FLOODS, WATER SCARCITY AND EXTREME EVENTS
2023

LNEC
LISBON
CONFERENCE

WATER REUSE: PROVEN SOLUTION TO SECURE WATER SUPPLY

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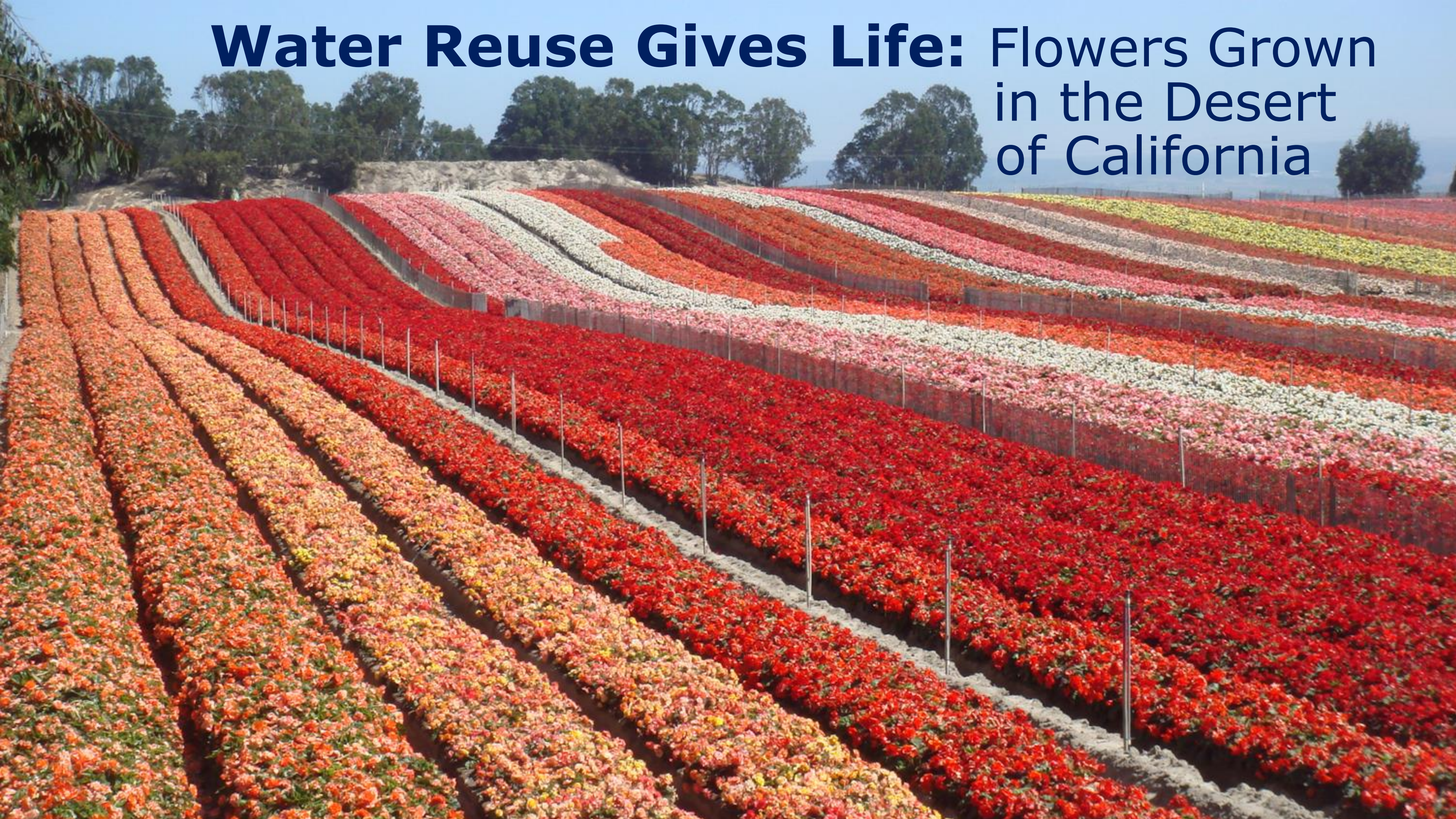
Water is Life: Flowers Bloom in the Desert

Atacama, Chile: The driest place in earth (0.1 to 50 mm rainfall per year)

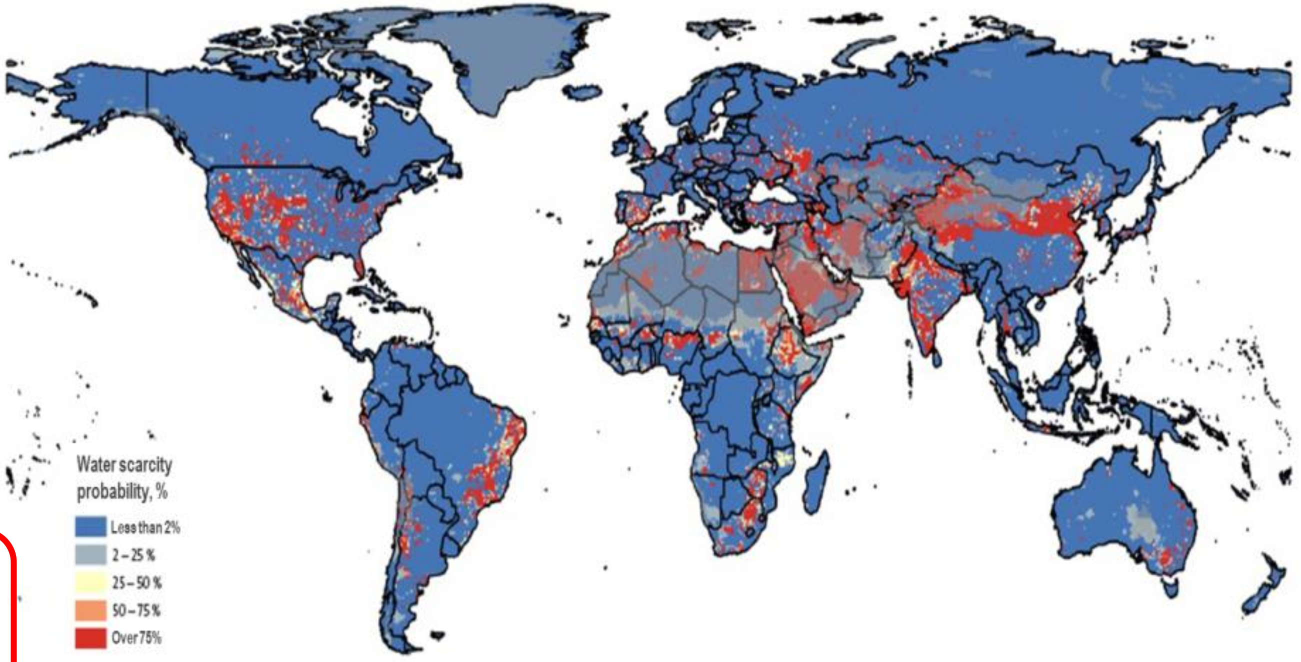
Water Reuse Gives Life: Flowers Grown in the Desert of California



Water Reuse Market Drivers

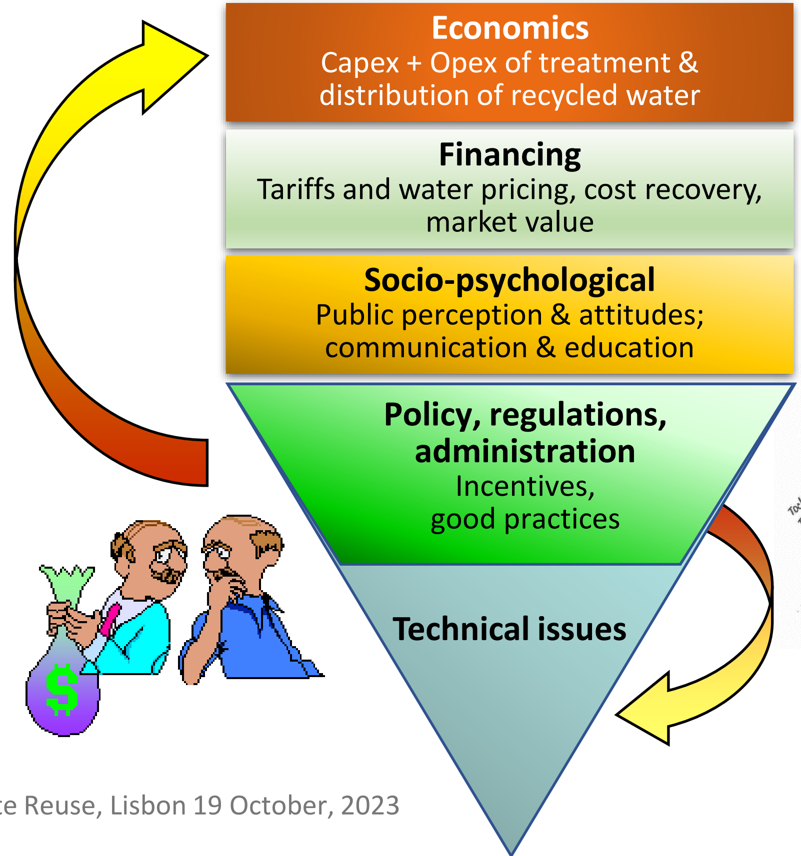
- Water scarcity
- Cost of water
- Regulatory drivers
- Technology drivers
- Corporate behavior
- Discharge limits

