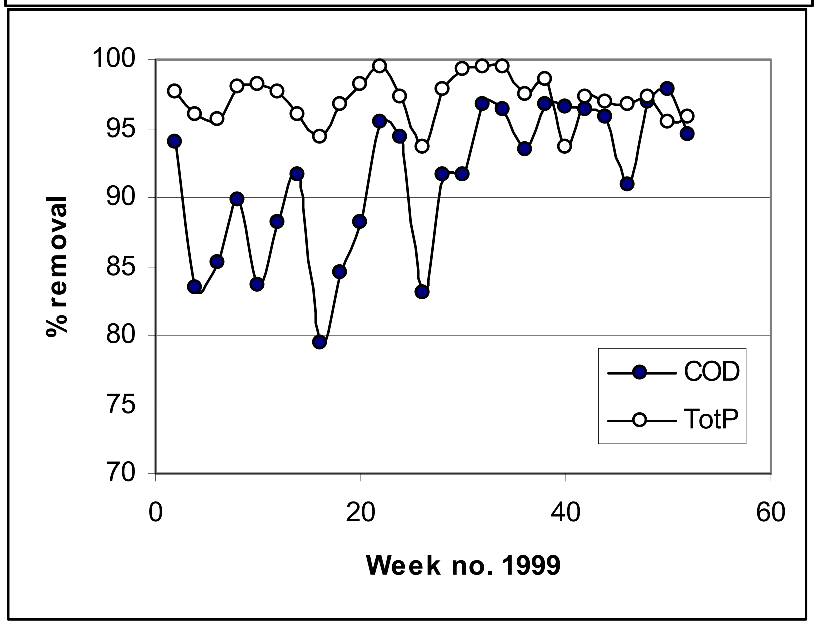
FLOTATION FOR FINAL SEPARATION



VOSS WASTEWATER TREATMENT PLANT







DATA VOSS TREATMENT PLANT

Overflow rate: 3 – 9 m/h

Effluent COD concentration : 19.6 ± 8.7 mg/l

COD-removal efficiency : 91.4 ± 5.2

Effluent Tot P concentration: 0.07 ± 0.04 mg/l

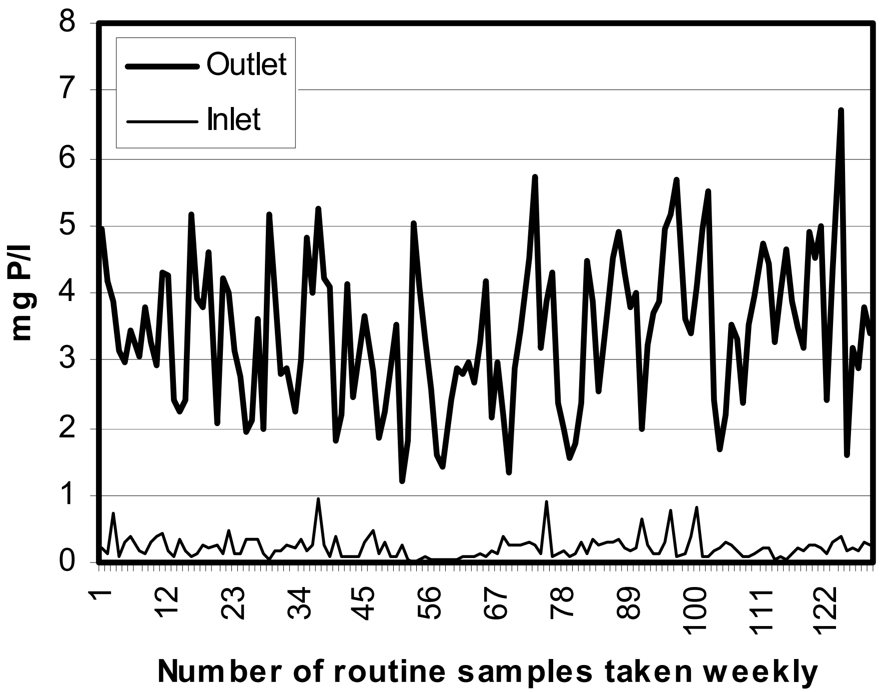
Tot P removal efficiency : 97.1 ± 1.6

Secci-depth in effluent : 2.0 – 3.75 m

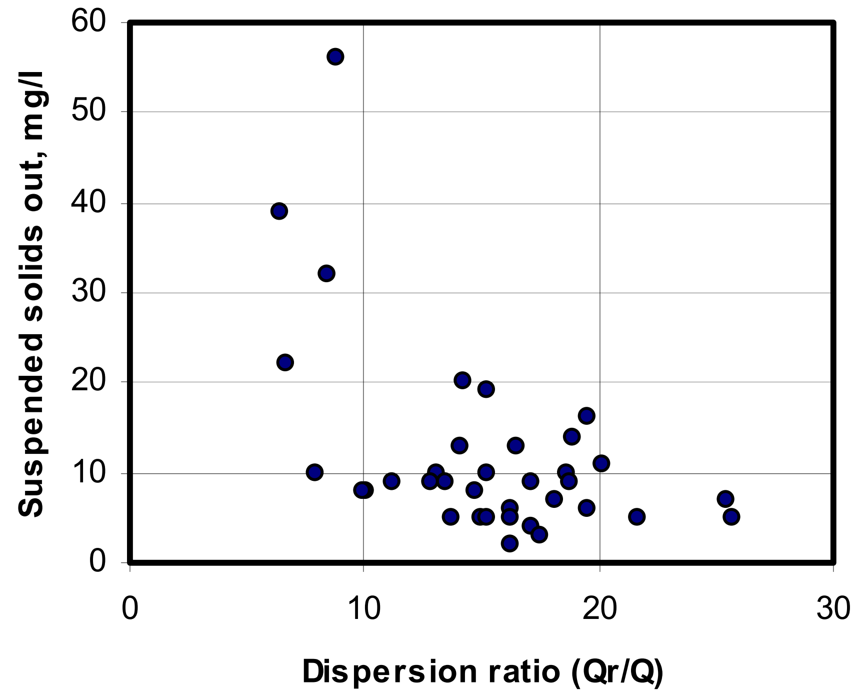
GARDERMOEN WWTP

OPERATIONAL EXPERIENCES NORDRE FOLLO

Inlet and outlet tot P conc.



Effluent SS versus Q_r/Q



SUMMARY

- A very good particle removal and hence organic matter removal can be obtained by the use of pre-coagulation
- If advanced phosphate removal is not the objective, sludge production can be minimised by replacing part of the metal cation for coagulant by a organic polymer cation
- The addition of an anionic organic polymer as flocculant can improve the settleability of flocs dramatically with corresponding reduction in plant space requirement
- The combination of a high-rate moving bed process and coagulation/flotation can result in an extremely compact and efficient secondary treatment process