The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Comparative Analysis – Natural Vs Conventional Systems

Comparative analysis natural versus conventional systems

SWIM OLC

on

Natural Treatment Systems

Compare technologies: tools

- LCA: Life Cycle Assessment: To compile and evaluate the environmental impacts of a product over its entire life cycle. (ISO process)

- MCA: Multi-Criteria Analysis: to evaluate the overall environmental consequences of an alternative, taking into account multiple criteria and their relative weights.

LCA <-> MCA

	LCA	MCA
Purpose of the analysis	To compile and evaluate the environmental impacts of a product over its entire life cycle.	To evaluate the overall environmental consequences of an alternative, taking into account multiple criteria and their relative weights.
Procedure	Goal and scope definition, inventory analysis, impact assessment and interpretation.	Establishing the decision context, identifying criteria, scoring, weighting deriving an overall value, examining the results and conducting a sensitivity analysis.
Final output of the instrument	A limited set of environmental scores for a number of impact categories.	One environmental score based on an aggregation of criteria.
Strengths of the instrument	Avoids problem shifting to other issues or areas, comprehensiveness through 'cradle-to-grave' approach.	Possibility of weighting the criteria, use of criteria with their own dimensions, single score for overall evaluation.
Weaknesses of the instrument	LCA is a complex process and requires considerable time and data input; dependence of normalisation on reference scenario; difficulties in interpreting the results.	MCA usually only takes a part of the production chain into account; relies on input from experts and stakeholders; weighting is subjective.

Assessing environmental performance by combining life cycle assessment, multi-criteria analysis and environmental performance indicators
B.G. Hermann, C. Kroeze, W. Jawjit, Journal of Cleaner Production 15 (2007) 1787-1796

How to compare technologies?: selection criteria

Nor complete, but like:

1. Average, or typical, efficiency and performance of the technology
2. Reliability of the technology
3. Institutional manageability
4. Financial sustainability
5. Application in reuse schemes
6. Regulatory determinants