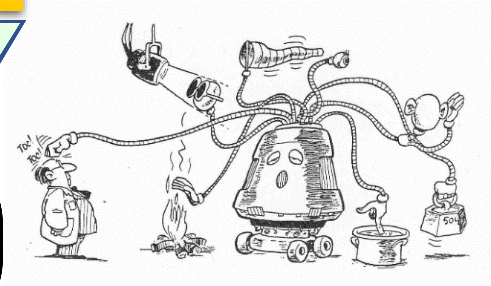
= Challenges

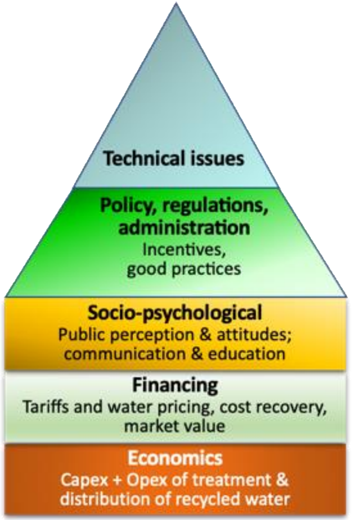


Water scarcity probability in 2030

Major Challenges for Sustainable Growth of Water Reuse





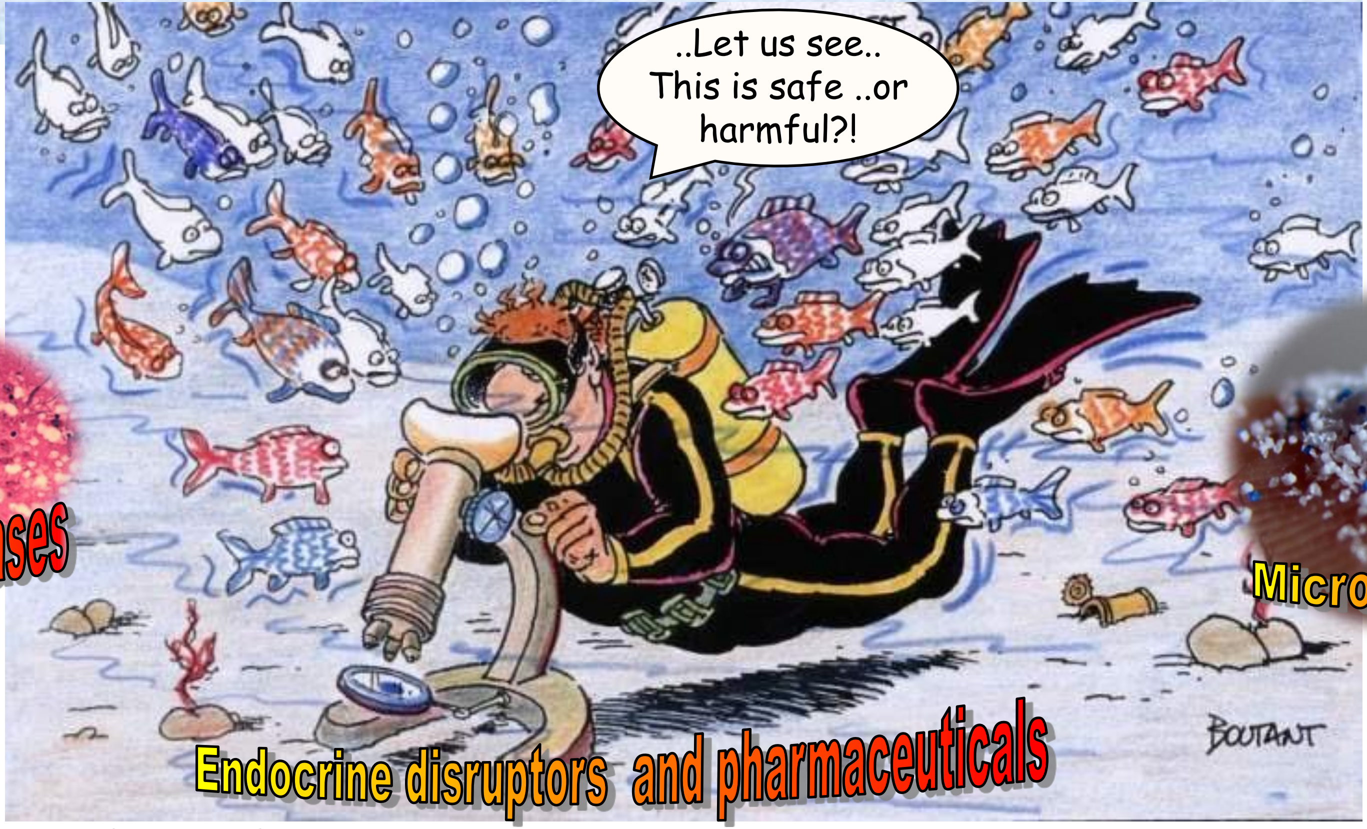


Key Issues and Challenges for Sustainable Growth of Water Reuse

1. **New policies and regulations**
   - Provide **incentives for water reuse** and reform water rights
   - Frame best management practice and **feasible regulatory frameworks**
2. **Implementation of Innovative technologies & tools**
   - Advance in **engineering and technology**
     - ✓ Long-term efficiency of full-scale installations
     - ✓ Compatibility with existing technologies and infrastructure
     - ✓ Failure risk management
     - ✓ Monitoring: sensor reliability, calibration and data analysis
   - **Energy and cost effetiveness**
     - ✓ Water & energy nexus
     - ✓ **Cost & risk nexus**
   - **Soft science:** health & environmental risk assessment, **monetary and non-monetary benefits,** public perception & education…

New Challenges of Regulatory Policy

Advance in Science and Precautionary Principle



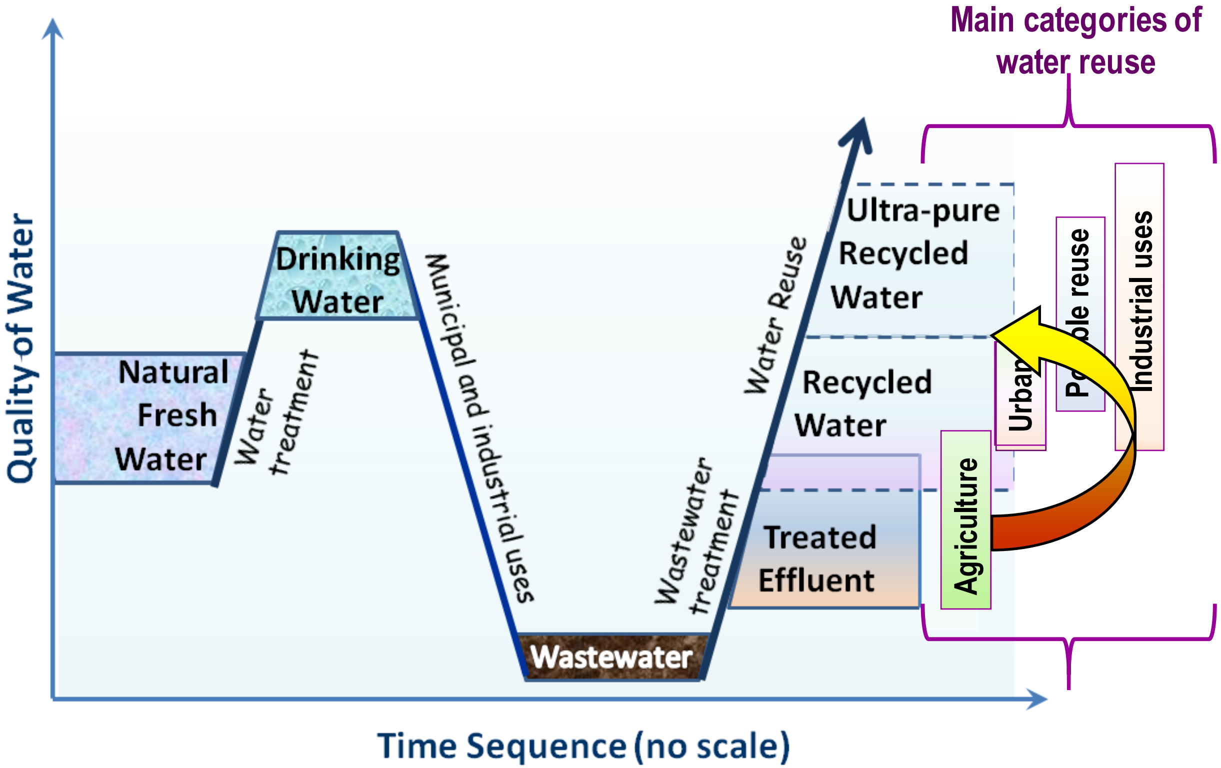
Technical Challenges – Considered as the Less Important Water Reuse Barrier ?!?

