Wastewater collection and treatment
WHY & HOW ?

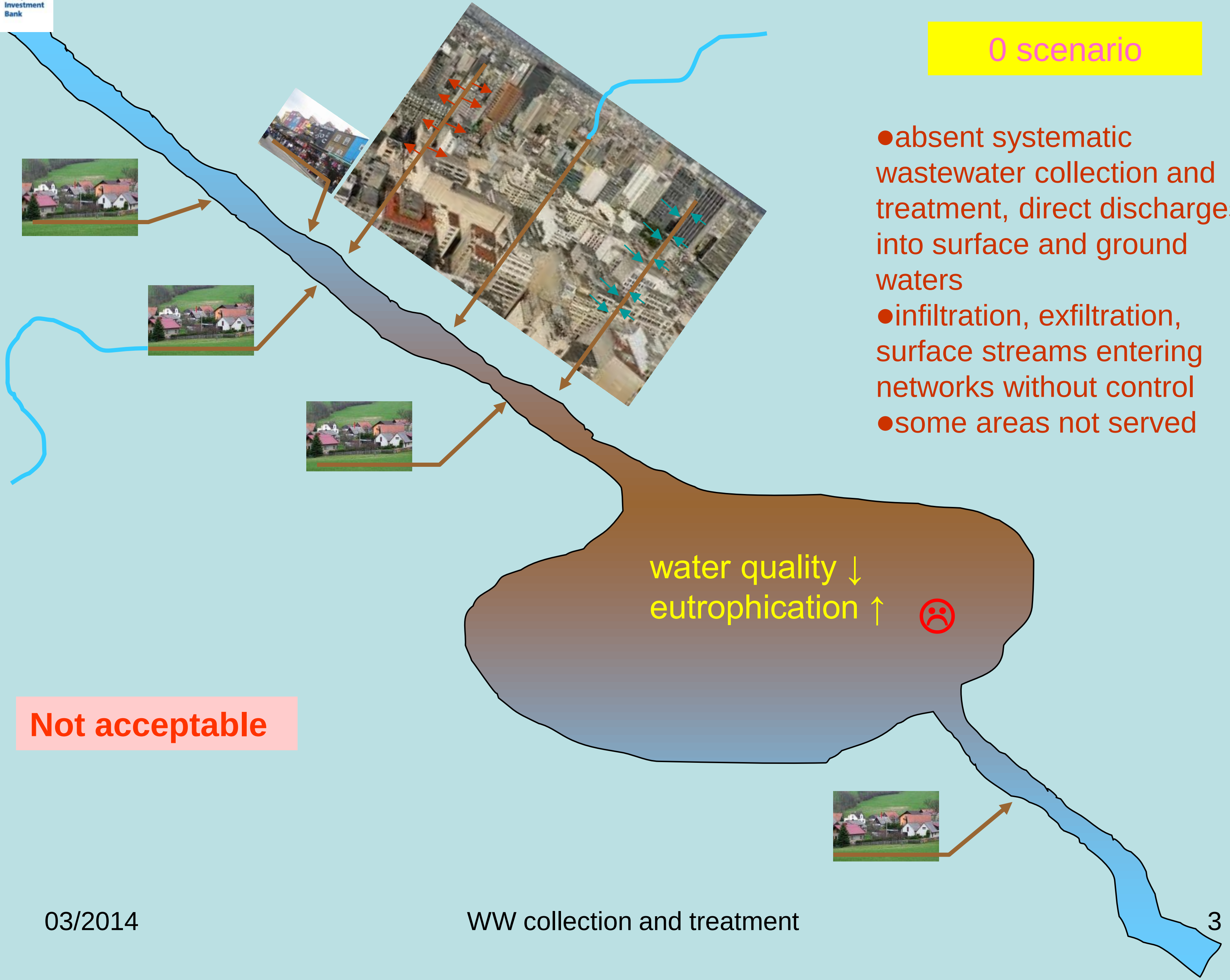
Ondrej Dusek

W&WM

Wastewater collection

0 scenario

- absent systematic wastewater collection and treatment, direct discharges into surface and ground waters
- infiltration, exfiltration, surface streams entering networks without control
- some areas not served

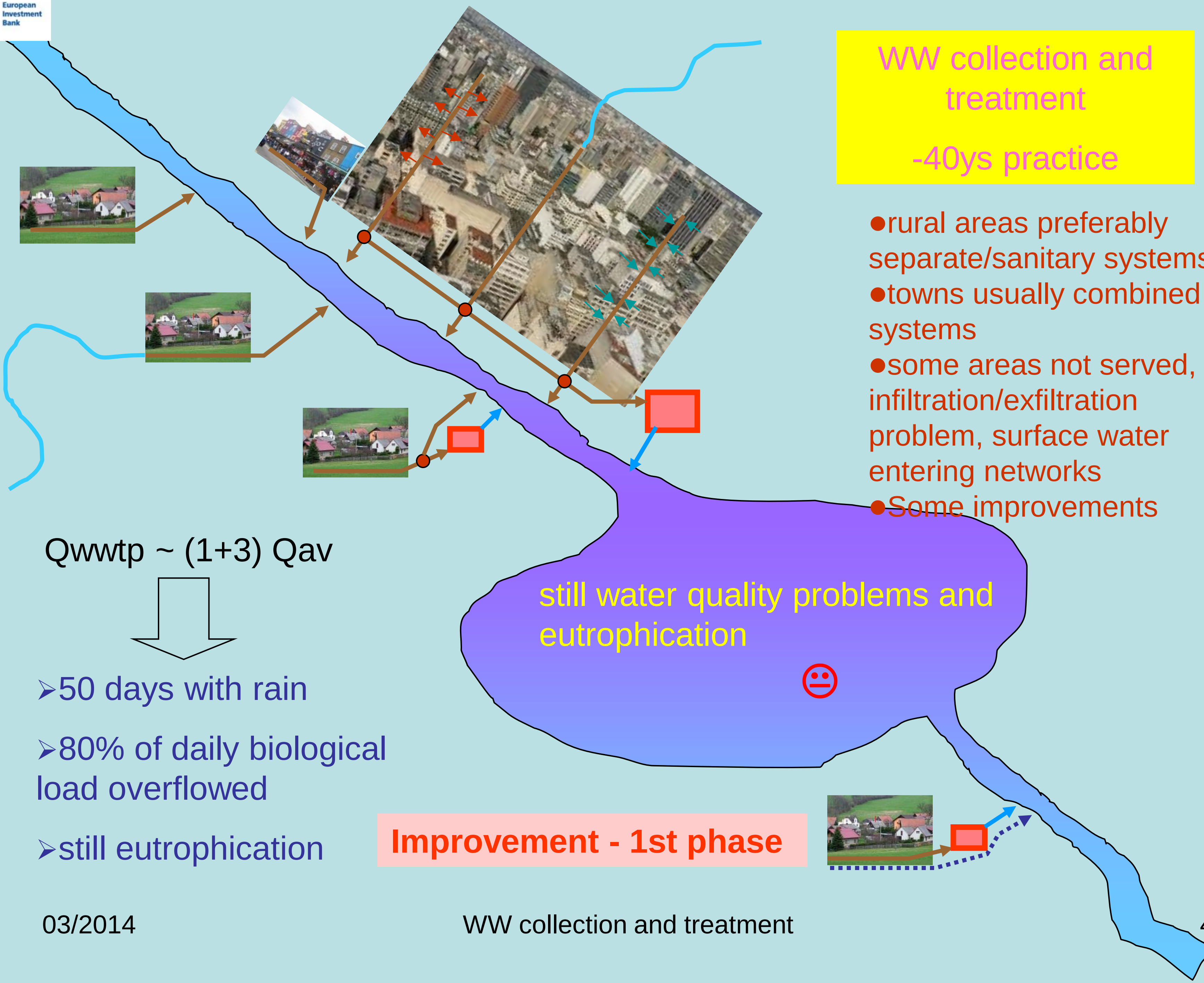


Not acceptable

WW collection and treatment

-40ys practice

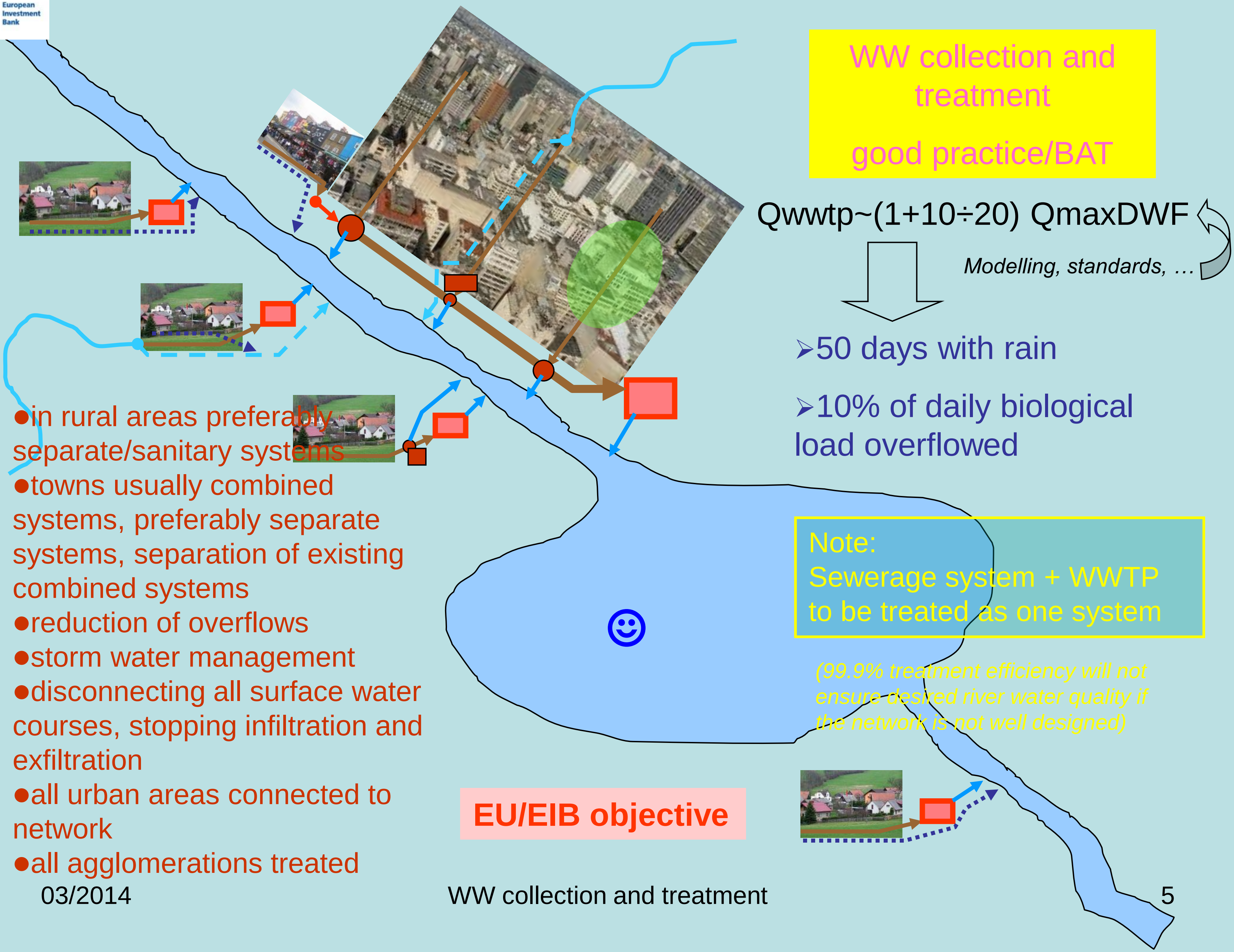
- ●rural areas preferably separate/sanitary systems
- ●towns usually combined systems
- ●some areas not served, infiltration/exfiltration problem, surface water entering networks
- ●Some improvements