1.Efficiency and performance of the technology indicators

System	Average removal efficiency							Land requirements (m^2/inhab)	Power for aeration		Sludge volume	
	BOD_5 (%)	COD (%)	SS (%)	Ammonia (%)	Total N (%)	Total P (%)	Thermo coli (log units)		Installed power (W/inhab)	Consumed power (kWh/inhab.year)	Liquid sludge to be treated (L/inhab.year)	Dewatered sludge to be disposed of (L/inhab.year)
Primary treatment (septic tanks)	30-35	25-35	55-65	< 30	< 30	< 35	< 1	0.03 - 0.05	0	0	110 – 360	15 - 35
Conventional primary treatment	30-35	25-35	55-65	< 30	< 30	< 35	< 1	0.02 - 0.04	0	0	330 – 730	15 - 40
Advanced primary treatment (chemically enhanced)	45-80	55-75	60-90	< 30	< 30	75-90	≈ 1	0.04 - 0.06	0	0	730 - 2500	40 - 110
Facultative pond	75-85	65-80	70-80	< 50	< 60	< 35	1-2	2.0 - 4.0	0	0	35 – 90	15 - 30
Anaerobic pond + facultative pond	75-85	65-80	70-80	< 50	< 60	< 35	1-2	1.2 - 3.0	0	0	55 – 160	20 - 60
Facultative aerated lagoon	75-85	65-80	70-80	< 30	< 30	< 35	1-2	0.25 - 0.5	1.2 - 2.0	11 - 18	30 – 220	7 – 30
Complete-mix aerated lagoon + sedimentation pond	75-85	65-80	80-87	< 30	< 30	< 35	1-2	0.2 - 0.4	1.8 – 2.5	16 - 22	55 – 360	10 - 35
Anaerobic pond + facult. pond + maturation pond	80-85	70-83	73-83	50-65	50-65	> 50	3-5	3.0 - 5.0	0	0	55 – 160	20 - 60
Anaerobic pond + facultative pond + high rate pond	80-85	70-83	73-83	65-85	75-90	50-60	3-4	2.0 - 3.5	< 0.3	< 2	55 – 160	20 - 60
Anaerobic pond – facultative pond + algae removal	85-90	75-83	> 90	< 50	< 60	< 35	3-4	1.7 - 3.2	0	0	60 – 190	25 - 70
Slow rate treatment	90-99	85-95	> 93	> 80	> 75	> 85	3-5	10 - 50	0	0	-	-
Rapid infiltration	85-98	80-93	> 93	> 65	> 65	> 50	4-5	1.0 - 6.0	0	0	-	-
Overland flow	80-90	75-85	80-93	35-65	< 65	< 35	2-3	2.0 - 3.5	0	0	-	-
Constructed wetlands	80-90	75-85	87-93	< 50	< 60	< 35	3-4	3.0 - 5.0	0	0	-	-
Septic tank + anaerobic filter	80-85	70-80	80-90	< 45	< 60	< 35	1-2	0.2 - 0.35	0	0	180 – 1000	25 - 50
Septic tank + infiltration	90-98	85-95	> 93	> 65	> 65	> 50	4-5	1.0 - 1.5	0	0	110 – 360	15 - 35
UASB reactor	60-75	55-70	65-80	< 50	< 60	< 35	1-2	0.03 - 0.10	0	0	70 – 220	10 - 35
UASB + activated sludge	83-93	75-88	87-93	50-85	< 60	< 35	1-2	0.08 - 0.2	1.8 - 3.5	14 - 20	180 – 400	15 - 60
UASB + submerged aerated biofilter	83-93	75-88	87-93	50-85	< 60	< 35	1-2	0.05 - 0.15	1.8 - 3.5	14 - 20	180 – 400	15 - 55
UASB + anaerobic filter	75-87	70-80	80-90	< 50	< 60	< 35	1-2	0.05 - 0.15	0	0	150 – 300	10 - 50
UASB + high rate trickling filter	80-93	73-88	87-93	< 50	< 60	< 35	1-2	0.1 - 0.2	0	0	180 – 400	15 - 55
UASB + dissolved-air flotation	83-93	83-90	90-97	< 30	< 30	75-88	1-2	0.05 - 0.15	1.0 - 1.5	8 - 12	300 - 470	25 - 75
UASB + maturation ponds	77-87	70-83	73-83	50-65	50-65	> 50	3-5	1.5 - 2.5	0	0	150 – 250	10 - 35
UASB + facultative aerated pond	75-85	65-80	70-80	< 30	< 30	< 35	1-2	0.15 - 0.3	0.3 - 0.6	2 - 5	150 – 300	15 - 50
UASB + compl.mix. aerated lagoon + sedim. pond	75-85	65-80	80-87	< 30	< 30	< 35	1-2	0.1 - 0.3	0.5 - 0.9	4 - 8	150 - 300	15 - 50
UASB + overland flow	77-90	70-85	80-93	35-65	< 65	< 35	2-3	1.5 - 3.0	0	0	70 - 220	10 - 35
Conventional activated sludge	85-93	80-90	87-93	> 80	< 60	< 35	1-2	0.12 - 0.25	2.5 - 4.5	18 - 26	1100 – 3000	35 - 90
Activated sludge – extended aeration	90-97	83-93	87-93	> 80	< 60	< 35	1-2	0.12 - 0.25	3.5 - 5.5	20 - 35	1200 – 2000	40 - 105
Convent. activated sludge with biological N removal	85-93	80-90	87-93	> 80	> 75	< 35	1-2	0.12 - 0.25	2.2 - 4.2	15 - 22	1100 – 3000	35 - 90
Convent. activated sludge with biolog. N/P removal	85-93	80-90	87-93	> 80	> 75	75-88	1-2	0.12 - 0.25	2.2 - 4.2	15 - 22	1100 – 3000	35 - 90
Conventional activated sludge + tertiary filtration	93-98	90-95	93-97	> 80	< 60	50-60	3-5	0.15 - 0.30	2.5 - 4.5	18 - 26	1200 - 3100	40 - 100
Low rate trickling filter	85-93	80-90	87-93	65-85	< 60	< 35	1-2	0.15 - 0.3	0	0	360 – 1100	35 - 80
High rate trickling filter	80-90	70-87	87-93	< 50	< 60	< 35	1-2	0.12 - 0.25	0	0	500 – 1900	35 - 80
Submerged aerated biofilter with nitrification	88-95	83-90	87-93	> 80	< 60	< 35	1-2	0.1 - 0.15	2.5 - 4.5	18 - 26	1100 – 3000	35 - 90
Submerged aerated biofilter with biolog. N removal	88-95	83-90	87-93	> 80	> 75	< 35	1-2	0.1 - 0.15	2.2 - 4.2	15 - 22	11000 – 3000	35 - 90
Rotating biological contactor	88-95	83-90	87-93	65-85	< 60	< 35	1-2	0.1 - 0.2	0	0	330 - 1500	20 - 75

