Ingenieurbüro Blumberg

Introduction To Ecological Engineering
Case Studies And Solutions

by Michael Blumberg

Constructed Wetlands For Wastewater Treatment

Start-up workshop in Damascus, Syria, January, 25 – 30th, 2009
on behalf of GTZ, Germany

Contents

Natural wetlands

Kidneys of big streams before entering the ocean

Delta of Ganges

Natural wetlands

Kidneys of big streams before entering the ocean

Delta of Nile

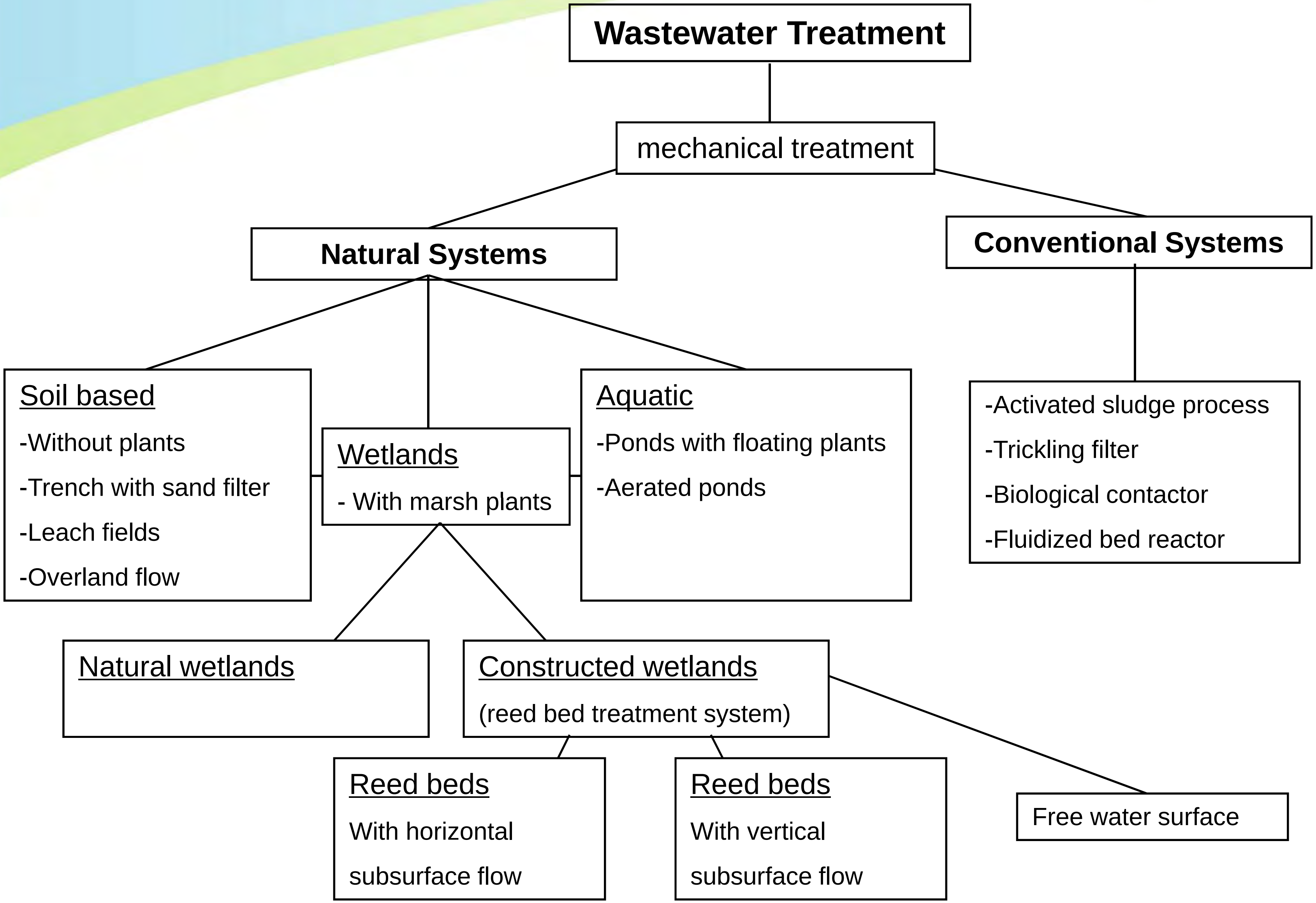
Delta of Yangtze river

Most of formerly existing wetlands destroyed

River Bank Wetlands at Yangtze

River Bank Wetlands at Yangtze, still existing at one side of the river

Wastewater Treatment



Definition “Ecological engineering” (ecotechnologies)

Systematic arrangement and use of naturally existing ecosystems for continuous purposes of production and / or disposal
(Blumberg 1988)

Constructed wetland

Definition "Constructed treatment wetlands"

Engineered systems, designed and constructed to utilize the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in surface water, groundwater or waste streams.

(ITRC 2003)

Constructed wetland

Network of roots and rhizomes of reed

Phragmites communis

Network of roots and rhizomes of reed

Other helophyte species like cattails, rushes and sedges, which tolerate continuously water saturated soil conditions (anaerobic soils) are also used. The emergent vegetation supplies oxygen to the substrate and allows biological growth of bacteria and fungi to accumulate on its roots and as a biofilm attached to the substrate particles.

Reed bed treatment system with network of roots and rhizomes flushed out

Reclaimed water application in the framework of water reuse projects

Irrigation of
-high added value crops
-public parks and lawns
-landscape and golf curses

Microbial decontamination also necessary for protection of
-bathing waters (tourist areas)
-groundwater quality

Prerequisites
-removal of pathogenic microorganisms
-low investment, operation and maintenance cost
-low skills of staff, no highly qualified personnel necessary
-reliable treatment performance
-no or very limited energy supply
-low electro-mechanical equipment

⇨ **Extensive and natural techniques e. g. constructed wetlands**

Advantages of constructed wetlands

1. Being self-regulating (self-sustaining) ecosystems, with nearly no electrical or mechanical parts, no chemical additives necessary.
2. Decentralized wastewater treatment, saving a large quantity of investment into the sewerage system.
3. Low energy and maintenance cost (low total lifetime cost).
4. No noise, no smell, much less sewage sludge production.
5. Tolerate fluctuations in water flow and pollutant concentrations.
6. Provide flood protection.

Advantages of constructed wetlands

7. Naturally regenerative, long lifetime.
8. Treatment capability for a wide variety of effluents, domestic and industrial.
9. Fitting into the local landscape and offering a great wildlife conservation potential (provide habitats for plants and wildlife).
10. Reed harvesting as a regenerative energy source may contribute to generate electricity (biogas).
11. Often lower capital cost than conventional treatment systems.
12. Enhance aesthetics of open spaces
13. Provide recreational and educational opportunities.

Main limitations to the use of constructed wetlands

1. They generally require larger land areas than conventional wastewater systems.

2. They can tolerate temporary water level drawdowns, but not complete drying (a base flow of water is required).

3. The evapotranspiration rate of aquatic macrophytes in treatment wetlands is high thus reducing the water volume available for irrigation.

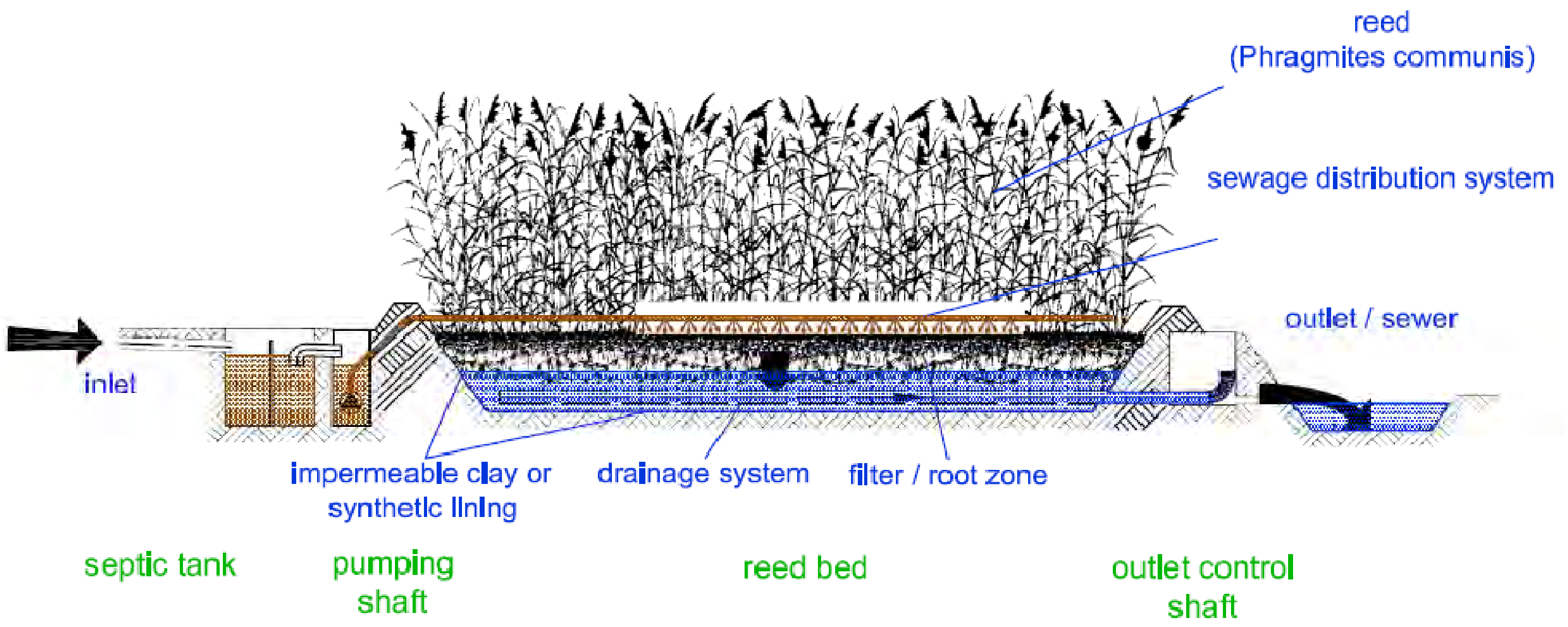
Contaminant removal mechanisms

The physical, chemical and biological contaminant removal mechanisms that are operative in aquatic treatment systems include:

Physical	Chemical	Biological
Sedimentation	Precipitation	Bacterial metabolism
Filtration	Adsorption	Plant metabolism
Adsorption	Hydrolysis reactions	Plant absorption
Volatilization	Oxidation – reduction	Natural die - off
	Photochemical reactions	

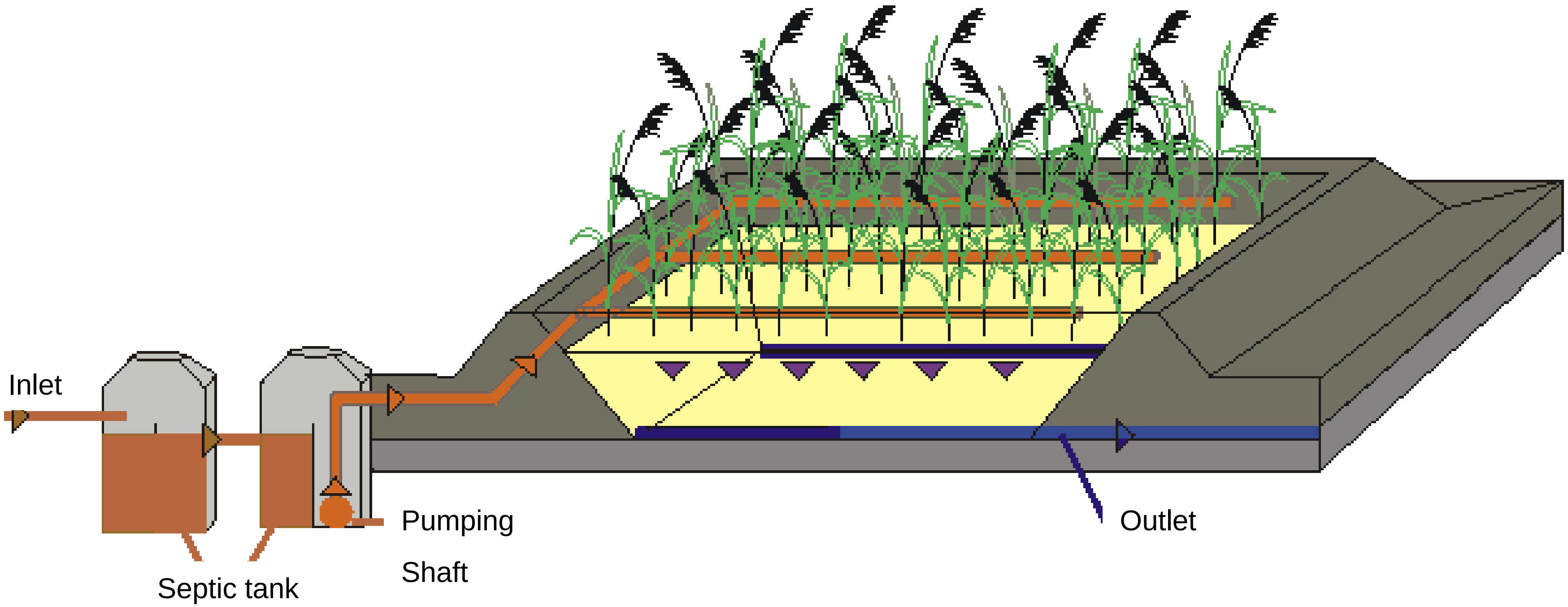
Reed bed treatment system

Vertical subsurface flow



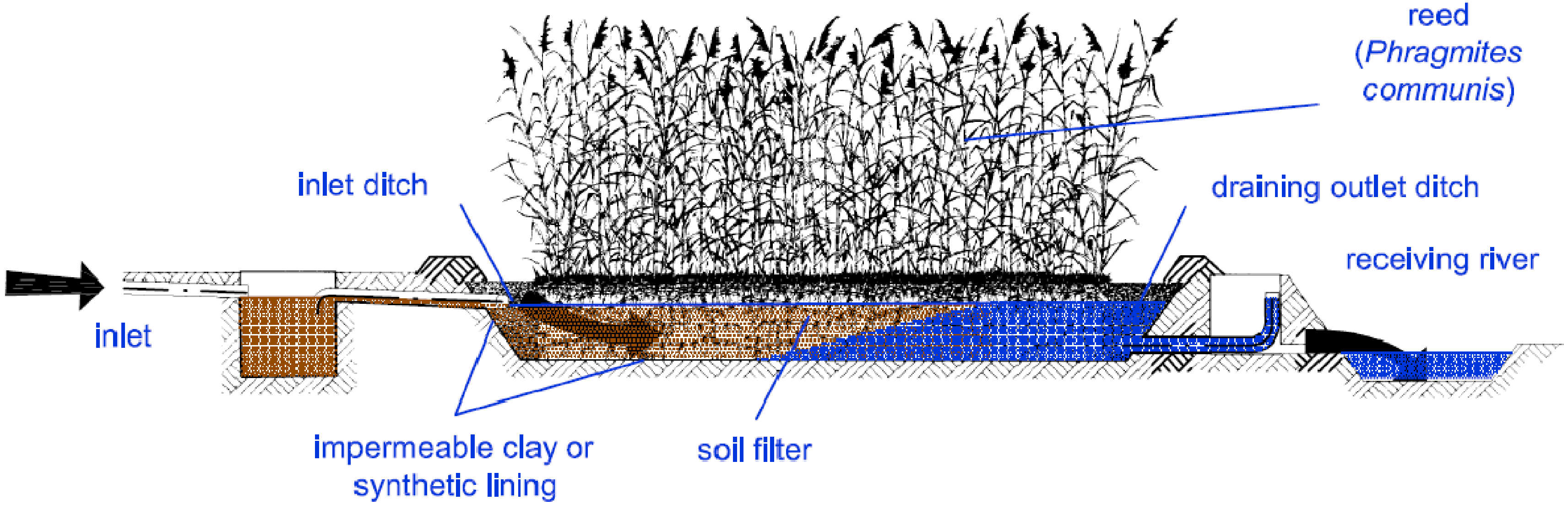
Reed bed treatment system

Vertical subsurface flow



Reed bed treatment system

Horizontal subsurface flow



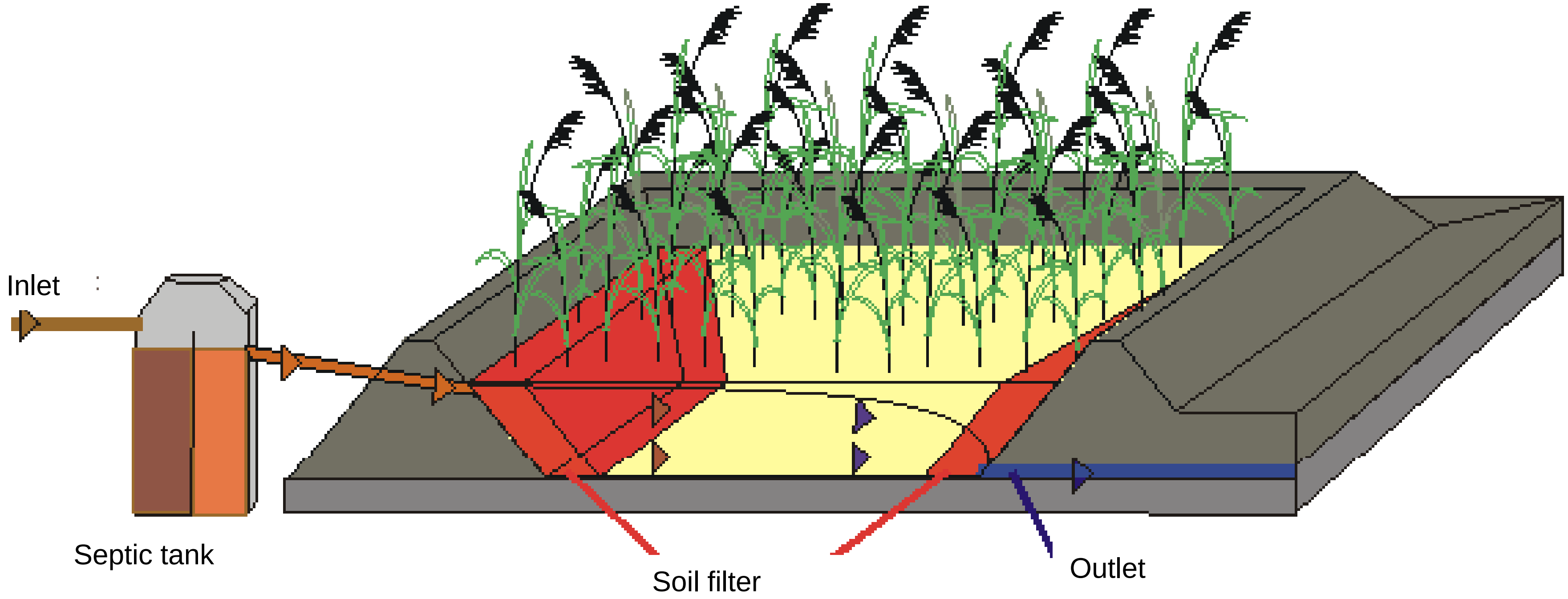
mechanical sedimentation

soil filter

outlet control shaft

Reed bed treatment system

Horizontal subsurface flow



Performance data

General performances of constructed wetland systems
in Mediterranean countries

Kind of CW	Organic Content	Nitrogen	Ammonia	Total Solids	Pathogens
HF	73 - 99	23 - 67	18 - 76	59 - 96	94 - 99.999
VF	52 - 95	---	78 - 99	48 - 98	96 - 99.9
FWS	11 - 63	21 - 76	15 - 82	36 - 67	90 - 99.999
Hybrid Systems	86 - 99	43 - 89	85 - 96	72 - 84	98 - 99.9995
VF raw ww	82 - 99.7	66 - 98	85	95 - 99.8	---

Source: Masi, F. and Martinazzi, N. in: Sustainable Watermanagement 1-2007

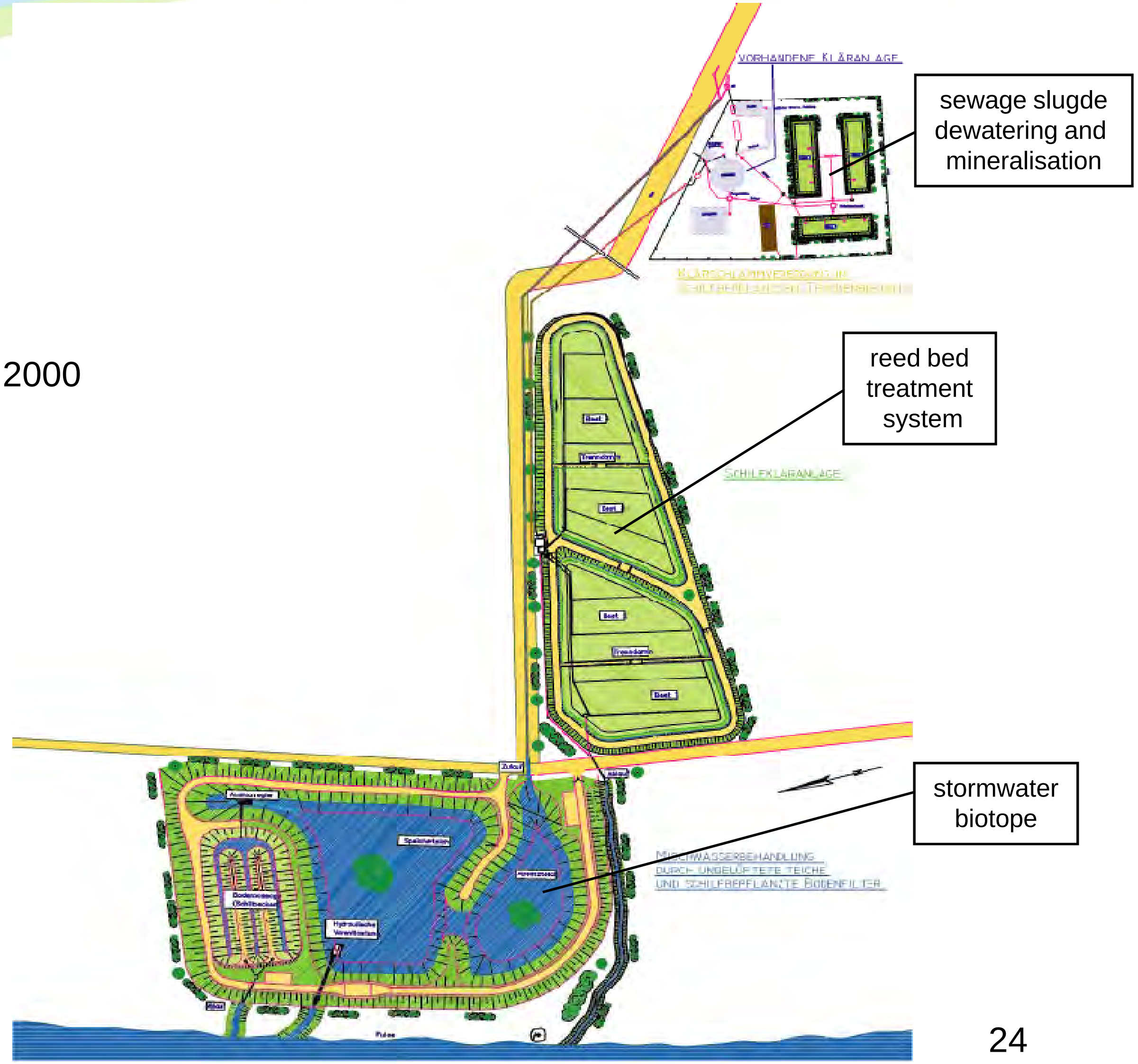
Case Studies And Solutions

1. Domestic Wastewater Treatment
2. Industrial Wastewater Treatment
3. Stormwater Treatment and Retention
4. Sludge Drying Reed Beds
5. Small sewage treatment plants
6. Tertiary Treatment of Effluents or Conventional Wastewater Treatment Plants
7. Natural Swimming Pools
8. Wetland Roofs
9. Natural Treatment of Polluted Rivers and Lakes

1. Domestic wastewater treatment

1.1 Wastewater treatment plant (Germany)
3.000 people

Project of world exhibition Expo 2000
Hanover, Germany



1. Domestic wastewater treatment

1.1 Wastewater treatment plant (Germany)
3.000 people

During construction

1. Domestic wastewater treatment

1.1 Wastewater treatment plant (Germany)
3.000 people

After planting

In winter

1. Domestic wastewater treatment

1.2 Wastewater treatment plant Mahshahr (Iran)
4.000 people

After construction,
before planting

1. Domestic wastewater treatment

1.2 Wastewater treatment plant Mahshahr (Iran)
4.000 people

After planting

1. Domestic wastewater treatment

1.2 Wastewater treatment plant Mahshahr (Iran)

4.000 people

Effluent parameters (2008):

COD < 30mg/l
BOD5 < 18 mg/l
NH_4-N < 5 mg/l
TSS < 3 mg/l

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)

500 people

Levelling

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

Soil drainage

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

HDPE lining and welding

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

Drainage pipes

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

Sand assembling

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

Septic tank

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)

500 people

Wastewater distribution system

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

One month after planting

1. Domestic wastewater treatment

1.3 Wastewater treatment plant (Germany)
500 people

Two month after planting.