Qwwtp ~ (1+3) Qav

- ➢50 days with rain
- ➢80% of daily biological load overflowed
- ➢still eutrophication

Improvement - 1st phase



WW collection and treatment

good practice/BAT

Qwwtp~(1+10÷20) QmaxDWF

Modelling, standards, …

- 50 days with rain
- 10% of daily biological load overflowed

- in rural areas preferably separate/sanitary systems
- towns usually combined systems, preferably separate systems, separation of existing combined systems
- reduction of overflows
- storm water management
- disconnecting all surface water courses, stopping infiltration and exfiltration
- all urban areas connected to network
- all agglomerations treated

Note:
Sewerage system + WWTP to be treated as one system

(99.9% treatment efficiency will not ensure desired river water quality if the network is not well designed)

EU/EIB objective

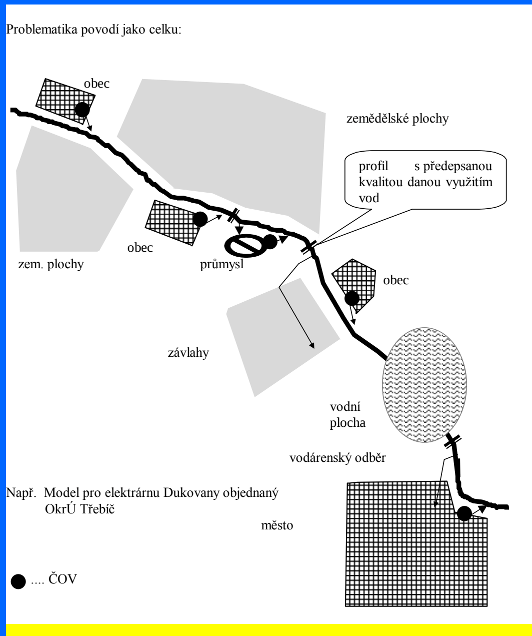
Wastewater treatment

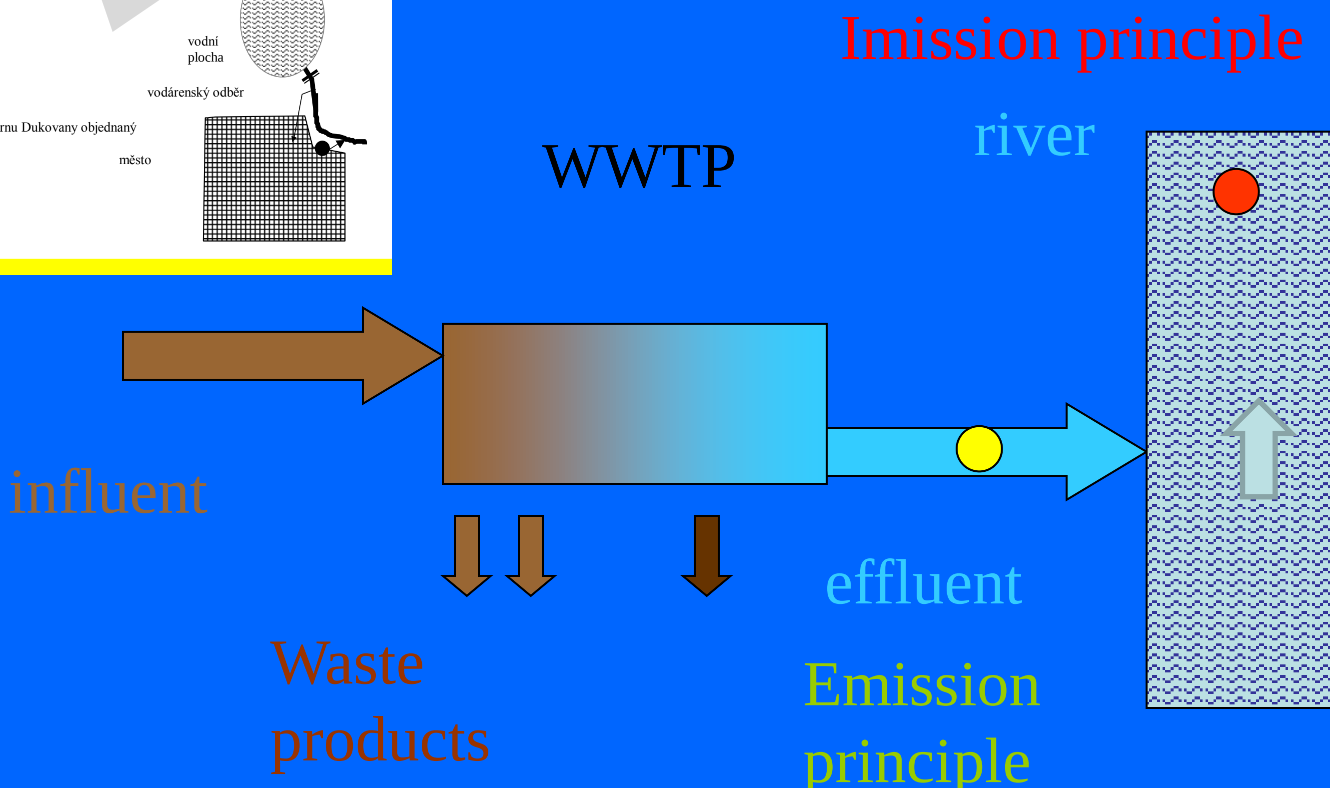
- This presentation focuses on biological processes for basic biological treatment (carbon removal) and nitrogen removal, and biological and chemical processes for phosphorus removal

- Why the above processes?
    - common and well known
    - very efficient, very good effluents
    - suitable for both municipal and most industrial waste waters
    - reliable, simple

- Although the processes are well known still many WWTPs have big problems with N-removal (optimistic dimensioning, too complicated, design mistakes, software etc.)

Schemes


Problematika povodí jako celku:
obec
zemědělské plochy
profil s předepsanou kvalitou danou využitím vod
obec
zem. plochy
průmysl
obec
závlahy
vodní plocha
vodárenský odběr
Např. Model pro elektrárnu Dukovany objednaný OkrÚ Třebíč
město
.... ČOV


Imission principle
river
WWTP
influent
effluent
Waste products
Emission principle

Basic biological treatment

- Practically all biological processes are capable to achieve high level C-removal, many microorganisms contribute to the process.
- They reproduce (multiple) quickly i.e. even low sludge age is enough (i.e. high sludge loads, less biomass → small activation tanks, or biocarries, etc.)
- Low O2 concentration needed (0.5 mg/l)
- Sound process design is necessary. Reliable systems work with sludge age of 5 days and more (conventional biological treatment and variations).

Efficiency = f (SA) *(Nopon manual)*

Type of process configuration	Treatment efficiency % Removal of: BOD	NH$_4$/N	Sludge age d	Organic volumetric load kgBOD/m^3·d
Conventional	85-95	–	5-10	0.3-0.6
Tapered aeration	85-95	–	5-10	0.3-0.6
Step aeration	80-90	–	5-10	0.6-1.0
Complete mixing	80-90	–	3-10	0.8-2.0
Contact stabilization	80-90	–	5-10	1.0-1.2
Kraus & Hatfield	85-95	–	3-10	0.6-1.6
High-rate	60-80	–	1- 3	2.0-6.0
Extended aeration	85-95	>90/–	15-30	0.1-0.4
Oxidation ditch	90-95	>90/50	15-30	0.1-0.3
Carousel	95-98	>90/50	20-40	0.2-0.4
Aerated lagoon	50-75	–	–	–
2-stage	>95	>90/–	1-3/5-10	2.0-3.0/0.3-0.7
Aerobic-anoxic	90-95	>90/60-90	7-15	0.2-0.4
Anoxic-aerobic	90-95	>90/60-90	10-20	0.2-0.4
Bardenpho	90-95	>90/60-90 P 80-90	14-20	0.1-0.3

Methods for N-removal

Process	Forms of N-load			Nc removal %
	Norg	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	
Basic biological treatment (focused on Carbon removal)				
Primary sedimentation	10-20 %	---	---	5 – 10
Activated sludge – basic biological treatment	15-50 % ($\rightarrow N\text{-}NH_4^+$)	< 10 %	slightly	10 – 30
Biological processes				
Assimilation by Microorganisms	---	40-70 %	slightly	30 – 70
Algae and similar biomass	($\rightarrow N\text{-}NH_4^+$)	$\rightarrow$ cells	$\rightarrow$ cells	50 – 80
Nitrification	10-50 %	$\rightarrow N\text{-}NO_3^-$	---	5 - 20
Denitrification	---	---	80-90 %	70 – 95
Biological ponds	($\rightarrow N\text{-}NH_4^+$)	partially	partially	20 - 90

Process	Forms of N-load			Nc Removal %
	Norg	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	
Chemical processes (problematic with untreated waste water)				
Chlorination	Not garanted	90-100 %	---	80 - 95
Coagulation	50-90 %	slightly	slightly	20 – 30
Active coal	30-50 %	slightly	slightly	10 – 20
Ion exchange NH_4^+	slightly	80-97 %	---	70 - 95
Ion exchange NO_3^-	slightly	slightly	75-90 %	70 - 90
Physical processes (problematic with untreated waste water)				
Stripping	---	60-95 %	---	50 – 90
Electrodialises	100 % of SS form	30-50 %	30-50 %	80 – 90
Filtration	30-100 % of SS form	slightly	slightly	20 – 40
Reverse osmosis	100 %	60-90 %	60-90 %	80 - 90

Process	Forms of N-load			Nc Removal %
	Norg	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	
Application on land				
Irrigation	$\rightarrow N\text{-}NH_4^+$	$\rightarrow N\text{-}NO_3^-$, plants	$\rightarrow N_2$, plants	60 – 90
Infiltration systems	$\rightarrow N\text{-}NH_4^+$	$\rightarrow N\text{-}NO_3$	$\rightarrow N_2$	30 – 80
Root systems, wetlands	$\rightarrow N\text{-}NH_4^+$	$\rightarrow N\text{-}NO_3$- plants	$\rightarrow N_2$, plants	70 – 90

