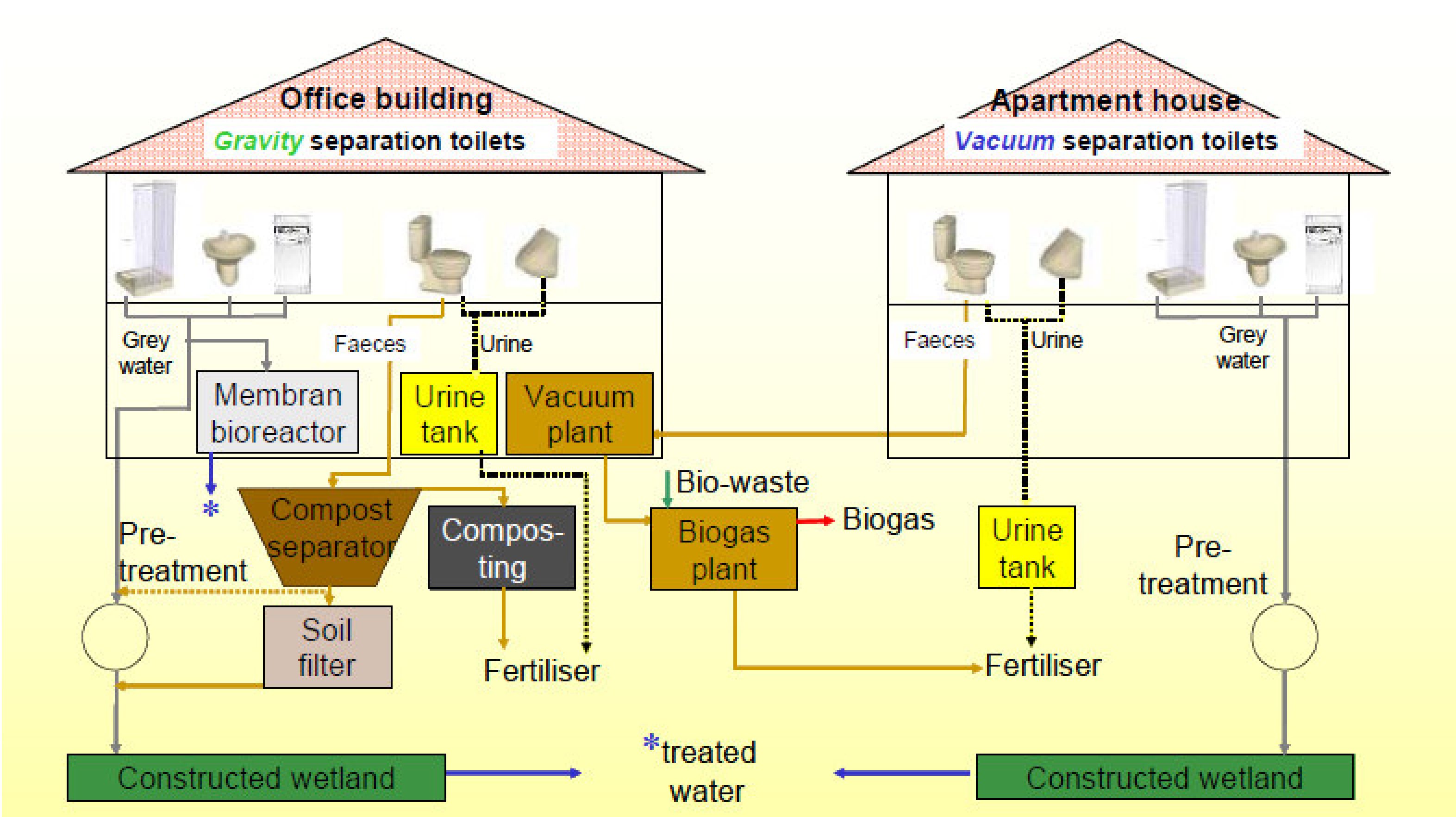
There is an energy in water…
…and even more

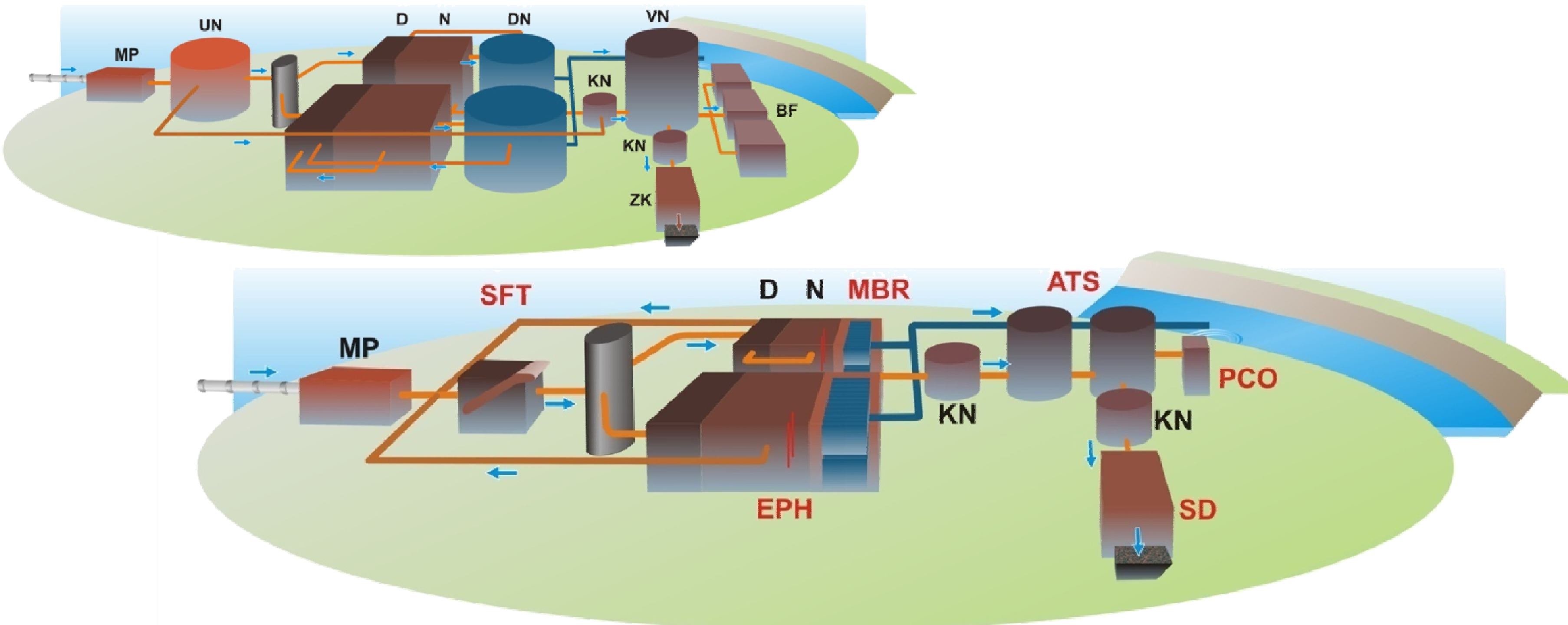
Prof. Ing. Blahoslav Marsalek, Ph.D.,
Masaryk University Brno,

Waste water? Used water? RESOURCE!