1. Domestic wastewater treatment

1.4 Wastewater treatment plant Shenyang (China)
6.000 people

After construction,
before planting

1. Domestic wastewater treatment

1.4 Wastewater treatment plant Shenyang (China)
6.000 people

After planting

1. Domestic wastewater treatment

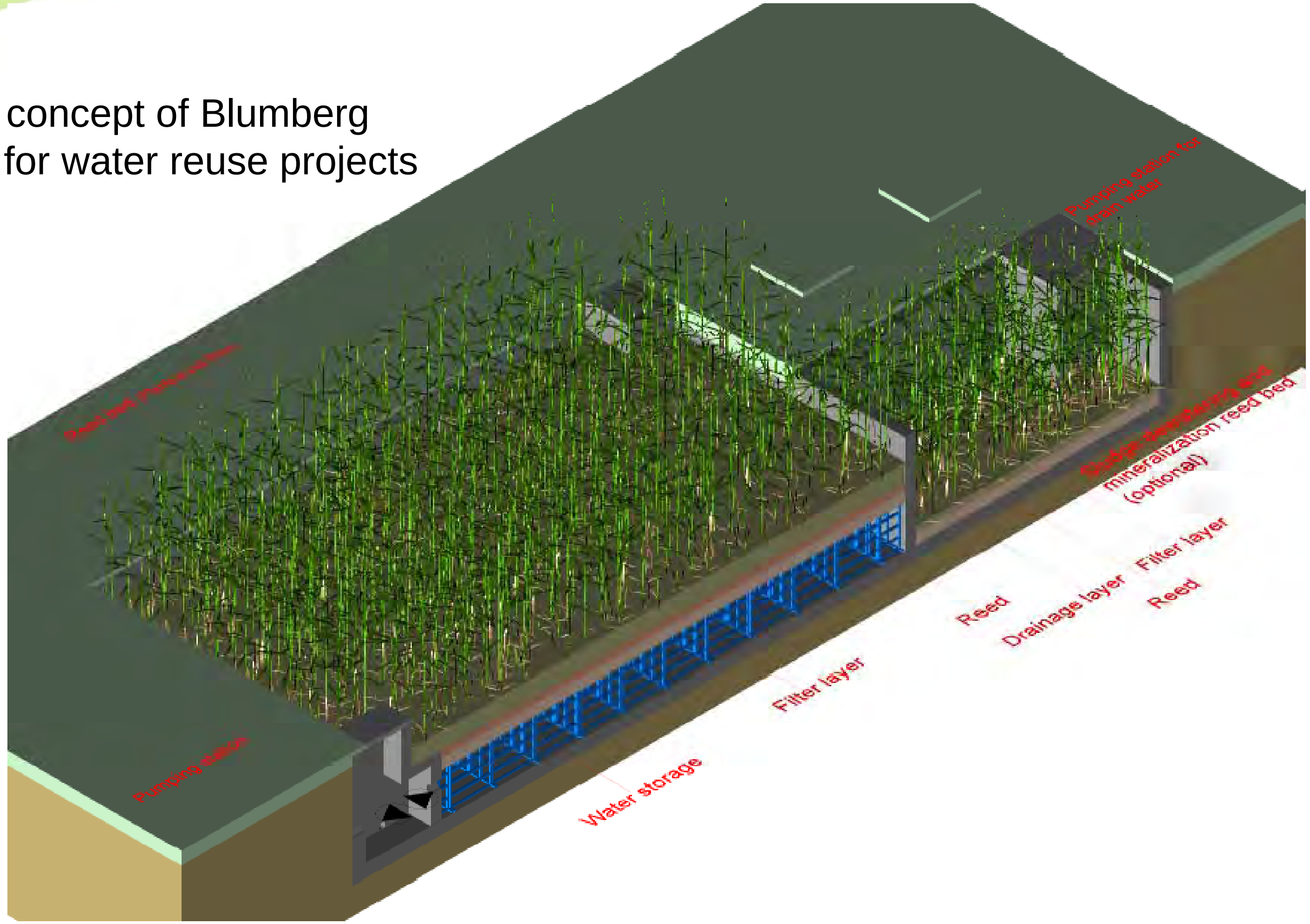
1.4 Wastewater treatment plant Shenyang (China)
6.000 people

2006/07	Influent Parameters	Effluent Parameters
COD cromate	191,0 mg/l	11,8 mg/l
NH3-N	39,2 mg/l	1,07 mg/l
Total P	4,61 mg/l	0,37 mg/l
BOD_5	69,63 mg/l	11,00 mg/l

1. Domestic wastewater treatment

1.5 Combi-clear water system

Innovative concept of Blumberg Engineers for water reuse projects



1. Domestic wastewater treatment

1.7 Palutec Filtersystem

Source: Ökolog Geller und Partner

2. Industrial wastewater treatment

2.1 (ICI Zeneca / England) / 70,000 m²

2. Industrial wastewater treatment

2.1 (ICI Zeneca / England) / 70,000 m²

2. Industrial wastewater treatment

2.2 Performance data

year of construction	1984	1989	1985	1985	1988
operation time	from 1984	from 1989	1985 - 1988	from 1985	1988 – 1999
origin of sewage	**oily and greasy sewage from a steel factory**	**oily and greasy sewage from a steel factory**	**oil-spilled effluents from a petroleum tank farm**	**oil collector tank contents from ships**	**pre-treated seepage water from dump grounds**
sewage quantity per hour per year	1-2 m^3 13.000 m^3	20 m^3 175.000 m^3	0,1 m^3 1.000 m^3	0,5 m^3 4.000 m^3	0,2 m^3 2.000 m^3
specific sewage load/area quotient	0,3 $m^3/m^2 \times d$	0,375 $m^3/m^2 \times d$	0,05-0,06 $m^3/m^2 \times d$	0,13-0,18 $m^3/m^2 \times d$	0,05 $m^3/m^2 \times d$
needed area per m^3 effluent per day	3 m^2	2,67 m^2	18 m^2	7 m^2	20 m^2

Source: DGMK Forschungsbericht 453, 1992

2. Industrial wastewater treatment

2.2 Performance data

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degradation rates:					
hydrocarbons inflow outflow efficiency (%)	15 – 20 mg/l 0,2 mg/l 98,8	2 – 10 mg/l 0,3 mg/l 85 - 96	5 mg/l 0,2 mg/l 96	30 mg/l 0,5 mg/l 98	-----
COD inflow outflow efficiency (%)	65 mg O_2/l 0,2 mg O_2/l 77	-----	1.800 mg O_2/l <250 mg O_2/l 86	6.500 mg O_2/l 500 mg O_2/l 90	175 mg O_2/l 70 mg O_2/l 60
BOD_5 inflow outflow efficiency (%)	-----	-----	700 mg O_2/l 20 mg O_2/l 97	-----	80 mg O_2/l 17 mg O_2/l 80

Source: DGMK Forschungsbericht 453, 1992

2. Industrial wastewater treatment

2.2 Performance data

year of construction	1984	1989	1985	1985	1988
operation time	from 1984	from 1989	1985 - 1988	from 1985	1988 – 1999
origin of sewage	**oily and greasy sewage from a steel factory**	**oily and greasy sewage from a steel factory**	**oil-spilled effluents from a petroleum tank farm**	**oil collector tank contents from ships**	**pre-treated seepage water from dump grounds**
phenolindex inflow outflow efficiency (%)	-----	-----	4 mg/l <0,1 mg/l 98	-----	-----
BTX aromatics inflow outflow efficiency (%)	-----	-----	4 mg/l <0,1 mg/l 98	-----	-----
cyanides inflow outflow efficiency (%)	-----	-----	-----	-----	0,045 mg/l 0,011 mg/l 75
AOX inflow outflow efficiency (%)	-----	-----	-----	-----	0,88 mg/l 0,25 mg/l 72

Source: DGMK Forschungsbericht 453, 1992

2. Industrial wastewater treatment

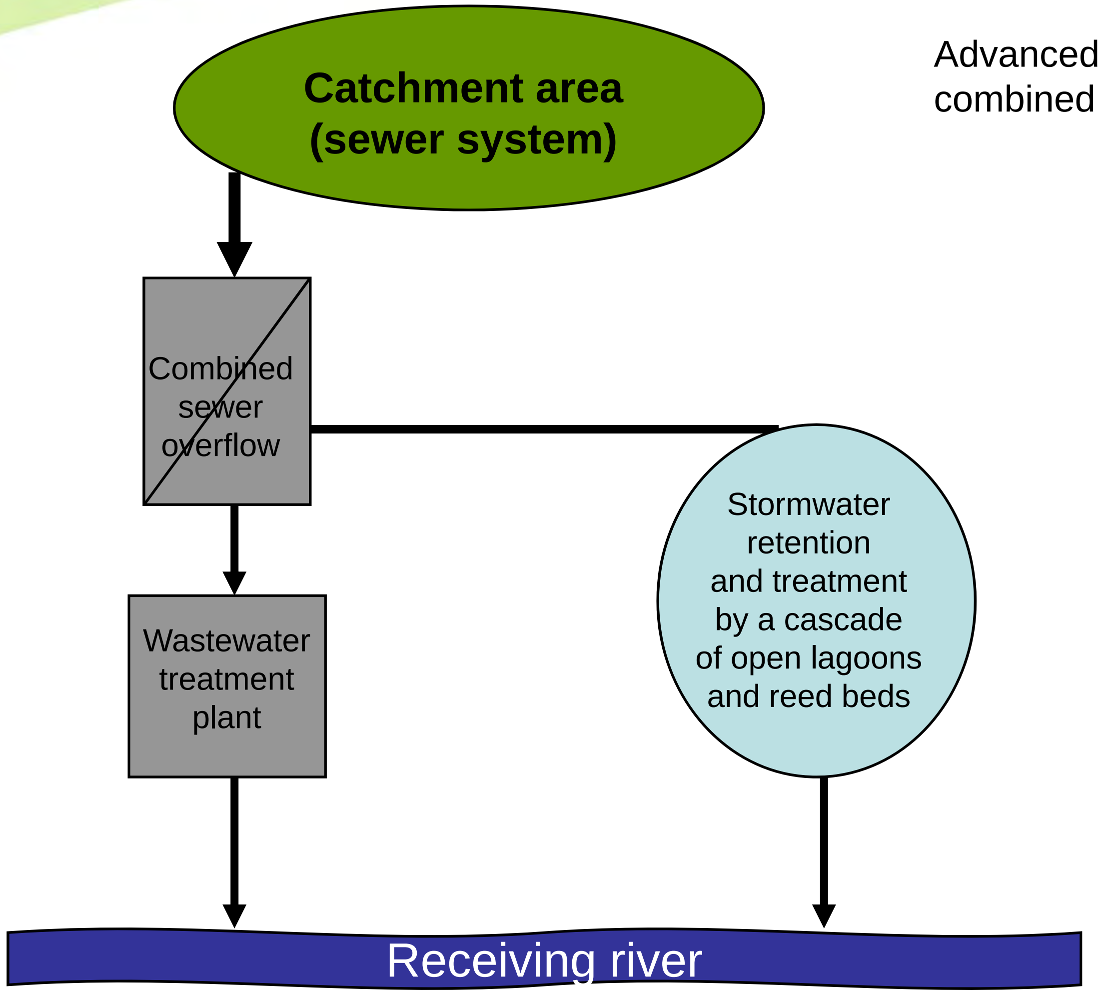
2.3 Other industrial applications of constructed wetlands