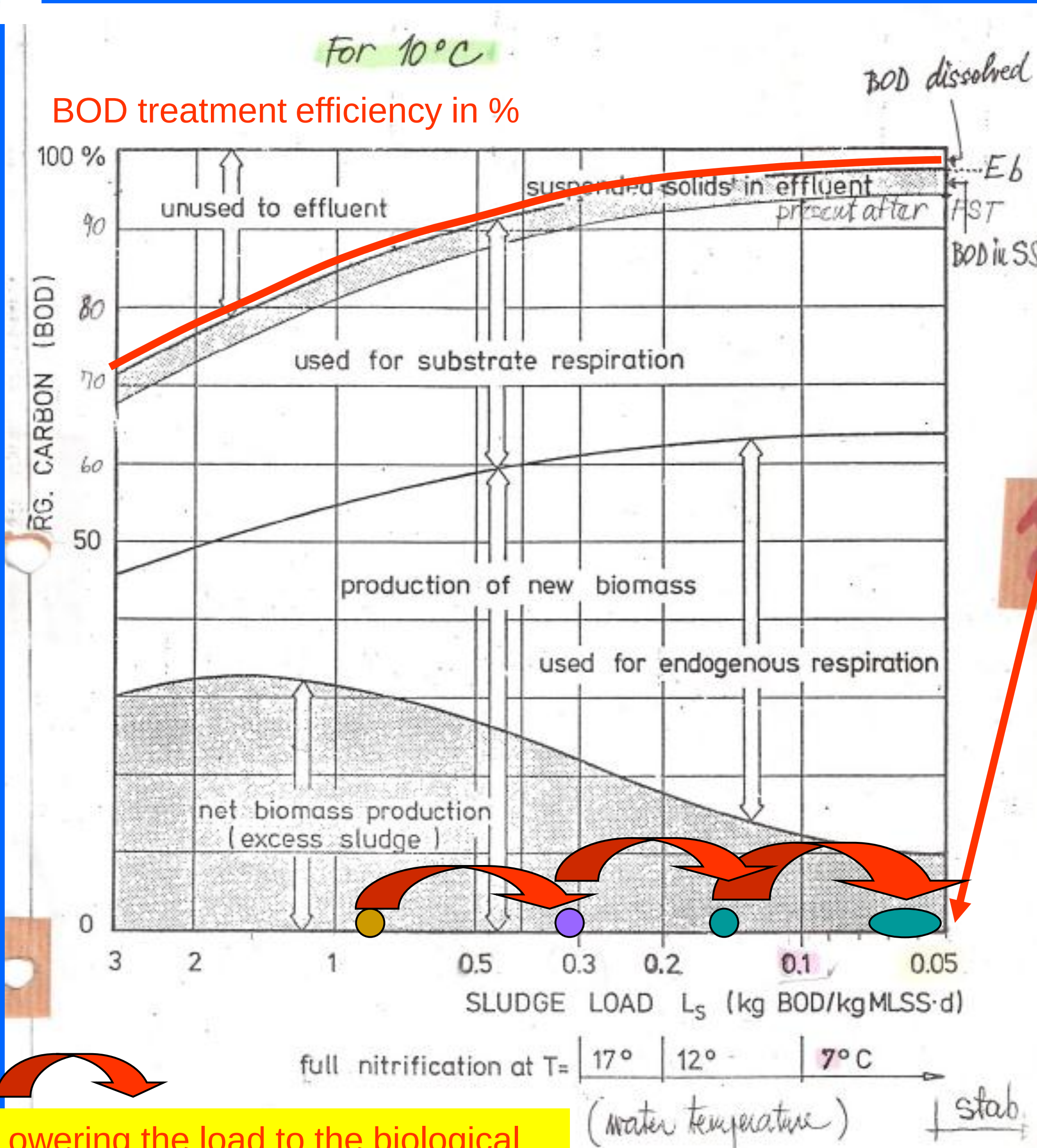
Activated sludge process is :

1. efficient all over the year
2. well controllable
3. suitable for municipal waste water
4. well operational all over the year

- Biological nitrification and denitrification becomes a part of biological treatment process if favorable conditions for activated sludge (mixed liquor) are set (by process design, civil and M&E part and operation)
- Oxic nitrification process converts N-NH_4 to N-NO_3.
- Anoxic denitrification process converts N-NO3 to N_2 and O_2 (O_2 is utilized for respiration, N_2 escapes to athmosphere)

How to assure N-removal ?

- Nitrificants are more sensitive and „slower“ then other microorganisms responsible for the basic biological treatment
- They reproduce (multiple) slowly i.e. higher sludge age is necessary (i.e. lower sludge loads, more biomass → bigger activation tanks, or biocarries, membrane technologies etc.)
- Higher O2 concentration required
- Sound process design is necessary. Reliable systems work with sludge age of 18 days and more (i.e. aerobic sludge age ~ 12 days).



University Stuttgart (Germany, prof.Hanish)

Basic biological treatment plus N-removal

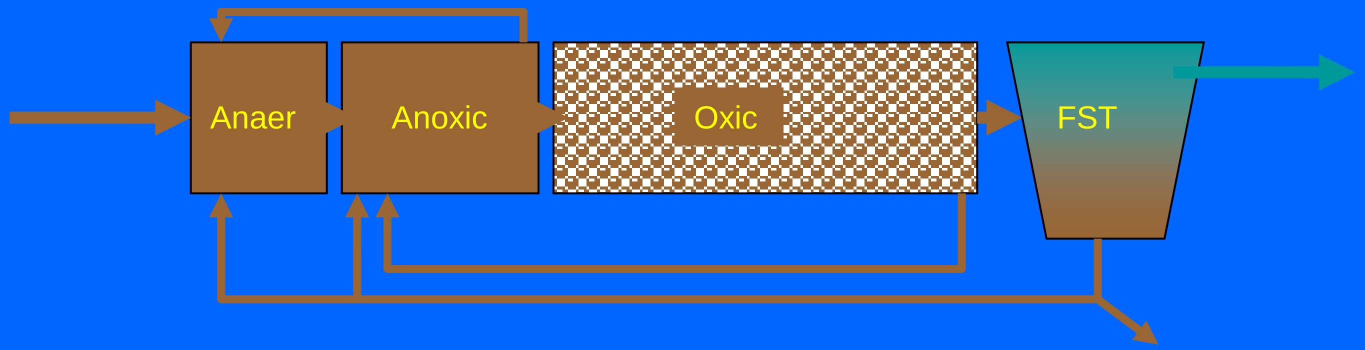
$$L_S = \frac{L}{V_{AT} * C_{MLSS}} = \frac{F_{ood}}{M_{ass}}$$

Note that with the same activation tank (given volume V_{AT} and concentration of activated sludge C_{MLSS}) you can get partial treatment, quality basic biological treatment, and high quality biological treatment with biological N-removal, and with anaerobic tank also even biological P-removal – just based on the actual load, i.e. the efficiency of WWTP can vary in the course of time according to the load conveyed by the sewerage system (L …here in kgBOD_5/day)

Lowering the load to the biological stage expressed in PE or kg BOD_5/day increases the waste water treatment efficiency

P-removal

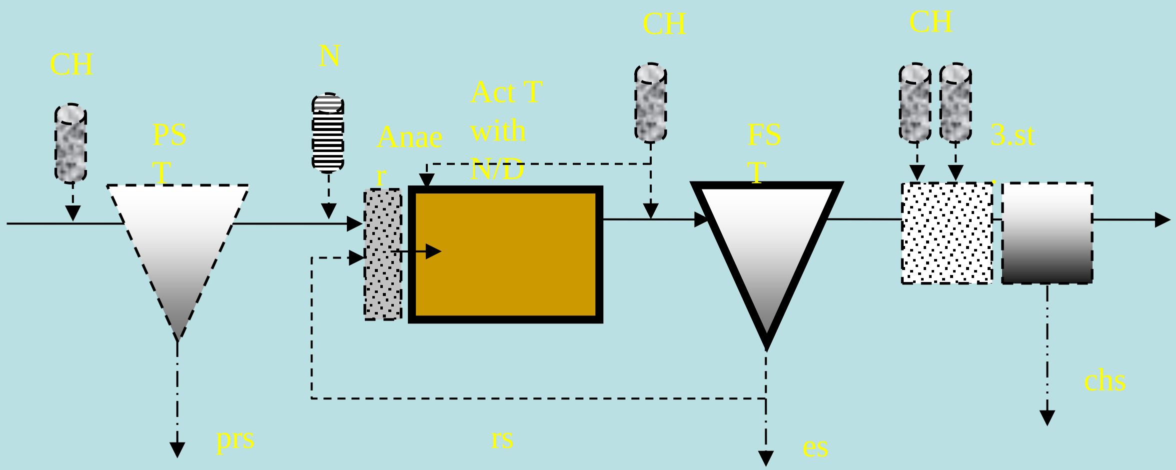
- Biological process – „luxury uptake“ (activated sludge subjected first to anaerobic and then to oxic conditions)



- Chemical precipitation by Fe or Al 3+ salts

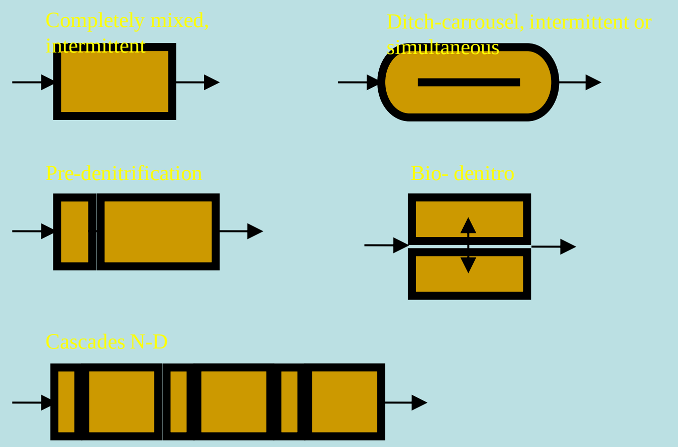
  (into AT, in front of FST, separate stage) – see next slide

