The Potential of Membrane Bioreactors for Wastewater Treatment

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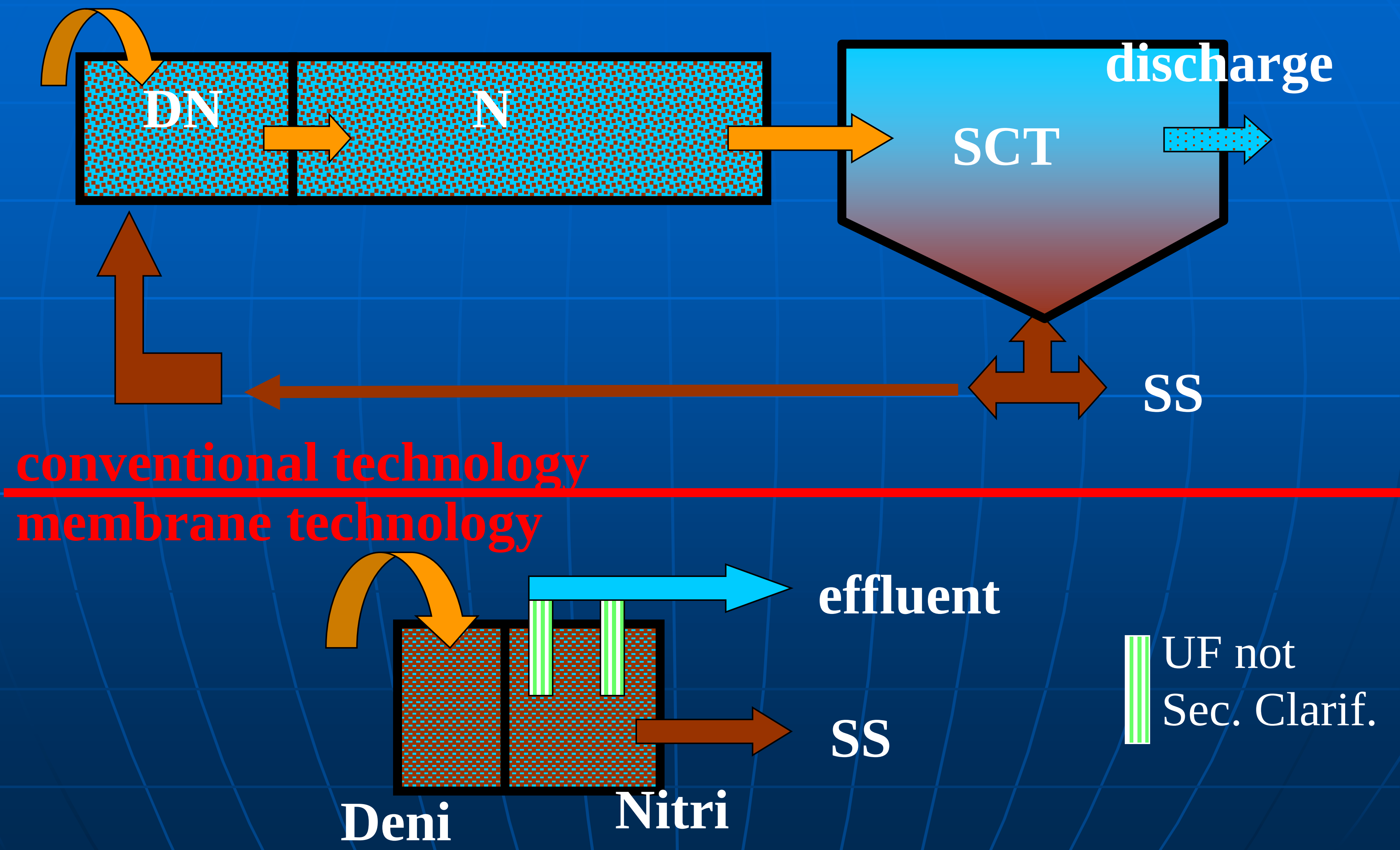
Presentation Aim & Layout