1. Compost and landfill leachates
2. Petroleum refinery wastes
3. Acid mine drainage
4. Agricultural wastes
5. Pulp and paper mills
6. Textile mills

3. Stormwater Treatment and Retention

3.1 Basic design

Advanced treatment of combined sewage



3. Stormwater Treatment and Retention (Germany)

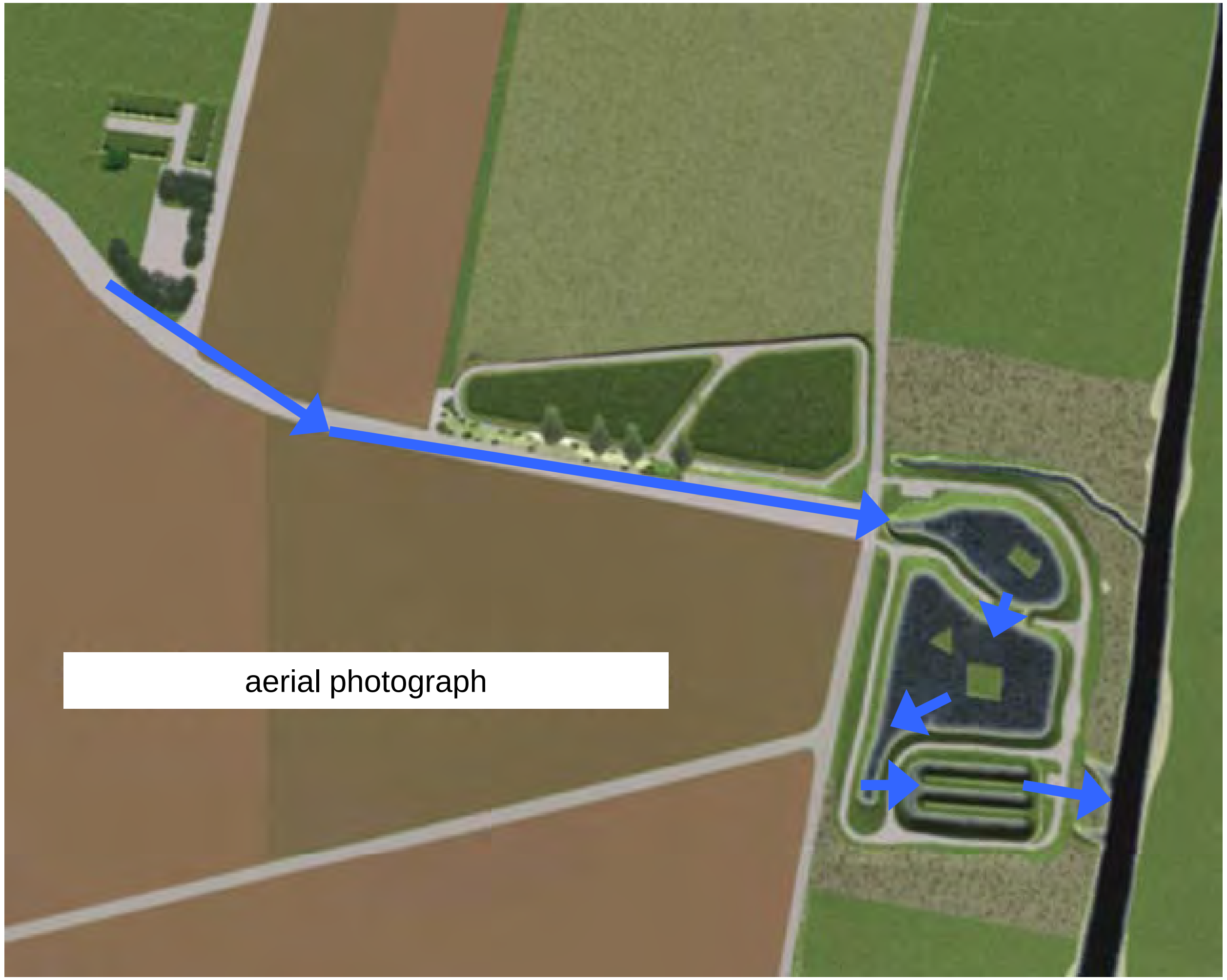
3.2 Cascade of ponds and reed bed treatment systems

Oberg

Gadenstedt

3. Stormwater Treatment and Retention (Germany)

3.2 Cascade of ponds and reed bed treatment systems



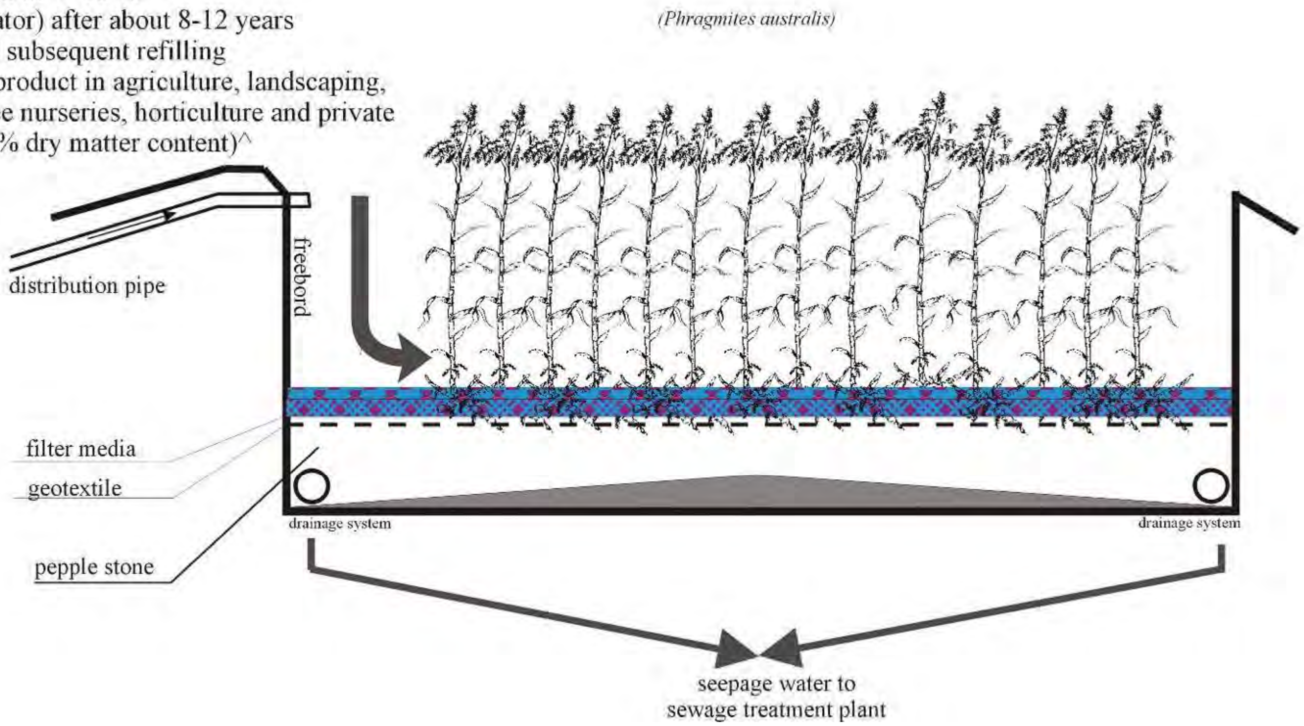
3. Stormwater Treatment and Retention (Germany)

