# IWRM DaMe
# BI-REGIONAL IWRM DIALOGUE AND MULTI-LOCAL TWINNING FOR SMALL SCALE WATER SUPPLY AND REUSE IN SUB-RIVER BASINS OF THE DANUBE AND MEKONG

*First Conference "Integrated Water Management: Technical Solutions for Small Settlements in Sub-River Basins of the Danube and Mekong"*

## Technologies applicable in Integrated Water Management for small settlements and reuse

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# **SPECIFICS** & **CHALLENGES** IN SMALL SCALE WATER SUPPLY MANAGEMENT

## SPECIFICS

- in general
  - Population growth
  - Urbanization
  - Water shortages
  - Irrigation
  - Industry
- in Bulgarian Sub-River Basins of the Danube
  - Negative population growth
  - Aging population
  - Low income
  - Agricultural areas
  - No industry

## CHALLENGES

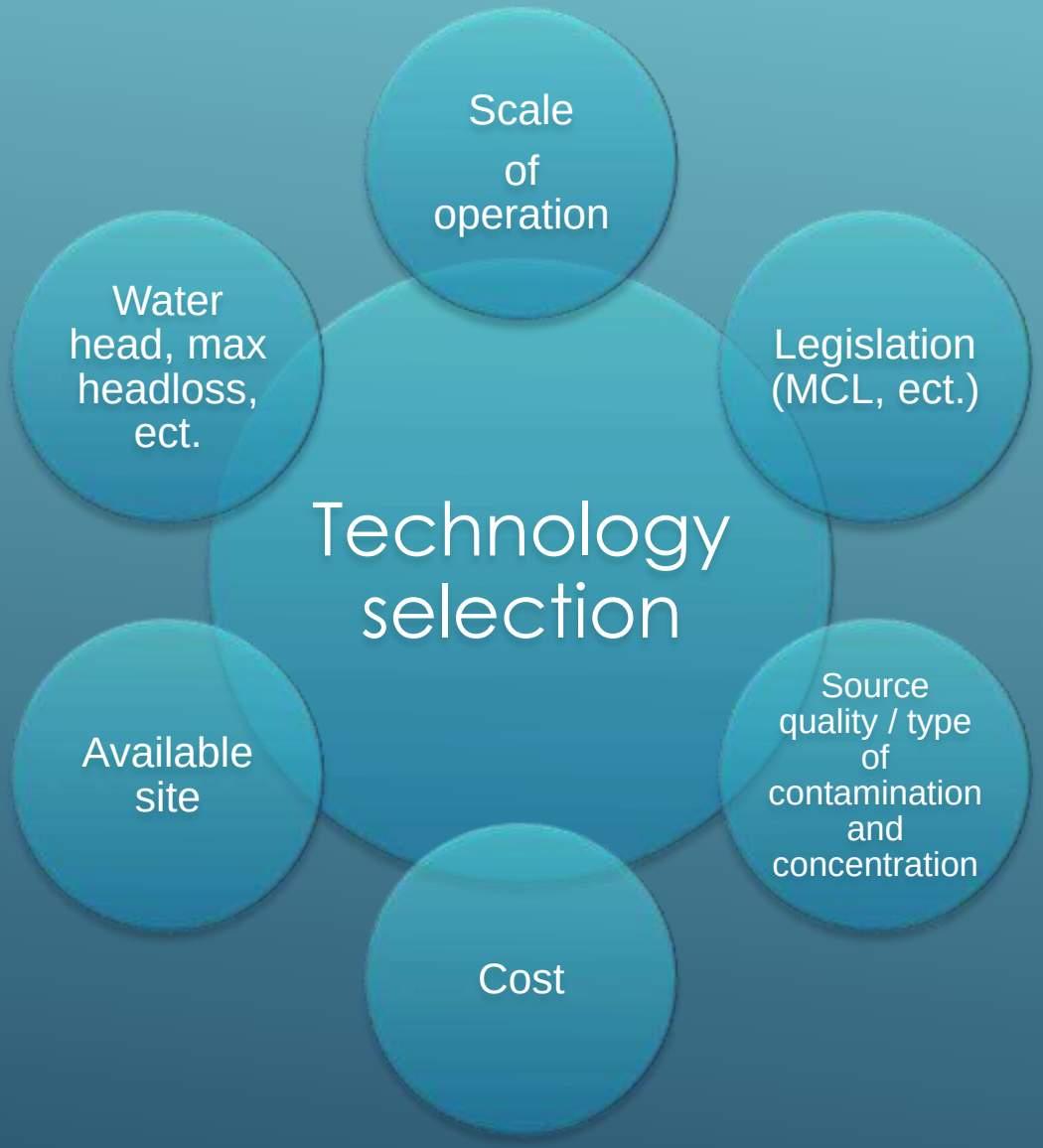
- in general
  - Climate change
  - Automated, low maintenance solutions
  - Simple, but effective technologies
- in Bulgarian Sub-River Basins of the Danube
  - Lack of qualified operating staff
  - Funding
  - Communication between stakeholders
  - Social acceptance of IWRM & reuse