- Aims
  - To assess the feasibility of Membrane Bioreactors (MBR) in Greece
  - To examine state-of-the-art research in the field of secondary treatment of municipal wastewater using MBR technology
- Layout
  - Basics on MBR for wastewater treatment
  - Examination of two full-scale MBR applications
  - Adoption of MBR technology in Greece
  - State-of-the-art research

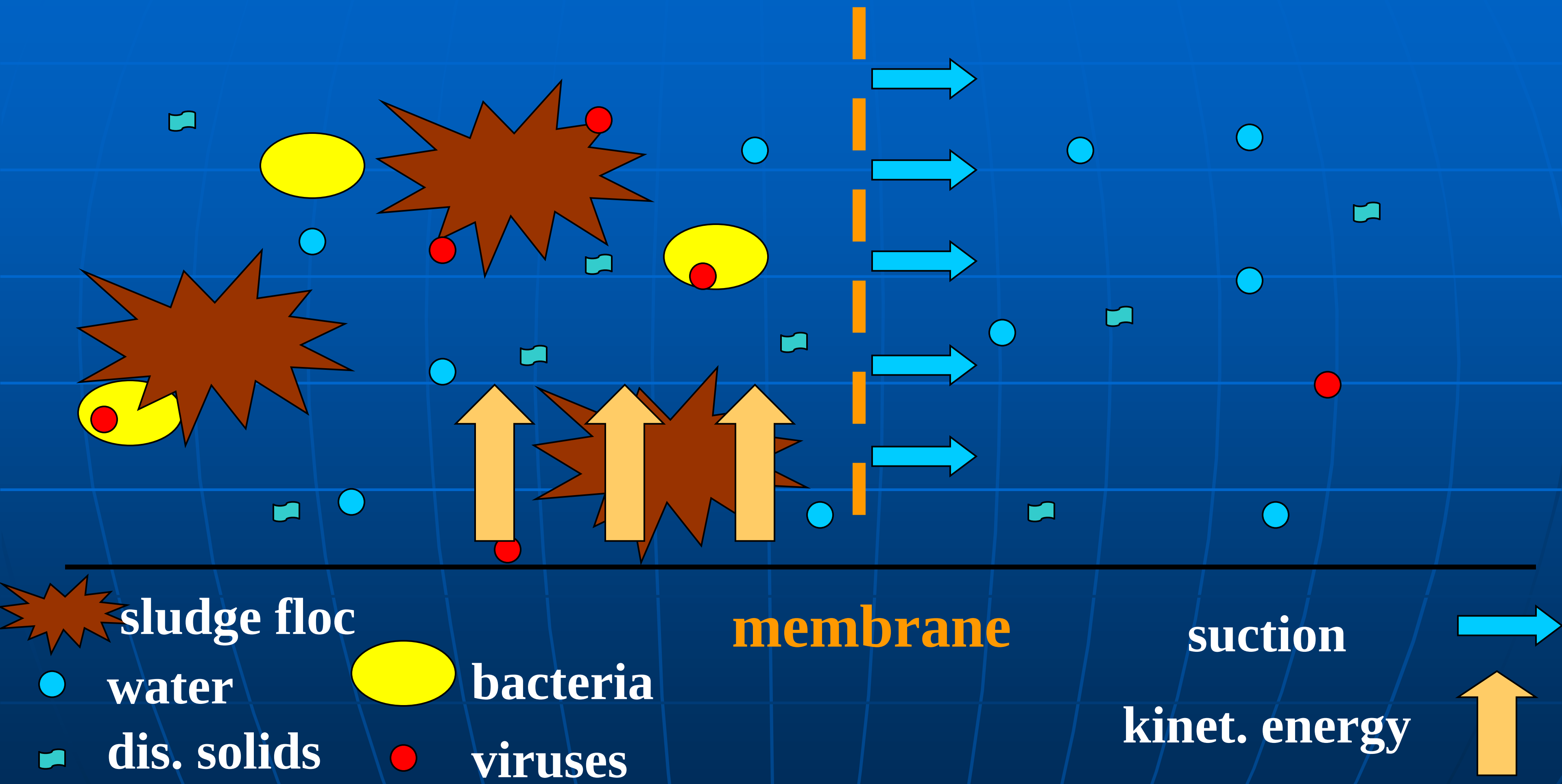
Basics on MBR

- Employ biological reactor and membrane filtration as a unified system for the secondary treatment of wastewater
- Membranes perform the separation of the final effluent from the biomass through filtration
- Filtration takes place by the application of a pressure gradient