3.2 Cascade of ponds and reed bed treatment systems

4. Sludge composting reed beds

4.1 Basic design

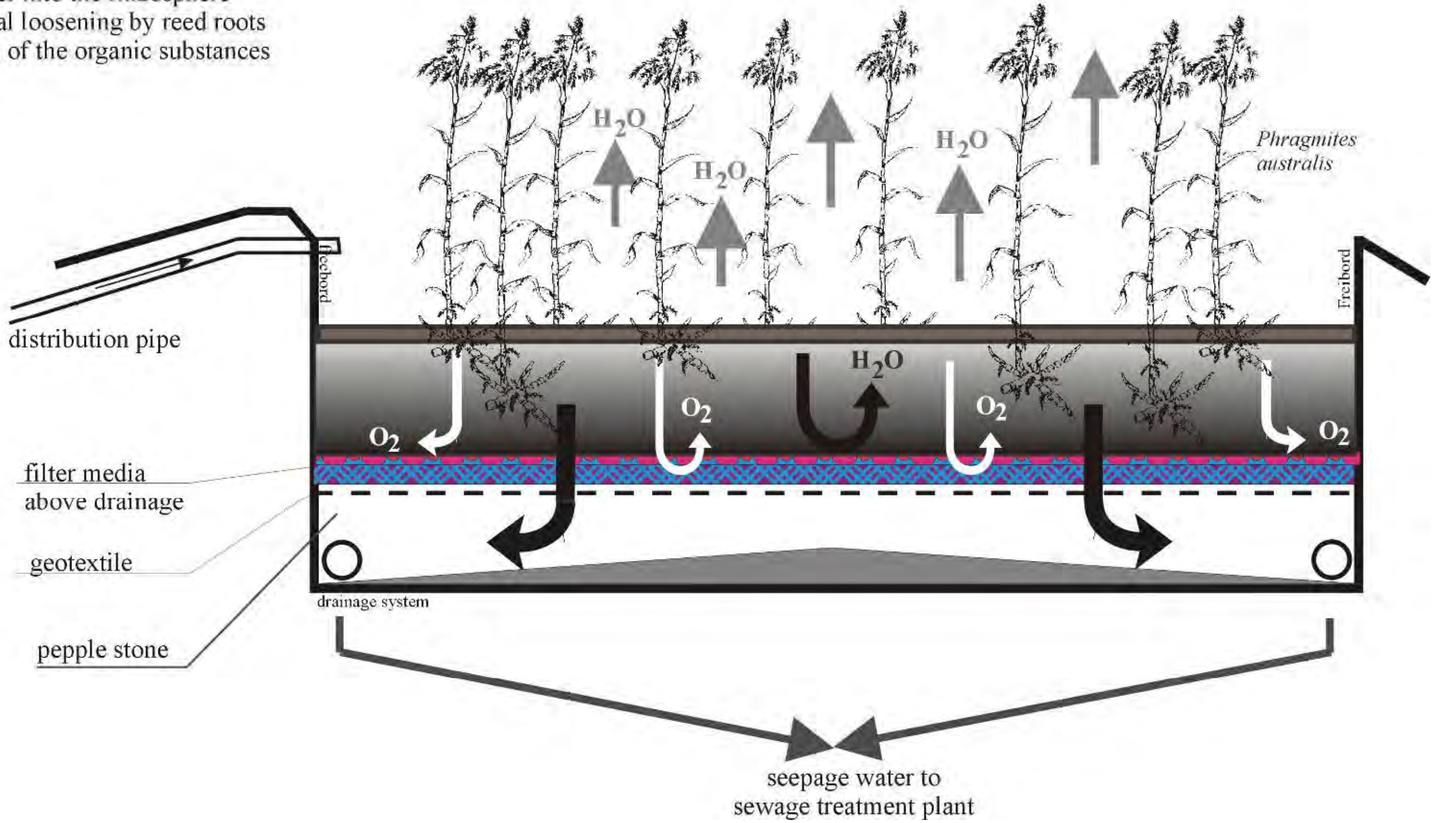
-sewage sludge dewatering and mineralization in reed beds
-intermittent loading
-loading rate dependent on dry matter content of raw sludge
-volume reduction of > 90 %
-removal (excavator) after about 8-12 years of operation and subsequent refilling
-use of the final product in agriculture, landscaping, recultivation, tree nurseries, horticulture and private gardening (> 40% dry matter content)^



4. Sludge composting reed beds

4.1 Basic design

- Infiltration
- Percolation
- Evapotranspiration
- Oxygen transfer into the rhizosphere and mechanical loosening by reed roots
- Mineralization of the organic substances
- Dewatering



4. Sludge composting reed beds

4.2 Practical applications (Germany)

4. Sludge composting reed beds

4.2 Practical applications (Germany)

4. Sludge composting reed beds

4.3 Goals of reed bed sewage sludge dewatering and mineralisation

- Dewatering of wet sludge to a dry matter content of more than 40 %, while the volume is reduced to 5 %.

- Reduction of costs for electricity, maintenance, repairing, personnel, and operation

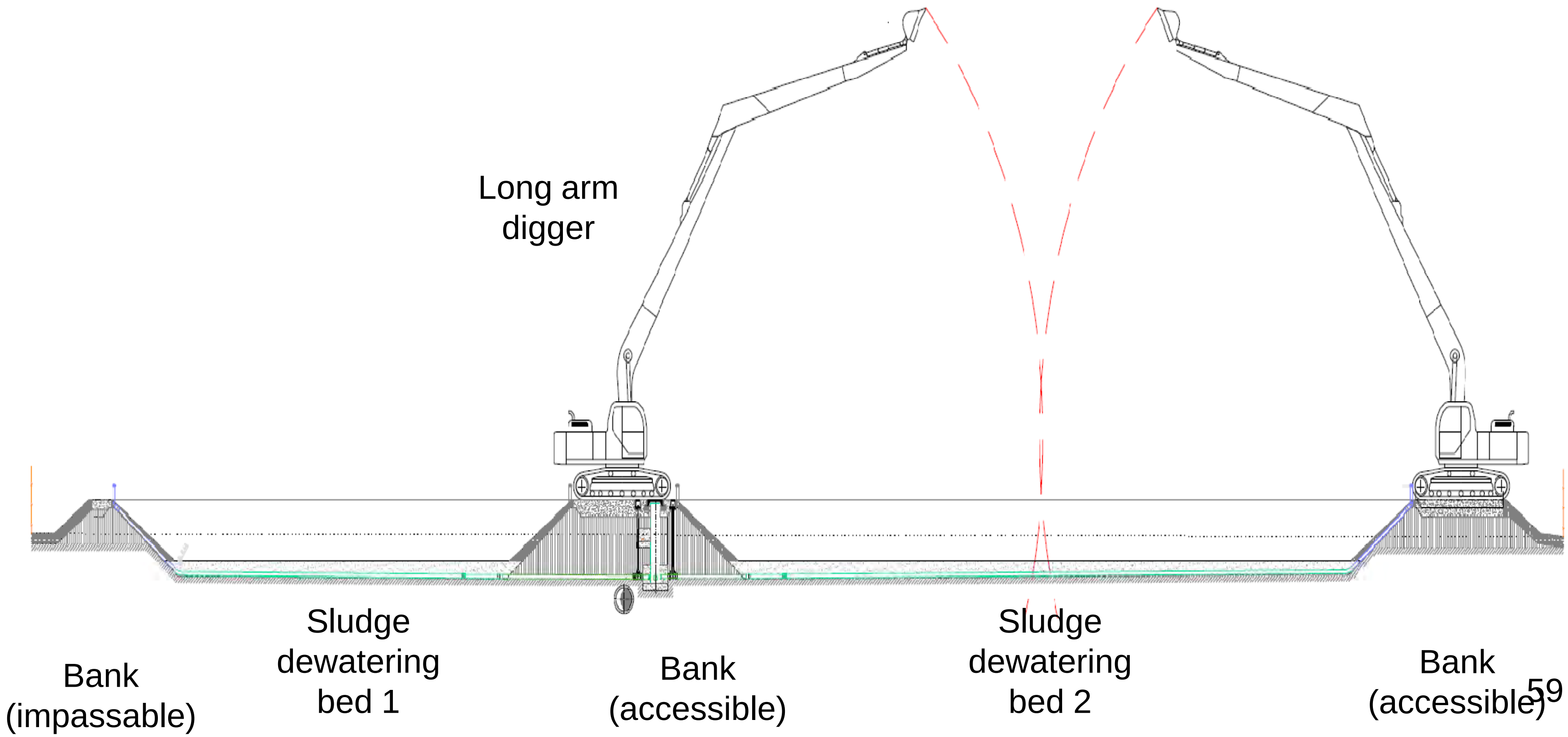
- Sanitising of the sludge humus by composting it for another year after an operation period of 8 to 12 years.

- Producing a dewatered material, which has a great variety of applications and recycling alternatives.

- Formation of a secondary biotope consistent of marsh plants (helophytes) and its associated wildlife.