- Waste water is concentrated resource of N, P, S) and energy

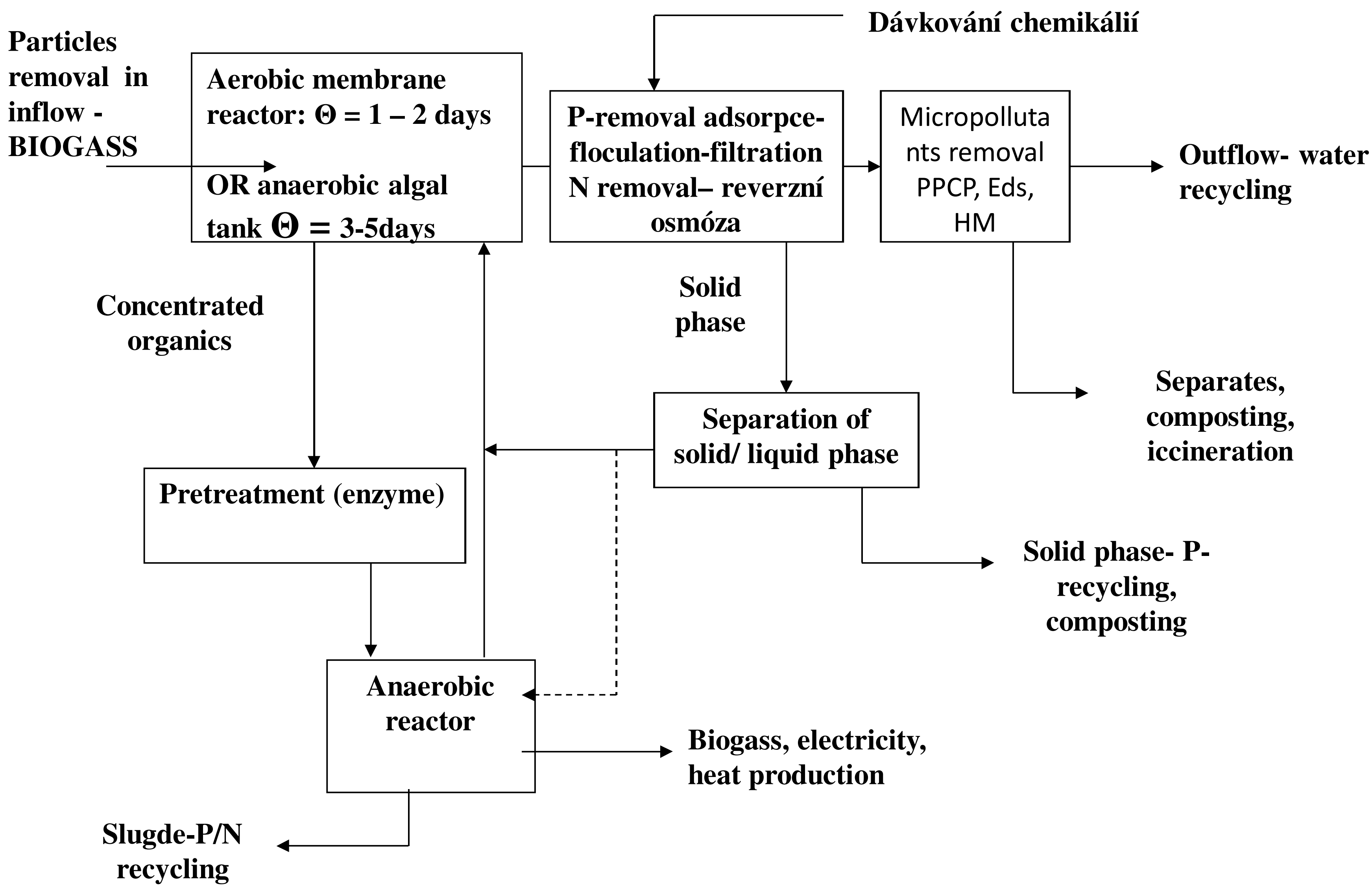


Our direction …

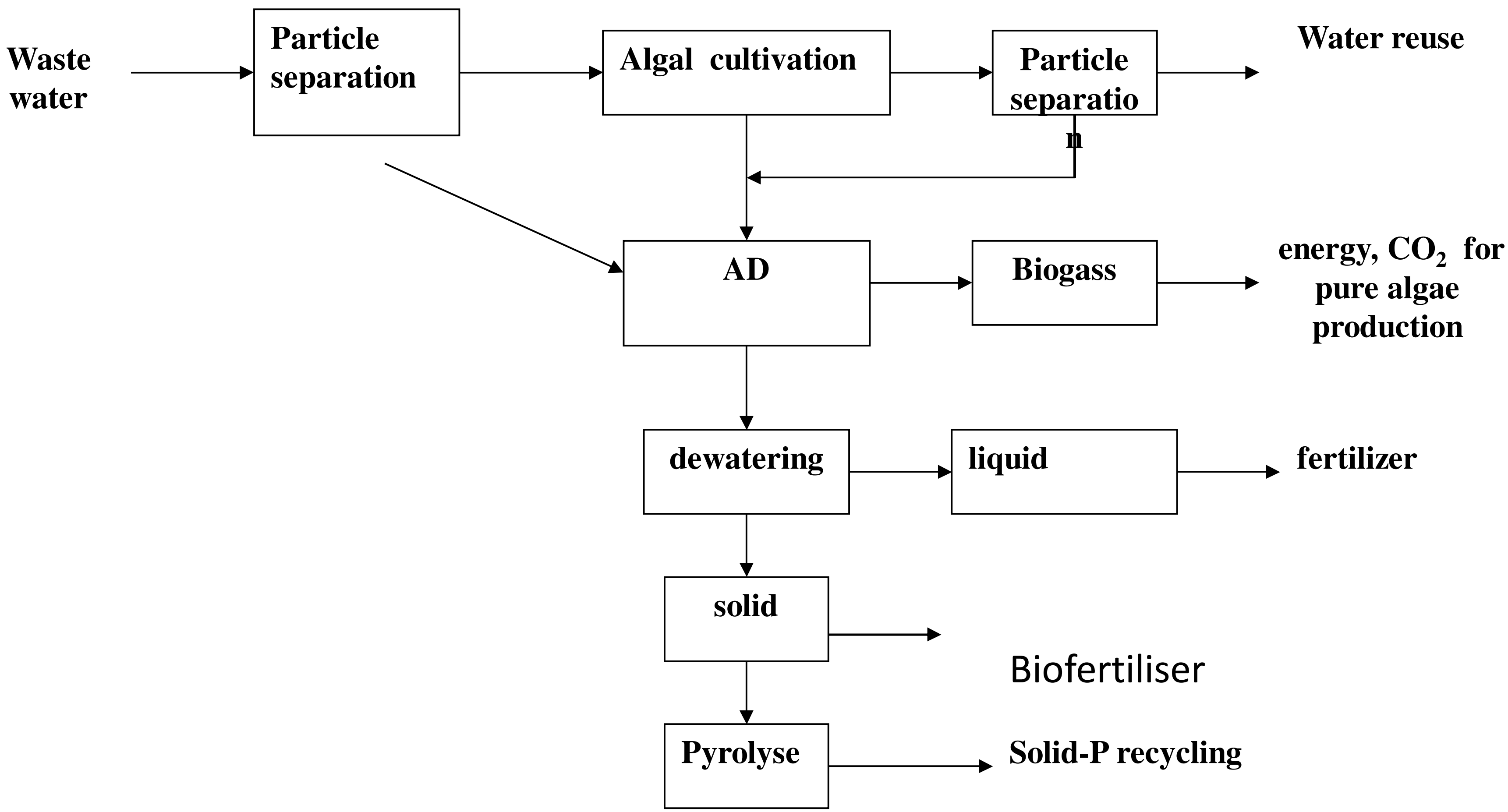


- to decrease costs for energy → **energy self-sufficient WWTP**
- advanced technologies → algal production→ **higher efficiency for same investment costs**

Furure scheme of WWTP?



WWTP with maximal recyclation



Energy in wastewater

Heat energy

- Heat energy of wastewater is derived from heat capacity of water – ca. 4.2 kJ/kg•K or **4.2 MJ/m³** per 1 °C of temperature change.

Hydraulic (kinetic and potential) energy

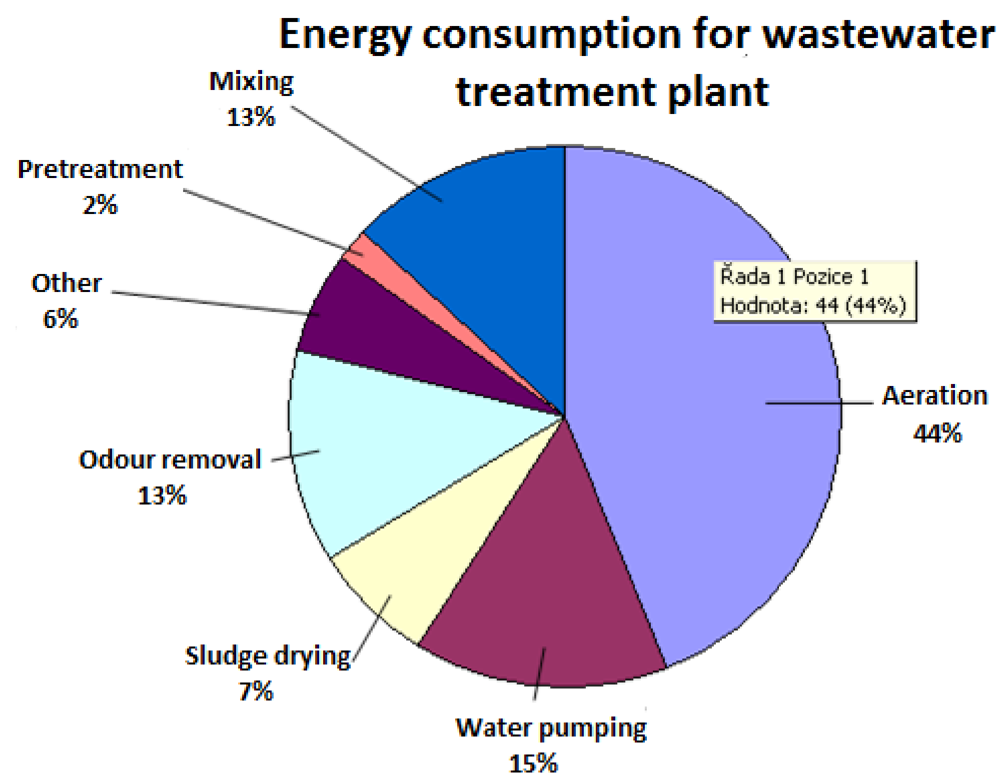
- Potential energy of water level is equal to 9.8 kJ/m³ per 1 meter of height. Kinetic energy is equal to **0.18 kJ/m³** at stream velocity 0.6 m/s.

Chemical energy

- Chemical energy is contained in organic matter present in wastewater, usually defined as COD in mg/L. Tchobanoglous [3] defines **chemical energy of sludge as 13 MJ/kg COD**, that can be recalculated as **5.6 MJ/m³** for municipal sewage. Real data at WWTP North Toronto showed value **6.3 MJ/m³**.

Effective and economical system

1. optimization of device and equipment at WWTP
2. energy recycling
3. **energy from biomass**
4. renewable energy



Energy consumption at the WWTP for 100 000 PE

Where to focus on?