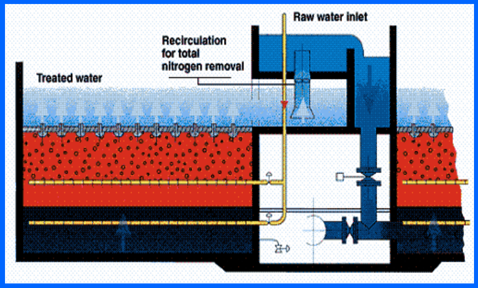
Nutrient removal



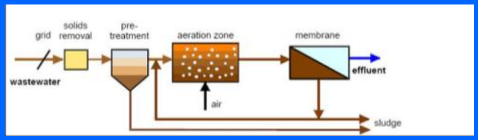
Possible activation tank arrangements

AT options





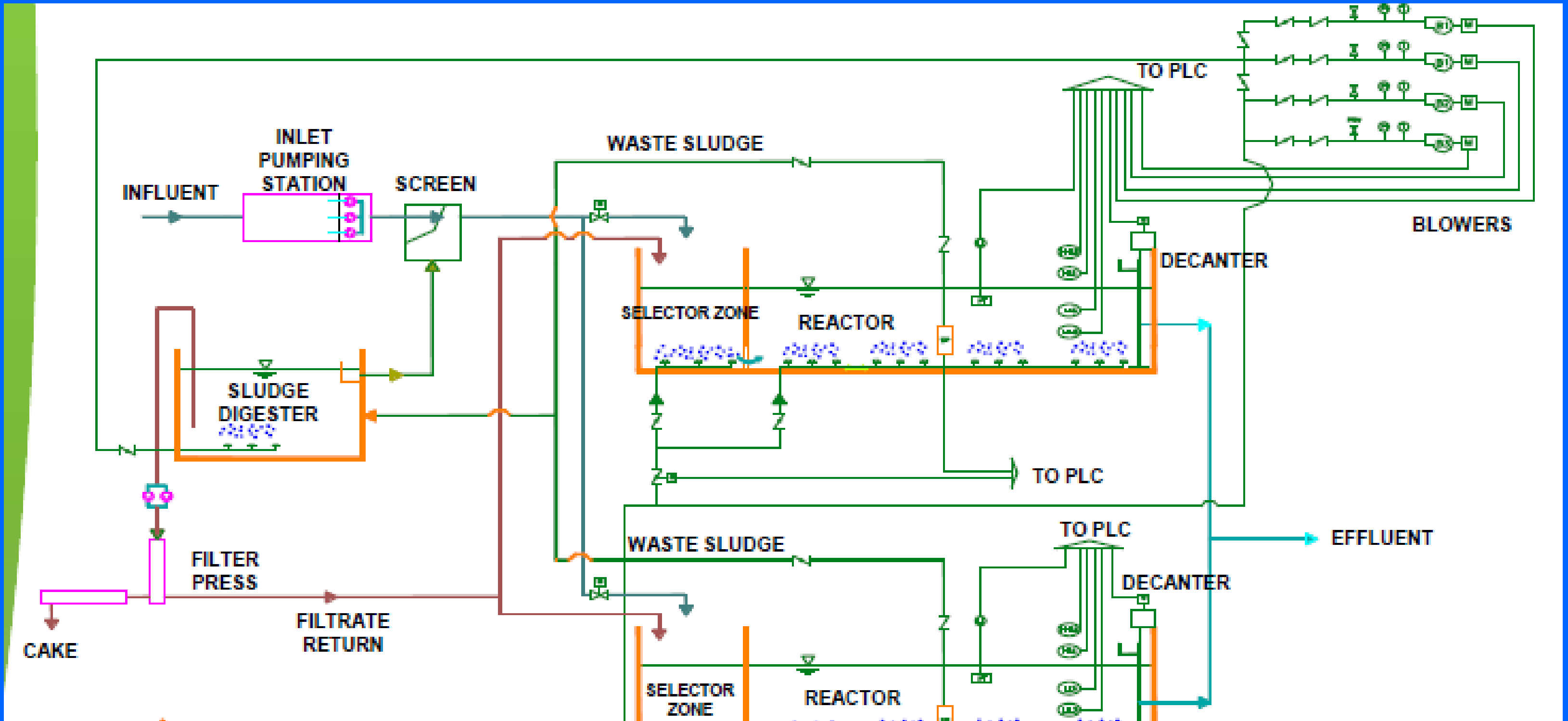
Biofilter



MBR

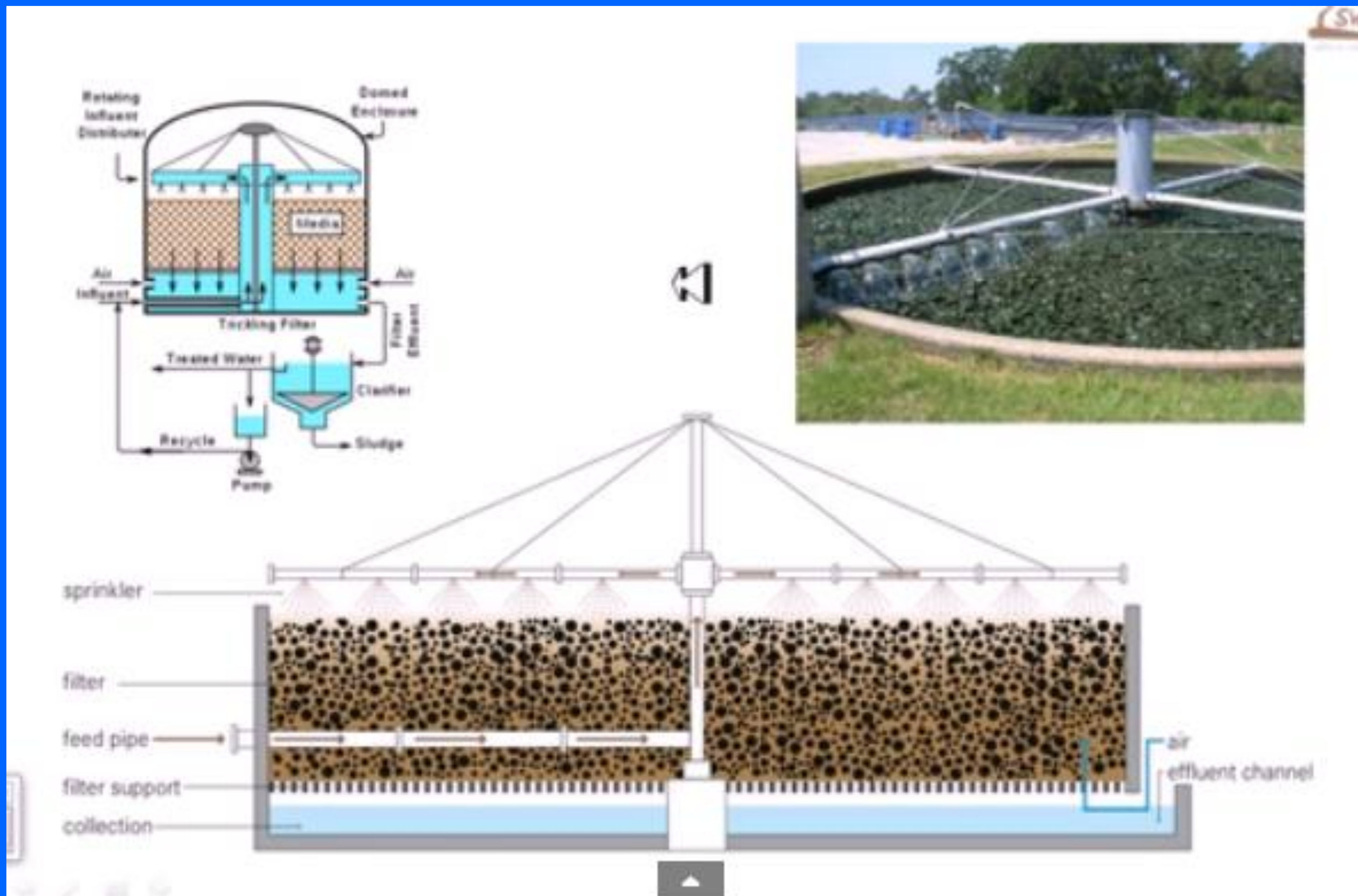
Conventional

SBR

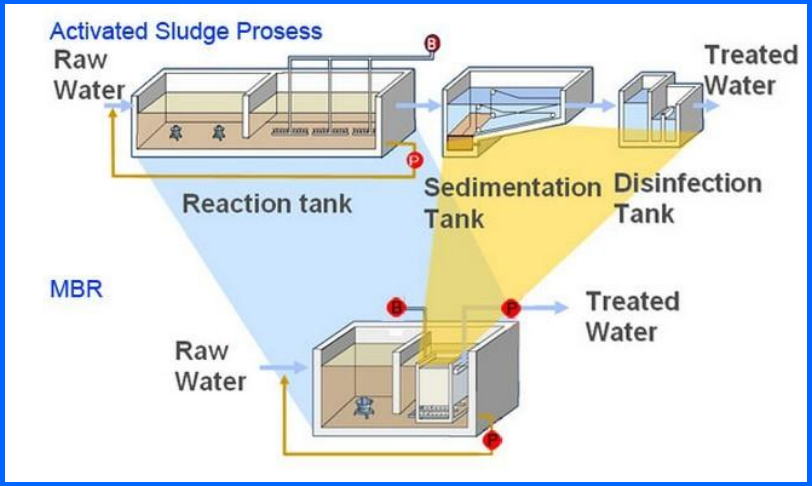


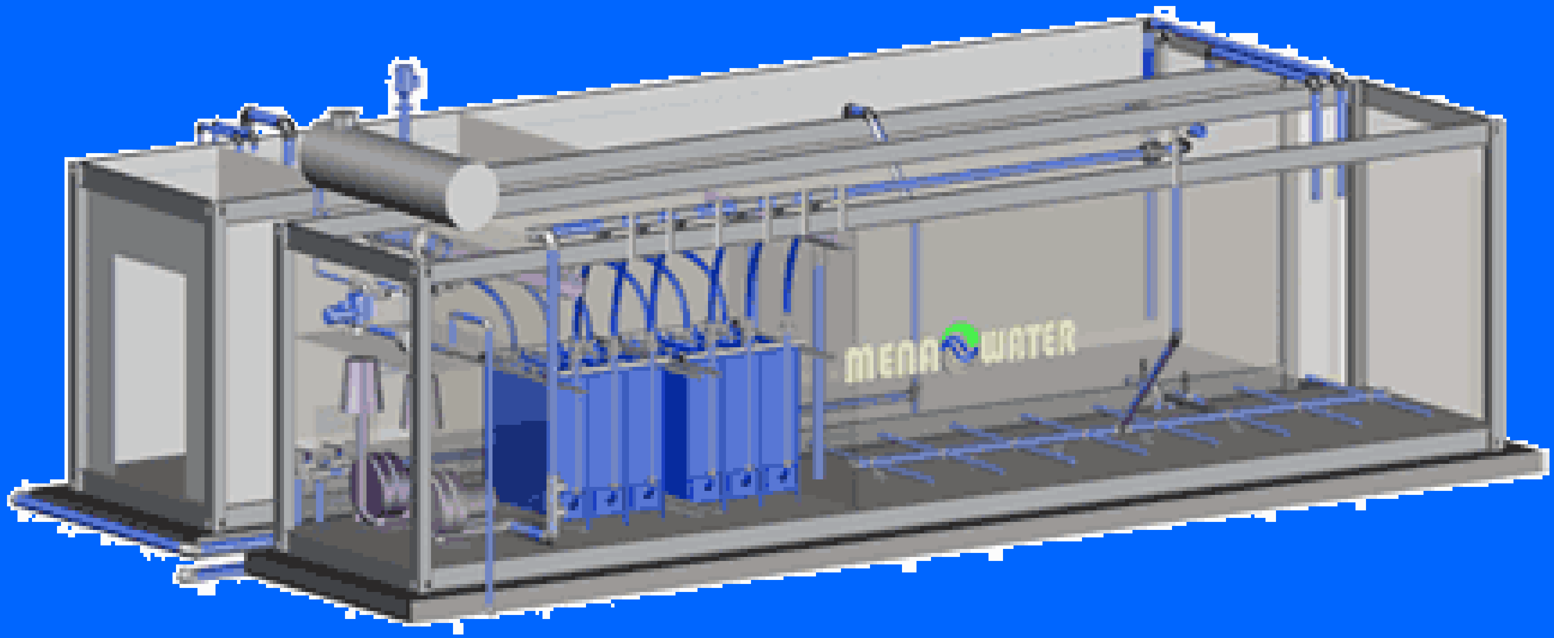
Simplified Process and Instrument Diagram of NR's Bio-Batch™