2. Reliability of the technology indicators

- Chemicals needed
- Meeting of quality standards
- Stable and resilient against shock loading
- Power supply (aerobic treatment performance)
- Easy to repair and to restart
- Spare parts
- Selling biogas
- Operational complexity: trained personel

3. Institutional manageability indicators

- Governmental agencies adequately equipped for wastewater management.
- Technical and managerial expertise/ eduation.
- Access to a local network of research for scientific support and problem solving.
- Devoted and experienced operators and technicians.

4. Financial sustainability indicators

- Availability of funds provided by the polluter
- Resource recovery
- Ultimate goal should be full cost recovery, but temporarily
  - cross-subsidisation
  - revolving funds
  - phased investment programmes

Costs

1. Investment costs:
    - cost of the land,
    - groundwork,
    - electromechanical equipment and construction
2. Recurring costs:
    - loans (interest and principal),
    - costs for personnel,
    - energy and other utilities,
    - laboratories,
    - repair,
    - sludge disposal.

Vary from country to country, as well as in time.

Operation and maintenance costs

- Essential part of wastewater management and affects technology selection
- On an annual basis, the O&M expenditures of treatment and sewage collection are typically in the same order of magnitude as the depreciation on the capital investment

Operation and maintenance requires

- Careful exhaustive planning.
- Qualified and trained staff devoted to its assignment.
- An extensive and operational system providing spare parts and O&M utilities.
- A maintenance and repair schedule, crew and facility.
- A management atmosphere that aims at ensuring a reliable service with a minimum of interruptions.
- A substantial annual budget that is uniquely devoted to O&M and service improvement.
- Preventive instead of corrective.

5. Application in reuse schemes indicators

- Resource recovery (environmental as well as to financial sustainability)
  - Sludge
  - Biogas
  - Water

- Esthetic / natural value (wetland)

6. Regulatory determinants

- Discharge standards (determined by technique)
- Enforcement

Complete overview of possible indicators (Adapted from Balkema, source: Balkema, 2003)

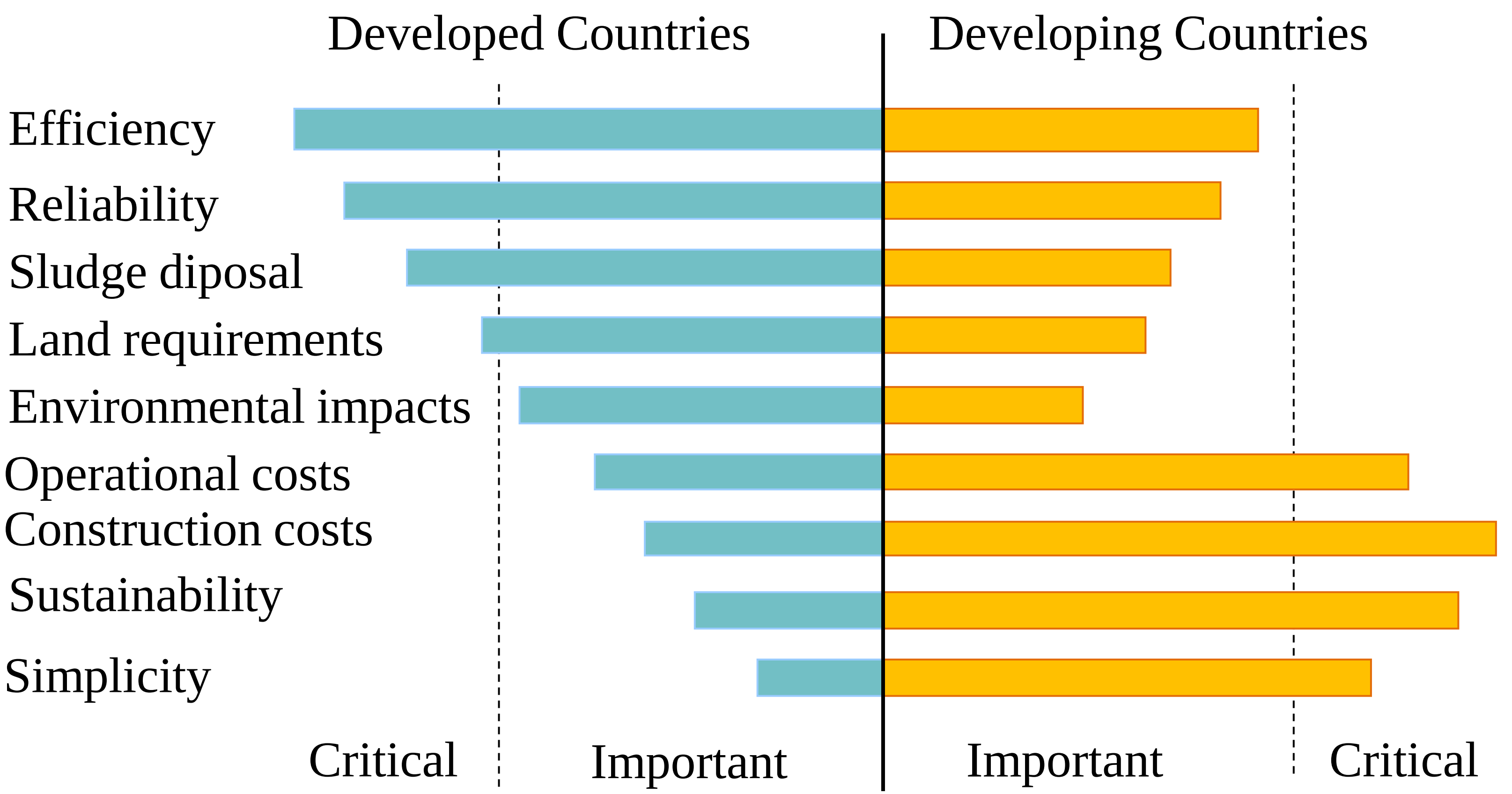
Economical indicators:
1 Costs
2 Labor
3 Affordability
4 Use of surface area
5 Financial risk exposure