- Level of the saved money depends more than on the site of WWTP than its technology

- Up to 20 000 PE we focus on energy audit of devices and its optimization or sludge dewatering. We can save **ca. 20 %** of overall costs

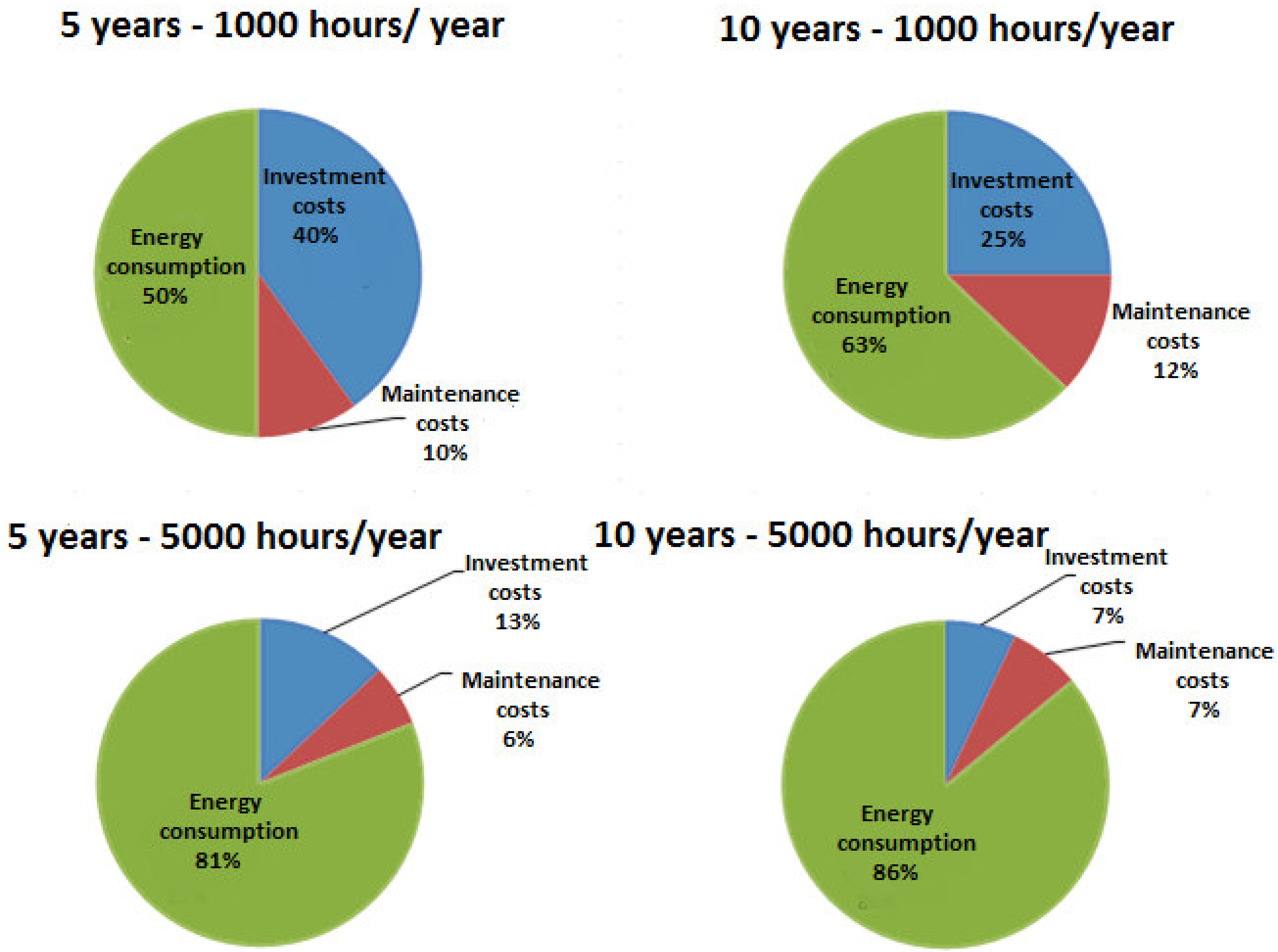
- WWTP with more than 20 000 PE have a big potential in **anaerobic sludge digestion with co-digestion and biogas utilization.** We can save **ca 30 %** of overall costs

Energy audit

- **device exchange for those with lower energy consumption**
  - blowers
  - pumps
  - mixers
- **process control optimization**
  - control
  - air supply
  - biological processes
  - sludge management
- **heat energy production**

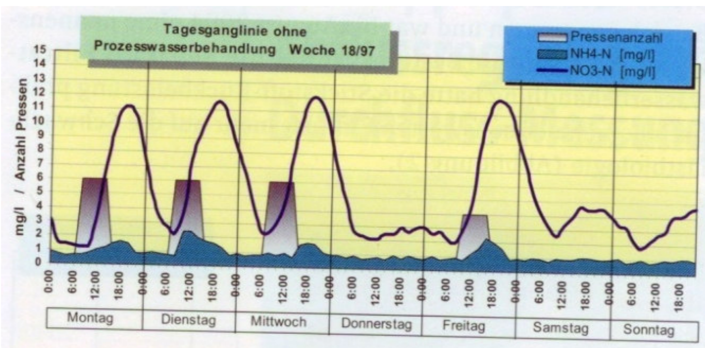
Comparison of pumps

- Comparison of pumps with pumps of 14 kW in pumping shaft at discontinuous and continuous operation