Trickling filter

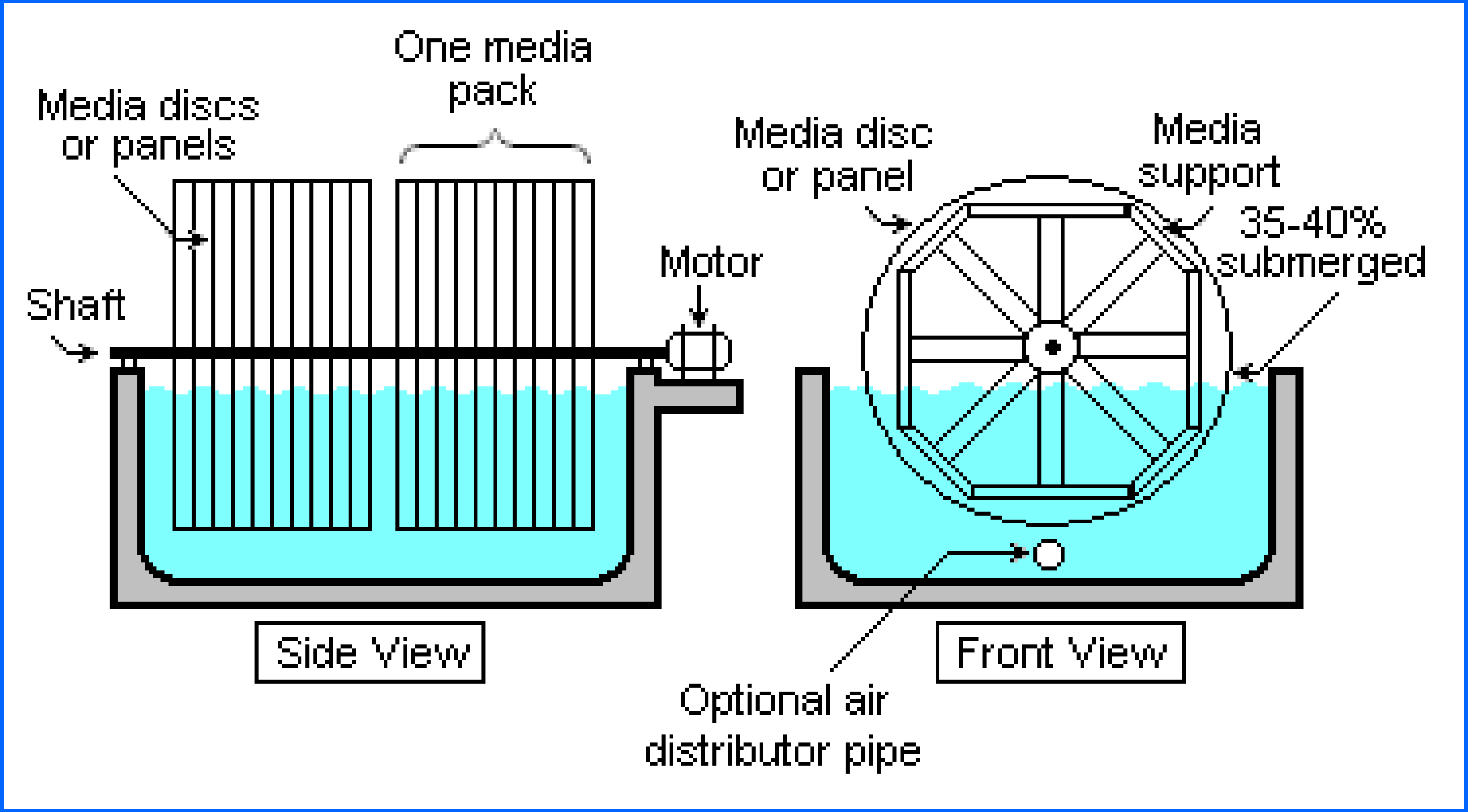


Membrane reactor

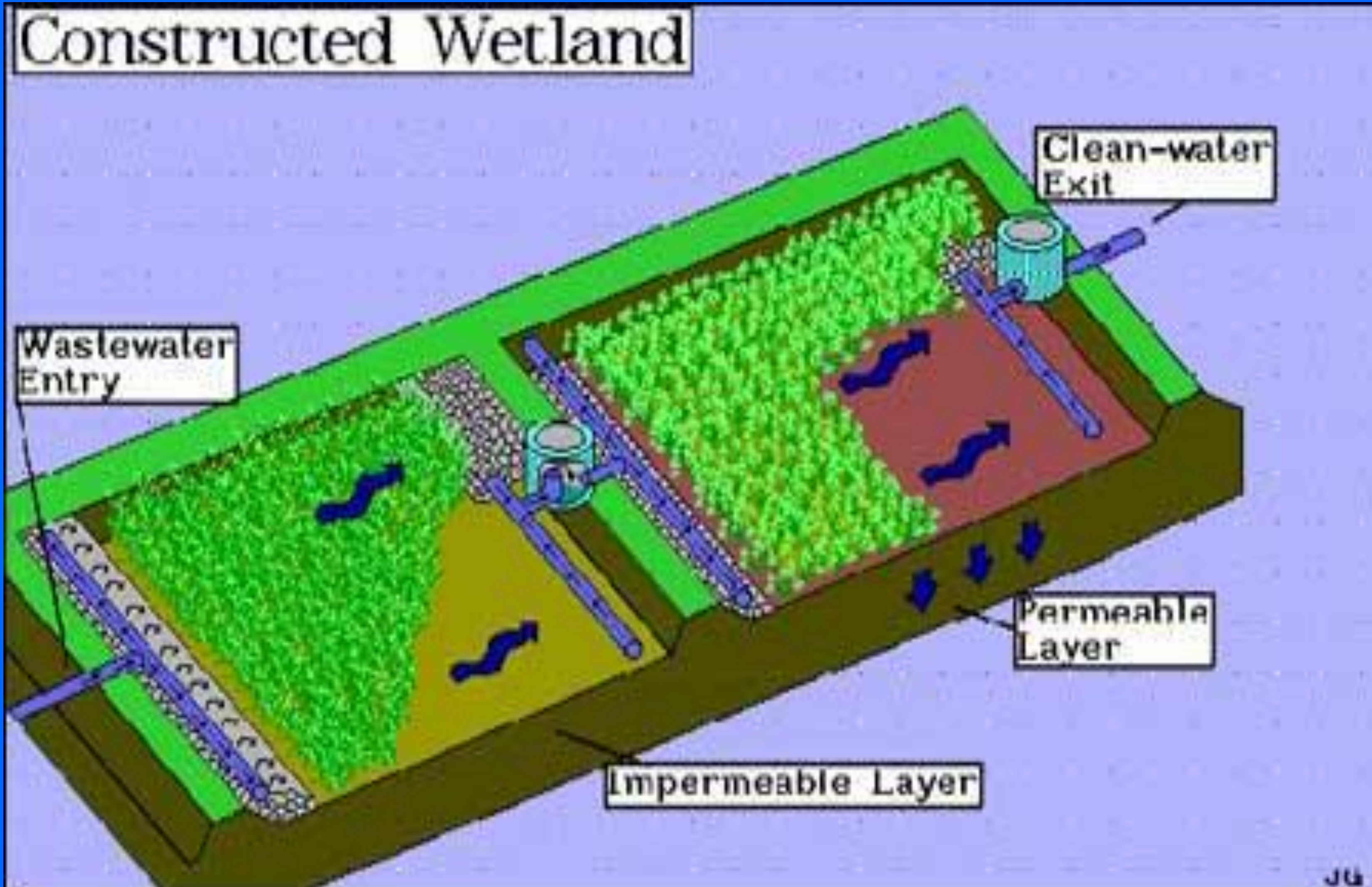




Rotating biological contactor (RBC)



Lagoons


Constructed Wetland
Clean-water Exit
Wastewater Entry
Permeable Layer
Impermeable Layer
JG

<u>Always it is necessary to respect the overall flow scheme and natural principles</u>

Different arrangements differ in reaction kinetics, treatment efficiencies, ask for different dimensioning, remote control etc.
(E.g. Detention times incl. recirculation, MLSS conc., availability of well biodegradable nutrients, N loads, temperature, min. oxic age, oxygen regime, good mixing, chemical dosing for simultaneous P-removal)

- For the highest treatment efficiency the separation of biological and chemical processes is recommended.

- Inflow - coarse treatment – primary treatment – biological stage(s) – chemical stage(s) - outflow

Directive 91/271/EEC

Parametry Parameters	Koncentrace Concentration	Minimální procento úbytku [1] Minimum percentage of reduction [1]
Celkový fosfor Total phosphorus	2 mg/l (10 000-100 000 EO - p.e.) 1 mg/l (nad - more than 100 000 EO - p.e.)	80
Celkový dusík [2] Total nitrogen [2]	15 mg/l (10 000-100 000 EO - p.e.) [3] 10 mg/l (nad - more than 100 000 EO.- p.e.) [3]	70-80

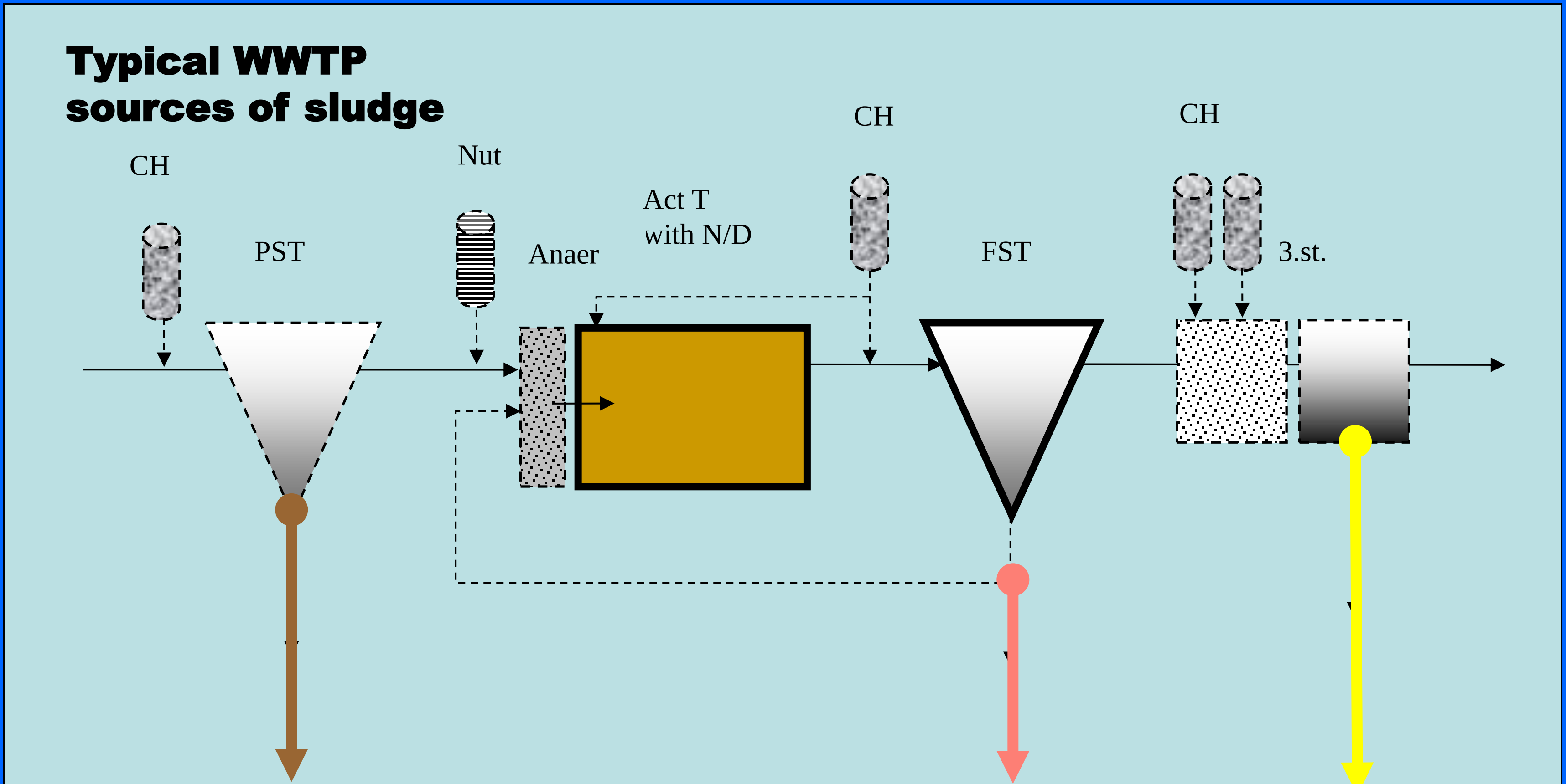
For 2 mg/l biological method or simultaneous precipitation is sufficient, for < 1 mg/l separate chemical stage is recommended (combination with biological method is possible)