What's this?


On the Way to Sustainable Water Reuse

Technology as Enabler of Sustainable Water Cycles – Water Quality ≠ Source of Water

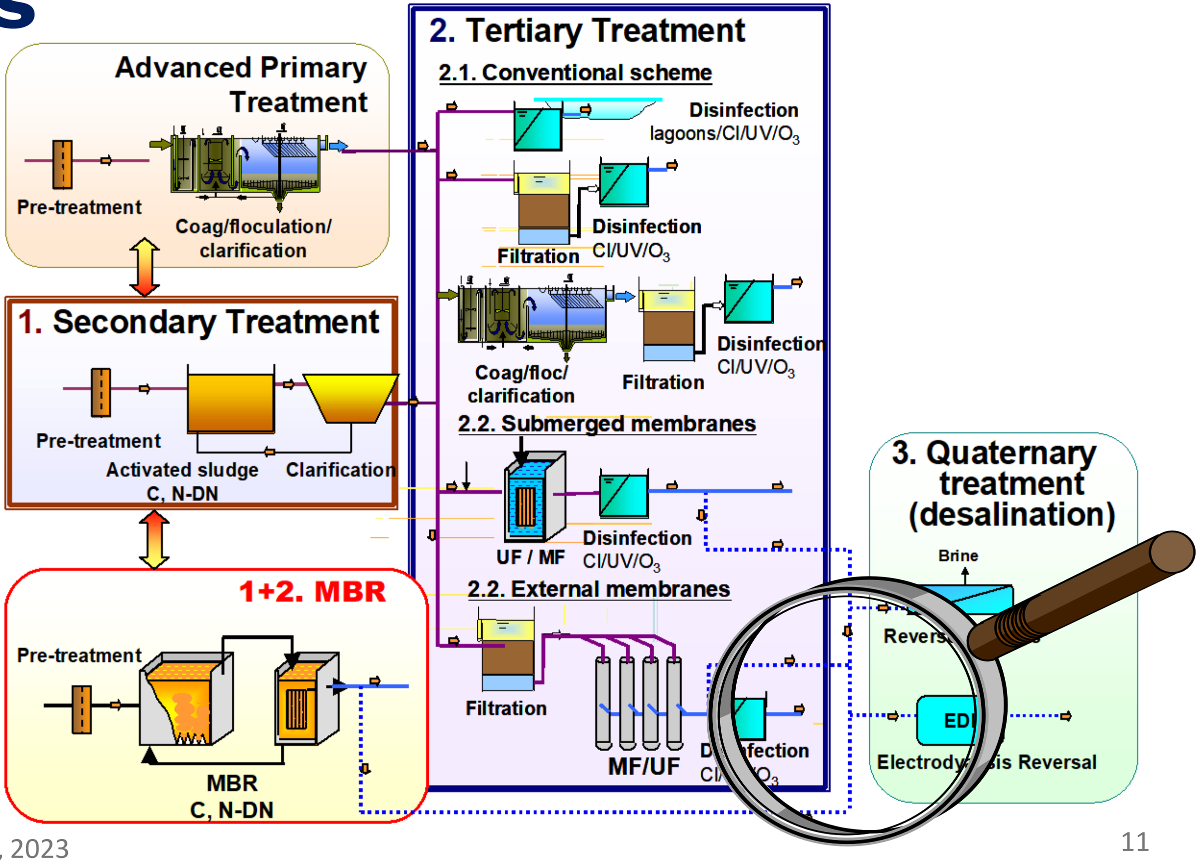
- With current technologies, source water quality no longer dictates product water quality



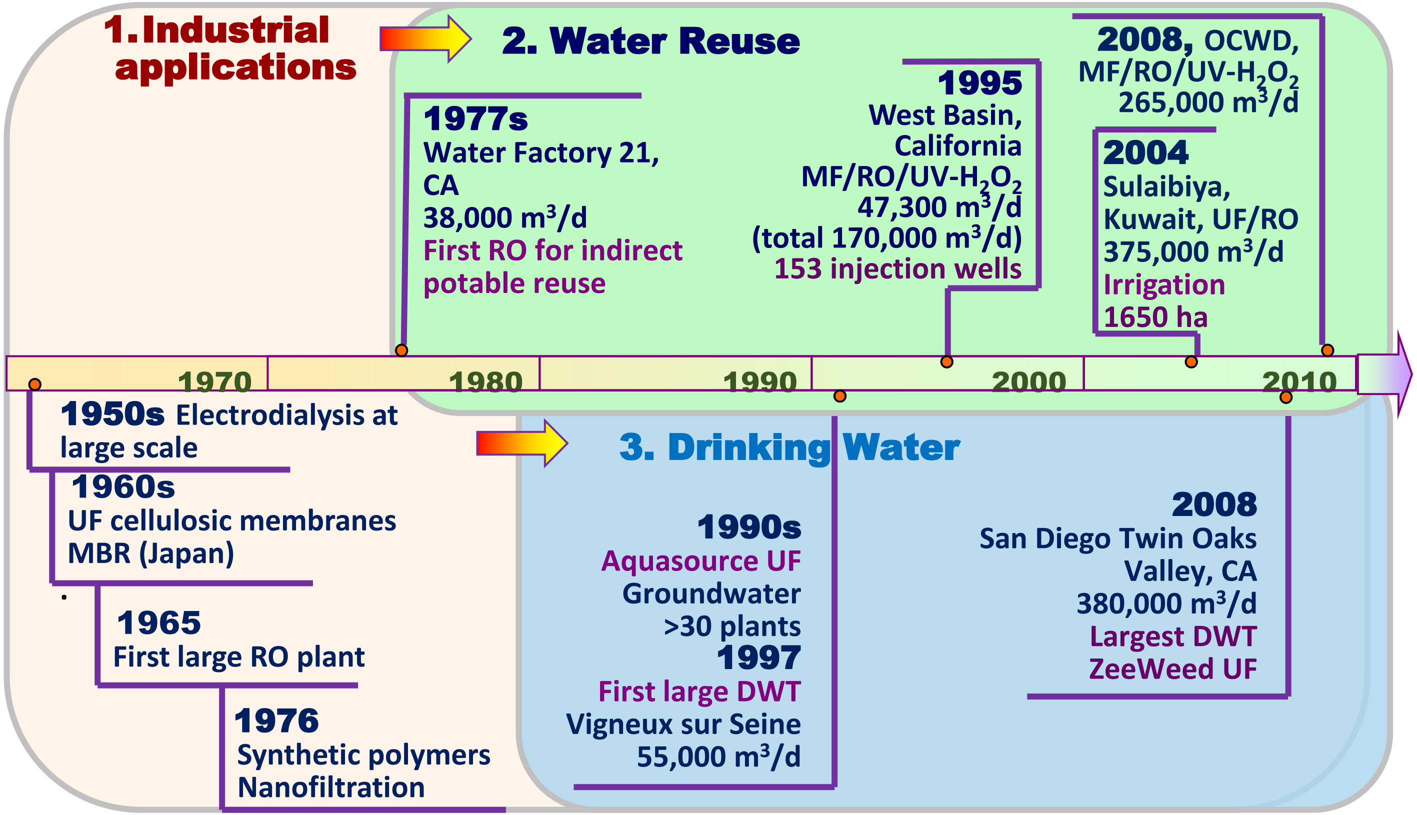
Source: Asano 2002; Lazarova et al. 2013