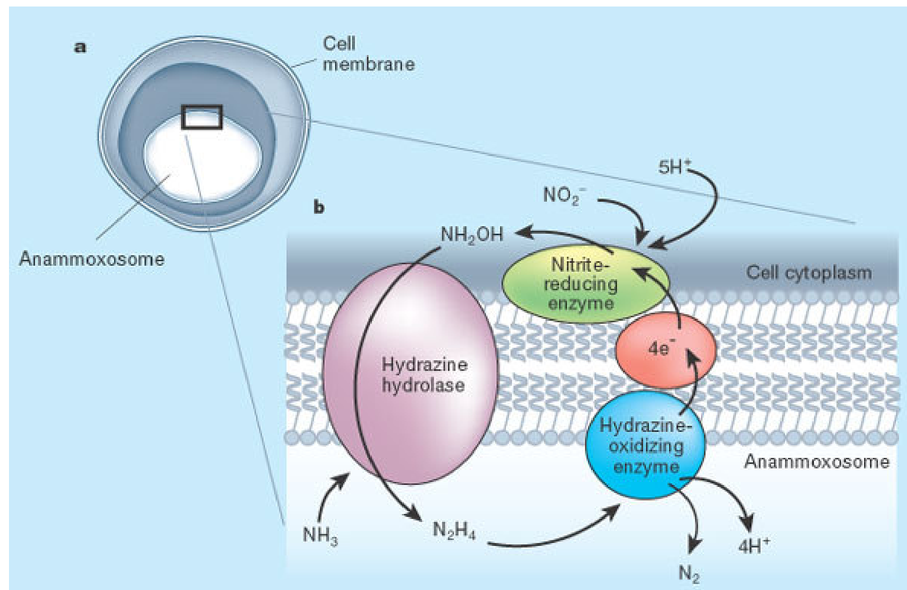
Biological process control optimization

- controlled by O_2 concentration
- novel technologies



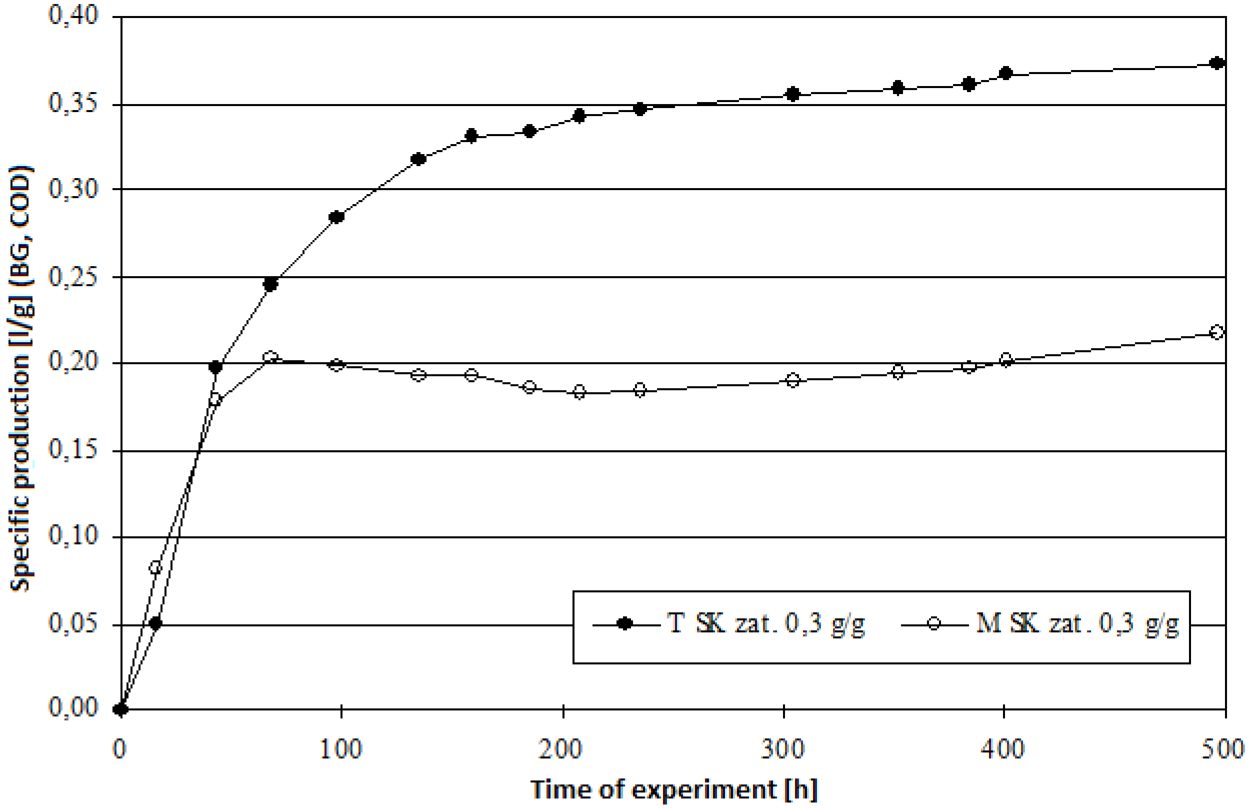
- SHARON
- DEMON
- ANAMMOX

$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$



Thermophilic/mesophilic digesters

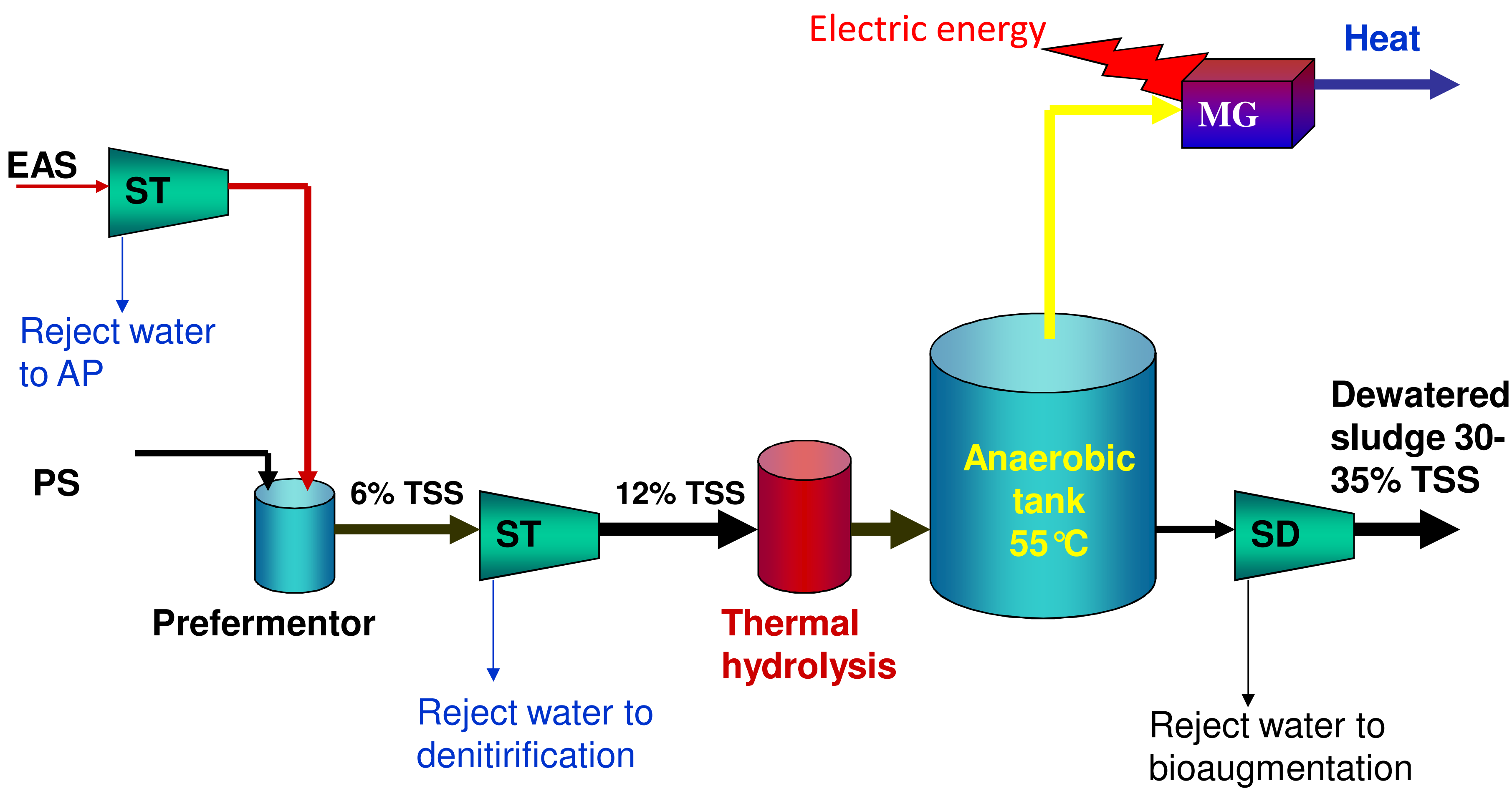
Specific production of biogas during anaerobic digestion of raw sludge by thermophilic and mesophilic anaerobic biomass



Increased production of biogas

	% energie in biogas	% overall efficiency	% electric efficiency	kWh_{el}/kg TSS
Mesophilic thickening - 7 %	**54,98**	**30,7**	15,5	**0,66**
Thermophilic thickening-7%	**66,41**	**41,2**	22,4	**0,97**
Thermophil. + 50% heat recuperation	**66.41**	**49,4**	22,4	**0,97**
Thickening to 8%,thermoph.	**66,41**	**43,3**	22,4	**0,97**
Desintegration, thermophilic	**71,5**	**45,7**	24,1	**1,05**
Entire hydrolysis, thermoph.	**82**	**56,5**	28,2	**1,23**
Sludge combustion	0	**45,8**	11,5	**0,50**

Algal biomass and sludge processing AD flowscheme



Energetic sludge potential

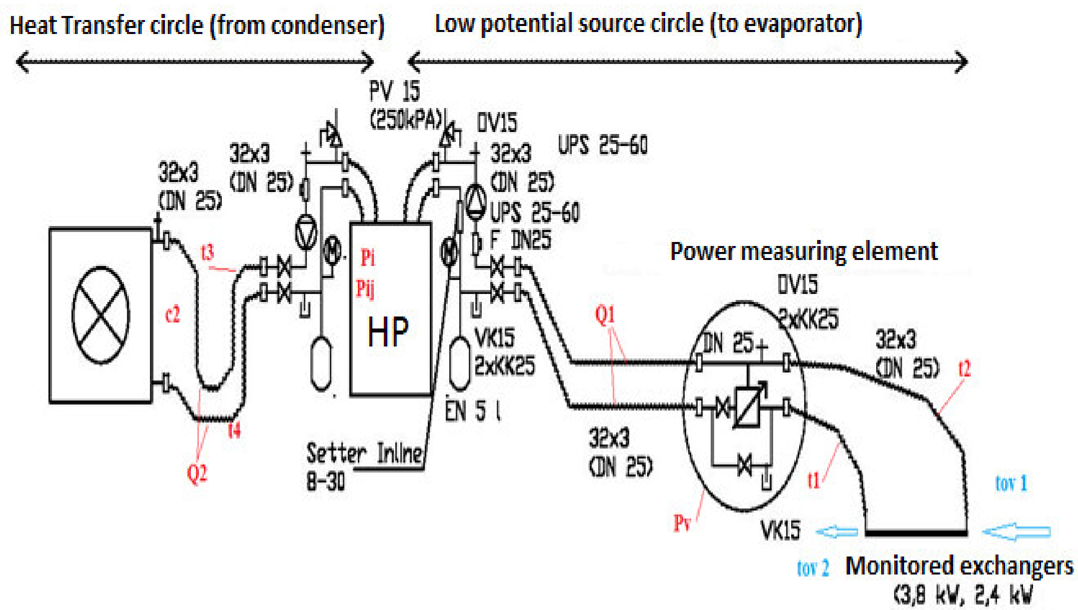
	kCal/kg TSS	EP in 1 kg TSS (MJ)
sludge	3200	13
Algae20%+sludge	3620	15
wood	3780	16
waste	2200	9
coal	8000	33

Heat energy production conditions

- minimum dry inlet 15 L/s (applicable ca. from 5 000 – 10 000 PE)
- heat potential in the inlet wastewater (average temperature in winter would be higher than 10 °C)
- heat energy consumers close to the heat energy production place
- competitive energy sources, e.g. heating
- it cannot influence proper function of sewerage and WWTP

Heat energy production

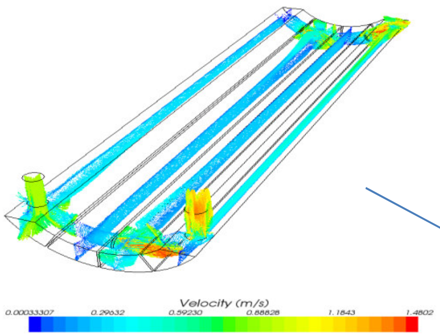
Pilot-plant solution at WWTP Letonice



- Inlet and outlet wastewater have big heat potential
- Low-potential heat through heat pump
- Utilization for building heating, sludge heating before fermentation tanks, sludge drying
- Outlet temperatue up to 80 °C

Heat energy production

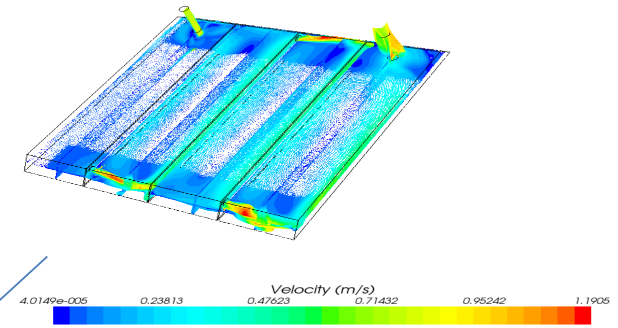
Mathematical modeling x reality



Performance:

Measured : 2 420 W

Modeled : 2 477 W
2.4 % error



Performance

Measured: 4 977 W

Modeled: 4 436 W

10 % error

Asio® čištění a úprava vod

ALGAL ONLINE MONITOR

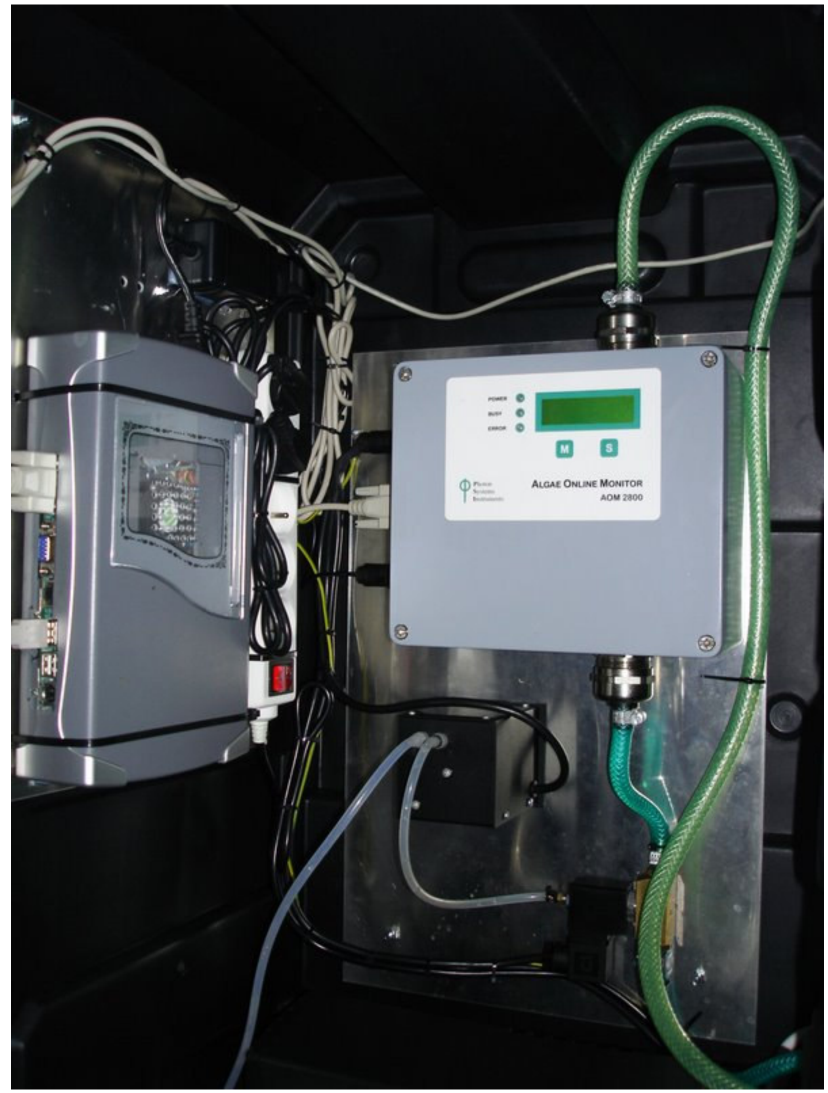
PARAMETERS

- Quantification of algal growth rate, (chl-a, µg/L)
- algal health and physiological status

PRINCIPLE

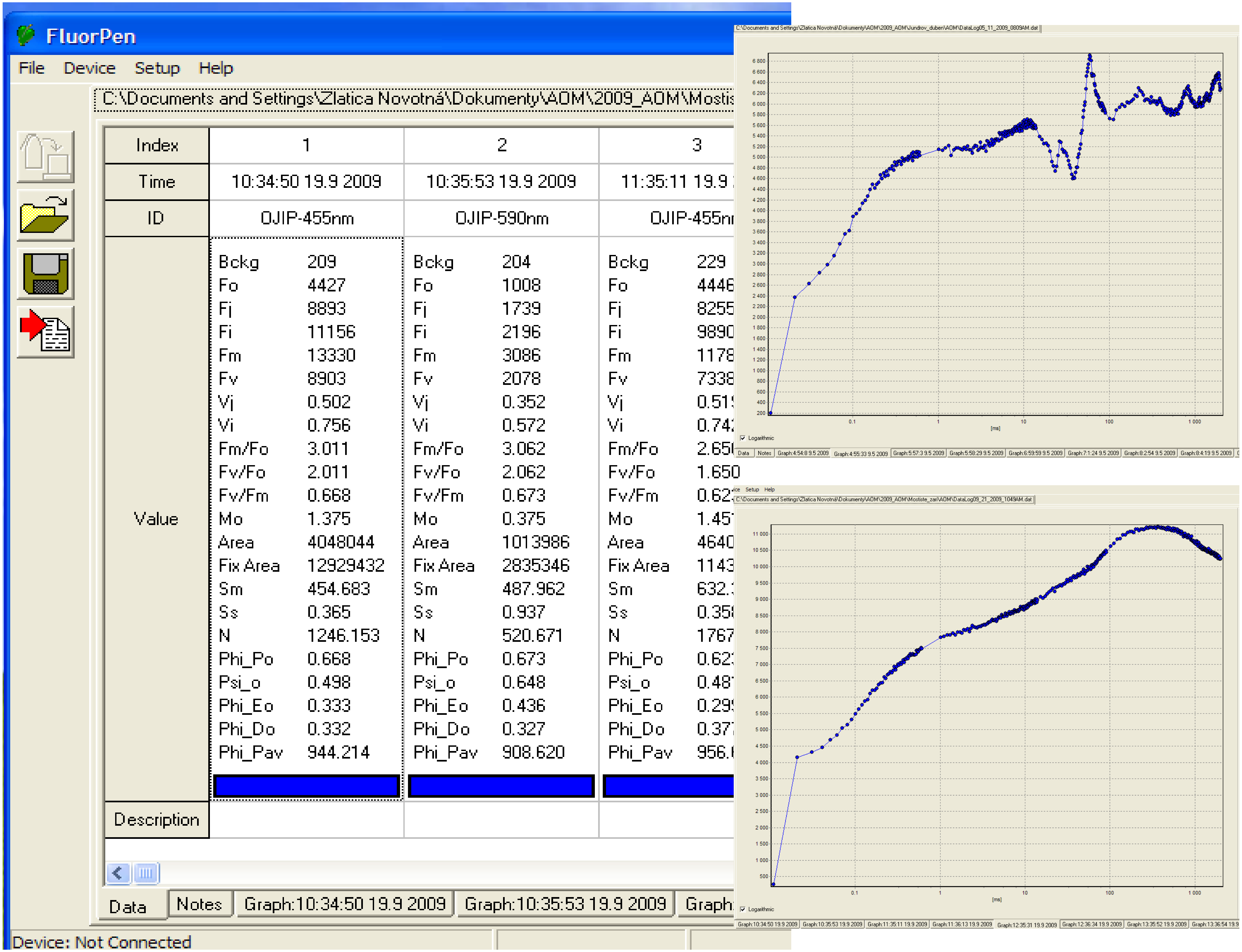
- fluorescence chl-a
- Induction of Kautsky effect
- chl-a

- Continual measurement
- High sensitivity
- Data transfer by GSM
- **ROBUST FOR HRAP**



Detekction of algal growth rate in waste water treatment

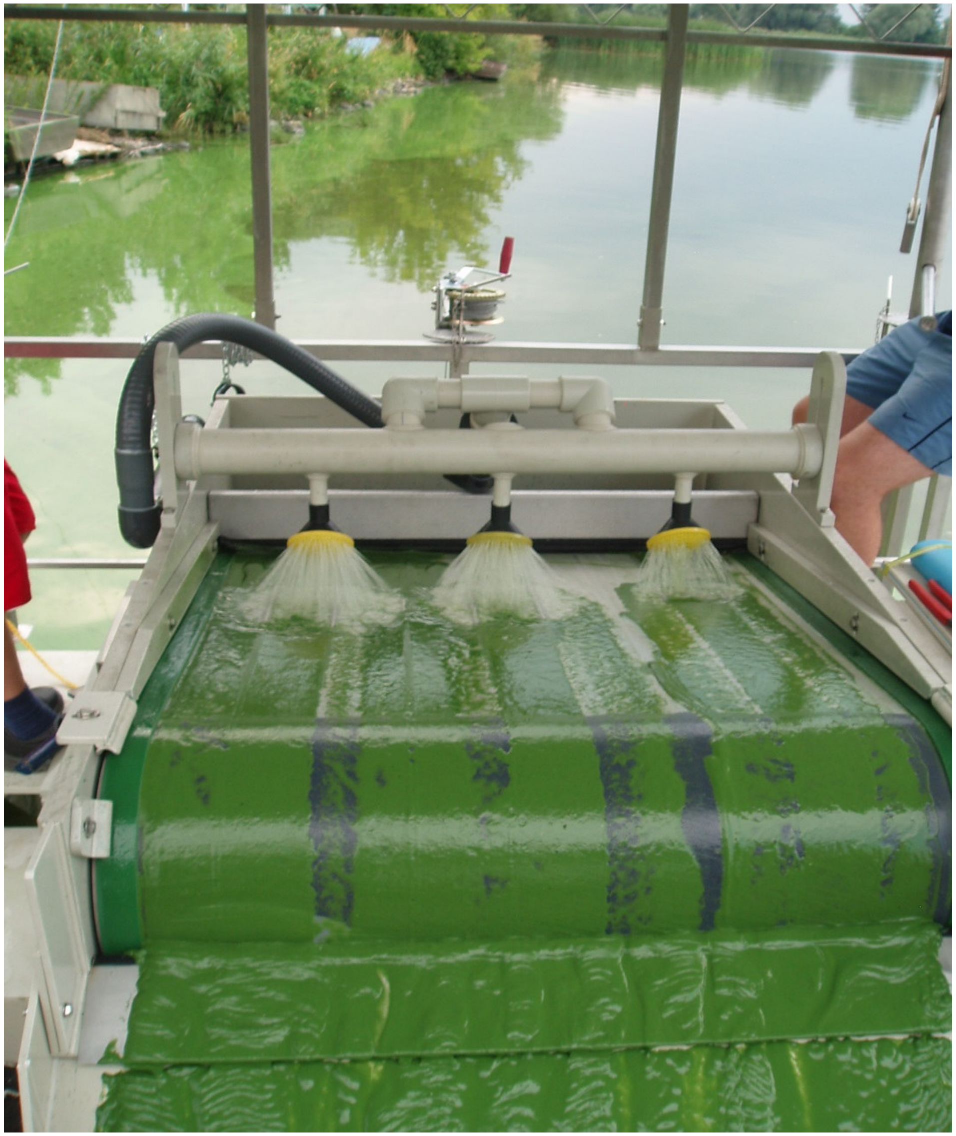
- Biomonitoring- fluoresence parameters
- On-line growth rate and algal physiology monitoring
- Expensive, but make you sure, if there is no problem – remote sensing – on line data