4. Sludge composting reed beds

4.4 Excavation of composted sludge after 10 – 12 years of operation



5. Small sewage treatment plants

5.4 Reed bed treatment system (vertical subsurface flow) (Germany)

5. Small sewage treatment plants

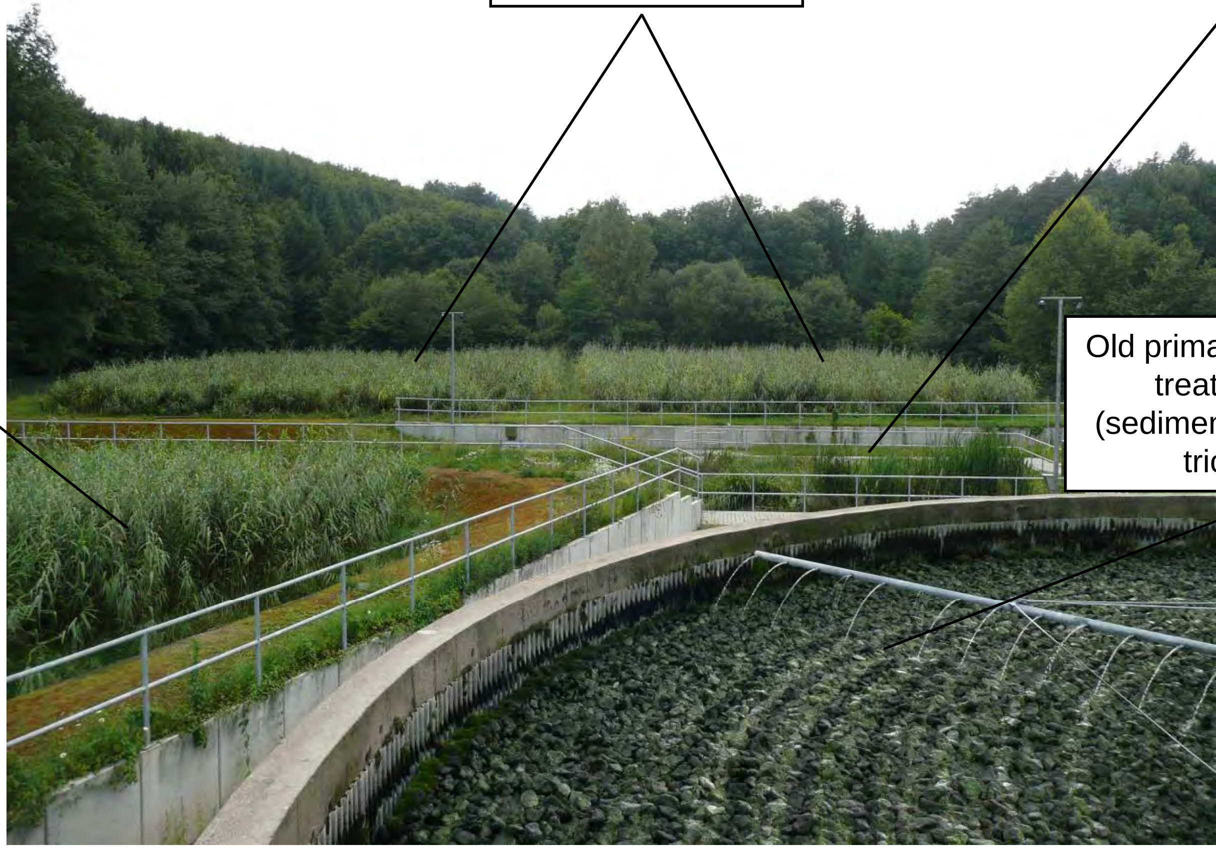
5.4 Reed bed treatment system (vertical subsurface flow) (Germany)

5. Small sewage treatment plants

5.5 Reed bed treatment system (horizontal subsurface flow) (Germany)

6. Tertiary Treatment of effluents of conventional wastewater treatment plants

6.1 (Germany) 4,000 People



6. Tertiary Treatment of effluents of conventional wastewater treatment plants

6.1 (Germany) 4,000 People

6. Tertiary Treatment of effluents of conventional wastewater treatment plants

6.2 (Germany) 5,000 people

6. Tertiary Treatment of effluents of conventional wastewater treatment plants

6.2 (Germany) 5,000 people

7. Natural Swimming Pools

7.1 Swimming Pool Göttingen (Germany) for public use

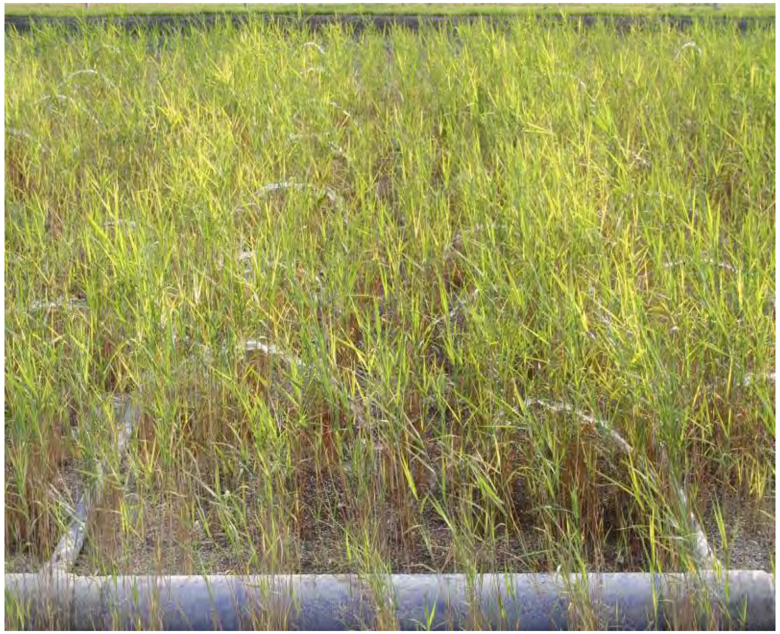
-Water treatment without any chlorine / chlorine dioxide by treatment in a constructed wetland and recirculation

7. Natural Swimming Pools

7.1 Outdoor Natural Swimming Pool Göttingen (Germany)

7. Natural Swimming Pools

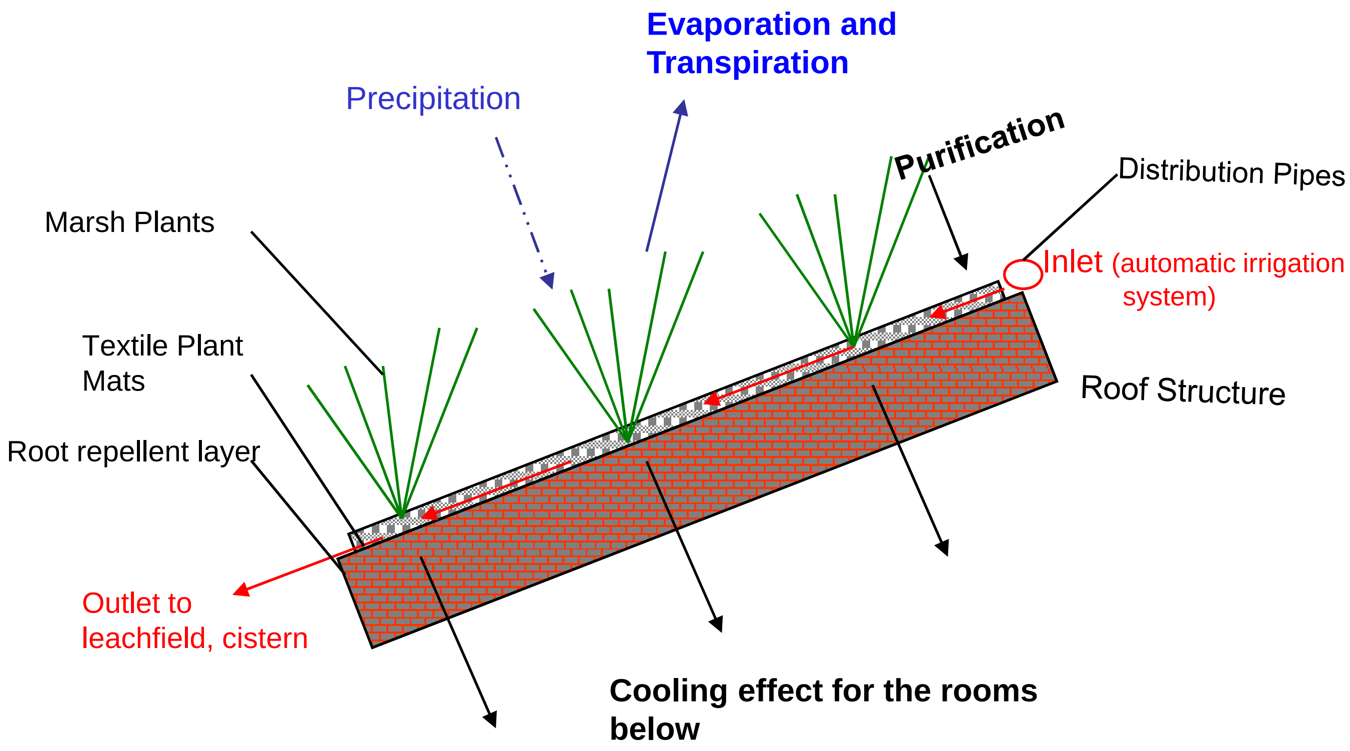
7.1 Outdoor Natural Swimming Pool Göttingen (Germany)



8. Wetland Roofs

8.1 Structure and principle of a wetland roof

Ecoroof with irrigation of rainwater



8. Wetland Roofs

8.2 Functions and advantages of a wetland roof

1. Compensation of temperature amplitudes
(of the roof skin, of the building, of the ambient microclimate) and cooling
- due to the irradiation shielding
- due to the evapotranspiration of the artificially irrigated roof caused by the lush roof vegetation even during the summer months.

2. Stormwater discharge reduction (retaining 60 % of runoff and thus reducing stormwater fees)

3. Increase of durability of the roof by a temperature reduction and protection against a direct impact of UV-radiation leading to a reduced surface ageing (reduced membrane replacement costs).

8. Wetland Roofs

8.3 Functions and advantages of a wetland roof

4. Compensation of the surface impermeability (factor ≥ 50 %).

5. Considerable reduction of the need for technical air-conditioning (supplied by fossil sources of energy) because of a passive cooling of the building (energy savings).

6. Improvement of the microclimate and contribution to the prevention of an overheating of urban conglomerates during the summer months (hot spots).

7. Filtration of dust emissions and of other air polluting matters.

8. Wetland Roofs

8.4 Functions and advantages of a wetland roof

8. Higher short-wave radiative reflexion compared to a dark bitumen roof.

9. Reduced roof loads due to a substrate-free planting procedure with only one textile water accumulating mat on which the selected types of wetland plants have been pre-cultivated. This procedure ensures that the roof surface is fully covered by plants after one period of egetation.