# **PROBLEMS** IN SMALL SCALE WATER SUPPLY MANAGEMENT IN BULGARIAN SUB-RIVER BASINS OF THE DANUBE

- Variable flow of surface water sources → Seasonal water scarcity
- Variable quality of surface water sources → Seasonal turbidity
- Constant flow of subsurface water sources
- Constant pollution of some subsurface water sources
  - Natural source (chromium, manganese, arsenic)
  - Anthropogenic source (nitrates)
- Water loss over 50% of the distributed water
  - Deteriorating infrastructure
  - Illegal connections
- Low percentage of constructed sewerage and WWTP in small settlements

# **IWRM STRATEGIES** FOR SMALL SCALE WATER SUPPLY IN BULGARIAN SUB-RIVER BASINS OF THE DANUBE

# **DRINKING WATER TREATMENT TECHNOLOGIES** FOR SMALL SCALE WATER SUPPLY



# **DRINKING WATER TREATMENT TECHNOLOGIES** FOR SMALL SCALE WATER SUPPLY

## CONVENTIONAL TREATMENT TECHNOLOGIES

| | |
|---|---|
| Settling | • Colloidal particles and solids<br>• Turbidity<br>• Colour |
| Filtration | • Suspended particles<br>• Parasites<br>• Bacteria<br>• Algae<br>• Viruses and fungi |
| Disinfection | • Microbial contamination<br>➢Fecal coliform<br>➢Escherichia Coli,<br>➢Legionella,<br>➢Giardia lamblia<br>➢ Cryptosporidium V<br>➢Viruses |
| Reagent mixing | • Coagulants<br>• Flocculants<br>• Base / Acid |

# **DRINKING WATER TREATMENT TECHNOLOGIES** FOR SMALL SCALE WATER SUPPLY

## MEMBRANES

| | |
|---|---|
| Microfiltration (MF) | • Turbidity<br>• Algae<br>• Bacteria<br>• Giardia<br>• Cryptosporidium |
| Ultrafiltration(UF) | • Asbestos<br>• Viruses<br>• Organic macromolecules<br>• Chlorine resistant bacteria |
| Nanofiltration (NF) | • Hardness<br>• Colour<br>• Nitrates, arsenic<br>• Radioactive isotopes<br>• Organic chemicals<br>• Trihalomethanes, pesticides, PFAS |
| Reverse osmosis (RO) | • Salts<br>• Ions |