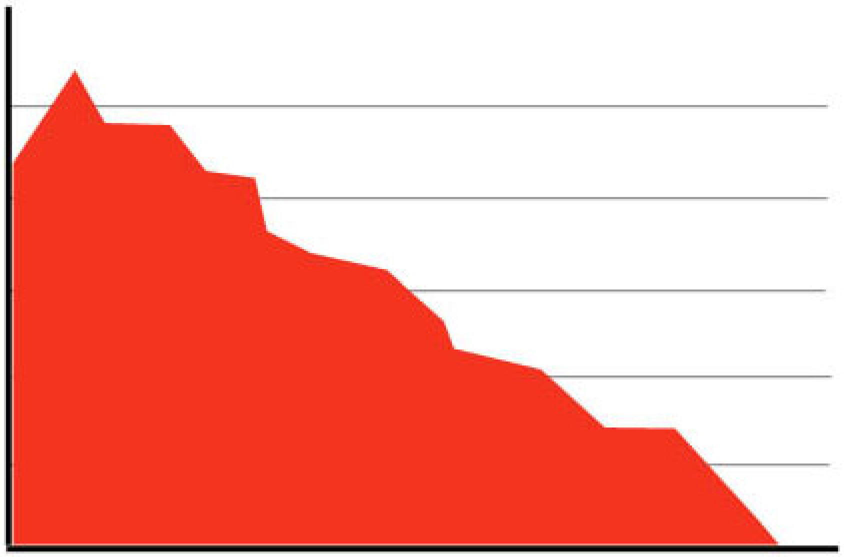
Index	1		2		3	
Time	10:34:50 19.9 2009		10:35:53 19.9 2009		11:35:11 19.9	
ID	OJIP-455nm		OJIP-590nm		OJIP-455n	
Value	Bckg	209	Bckg	204	Bckg	229
	Fo	4427	Fo	1008	Fo	4446
	Fj	8893	Fj	1739	Fj	8255
	Fi	11156	Fi	2196	Fi	9890
	Fm	13330	Fm	3086	Fm	1178
	Fv	8903	Fv	2078	Fv	7338
	Vj	0.502	Vj	0.352	Vj	0.51
	Vi	0.756	Vi	0.572	Vi	0.74
	Fm/Fo	3.011	Fm/Fo	3.062	Fm/Fo	2.65
	Fv/Fo	2.011	Fv/Fo	2.062	Fv/Fo	1.650
	Fv/Fm	0.668	Fv/Fm	0.673	Fv/Fm	0.62
	Mo	1.375	Mo	0.375	Mo	1.45
	Area	4048044	Area	1013986	Area	4640
	Fix Area	12929432	Fix Area	2835346	Fix Area	1143
	Sm	454.683	Sm	487.962	Sm	632.
	Ss	0.365	Ss	0.937	Ss	0.35
	N	1246.153	N	520.671	N	1767
	Phi_Po	0.668	Phi_Po	0.673	Phi_Po	0.62
	Psi_o	0.498	Psi_o	0.648	Psi_o	0.48
	Phi_Eo	0.333	Phi_Eo	0.436	Phi_Eo	0.29
	Phi_Do	0.332	Phi_Do	0.327	Phi_Do	0.37
	Phi_Pav	944.214	Phi_Pav	908.620	Phi_Pav	956.
Description						

Cyanobacterial biomass separator
Up to 40t/ha, 3-4xtimes a year!!!

AND CLEANED DRINKING WATER



EXPECTED PHOSPHORUS SHORTAGE



-non-renewable source

-peak in 2030

-rock phosphate reserves for 50 – 100 years

-concentration of mines in Western Sahara, China and USA

DOES PHOSPHORUS SHORTAGE AFFECT US?

WHY DO WE NEED PHOSPHORUS?

-79 % OF PHOSPHORUS GOES TO MAKE FERTILIZERS

-11 % FOR FEED GRADE ADDITIVES

-7 % FOR DETERGENTS

PLANTS NEED PHOSPHORUS TO GROW

Long term consequences could result in large-scale famine and social-political turmoil

PHOSPHORUS SHORTAGE SOLUTIONS

THERE IS NO SUBSTITUTE FOR PHOSPHORUS

to improve the efficiency of nutrient management in agriculture

demand for technological innovation in (waste) water technology and recycle industries

recovery of nutrients from waste (water), manure or urine

recovering (and selling) of nutrients will turn sanitation into a financial sustainable business

PHOSPHORUS SOURCE IDENTIFICATION

URINE

HUMAN EXCRETA

BIOMASS

FOOD WASTE

GREYWATER

AQUATIC VEGETATION

ANIMAL MANURE

SEAWATER

SEDIMENTS

PHOSPHORUS IN ENVIRONMENT

Phosphorus content in (un)treated wastewater brings problems with increased trophication in water bodies

Phosphorus conversion into solid fraction

Salt precipitate

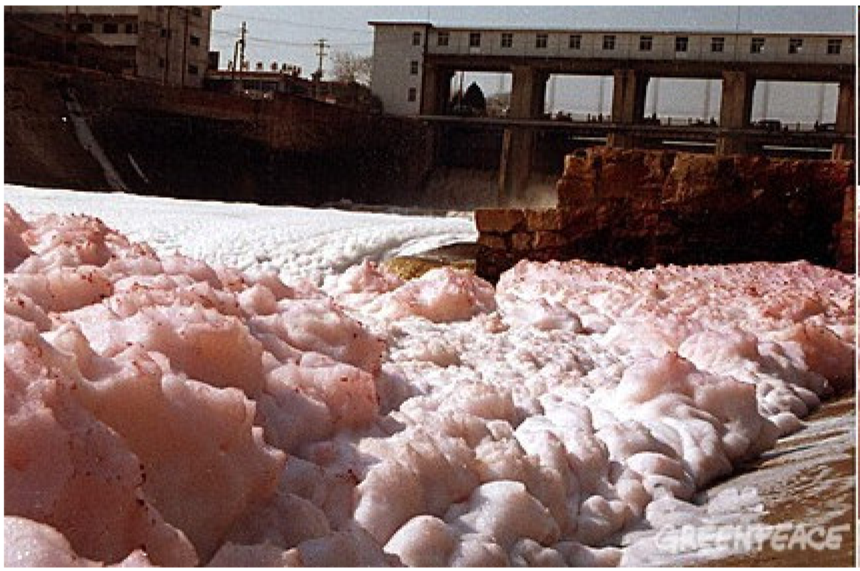
Plant biomass

Microbial biomass

CHANGE OF THE PARADIGMS

PHOSPHORUS DOES NOT BELONG TO WATER BUT INTO SOIL

HOW TO AVOID IT?



SOLUTION OF THE CAUSE

e.g. prevention of the diffusive and point source intake

HOW TO FIGHT WITH IT?

SOLUTION OF THE CONSEQUENCES

water bloom removal

HOW TO SOLVE IT?

WE HAVE LACK OF PHOSPHORUS

X

EXCESSIVE PHOSPHORUS CONCENTRATION HAS DETRIMENTAL EFFECT IN WATER ENVIRONMENT

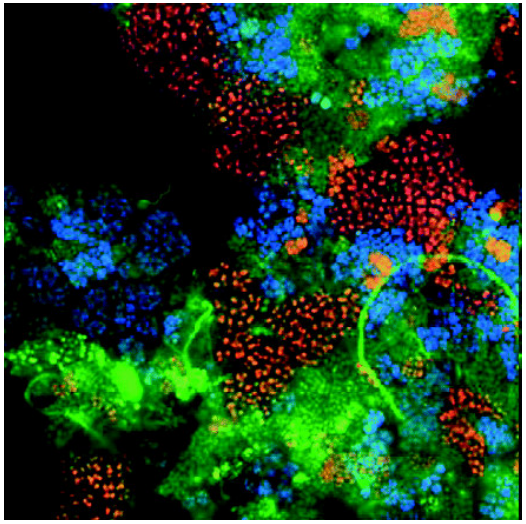
LET'S REMOVE PHOSPHORUS AT ITS SOURCE AND RECYCLE IT

HOW TO REMOVE AND RECYCLE PHOSPHORUS?

PHYSICAL PROCESSES

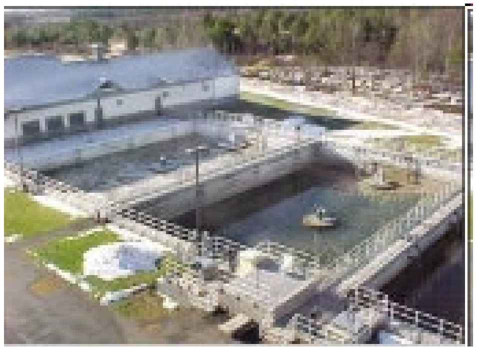
-PARTICULATE PHOSPHORUS FILTRATION (e.g. tertiary filtration)

-MEMBRANE TECHNOLOGIES (from microfiltration to reverse osmosis)



CHEMICAL PROCESSES

- PRECIPITATION
- SORPTION
- MAGNETIC COAGULATION



BIOLOGICAL PROCESSES

-BIOMASS INCORPORATION (wetland systems)