Environmental indicators:
6 Accumulation
7 Biodiversity / land fertility
8 Desiccation
9 Export of problems in time & space
10 Extraction
11 Integration in natural cycles
12 Land area required / space
13 Odor / noise / insects / visual
14 Optimal resource utilization
15 Resources reuse
16 Water reuse
17 Nutrients reuse
18 Energy reuse
19 Raw materials
20 Pathogen removal / health
21 Pollution prevention
22 BOD / COD Emissions
23 Emissions of nutrients x
24 Emissions of Heavy metals
25 Others emissions
26 Sludge / waste production
27 Use of chemicals
28 CSO
29 Discharge

- 30 Energy use
- 31 Gas produced
- 32 Soil conditioner
- 33 Contribution to eutrophication
- 34 Contribution to acidification
- 35 Contribution to global warming
- 36 Drinking water
- 37 Household water
- 38 Construction materials
- 39 Micropollutants
- 40 Impact on air
- **Technical indicators:**
- 41 Durability
- 42 Ease of construction / low tech
- 43 Endure shock loads/seasonal effects
- 44 Flexibility / adaptability
- 45 Maintenance
- 46 Reliability / security
- 47 Small scale / onsite / local solution
- 48 Robustness
- 49 waste
- 50 Abuse of system
- 51 Possibility to use local competence
- for construction and O&M
- 52 Ease of system monitoring
- 53 Compatibility with existing systems
- 54 Quality of supplied water
- **Health and Hygiene**
- 56 Protection of water resources
- 57 Direct transmission of infection
- 58 Indirect transmission of infection
- 59 Reliability / security
- 60 Spreading of toxic compounds
- 61 Risk of exposure to hazardous
- substances

Social-cultural indicators:
- 62 Awareness / participation
- 63 Competence / information requirements
- 64 Cultural acceptance
- 65 Institutional requirements
- 66 Local development
- 67 Responsibility
- 68 Expertise
- 69 Sustainable behavior
- 70 Labor
- 71 Future trends
- 72 User friendliness /System perception
- 73 Transparency
- 74 Willingness to pay
- 75 Convenience
- 76 Current legal acceptability
- 77 Willingness to change behaviour

Selection of wastewater treatment systems in developed and developing regions



von Sperling, 1996

Relative evaluation of the main domestic sewage treatment systems by criteria and indicators