Technology as Enabler of Sustainable Water Cycles

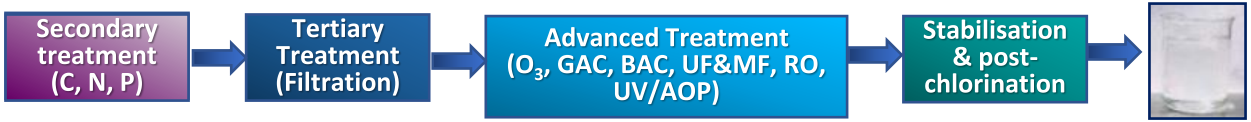
Typical Treatment Schemes for Water Reuse



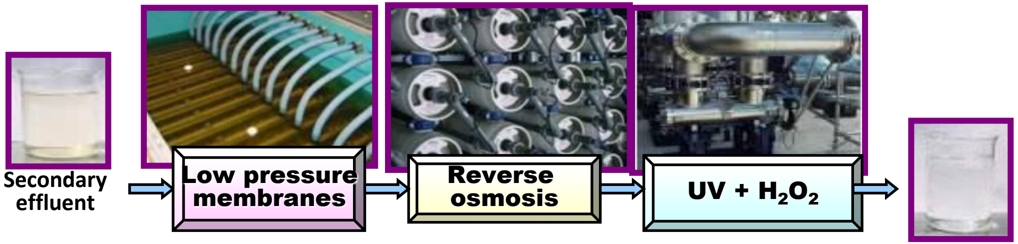
Technology as Enabler of Sustainable Water Cycles – The Role of Membranes



Technology as Enabler of Sustainable Water Cycles – Production of High Quality Recycled Water



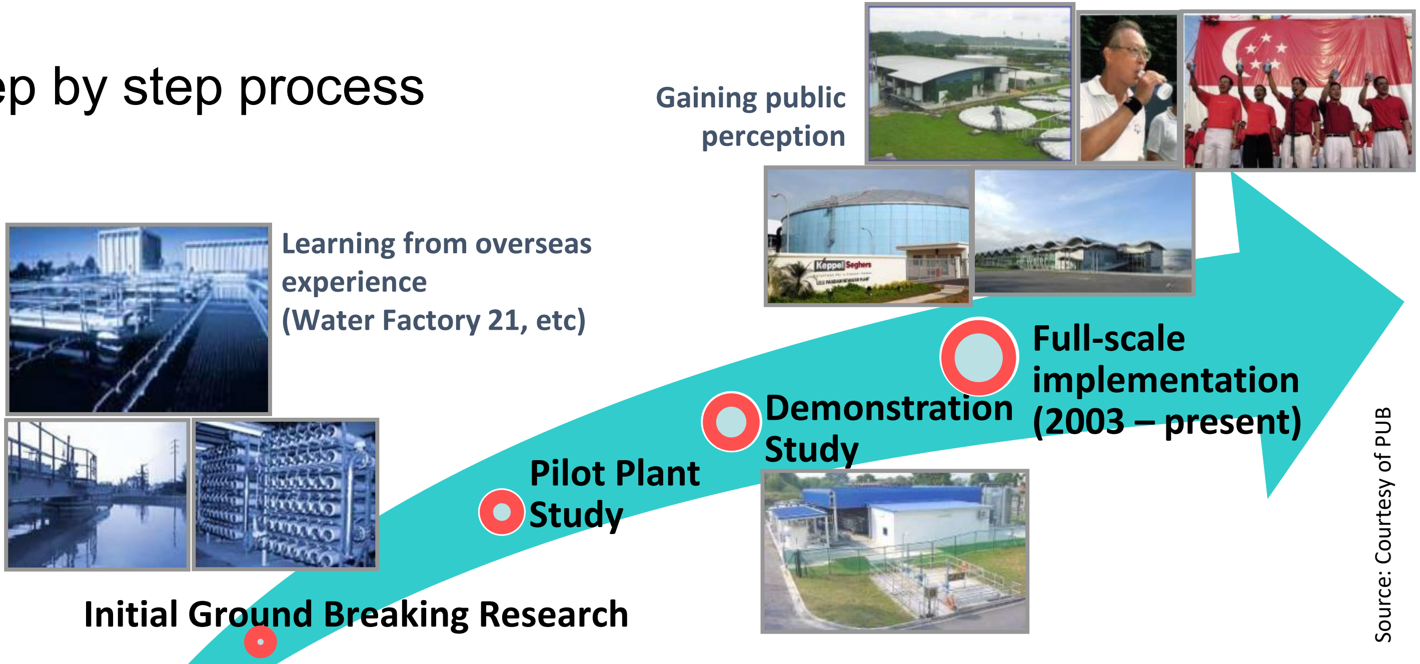
- Advanced **membrane** treatment (MF/RO & UF/RO) is considered as «Best Available Technology» (plus AOP for potable reuse)
  - ✓ Potable reuse and aquifer recharge (Australia, California, Belgium, Singapore…)
  - ✓ Industrial reuse (Australia, California, China, Hawaii, India, Singapore..)
  - ✓ Agricultural and landscape Irrigation (China, Kuwait, Spain…)



- **Increasing interest** in non-membrane technologies (BF, O_3, AC…)

Technology as Enabler of Sustainable Water Cycles – The NeWater Story

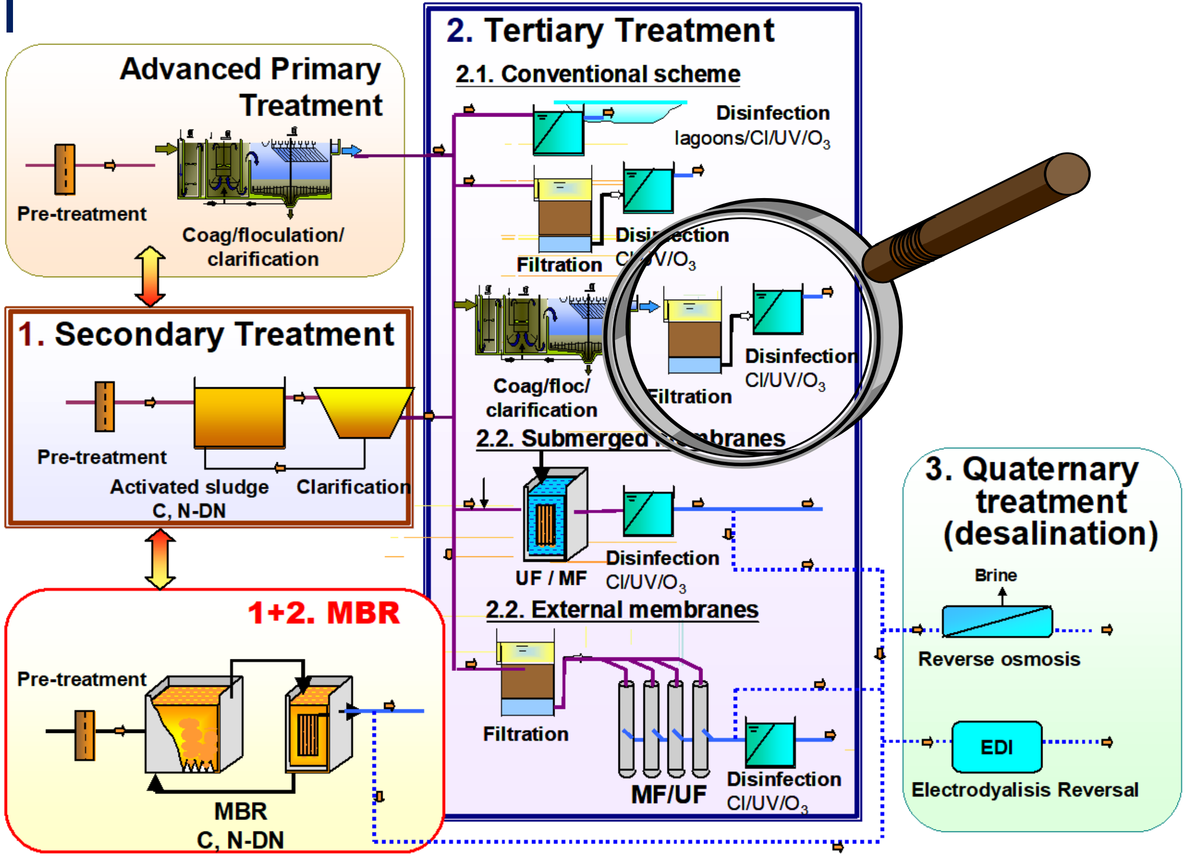
- Step by step process



- Test of reliability and robustness of MF/RO, UF/RO, UV…
- Operational experience used for the design of full-scale plants
- Lessons learned applied to new plants and expansions