-EBPR **ALGAL CULTURES, PONDS**

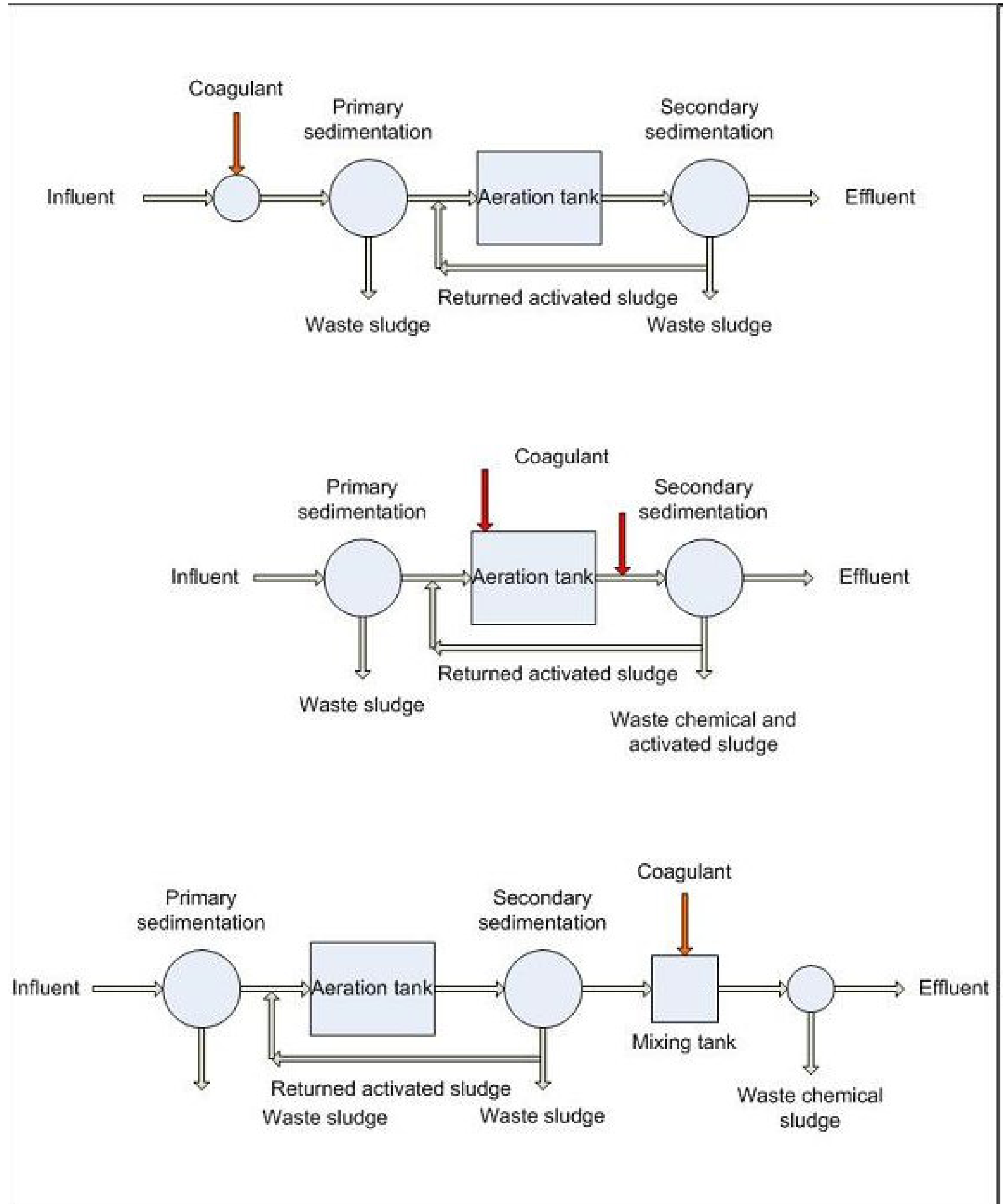
OTHER PROCESSES

-ION EXCHANGE, ELECTROCOAGULATION, etc.

PRECIPITATION BY METAL SALTS

Chemical precipitation by iron, alum or lime

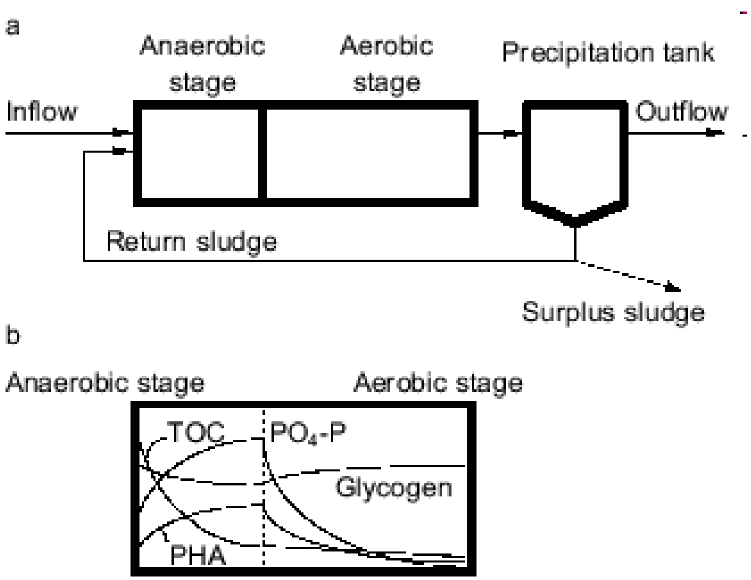
Low bioavailability of phosphorus for plants from iron and alum precipitates

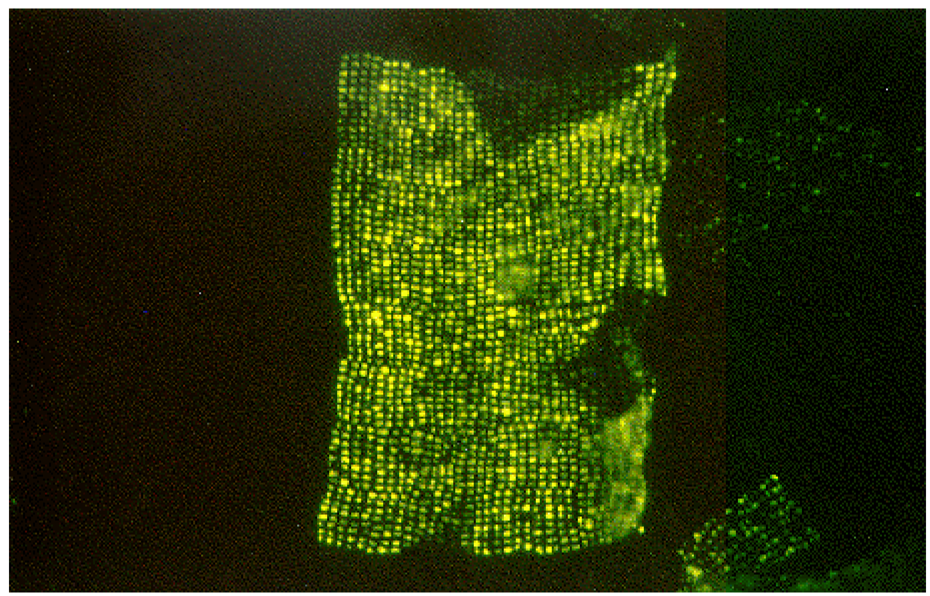


ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL

-direct incorporation of phosphorus to activated sludge biomass

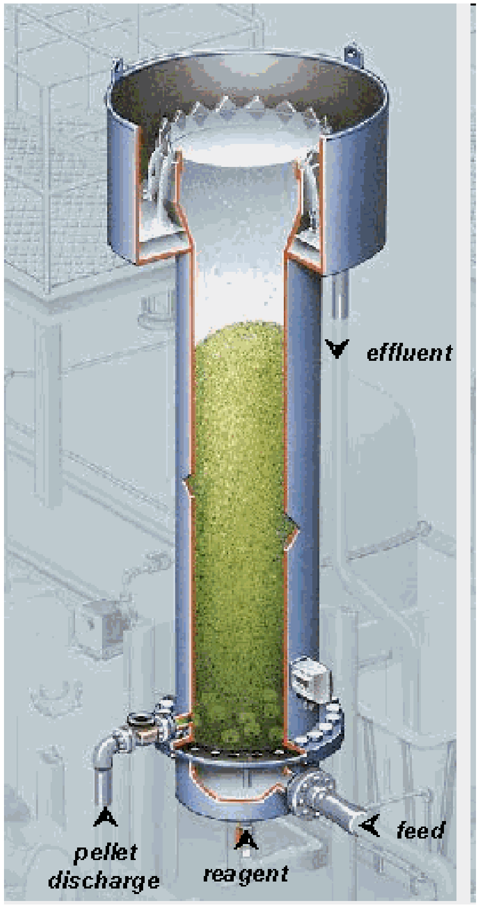
-enhancing the storage capacity of phosphorus as polyphosphate by the microbial biomass in activated sludge





CRYSTALLIZATION

- focused on struvite crystallization using nucleation seeds
- addition of Mg is necessary



SLUDGE APPLICATION

-sludge application on agricultural land or for recultivation and site remediation

-stringent demands for application: stabilization, hygienization, heavy metal content, *Salmonella spp.* presence

-dried sludge or ash application

OTHER SIGNIFICANT TECHNOLOGIES

Adsorption

Ion exchange

Electrocoagulation

Filtration

Magnetic field

Bacteria and microalgae

Floating islands (submerged and emerged macrophytes + periphyton)