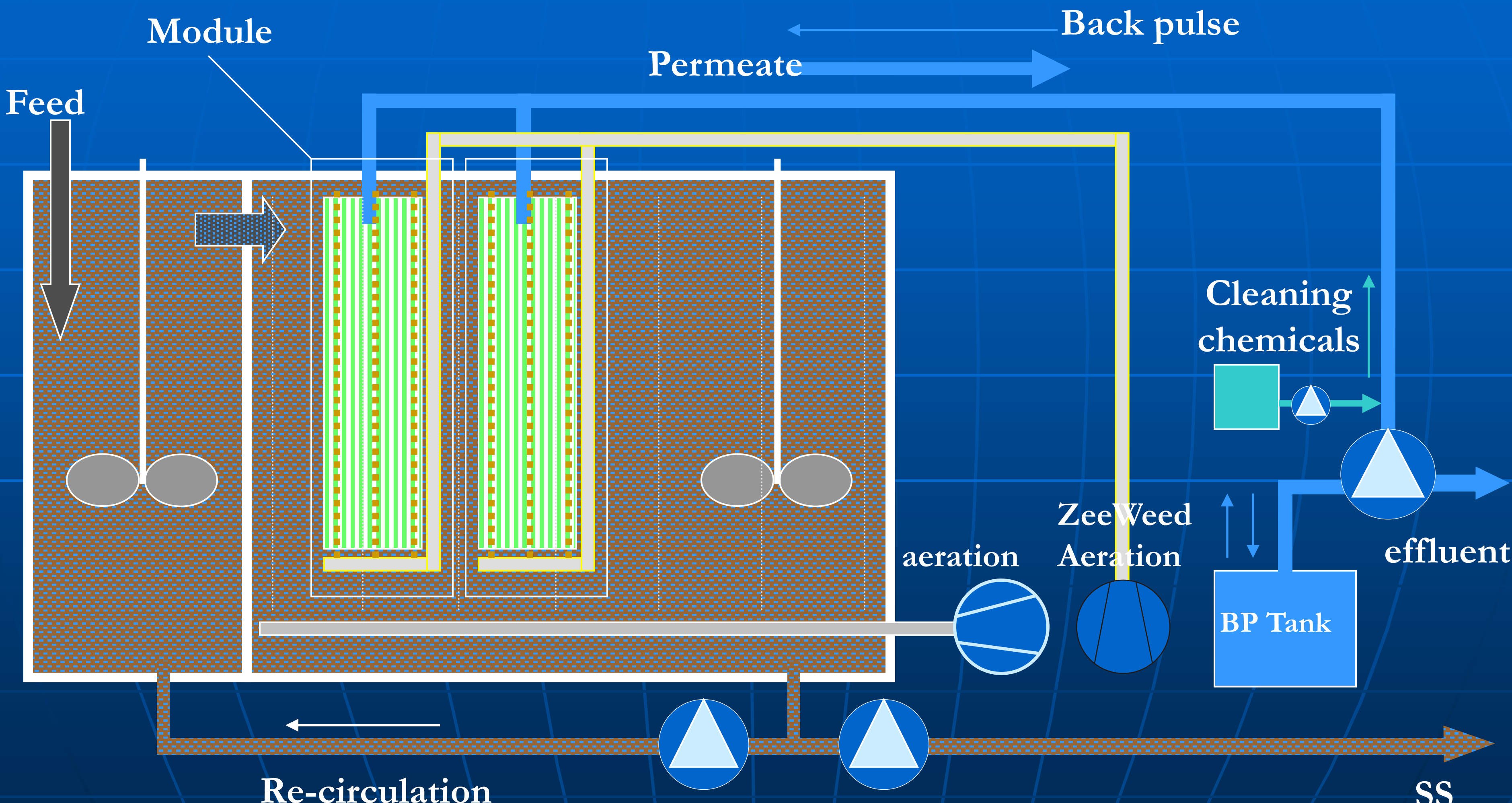
Process Basics



Process Basics



Submerged MBR System



Assessment of MBR Technology

- Advantages
  - High effluent quality
  - No sludge settling problems
  - Reduced volume requirements
- Disadvantages
  - Membrane fouling
  - Increased operational costs