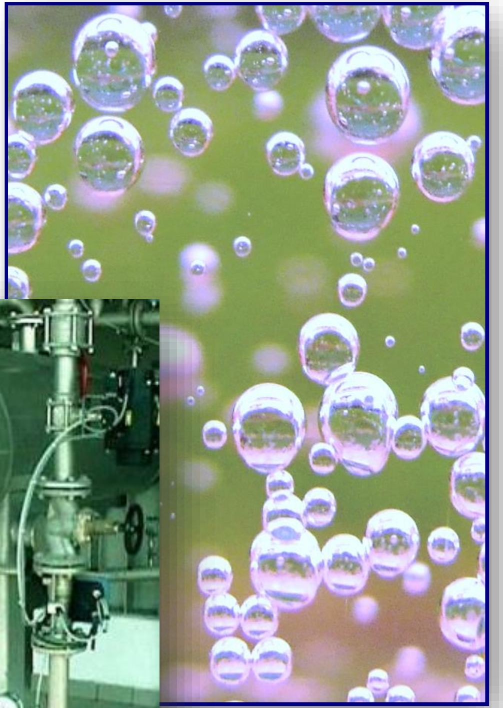
Source: Courtesy of PUB

Technology Innovation – Unexplored Potential



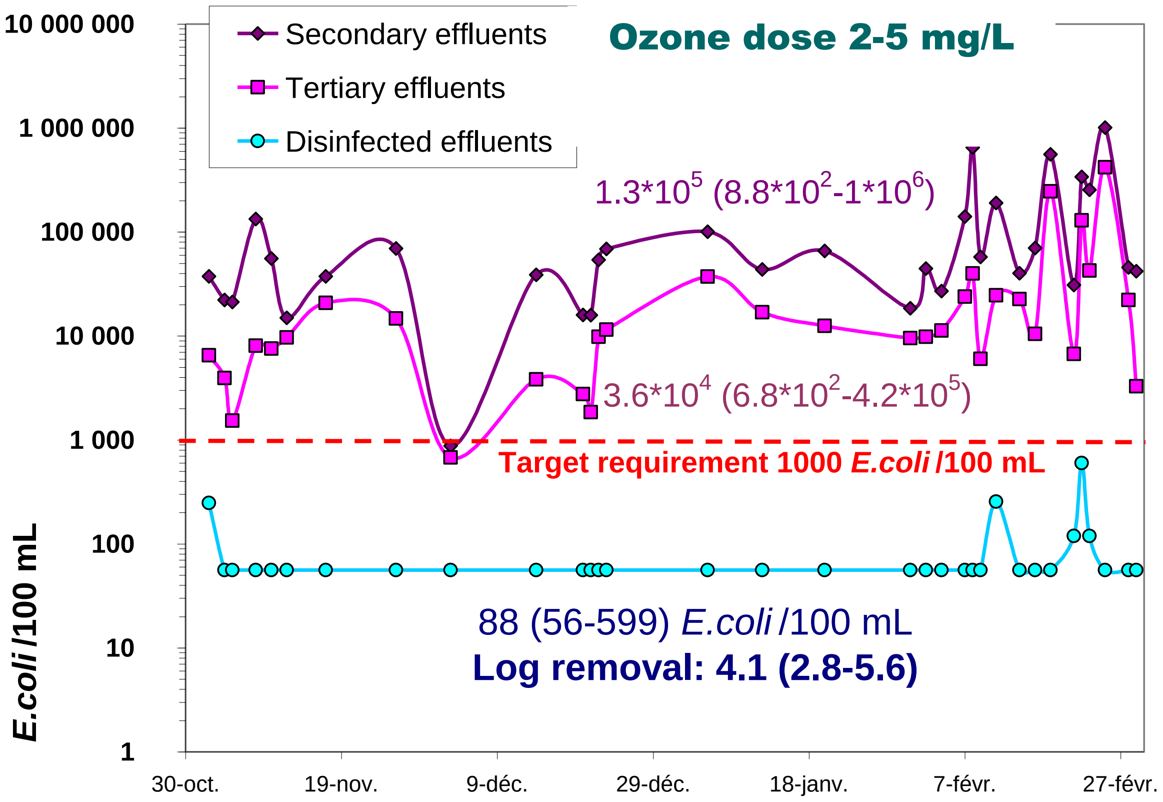
Ozonation – Major Advantages

- Suitable for all microorganisms: viruses, bacteria and protozoa cysts
- Yields additional water quality improvement: removal of colour, odour and **refractory organics**
- Efficient for low quality effluents
- Near-complete removal of emerging organic micropollutants



Ozone Disinfection

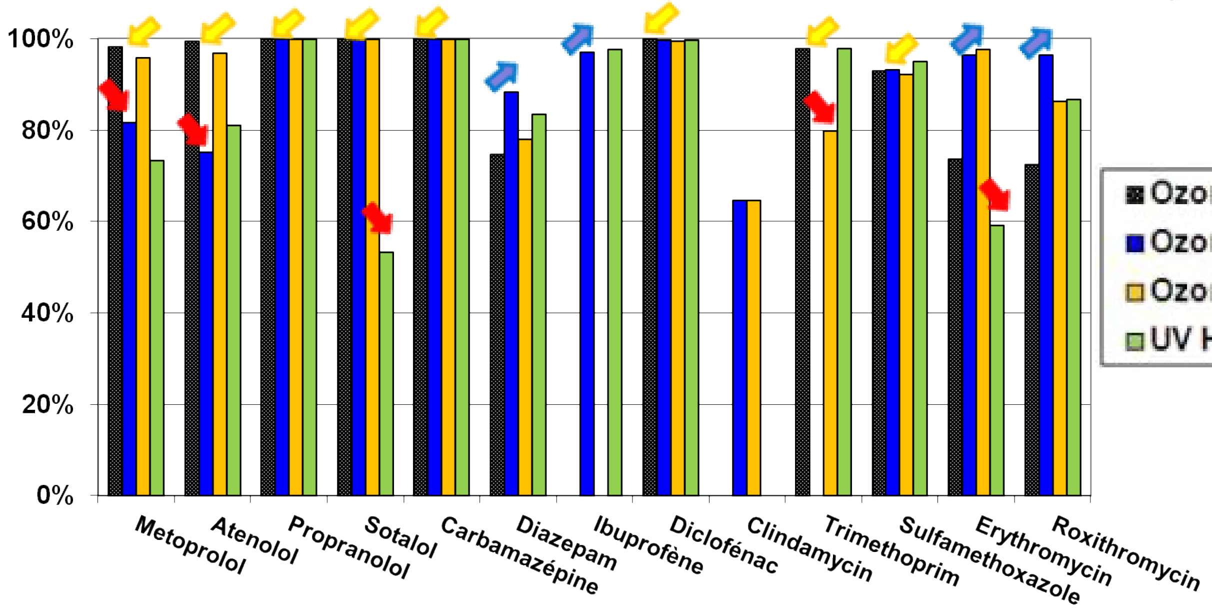
Long-term Ozonation Performance (full-scale)

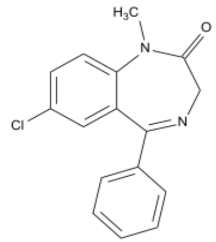


Micropollutants Removal
Comparison of Ozone with Other AOP Processes

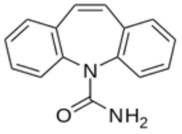
- Betablockers, carbamazepine, diclofenac, sulfamethoxazole, etc. – **very high removal (>98% ↙)** with ozone alone at low dose (5 mg/L)
- Removal may increase (↗) or decrease (↘) with H_2O_2 addition or UV irradiation