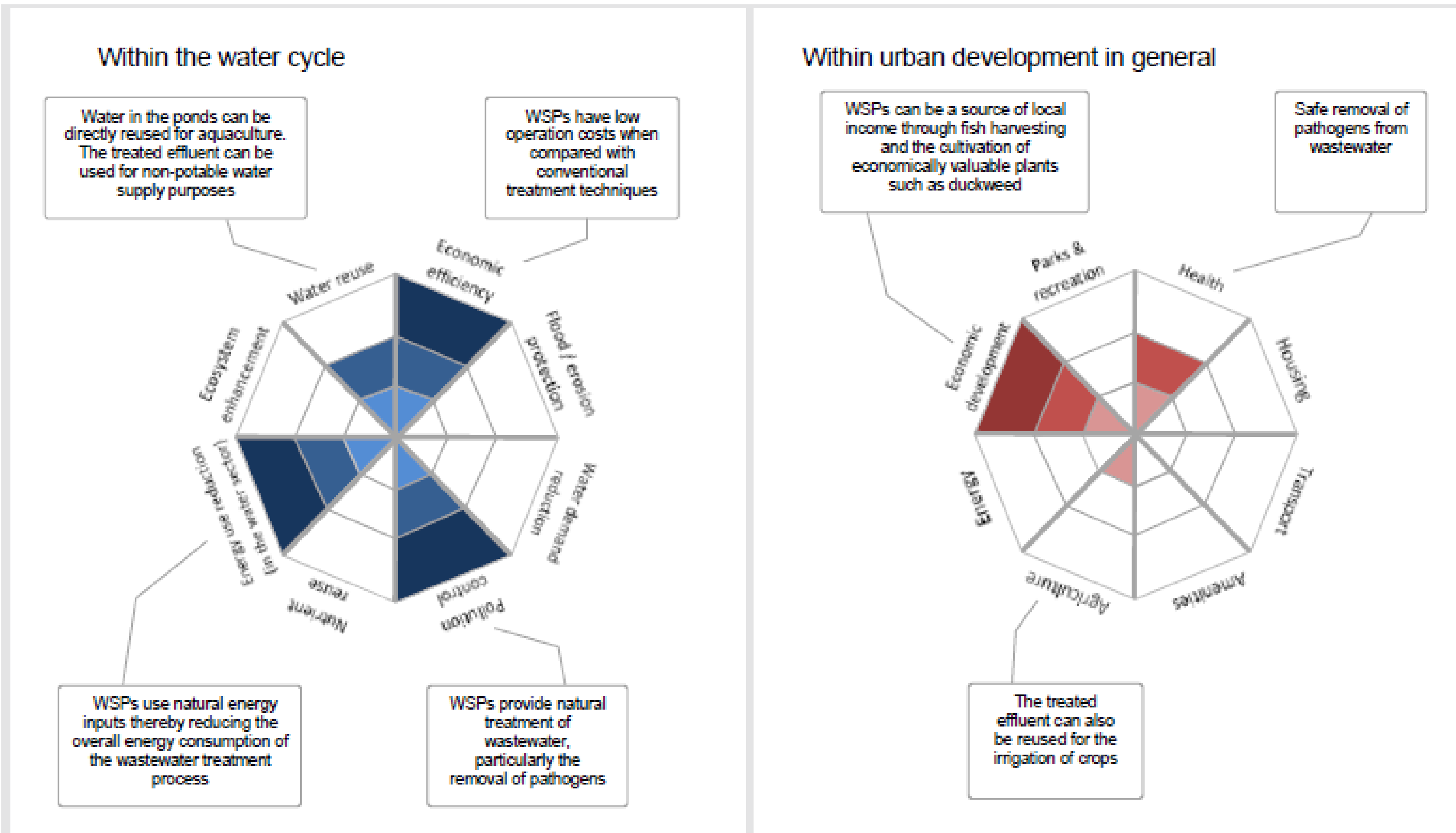
Treatment system	Removal efficiency			Economy					Resistance capacity to influent variations and shock loads			Reliability	Simplicity in O & M	Independence of other characteristics for good performance		Lower possibility of environmental problems			
	BOD	Nutrients	Coliforms	Requirements		Costs		Generation	Flow	Quality	Toxic compounds			Climate	Soil	Bad odours	Noise	Aerosols	Insects and worms
				Land	Energy	Construction	O & M	Sludge											
Preliminary treatment	0	0	0	+++++	+++++	+++++	++++	+++++	+++++	+++++	+++++	+++++	+++	+++++	+++++	+	++++	+++++	+++
Primary treatment	+	+	+	+++++	++++	++++	+++	+++	++++	+++++	++++	++++	+++	++++	+++++	++	++++	+++++	+++
Advanced primary treatment	++	+/++++	++	+++++	++++	+++	++	+	++++	+++++	++++	++++	+++	+++++	+++++	+++	++++	+++++	+++
Facultative pond	+++	++	++/++++	+	+++++	+++	+++++	+++++	++++	++++	+++	++++	+++++	++	+++	+++	+++++	+++++	++
Anaerobic pond – facultative pond	+++	++	++/++++	++	+++++	++++	+++++	+++++	++++	++++	+++	++++	+++++	++	+++	+	+++++	+++++	++
Facultative aerated lagoon	+++	++	++/++++	++	+++	+++	++++	+++++	++++	++++	+++	++++	++++	+++	+++	++++	+	+	+++
Compl. mix aerated – sedim. pond	+++	++	++/++++	+++	+++	+++	+++	+++	+++	++++	+++	+++	+++	+++	++++	+++	+	+	++
Pond – maturation pond	+++	+++	+++++	+	+++++	+++	+++++	+++++	++++	++++	+++	++++	+++++	++	+++	+++	+++++	+++++	++
Pond – high rate pond	+++	++++	++++	++	++++	+++	++++	+++++	++++	++++	+++	++++	+++	+++	+++	+++	++	++	++