10. Possible design as a roof garden (flat roof) with a highly aesthetic component due to the variety of usually untypical types of roof plants like wetland or marsh plants (aquatic acrophytes) and by the animals belonging to such a kind of ecosystem (e.g. butterflies and birds) instead of succulent or grass roofs with their poor vegetation during the summer months. Employees use the roof space for recreation during breaks.

8. Wetland Roofs

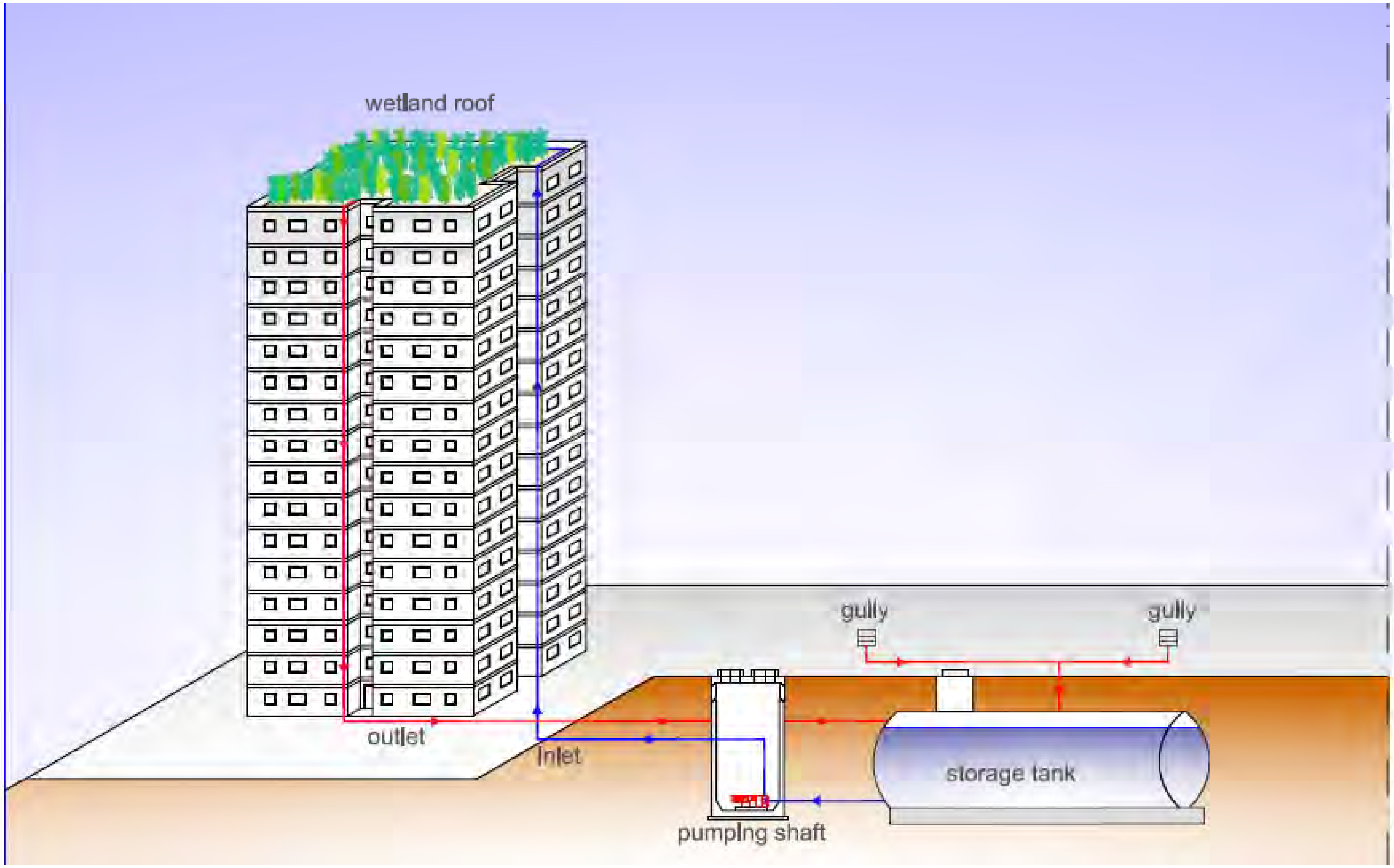
8.5 Functions and advantages of a wetland roof

11. Possible use as a roof sewage treatment plant both for municipal and for industrial waste water (constructed wetlands) or for greywater recycling or stormwater treatment (benefits of natural water purification).

12. Irrigation system that is activated by means of an irrigation computer automatically when water in the drainage layer gets low.

8. Wetland Roofs

8.5 Functions and advantages of a wetland roof



8. Wetland Roofs

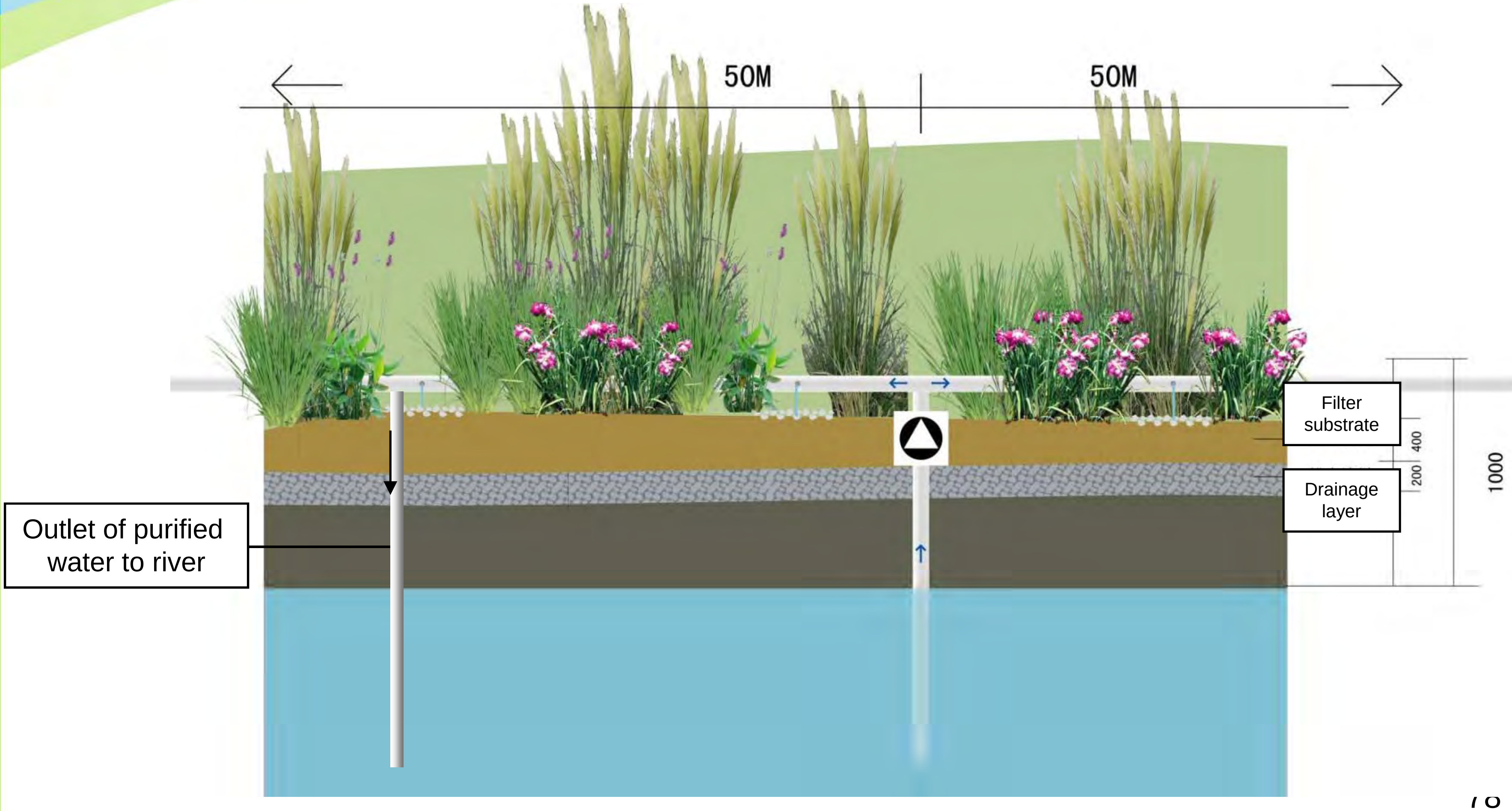
8.6 Wetland Roof Brunswick (Germany)

9. Natural Treatment of Polluted Rivers and Lakes

9.1 Useful areas for river bank wetland gardens

9. Natural Treatment of Polluted Rivers and Lakes

9.3 Riverbank wetland garden (longitudinal section)



9. Natural Treatment of Polluted Rivers and Lakes

9.4 Riverbank wetland garden

9. Natural Treatment of Polluted Rivers and Lakes

9.6 Water circulation system for polluted river water Rosebush park, Changzhou (China)

Quelle.:…………

Distribution pipe

Source: Ökolog Geller und Partner

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