⚠ Coexistence of **radical and molecular pathways**





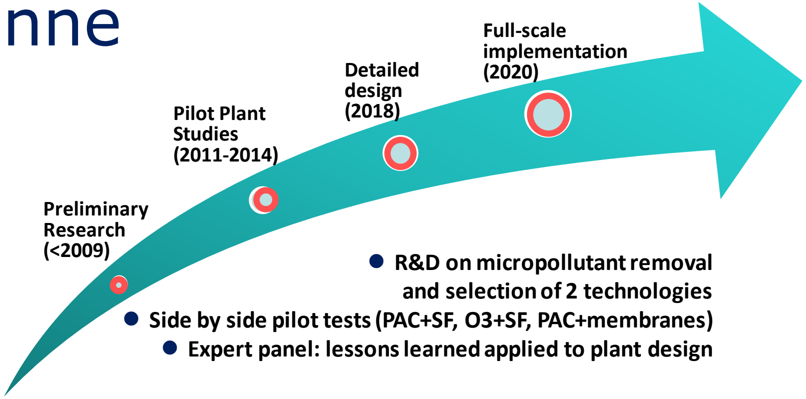
diazepam



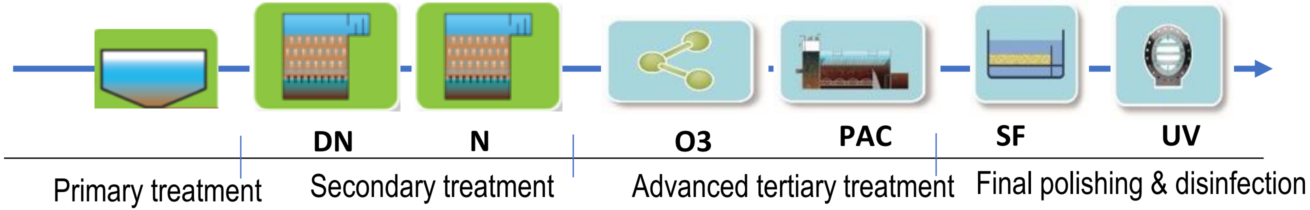
carbamazepine

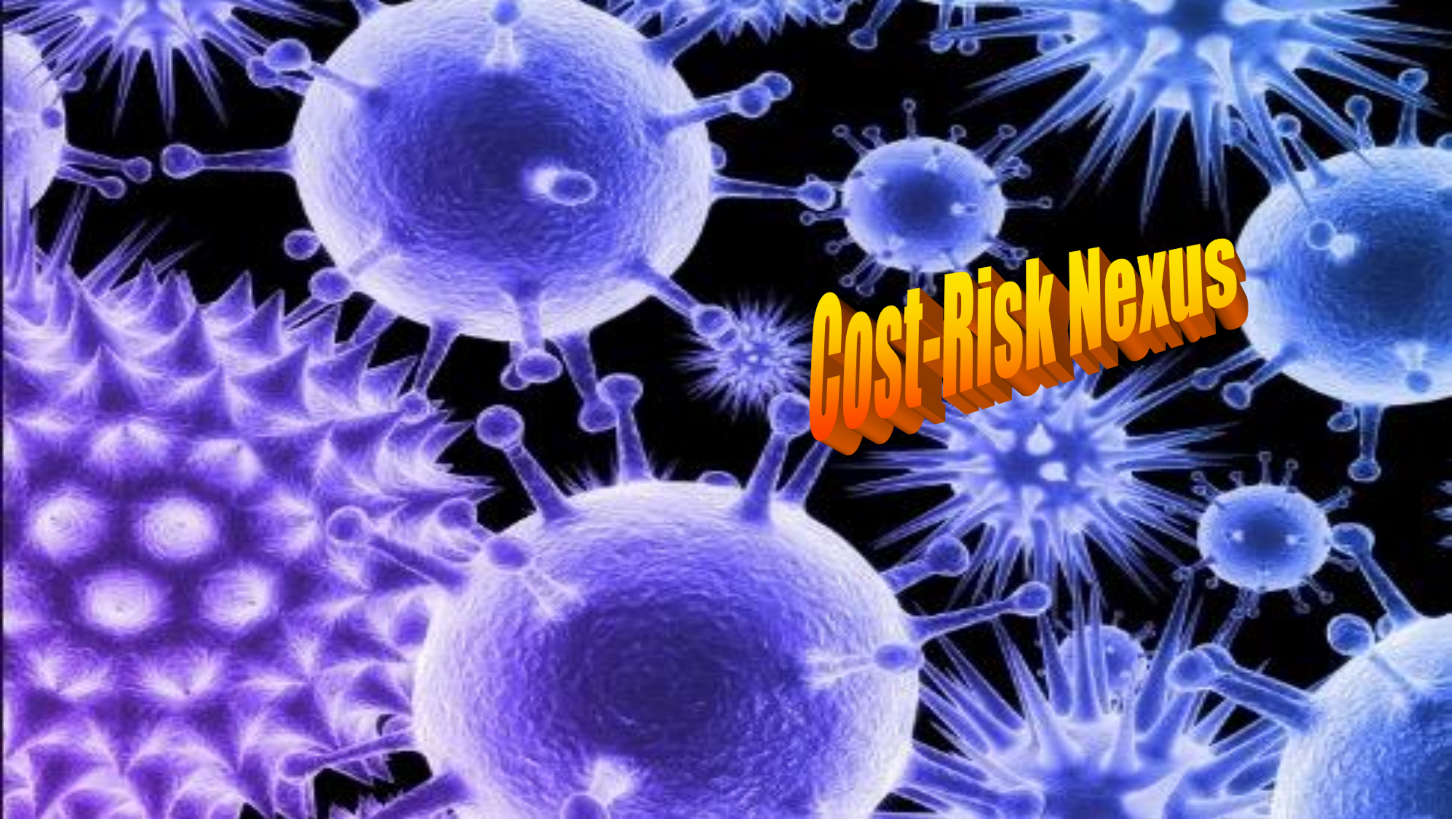
Source: Armistiq project

Production of High-Quality Recycled Water - The case of Lausanne



- Objectives
  - ✓ Leman Lake health protection and safety
  - ✓ Control of Capex and Opex
  - ✓ High reliability of operation and treatment flexibility
- Treatment solution
  - ✓ Enhanced primary treatment
  - ✓ Enhanced secondary treatment by biofiltration (DN+N)
  - ✓ Advanced tertiary treatment by ozonation, powdered activated carbon, sand filtration and final UV disinfection
    - Design capacity 8640 m^3/d
    - Water quality: <10 mgDOC/L, <100 *E.coli*/100 mL, <100 Enterococci/100 mL, 12 micropollutants (pharmaceuticals, additives, pesticides)




Cost-Risk Nexus

EU Minimum Quality for Agricultural Irrigation (EU regulation 2020/741)

Minimum reclaimed water quality class	Crop category	Irrigation method
A <10 *E.coli* /100mL	All food crops, including root crops consumed raw and food crops where the edible part is in direct contact with reclaimed water	All irrigation methods
B <100 *E.coli* /100mL	Food crops consumed raw where the edible part is produced above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops including crops to feed milk- or meat-producing animals	All irrigation methods **Alfafa, corn, potatoes….**
C <1000 *E.coli* /100mL		Drip irrigation* only
D	Industrial, energy, and seeded crops	All irrigation methods

- Class A & B for all type of crops
- Maturation ponds are excluded (class C)

Very difficult in practice:
Drip irrigation needs filtration

EU regulation 2020/741 – Microbial Performance Targets for Agricultural Irrigation

- WHO 2006: theoretical credit for log removal
- Australia 2006: log removal is impossible to measure inlet-out of the reclamation plant, includes the addition barriers
- France 2010: 4 log removal inlet-outlet of the reclamation plant, impossible to demonstrate

Reclaimed water quality class	**Indicator microorganisms (*)** **EU regulation 2020/741**	**Performance targets for the treatment chain (log_{10} reduction)**
A	*E. coli*	≥ 5.0
	Total coliphages/ F-specific coliphages/somatic coliphages/coliphages(**)	≥ 6.0
	Clostridium perfringens spores/spore-forming sulfate-reducing bacteria(***)	≥ 5.0