Full-Scale WWTP in Germany (1)

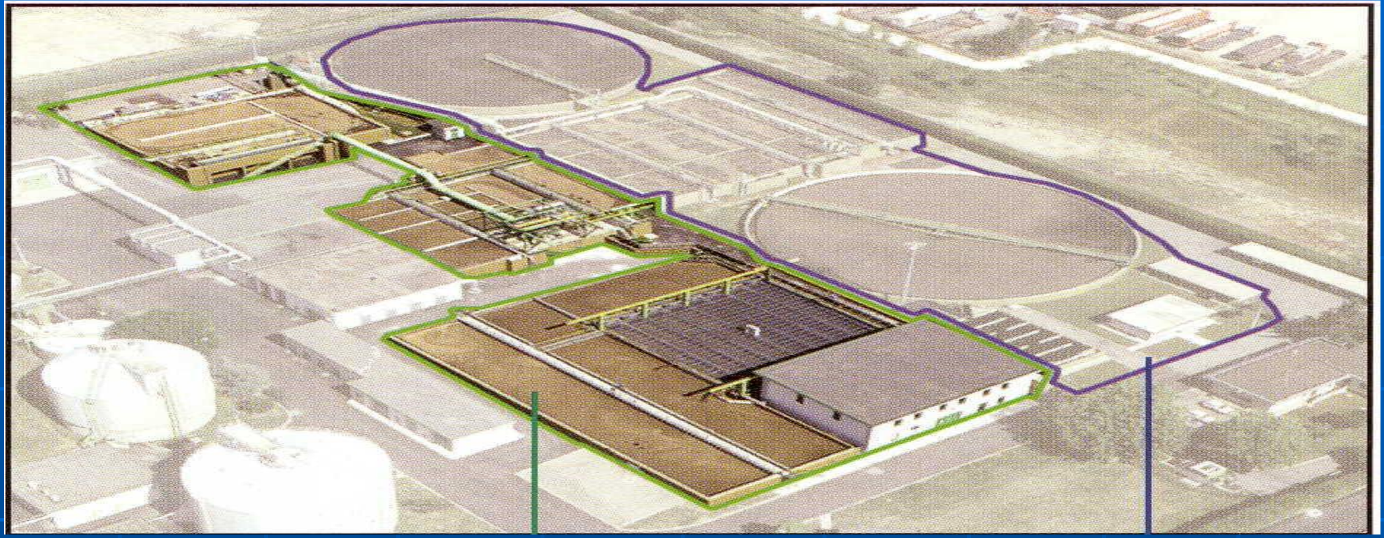
- P.E. = 80,000 Largest MBR full-scale installation in the world
- 4 parallel biological reactors:
  - Anoxic zone
  - Swing zone
  - Aerobic zone with immersed membranes
- SRT = 25 days
- MLSS = 10-15 g/l
- 192 cassettes (8 parallel trains)
- Total filtration area = 84,480m^2

Full-Scale WWTP in Germany (2)

Parameter	Final Effluent
SS (mg/l)	Non detectable
COD (mg/l)	15-20
BOD_5 (mg/l)	<3
NH_4^+-N (mg/l)	<1
TN (mg/l)	5-10
TP (mg/l)	0.7
Total Coliforms / 100 ml	<100
Fecal Coliforms /2000 ml	<500
Salmonella /1000 ml	0

- Final Effluent disposed to a sensitive river

Full-Scale WWTP in Italy (1)



Consists of 3 parallel lines

- Lines A & C: Conventional Lines
- Line B: Upgraded from conventional to MBR system

- Total P.E. = 380,000
- Upgrading of Line B to MBR increased its capacity from 12,200 m^3/d to 42,000 m^3/d within the same space
- MLSS = 6.5-10 g/l
- SRT > 20 d

Full-Scale WWTP in Italy (2)