# **DRINKING WATER TREATMENT TECHNOLOGIES** FOR SMALL SCALE WATER SUPPLY

## ION EXCHANGE

| | |
|---|---|
| Strong - base anion (SBA) exchange resign | • $R\text{-}N^+$ functional group<br>• Removes all anions in hydroxide form, nitrates and sulfates in chloride form<br>• Total exchange capacity from 1,0 to 1,5 eq/L [$Cl^-$] |
| Weak – base anion (WBA) exchange resin | • $R - NH_3^+$ or $R - NH_2^+$ functional group<br>• After cation exchange removes chlorides, sulfates, nitrates and other anions of strong acids, but do not remove anions of weak acids<br>• Total exchange capacity from 1,1 to 1,7 eq/L [free base] |
| Strong - acidic cation (SAC) exchange resign | • $SO_3^-$ functional group<br>• Removes hardness in sodium form<br>• Removes all cations in hydrogen form<br>• Total exchange capacity from 1,9 to 2,2 eq/L [$Na^+$] |
| Weak - acidic cation (WAC) exchange resign | • $R - COO^-$ as functional group<br>• Divalent ions from solutions containing alkanity<br>• Total exchange capacity from 3,7 to 4,5 eq/L [$H^+$] |

# **DRINKING WATER TREATMENT TECHNOLOGIES** FOR SMALL SCALE WATER SUPPLY

## BIOLOGICAL TREATMENT

- Heavy metals (arsenic (As), copper (Cu), zinc (Zn), nickel (Ni), chromium (Cr) and plumbum (Pb))
- Natural organic matter
- Disinfection by-products (trihalomethanes (THMs) and haloacetic acids (HAA))
- Nitrogen compounds, sulfate, Fe&Mn
- Microbial contamination (fecal coliform and Escherichia Coli, Legionella, Giardia lamblia, Cryptosporidium and viruses)
- Endocrine disrupting chemicals (EDCs)

| | |
|---|---|
| Fixed biofilm systems | • Slow and rapid sand biofiltration in anaerobic condition<br>• Biological Activated Carbon (BAC)<br>• Trickling filter (TF)<br>• Biological aerated filter (BAF) |
| Suspended growth systems | • Membrane bioreactor (MBR)<br>• Moving bed biofilm reactor (MBBR)<br>• Fluidized Bed Biofilm Reactor (FBBR) |
| Mixed systems | • Membrane coagulation bioreactor (MCBR)<br>• Biological Activated Carbon and Membrane Bioreactor (BAC-MBR) |

# DRINKING WATER TREATMENT TECHNOLOGIES FOR SMALL SCALE WATER SUPPLY

## COMPARISON

| Criteria | Technology / Score | | | |
|---|---|---|---|---|
| | Conventional | Ion exchange | Membrane | Biological |
| Eelectricity consumption | + | + | +++ | ++ |
| Complexity of operation | + | + | ++ | +++ |
| Installation area | +++ | + | + | ++ |
| Waste production | ++ | ++ | +++ | ++ |
| Sensitivity to change in inflow parameters | +++ | + | + | ++ |
| Investment costs | ++ | + | +++ | ++ |
| Operation costs | ++ | ++ | +++ | ++ |