Pond – algae removal	++++	++	++/++++	++	+++++	+++	++++	+++	++++	++++	+++	++++	+++	+++	+++	+++	+++++	+++++	++
Slow rate treatment	+++++	++++	++++	+	+++++	+++	+++++	+++++	++++	++++	++++	++++	++++	++	+	++	+++++	+/+++++	++
Rapid infiltration	+++++	++++	++++	+	+++++	++++	+++++	+++++	++++	++++	++++	++++	++++	++	+	++	+++++	+++++	++
Overland flow	++++	+++	++/+++	+	+++++	+++	++++	+++++	++++	++++	+++	++++	+++++	+++	++	++	+++++	+/+++++	++
Constructed wetlands	++++	++	+++	+	+++++	+++	++++	+++++	++++	++++	+++	++++	+++++	++	++	++	+++++	+++++	++
Septic tank – anaerobic filter	+++	+	++	+++++	+++++	+++	+++	++++	+++	+++	++	+++	++++	++	+++++	++	++++	+++++	++++
UASB reactor	+++	+	++	+++++	+++++	++++	++++	++++	++	++	++	+++	++++	++	+++++	++	++++	+++++	++++
UASB reactor – post-treatment	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(b)	(b)	(b)	(a)	(a)	(a)	(a)	(b)	(a)	(a)	(a)
Conventional activated sludge	++++	++/++++	++	++++	++	+	++	+	+++	+++	++	++++	+	+++	+++++	++++	+	+/+++++	++++
Activated sludge (extended aeration)	+++++	++/++++	++	++++	+	++	+	++	++++	++++	+++	++++	++	++++	+++++	+++++	+	+/+++++	++++
Trickling filter (low rate)	++++	++/++++	++	+++	++++	+	+++	++	+++	++	++	++++	+++	++	+++++	++++	++++	++++	++
Trickling filter (high rate)	++++	++/+++	++	++++	+++	++	+++	+	++++	+++	+++	++++	+++	++	+++++	++++	++++	++++	+++
Submerged aerated biofilter	+++++	++/+++	++	+++++	++		+++	+	+++	+++	++	++++	++	++++	+++++	+++++	++	+++++	++++
Rotating biological contactor	++++	++/+++	++	++++	+++	+	+++	+	+++	+++	++	+++	+++	++	+++++	++++	++++	+++++	+++