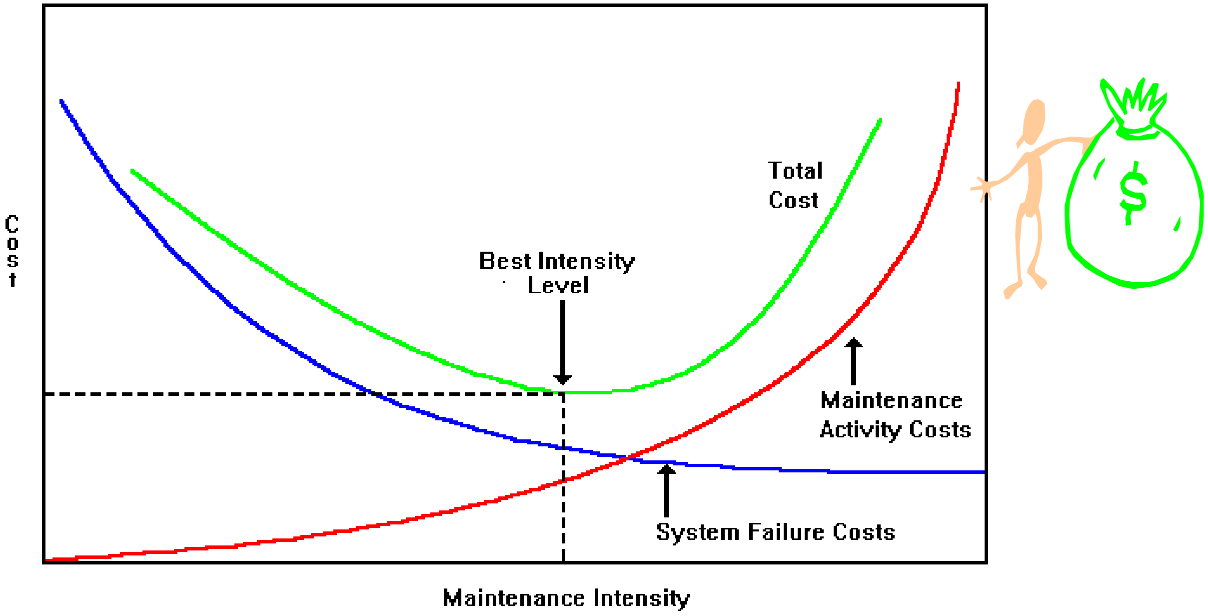
(*) The reference pathogens Campylobacter, Rotavirus and Cryptosporidium can also be used for validation monitoring purposes instead of the proposed indicator microorganisms. The following log_{10} reduction performance targets should then apply: Campylobacter (≥ 5.0), Rotavirus (≥ 6.0) and Cryptosporidium (≥ 5.0).

(**) Total coliphages is selected as the most appropriate viral indicator. However, if analysis of total coliphages is not feasible, at least one of them (F-specific or somatic coliphages) has to be analyzed.

(***) Clostridium perfringens spores is selected as the most appropriate protozoa indicator. However sporeforming sulfate-reducing bacteria is an alternative if the concentration of Clostridium perfringens spores does not allow to validate the requested log10 removal.

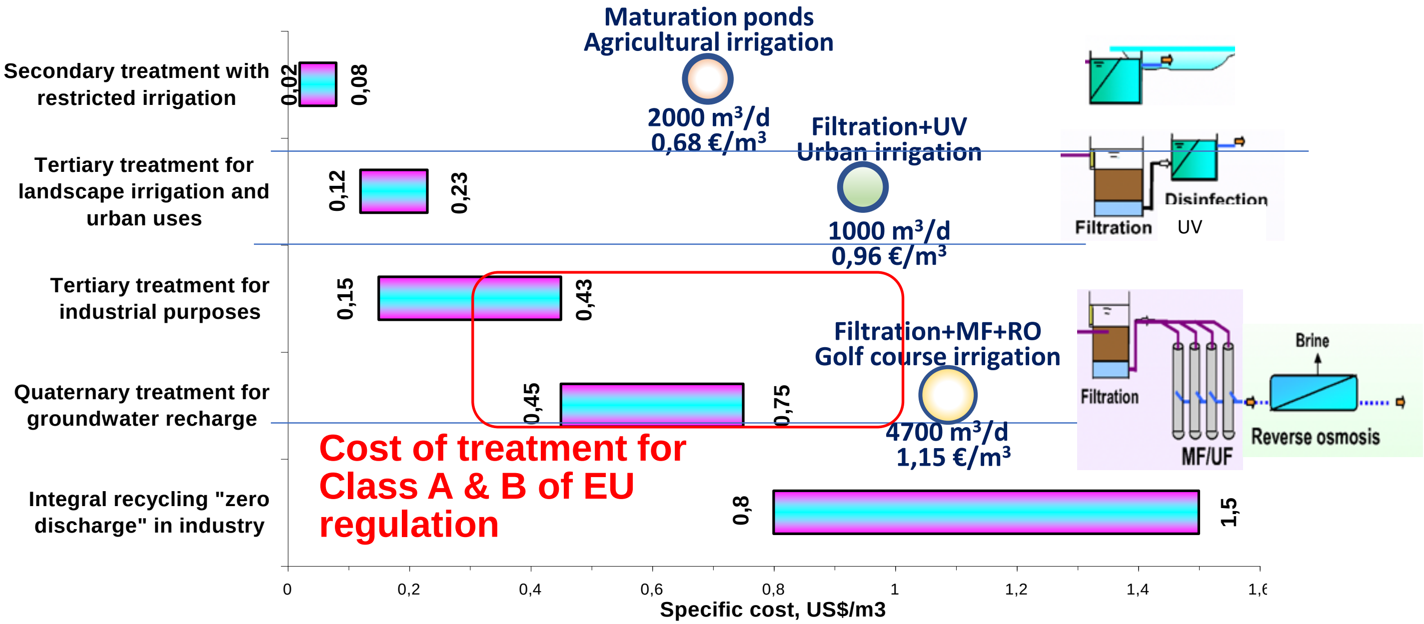
Towards Zero Health Risk

- Increasing health risk requirements (theoretical basis)
- **Risk of failures should be minimised with reasonable O&M costs**



Cost of Water Reuse

Range of treatment costs for water reuse (without distribution costs)



(Data 2005)

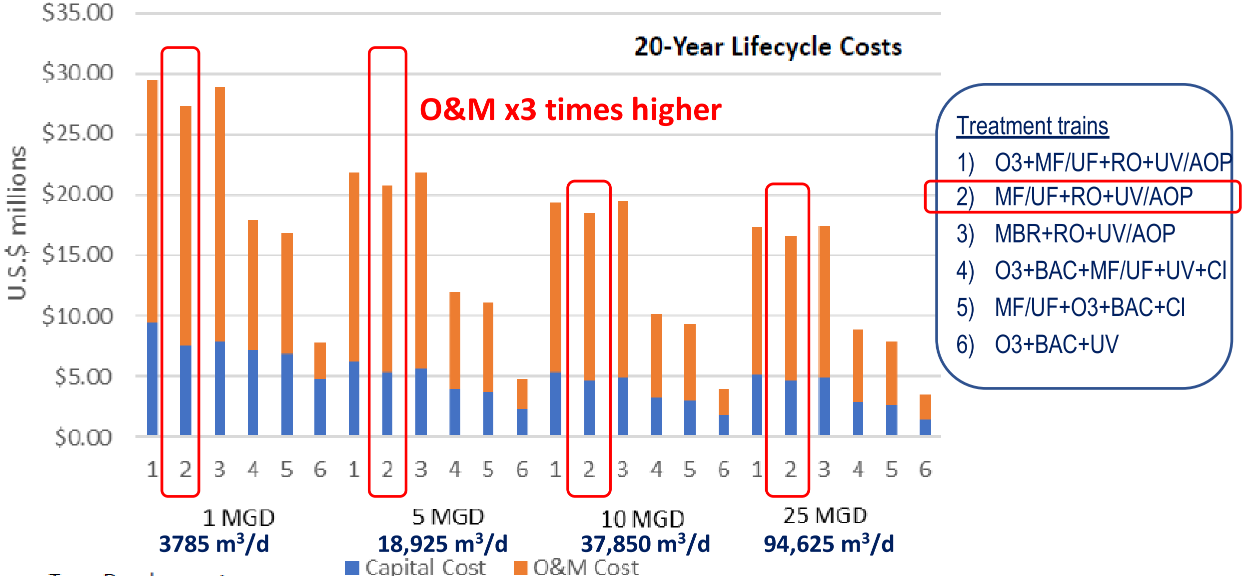
Theoretical estimation for plant capacity of 40,000 m³/d