For 10 mg/l much safer dimensioning is necessary

Possible situations

PE	0 treat-ment	Primary treat-ment	Basic biological treatment	BBT + P rem oval	BBT + N removal	BBT + N + P removal 15 10 2 1
< 500 PE						
500 - 2000 PE						
2000 – 10000 PE						
10000 – 100000 PE						
> 100000 PE						

Sludge treatment



Primary sludge

The main source of biogas during anaerobic digestion

Excess sludge

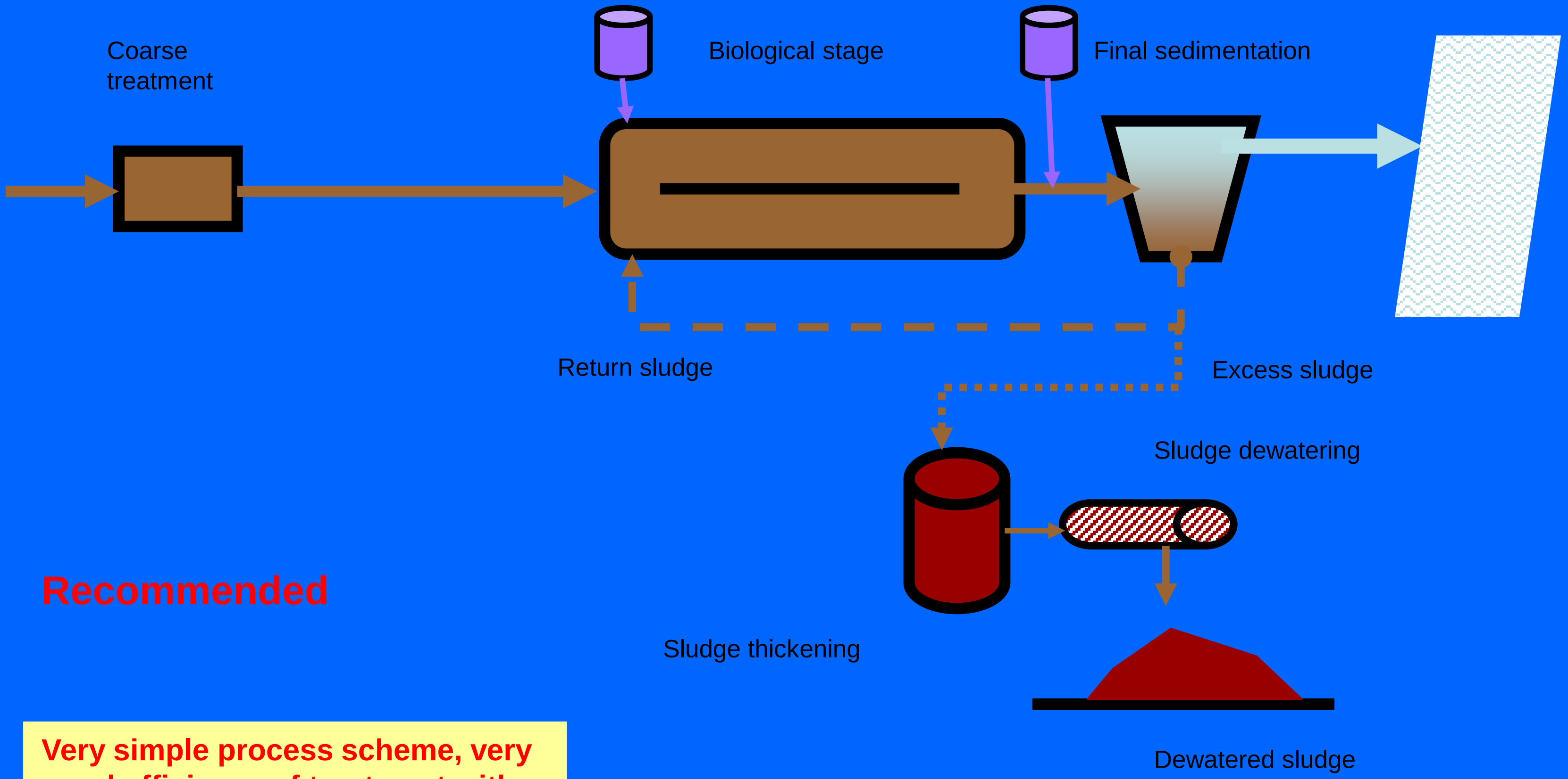
Depending on BOD load in kgBOD5/kgMLSS.day with different level of aerobic stabilization (mineralization). The higher stabilization the lower biogas production.

Chemical sludge

Usually after P-removal. No biogas production potential.

Aerobic stabilization

WWTP with extended aeration Sludge age around 25 days	These WWTPs are designed for waste water treatment with simultaneous sludge aerobic stabilization and produce aerobically stabilized sludge. These plants should never have primary sedimentation. The process removes nitrogen and can remove phosphorus. For small and middle size WWTPs this is the best process option.

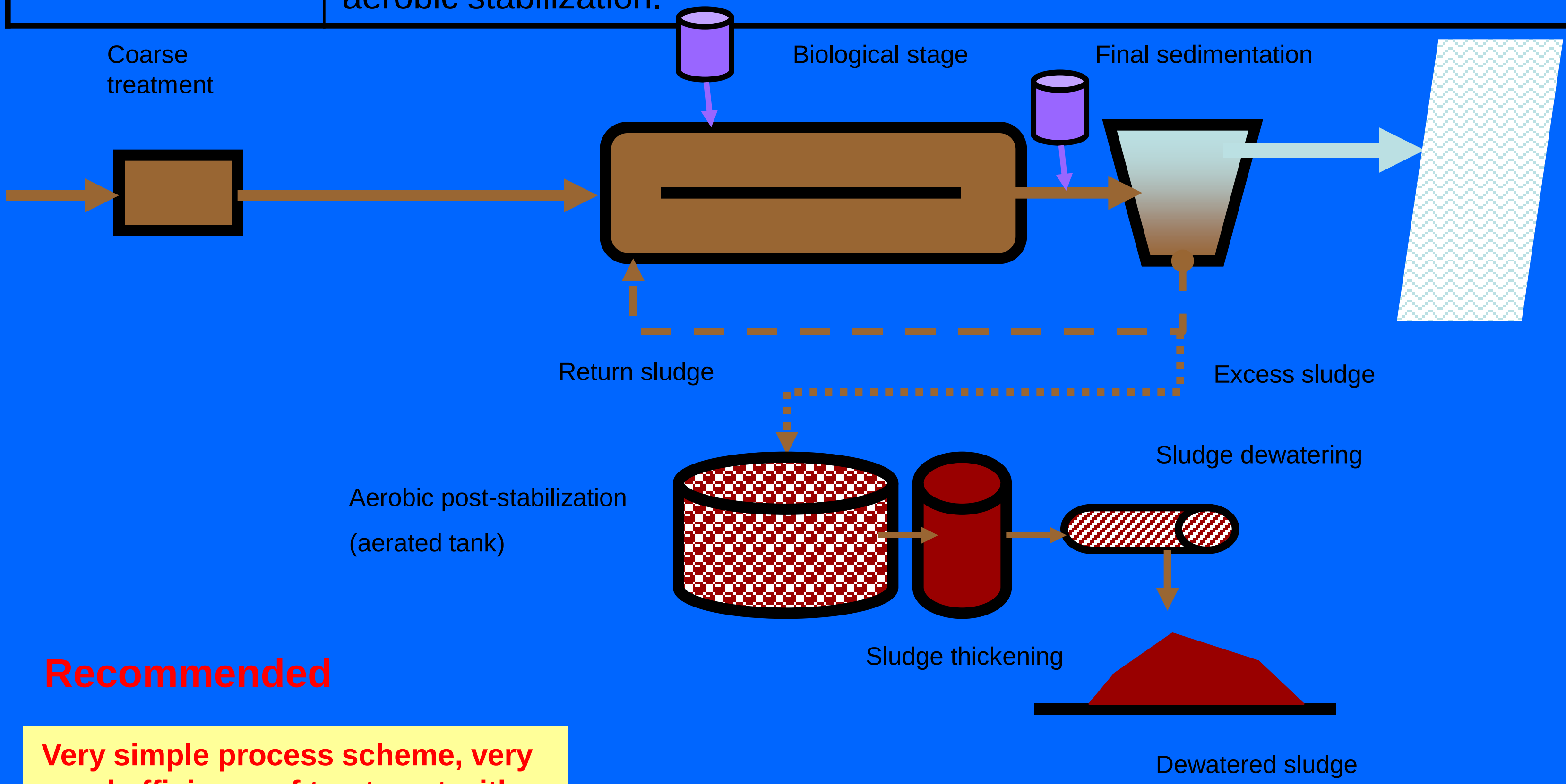


Recommended

Very simple process scheme, very good efficiency of treatment with N-removal & P-removal

Aerobic stabilization

WWTP with low loaded aeration Sludge age around 15 - 25 days	These WWTPs are designed for waste water treatment with simultaneous sludge aerobic stabilization and produce aerobically stabilized sludge. These plants should never have primary sedimentation. The process removes nitrogen and can remove phosphorus. This scheme is a modification of the previous one; ensuring high degree of aerobic stabilization.