+ low ++ moderate +++ high

# TYPES OF WATER FOR REUSE

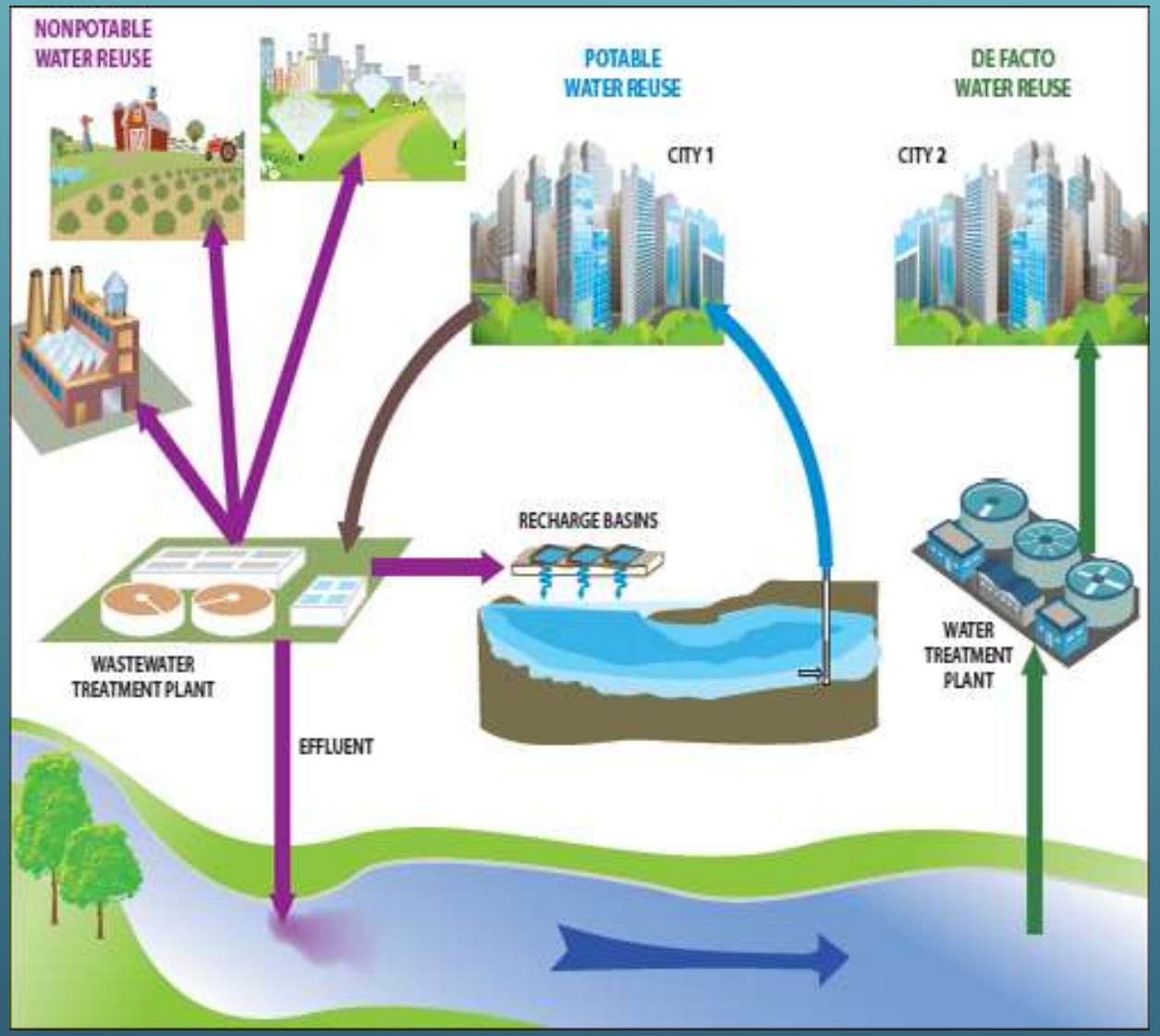
| | |
|---|---|
| Sewage | • Domestic wastewater<br>➢ High organic contamination<br>➢ Pharmaceuticals, drug metabolites, hormones, household chemicals, etc. |
| Graywater | • Domestic wastewater excluding toilet flush<br>➢ 50 - 80% of total household wastewater<br>➢ 30% of the organic fraction and from 9 to 20% of the nutrients of the domestic wastewater |
| Rain water | • Storm water runoff<br>➢ Low organic and inorganic contamination<br>➢ Fluctuating flow |
| Light greywater | • Mixed rain and grey water including only the sources from the bathroom |
| Industrial wastewater | • Cooling water, condensation of steam, washing, production, etc.<br>➢ Specific quality (very high to moderate contamination)<br>➢ Specific water flow |