O&M Costs of Advanced Water Reuse

❖ O&M costs increase with increasing treatment intensity

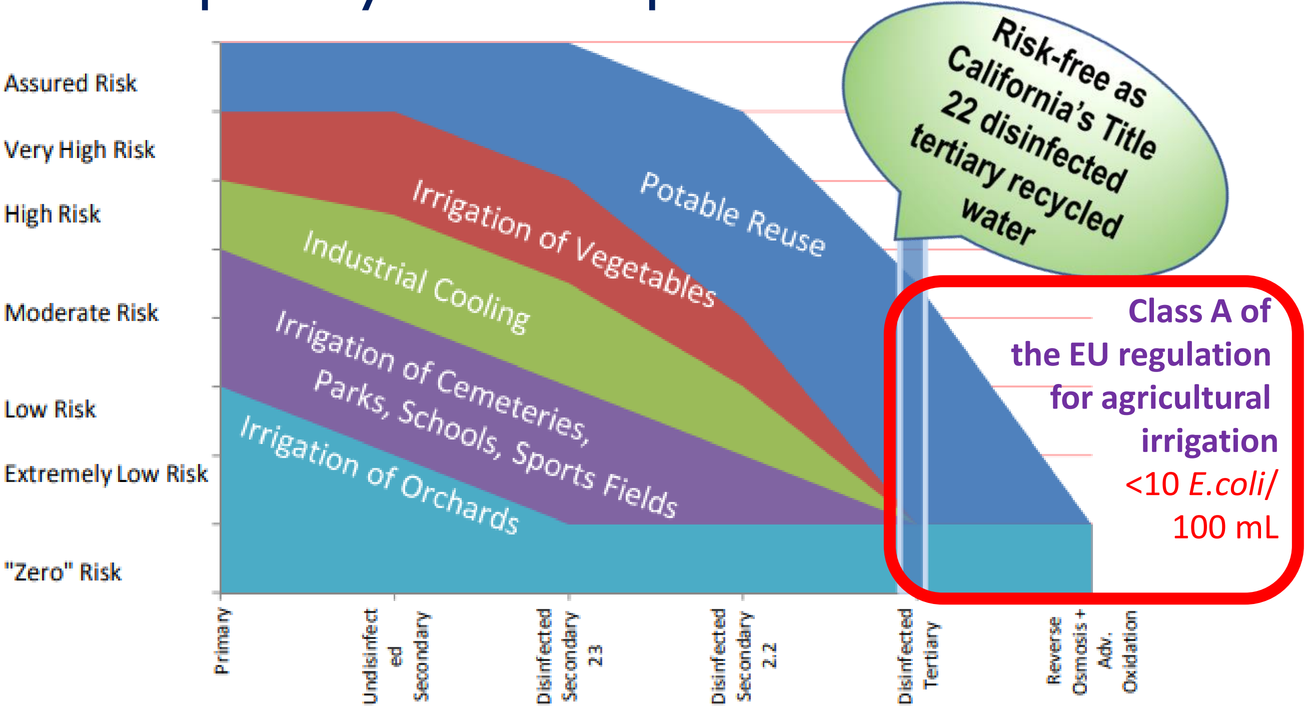
✓ California: 1,22-1,78 $/m³ for DPR plant capacity <34,000 m³/d; 0.89-1.3 $/m³ for large plants

✓ Texas: 0.105-1.00 $/m³ depending on size O&M costs representing 39 to 82% of lifecycle costs



Source: Texas Development Board, 2015.

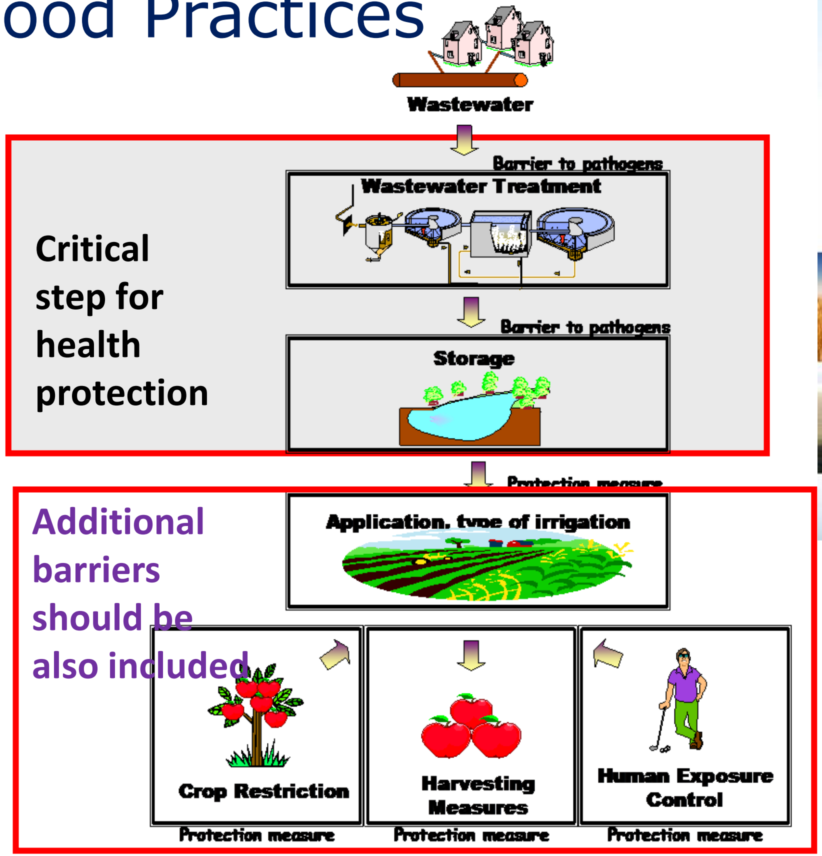
Ensuring Recycled Water Safety - Risk, recycled water quality and required treatment

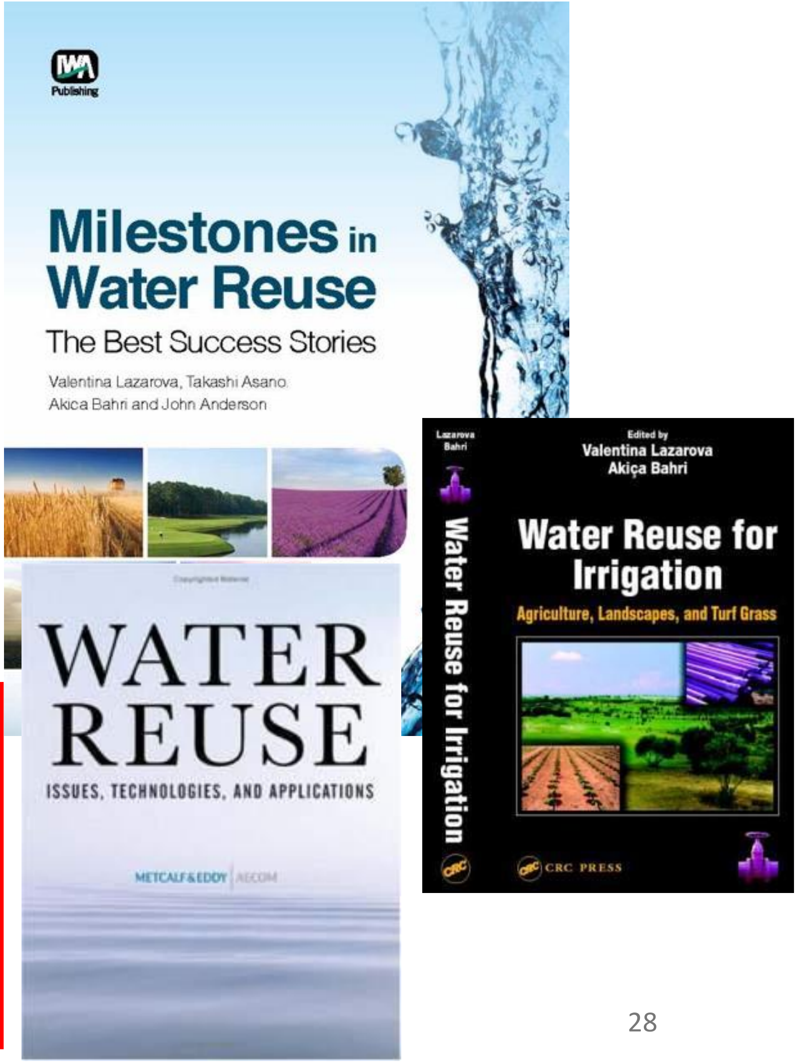


Qualitative risk level associated with each level of treatment and for each type of water reuse (US experience)

Concluding Remarks

How to Succeed Water Reuse ? - Cost Efficiency and Good Practices





Global Water Reuse Technology Innovation Needs

- **Improvement** of reliability, performance, flexibility and robustness **of existing technologies**
  - ✓ MBR, biofiltration, advanced oxidation, UV disinfection….
  - ✓ Multi-barrier membrane treatment (MF/RO, UF/RO…)
- **New cost and energy effective technologies** for conventional and advanced treatment
  - ✓ N&P removal and recovery, micropollutants removal, new membranes…
  - ✓ Small scale and rural facilities – ease of operation
- **Improved monitoring** of water quality and process performance
  - ✓ On-line monitoring and new surrogate parameters
  - ✓ Broad-spectrum analysis of pathogens, emerging contaminants, toxicity, bioassays…
  - ✓ Analytical methods for nanoparticles, microplastics, antibiotic resistance, trace organics…


Thank You!