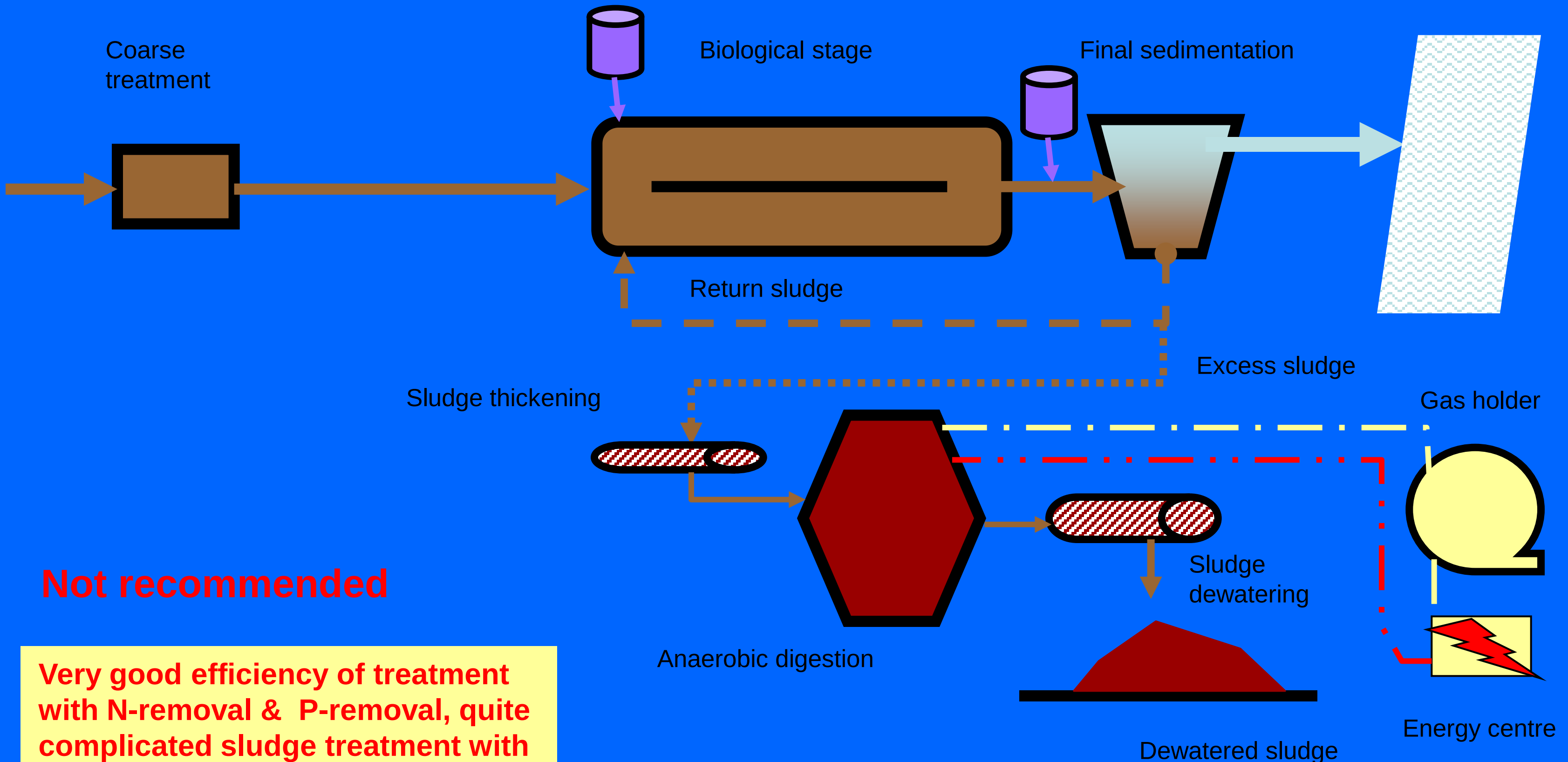


Recommended

Very simple process scheme, very good efficiency of treatment with N-removal & P-removal

Anaerobic stabilization

WWTP with low loaded biological stage, with nutrient removal Sludge age around 15 – 20 days	These WWTPs are designed for very good efficiency of treatment including nutrient removal. This option should be justified by detail process design preferably with process modeling. As there is no primary sludge produced the production of biogas will be very low – economy of the process ??

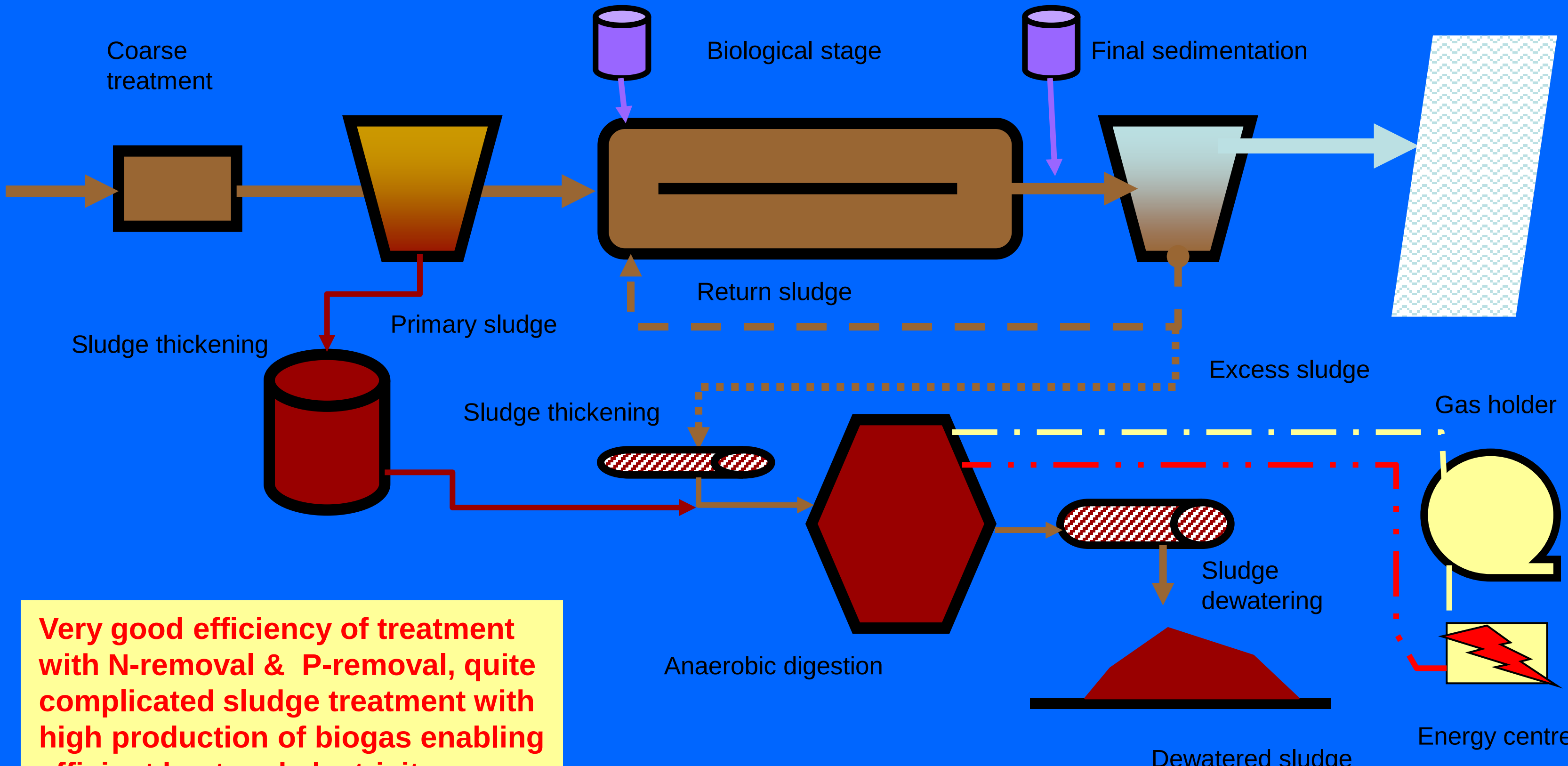


Not recommended

Very good efficiency of treatment with N-removal & P-removal, quite complicated sludge treatment with low production of biogas

Anaerobic stabilization

WWTP with low loaded biological stage, with nutrient removal Sludge age around 15-20	These WWTPs are designed for very good efficiency of treatment including nutrient removal. This is the best option for big WWTPs.

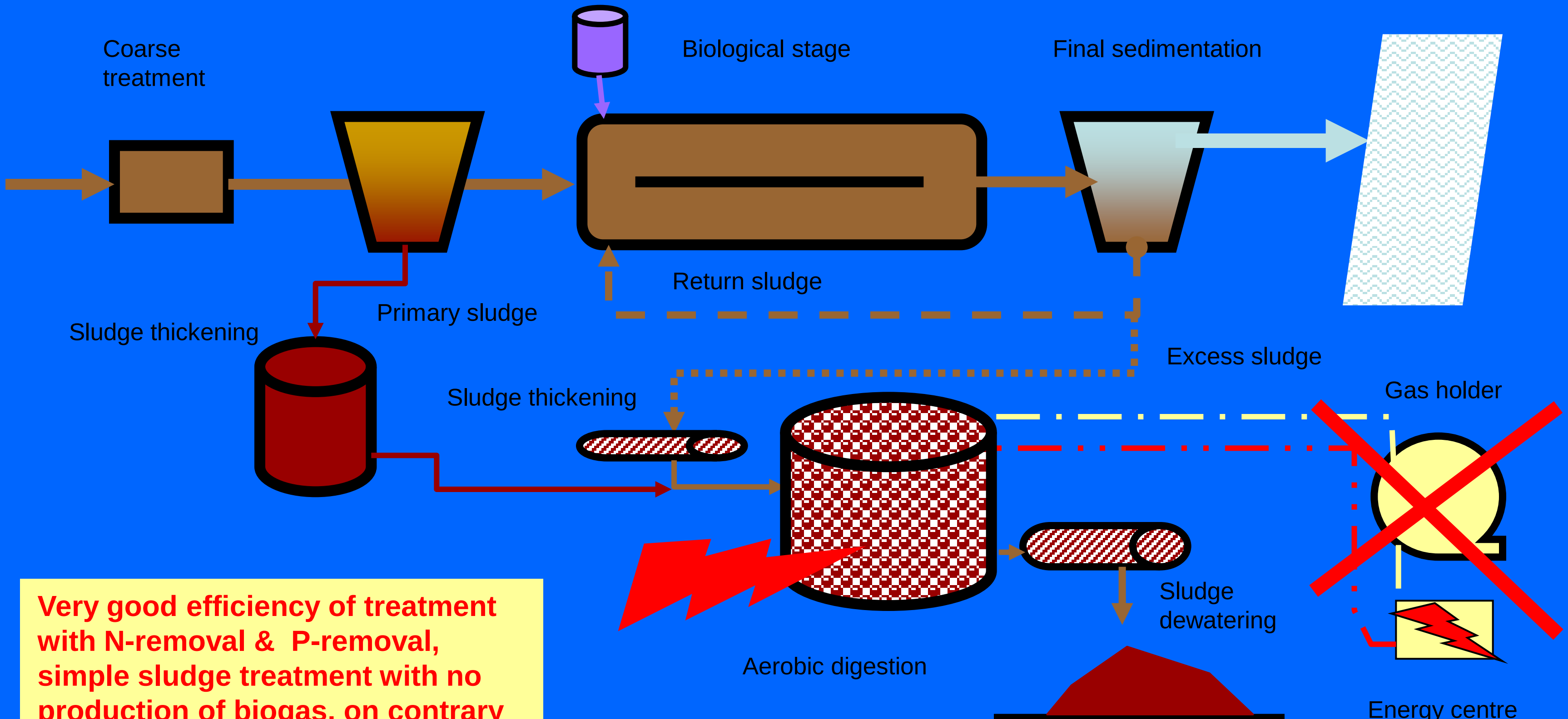


Very good efficiency of treatment with N-removal & P-removal, quite complicated sludge treatment with high production of biogas enabling efficient heat and electricity production