Parameter	MBR Effluent mg/l (%)	Conventional Effluent mg/l (%)
SS (mg/l)	<2 (99)	25 (73.2)
BOD_5 (mg/l)	4 (95.8)	19 (82.3)
COD (mg/l)	27 (88.5)	66 (77.2)
TN (mg/l)	9.2 (73.7)	15.9 (54.5)
TP (mg/l)	2.4 (36.1)	3.4 (8.6)

Conclusions from the examination of full-scale installations (1)

- Full-scale MBR provide a superior effluent quality compared to conventional methods
- The final effluent can meet the requirements of the Urban Wastewater Directive 91/271/EEC even for P.E. >100,000 with disposal to sensitive recipients (TN <10 mg/l, TP < 1mg/l)
- Final effluent conforms to the microbiological requirements for bathing waters (Directive 76/160/EEC), without the need for further disinfection with chlorine or ozone

Conclusions from the examination of full-scale installations (1)

- Enhance reuse options of secondary effluent

However:

- the stricter microbiological criteria for agricultural reuse are not met and further disinfection is required

- Main barrier to their wider full-scale adoption is the high operational cost and the lack of economies of scale

Adoption of full-scale MBR in Greece

- Currently there is no full-scale MBR system
- It is an attractive solution for arid and semi-arid regions and islands characterized by:
  - Water scarcity
  - Small/Medium P.E.
  - Coastal zones and seas of high aesthetic value
  - Limited land availability
  - Large seasonal changes in populations

State-of-the-art Research

- MBR technology has resulted in multidiscipline research, since it brings together the topics of system design and construction, hydrodynamics, chemistry and microbiology.
- This work focuses on the topics of:
  - Membrane fouling
  - System microbiology

Membrane Fouling (1)

- Biofouling is the dominant type of membrane fouling in MBRs
- Definition: the undesirable deposition and accumulation of microorganisms, EPS and cell debris
- Main operating problem impeding the widespread adoption of MBR to full-scale plants

Membrane Fouling (2)

- Biofilm develops due to the following mechanisms:
  - Adsorption of macromolecules
  - Adhesion of micro-molecules which are easily attached from the liquid under suspension to the membrane’s surface
  - Creation of colonies and growth of micro-organisms on and within the biofilm
  - Detachment mechanisms attributed mainly to shear forces

Main Parameters Influencing Fouling (3)

- Membrane parameters
  - Configuration
  - Material
  - Pore Size
  - Hydrophobicity
- Operating Parameters
  - HRT/SRT
  - Aeration system
  - TMP and flux
- Biomass characteristics
  - EPS
  - SMP
  - MLSS

- The degree of influence of each biomass characteristic varies depending on the operating conditions and particularly SRT
- Research is often contradictory
- No universally adopted relationships relating fouling to its main influencing parameters

Promising research areas related to membrane fouling (4)

- Modeling the development of biofilm (determining thickness, concentration gradient of nutrients and DO etc)

- Derive relationships describing the degree of fouling with respect to operating and biomass characteristics