# **REUSE** FOR SMALL SCALE WATER SUPPLY

## REUSE SCHEMES

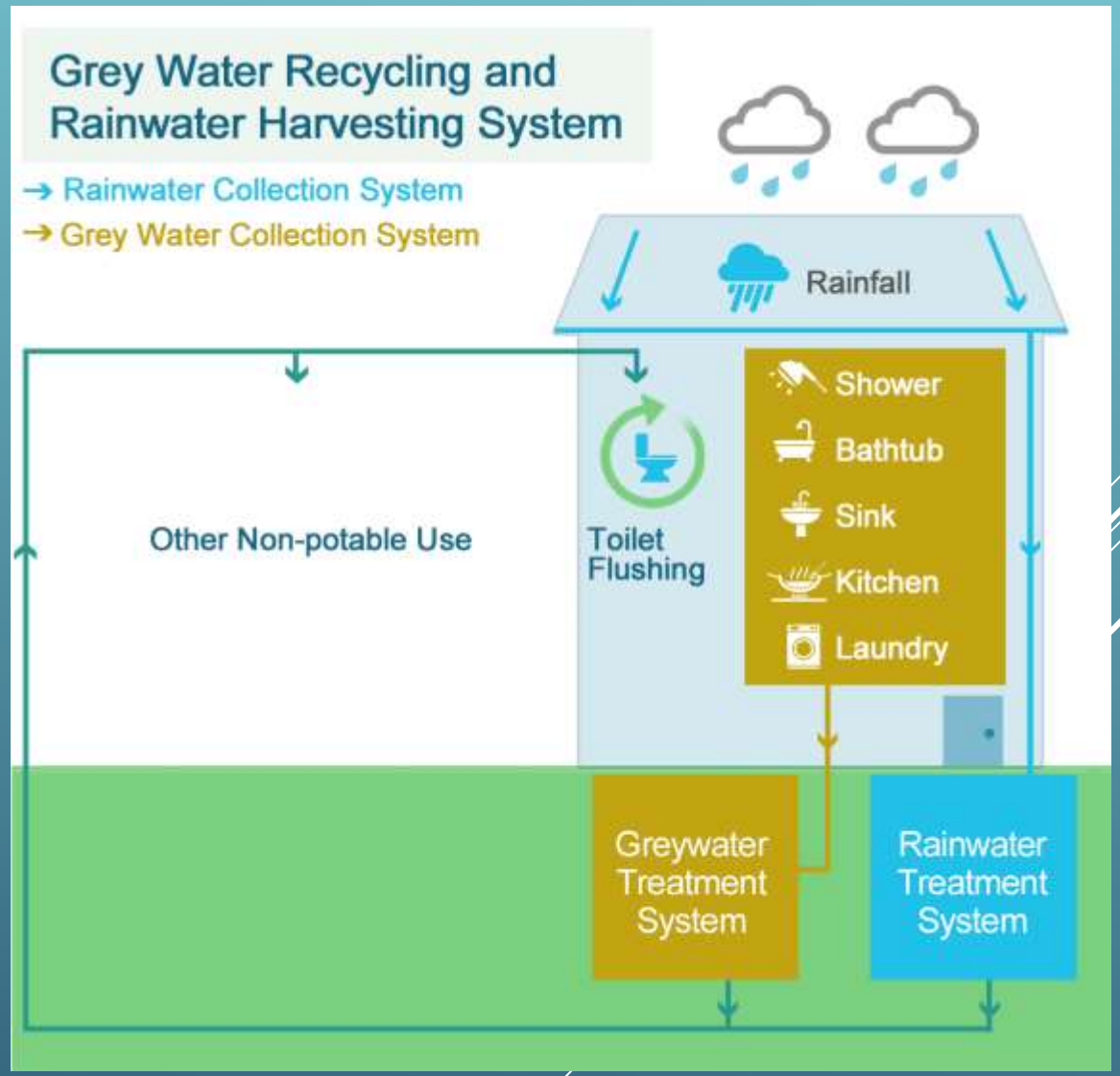
| | |
|---|---|
| De facto reuse | • Downstream communities use surface water as a drinking water source that has been subject to upstream wastewater discharge |
| Nonpotable reuse | • Recycled or reclaimed water that is not used for drinking but is safe to use for irrigation or industrial processes |
| Indirect potable water reuse | • Recycled or reclaimed water that is discharged in the water source after advanced treatment |
| Potable reuse | • Recycled or reclaimed water that is safe for drinking |