Recommended

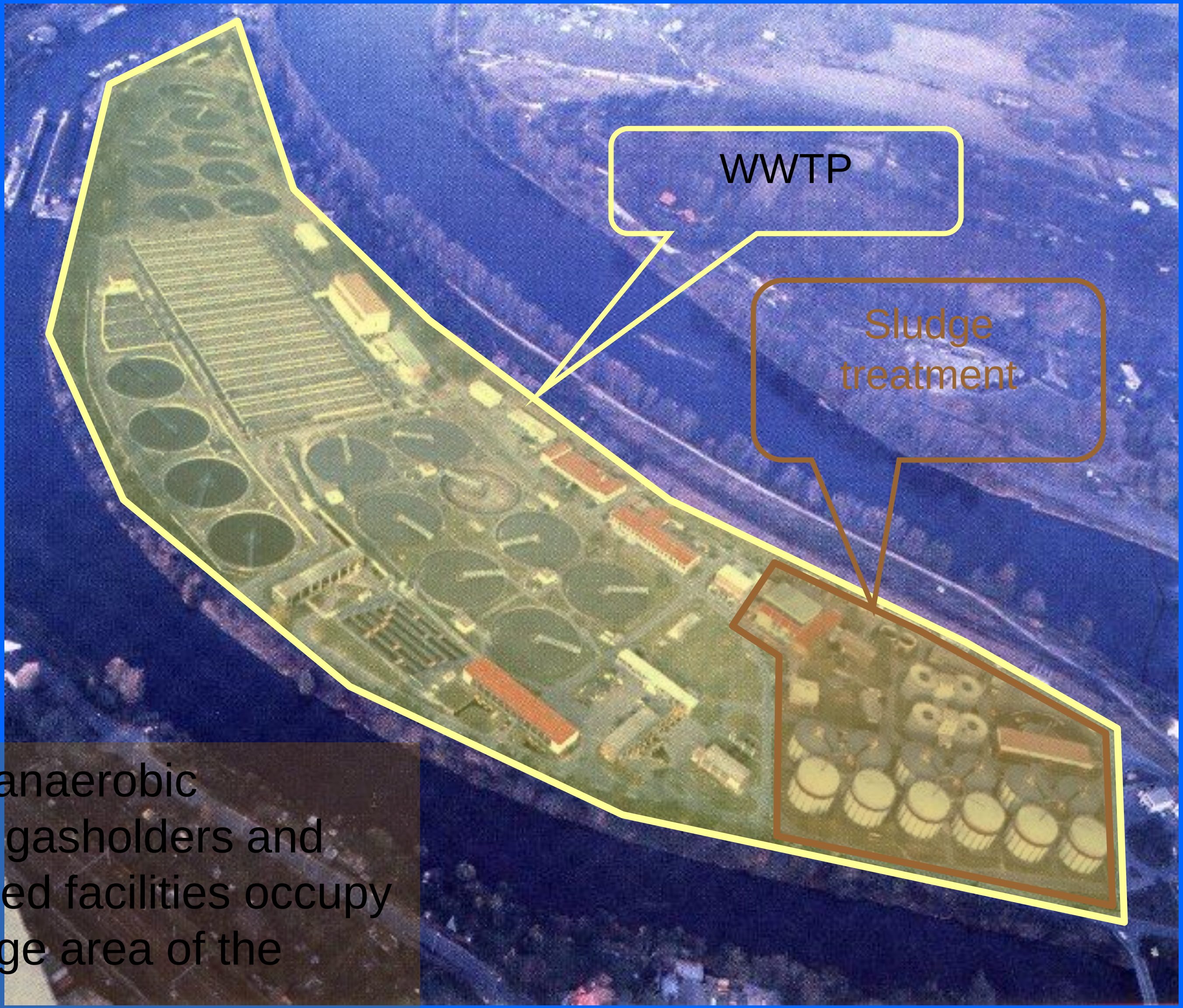
Aerobic stabilization

WWTP with low loaded biological stage, with nutrient removal Sludge age around 15-20	These WWTPs are designed for very good efficiency of treatment including nutrient removal. This is the option for middle sized WWTPs.



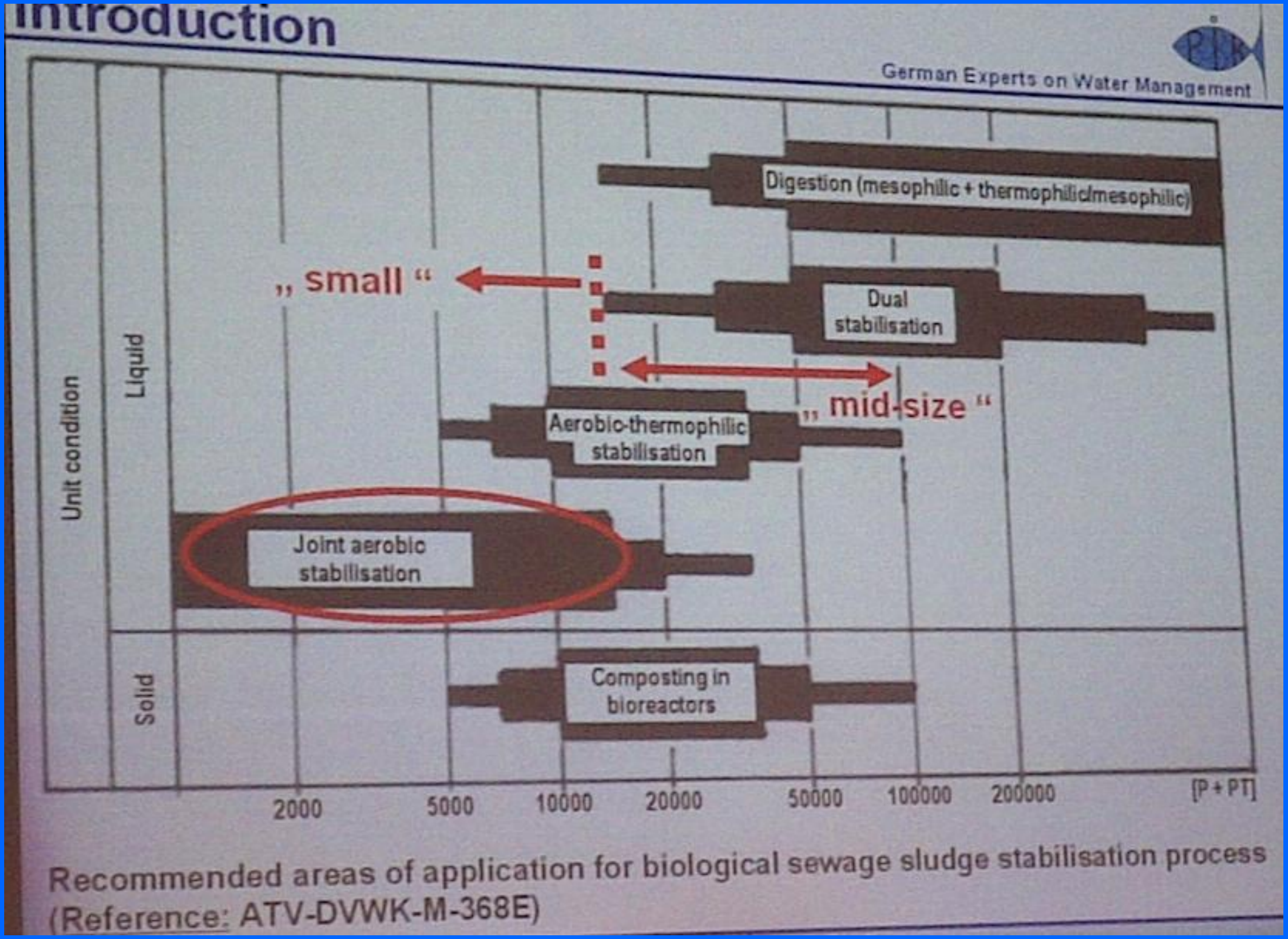
Very good efficiency of treatment with N-removal & P-removal, simple sludge treatment with no production of biogas, on contrary with high energy consumption

Not recommended



Note that anaerobic digesters, gasholders and other related facilities occupy quite a large area of the WWTP.

Sludge stabilization options = f (PE)



Comments

- The above schemes indicate that the anaerobic sludge stabilization is far more complicated then the extended aeration with simultaneous aerobic sludge stabilization
- Biological treatment lines can be designed for very high efficiency of treatment including N and P removal, i.e. for tertiary treatment
- Many CBAs indicate that anaerobic digestion is not good option for middle size WWTPs as the energy and heat production asks for a big first cost and then NPV is higher. The decision making is frequently influenced by the “cheap” EU money (grants around 80%)

Sludge disposal options

• Composting	+
• Direct fertilizing	+
• (Co-) Incineration	-
• Land-filling (>35%DS)	-
• Synthetic soil production	+
• Cement works	-
• Energy compost	-+

\+ cheap, available

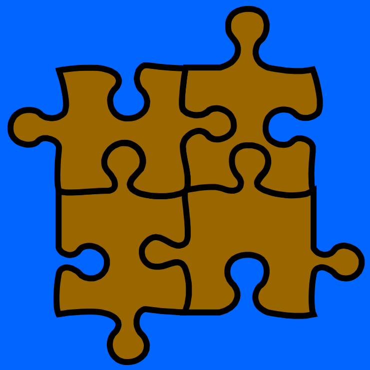
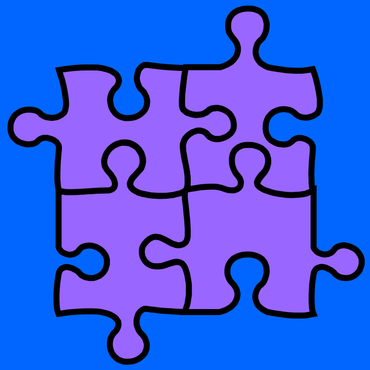
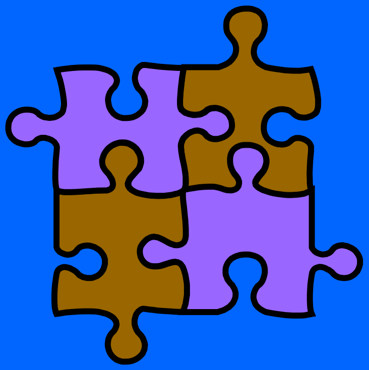
What is frequently absent ?

- National or at least regional sludge disposal strategy
- Knowledge of EU and local legislation ► knowledge of real needs
- Knowledge of aspects influencing WWTP design according to different options of sludge treatment (e.g. different quantity and quality of sludge water)
- Realistic approach
- Preference of simple and environment friendly solutions (win-win, ….)

Be careful: The higher % of grant – the more elaborate and expensive option with the minimum added value and sustainability can occur

Remember:

- WWTP including sludge treatment is like puzzle
- All parts have to fit together and especially to (i) effluent standards, i.e. wastewater treatment process, (ii) sludges produced in the treatment processes (excess, primary, raw, chemical); (ii) sludge final disposal option, i.e. sludge treatment process; (iii) and of course economy (NPV) → one has to create a meaningful and sustainable system

Either:  Or:  Not: 

This virtually fits together but will not work properly

Check list - existing WWTP

WWTP load	Present load and design load: Number of PE Q … m3/d … average, maximum day Q … m3/h … maximum dry weather flow and maximum wet weather flow BOD5, COD, SS, Ntot, N-NH4, Ptot …….. kg/day Specific industrial waste waters ? Combined or separate sewerage system? If combined how overflows and rain detention tanks are designed, other measures, by-passes? Design wet weather flow through the secondary stage?
Primary treatment	Shape, surface area and volume of primary sedimentation tanks
Secondary treatment	Shape and volume of activated sludge tanks (anaerobic, anoxic, oxic, reaeration, contact – mixed, ditch, circular, rectangular, depth), blower capacity Shape, surface area and volume of secondary sedimentation tanks Dosing of chemicals ?
Other stages	e.g. Chemical precipitation, filtration, disinfection – description, volumes, design capacities
Other data	Simple flow scheme Contact person + tel + e-mail
Sludge treatment	Short description, volumes of tanks

The above data will enable a fast assessment of WWTP capability to remove nutrients.

Thank you for listening

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