- The ultimate goal is to model long-term fouling

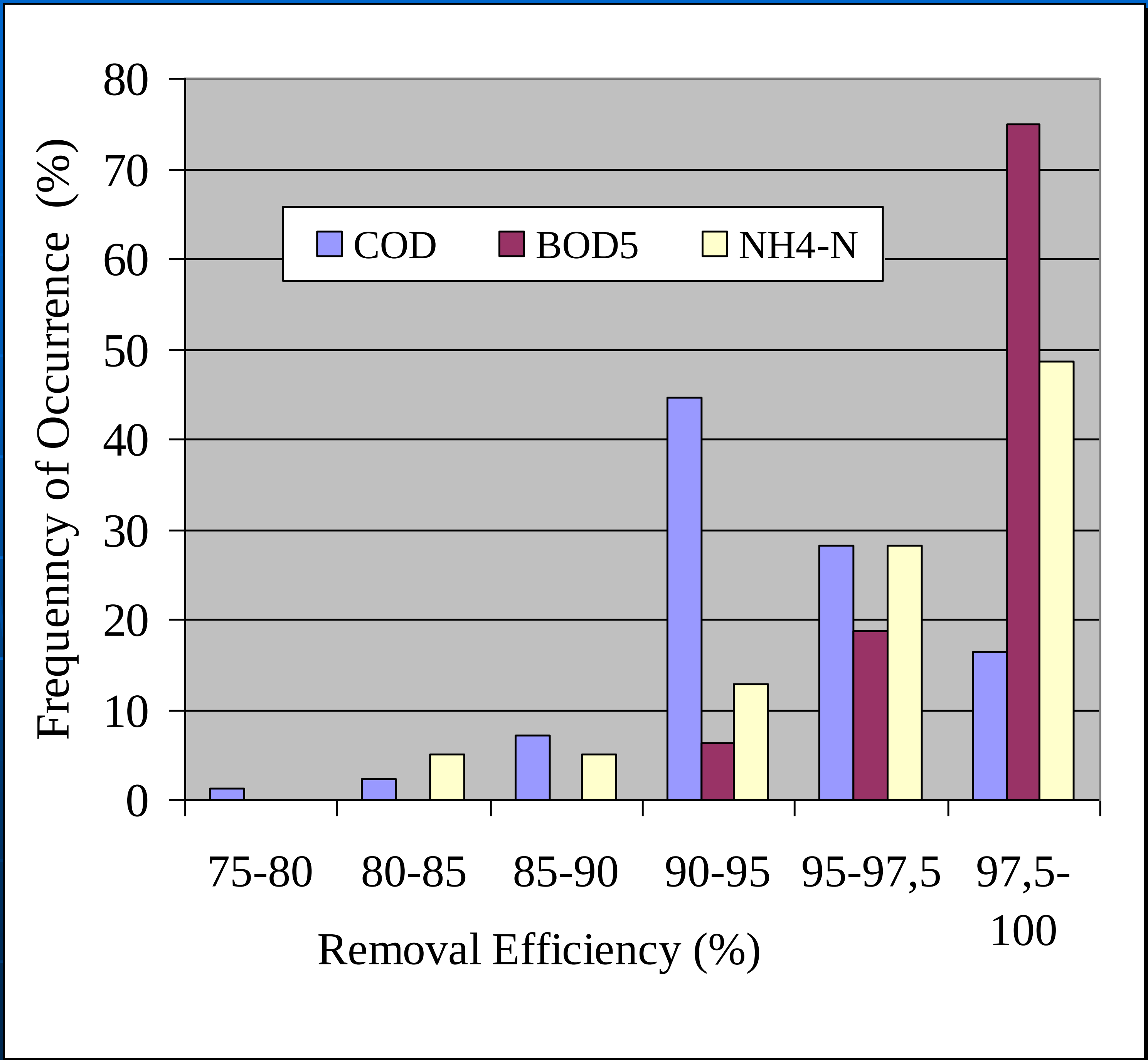
- Examination of the influence of certain additives (alum, zeolite, activated carbon) on fouling

System Microbiology (1)