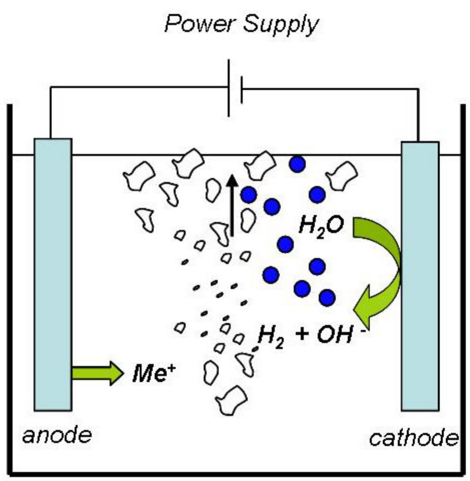


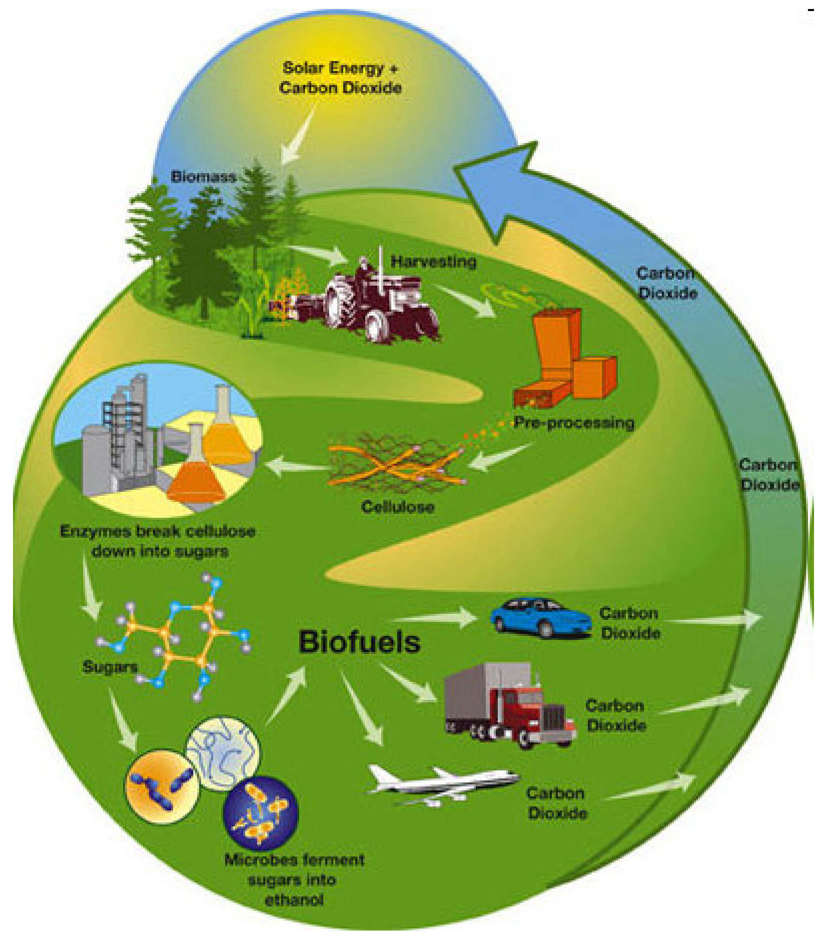
Fig. 1: Schematic of basic electrocoagulation process

CONSTRUCTED WETLAND PLANTS AND BIOMASS

- phosphorus is incorporated into leaves, roots and stalks of CW plants as well as into biomass

- sometimes is problematic to harvest biomass efficiently

- energetic utilization of biomass (biofuels)



CONSTRUCTED WETLANDS

- low-cost, low-tech solutions
- constructed engineering wetland systems (CEWS)
- performance enhanced by reactive sorbents with high phosphorus-sorption capacity

OTHER PHOSPHORUS SOURCES OR TECHNIQUES

-reject water, ashes

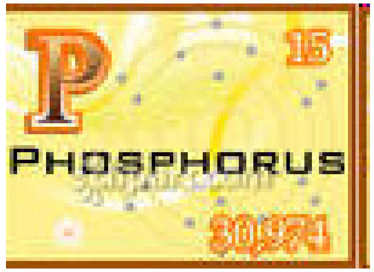
-activated sludge

-crop residues

-minimising phosphorus losses

-reducing phosphorus demand

-increasing phosphorus uptake



URINE APPLICATION

-hygienisation and stabilisation necessary (WHO says 3 – 6 months)

-struvite fertilizer production from urine

-urine concentration necessary – thawing, freezing, evaporation

-**problematics of xenobiotics, micropollutants and faecal contamination ALGAE!!!**

PHOSPHORUS RECYCLING CONCEPT

- utilization of concentrated phosphorus streams

- point source phosphorus separation

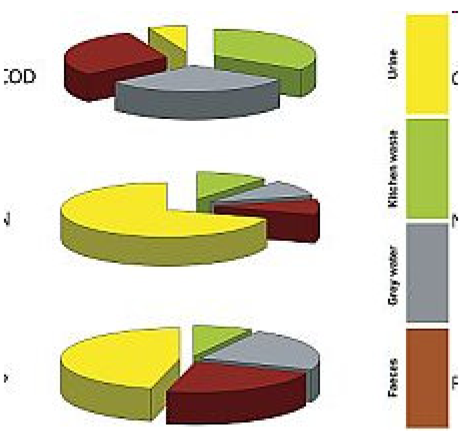
DESAR concept – separate collection and treatment of

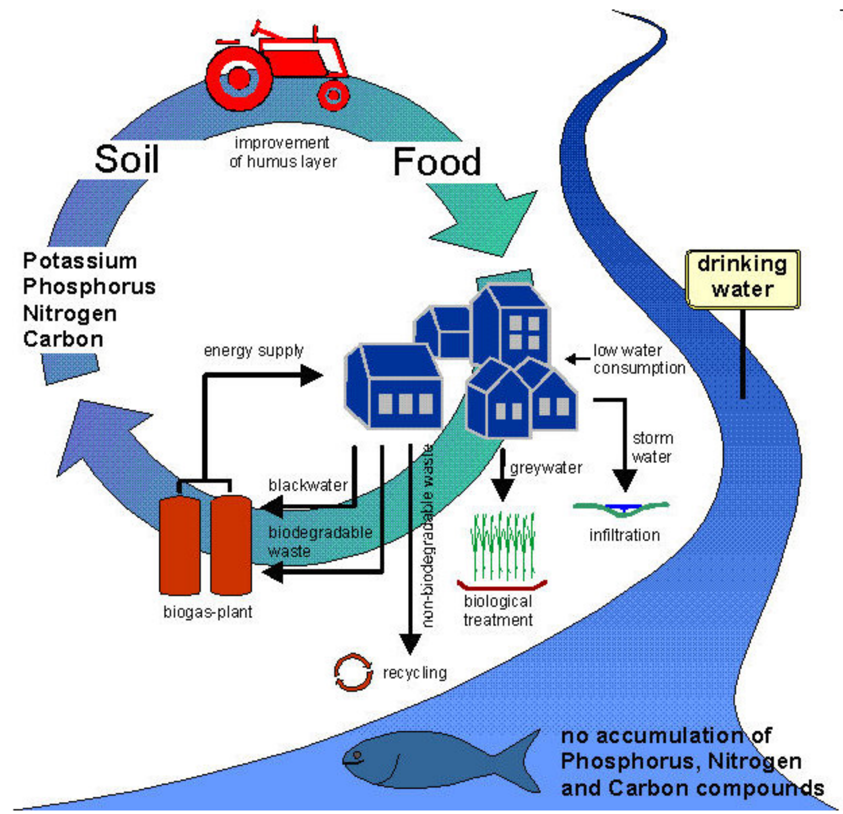
-yellow water, brown water (black water)

-grey water

-storm water

-organic, solid kitchen waste





Summary

1) **Optimalization of energy management – saving ca. 20 % of the costs**

energy audits of pumping shafts, change of devices for those with lower consumption, flowscheme optimization, process control optimization, etc.

2) **Recycled energy – saving 10 % costs**

utilization of heat, hydraulic and kinetic energy and hydroturbine, heat pump, heat exhcangers application, utilization of energy of outlet and inlet

3) **Biomass utilization – saving more than > 60 % costs**

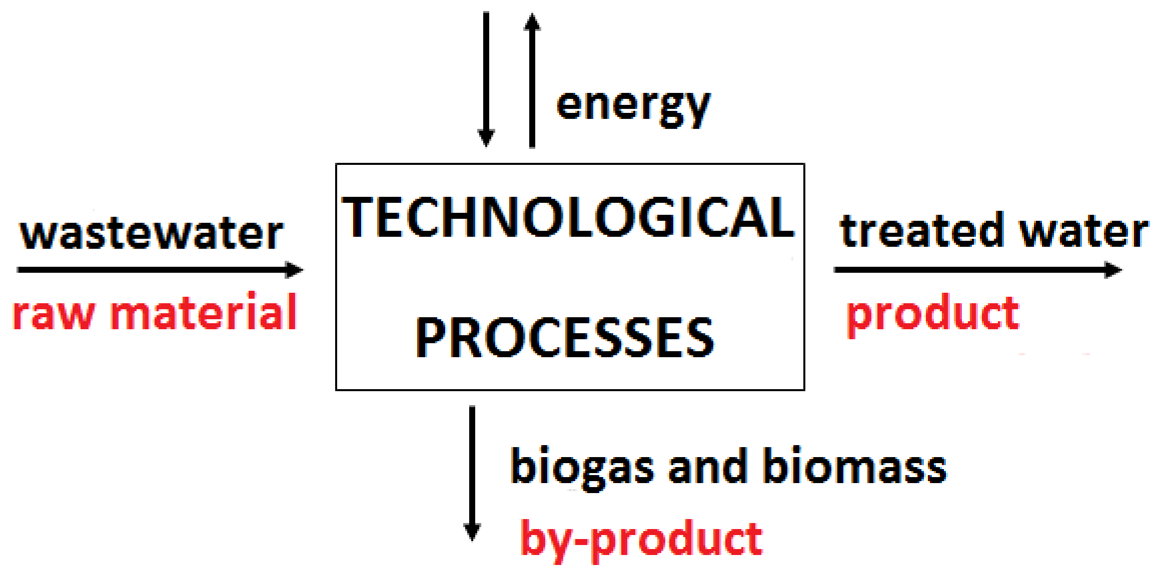
biogas production during anaerobic digestion, co-digestion (fats from grease traps, municipal waste, food industry, etc.), energy obtained during thermal processing of dried sludge

4) **Renewable energy – saving more than 10 % costs**

(external sources of energy – solar energy, photovoltaic energy, wind energy, etc.)

Conclusions …there is energy and nutrients!!!

Wastewater contains 9x more energy than it is necessary for its treatment (Shizas and Bagley, 2004)



But the technology must be under continual control to prevent collapses …