- Notes: the grading is only relative in each column and is not generalized for all the items. The grading can vary widely with the local conditions.
- +++++ : most favorable + : least favorable ++++, +++, ++: intermediate grades, in decreasing order 0 : zero effect + / +++++: variable with the type of process, equipment, variant or design.
- UASB reactor + post-treatment: (a) post-treatment characteristics prevail; (b) UASB reactor characteristics prevail O&M: operation and maintenance.

VON SPERLING, M., CHERNICHARO, C.A.L. (2005). Biological wastewater treatment in warm climate regions. IWA Publishing, 2005, ISBN 9781843390022

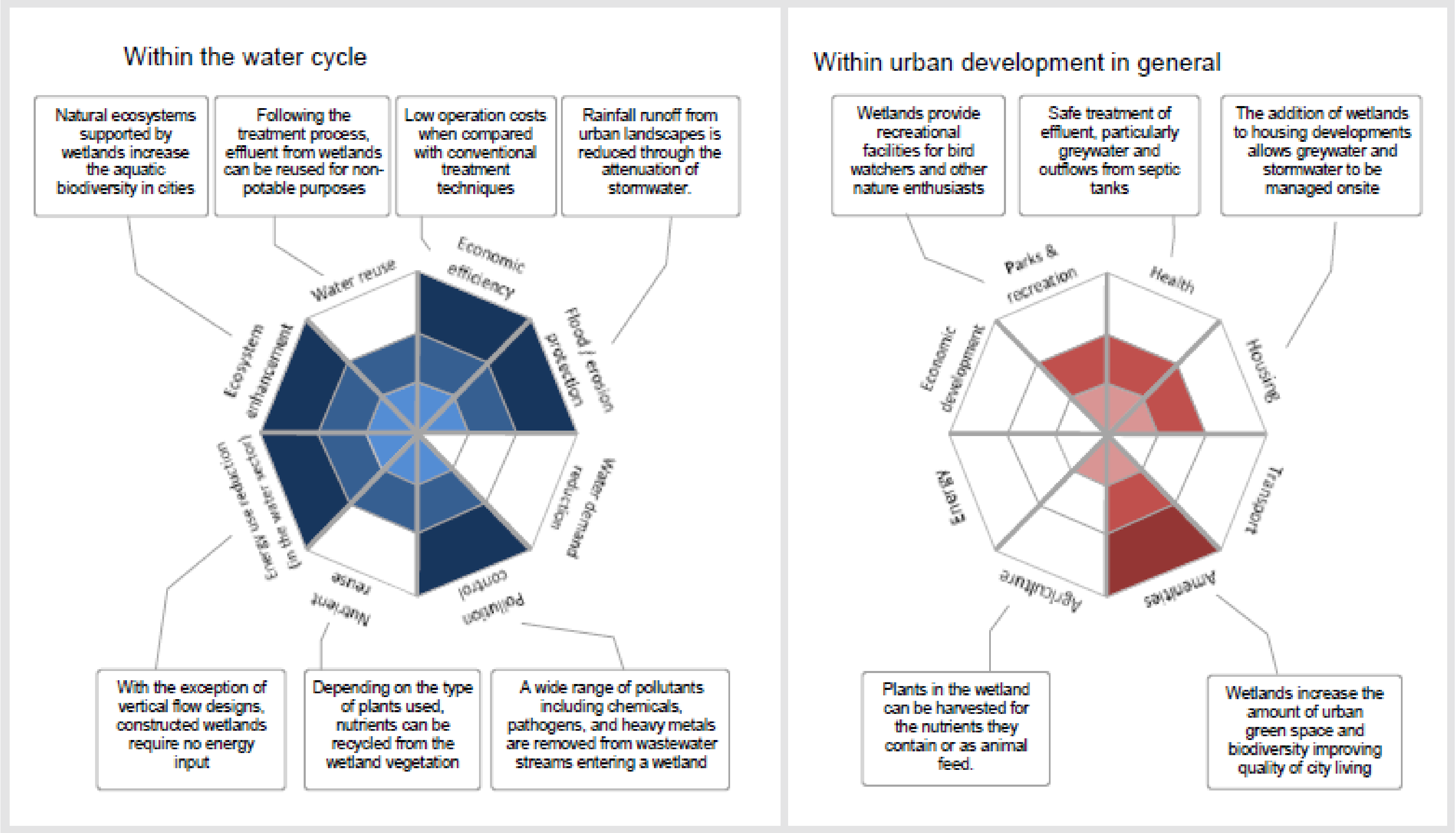
VON SPERLING, M. (1996). Comparison among the most frequently used systems for wastewater treatment in developing countries. Water Science and Technology, 33 (3). pp. 59-72

Positive influences of WSPs on the urban water cycle and urban development



http://www.switchurbanwater.eu/

Positive influences of constructed wetlands on the urban water cycle and urban development