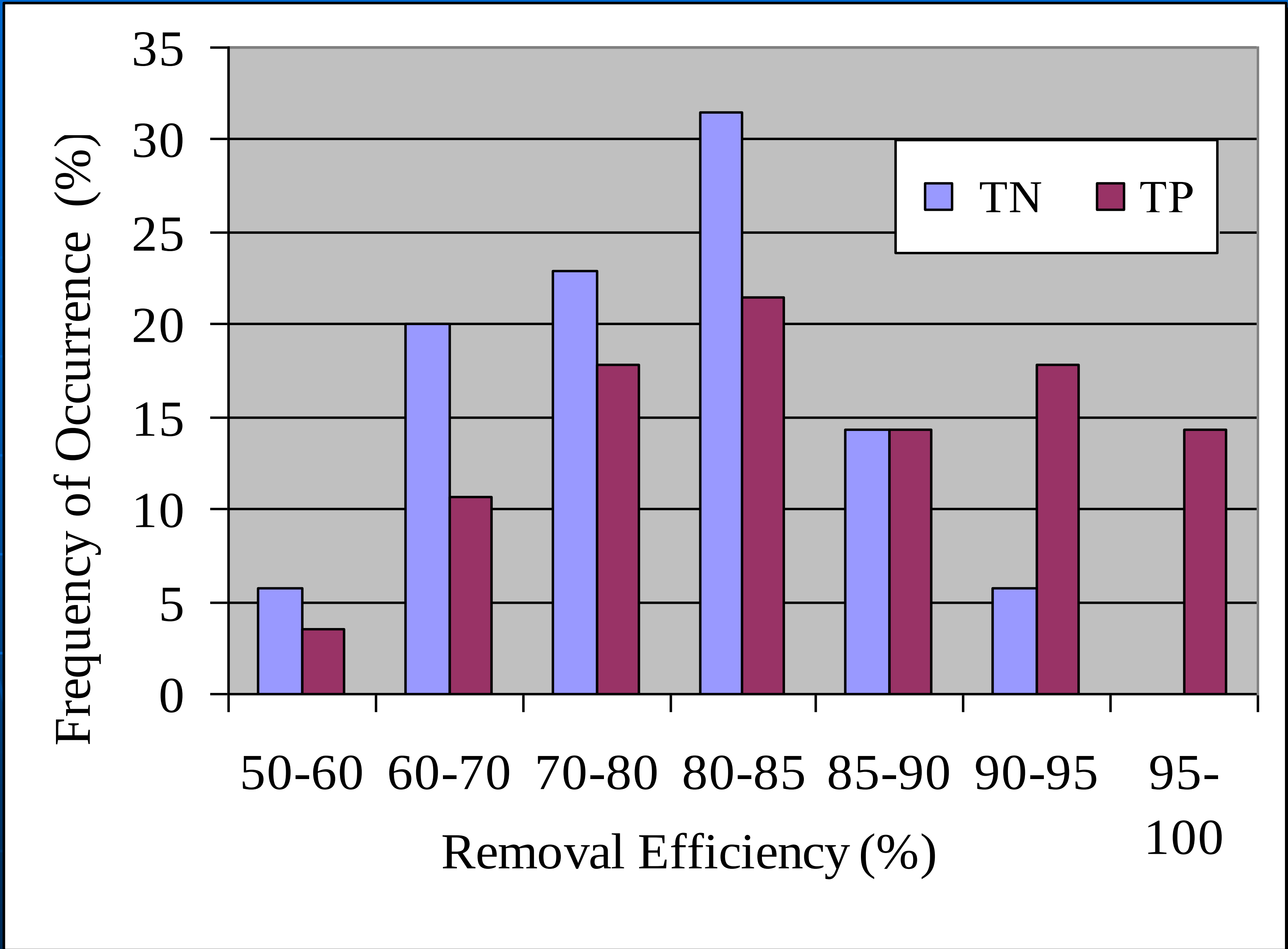
- Sludge Filterability
  - Impacts on filtration and fouling
  - Improved sludge filterability retards the degree of fouling and thus prolongs the life of the membrane
- Biomass characteristics
  - MBR produce 20-50% less sludge than conventional systems as they operate at higher SRT
  - Floc size depends on the SRT value and on the MBR configuration
  - Presence of small flocs, single cells and free-swimming bacteria
  - Filamentous micro-organisms are favored (absence of FST, low F/M ratios)

System Microbiology (2)

- Organic & nutrient removal
  - Examined extensively through pilot-plants and bench-scale experiments
  - Innovative processes have been tested (e.g. use of a single reactor for simultaneous nitr-denitr by maintaining the DO level at 1mg/l)



80
70
60
50
40
30
20
10
0
Frequenncy of Occurrence (%)
COD
BOD5
NH4-N
75-80
80-85
85-90
90-95
95-97,5
97,5-
100
Removal Efficiency (%)



35
30
25
20
15
10
5
0
Frequency of Occurrence (%)
TN
TP
50-60
60-70
70-80
80-85
85-90
90-95
95-100
Removal Efficiency (%)

Promising research areas related to microbiology (4)

- Extensive analysis of the microbiology and physiology of micro-organisms which develop both in the liquid under suspension and on the membrane surface. Examination of the differences in the microbial populations

- Determine the influence of certain factors (e.g. pH, organic loading, SRT) on filterability

Conclusions

- MBR technology is compatible with Greek needs of wastewater treatment
- Promising research themes:
  - Develop model that will predict long-term fouling
  - Find cost effective additives which can reduce fouling
  - Determine the operating factors which affect filterability
  - Extensive microscopic analysis of the biomass