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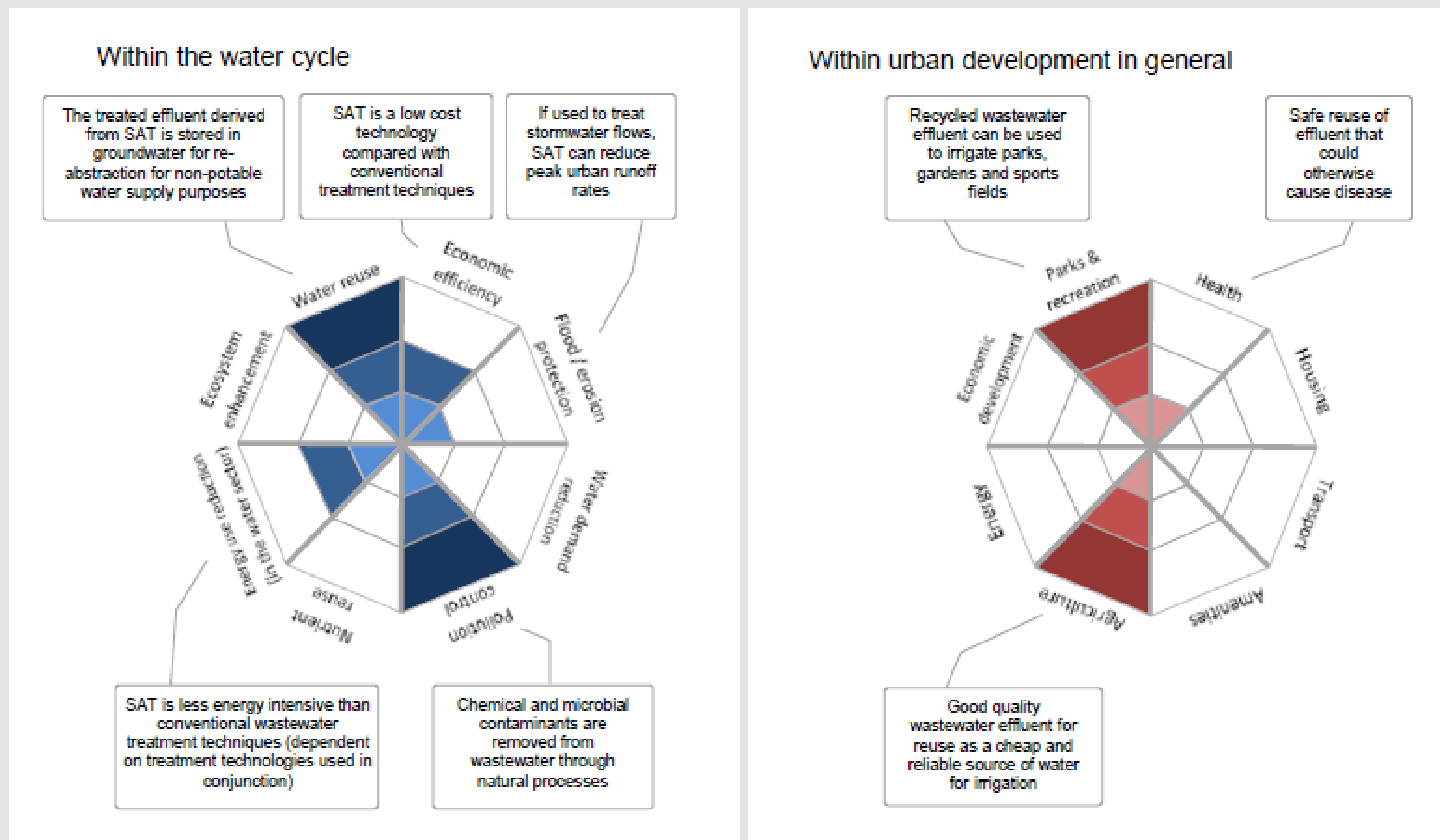
Positive influences of SAT on the urban water cycle and urban development



http://www.switchurbanwater.eu/

Conclusion

- Availability of treatment technologies to be potentially applied for the treatment of urban wastewater is very large.
- Engineered systems can always meet standards when operated correctly (O&M).
- Are expensive in construction and O&M.
- Esp. suitable in concentrated urban areas.
- Natural systems are less reliable, but need less operators expertise .
- Land requirement is high cost factor.
- Criteria or weightings: local reality in focus: selection really leads to the most adequate system.
- Common sense and experience.