# LARGE SCALE REUSE



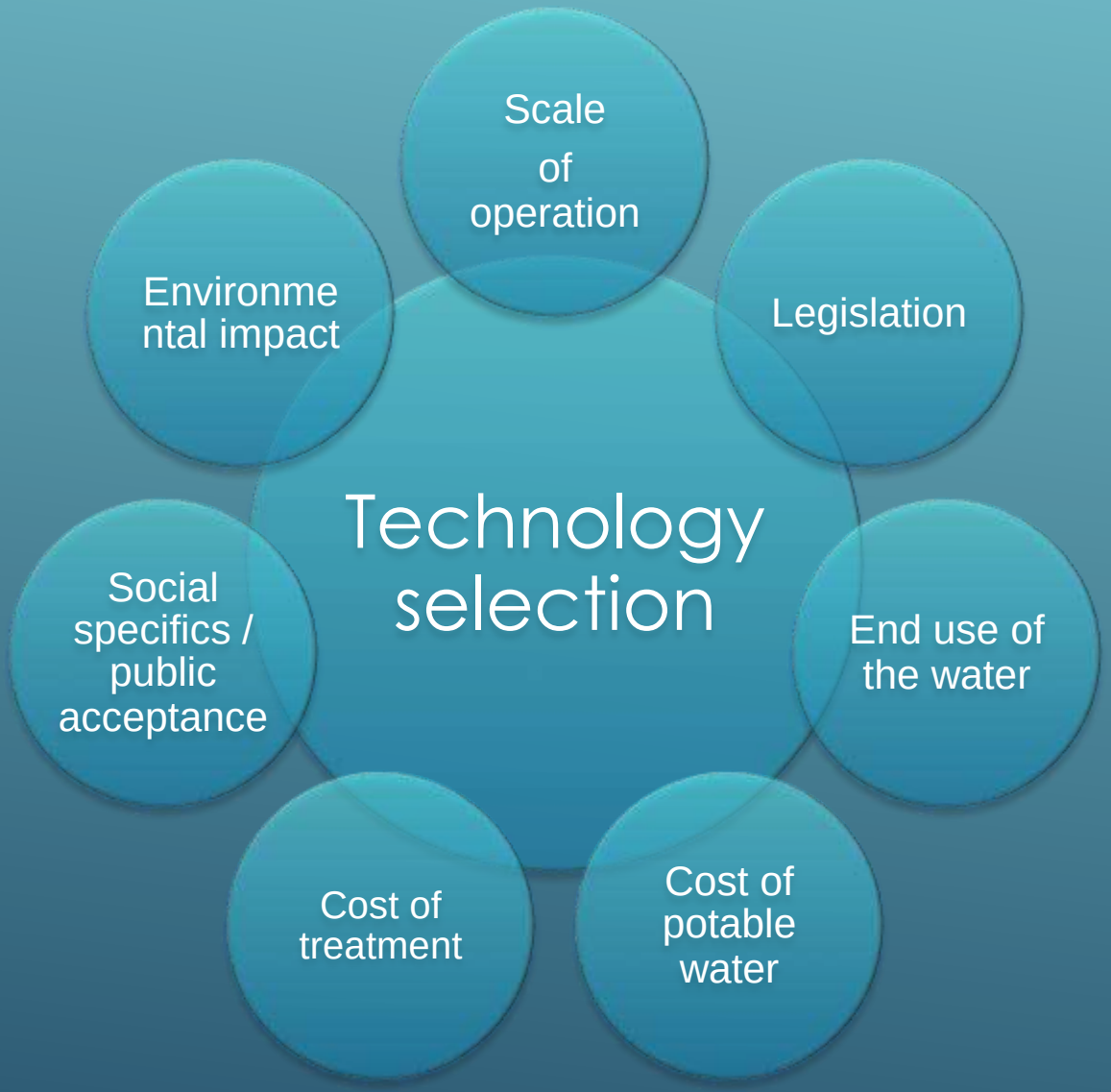

https://nap.nationalacademies.org/read/13514/chapter/1

# INDIVIDUAL REUSE




https://www.wsd.gov.hk/en/core-businesses/water-resources/recycled-water/index.html

# **REUSE** FOR SMALL SCALE WATER SUPPLY



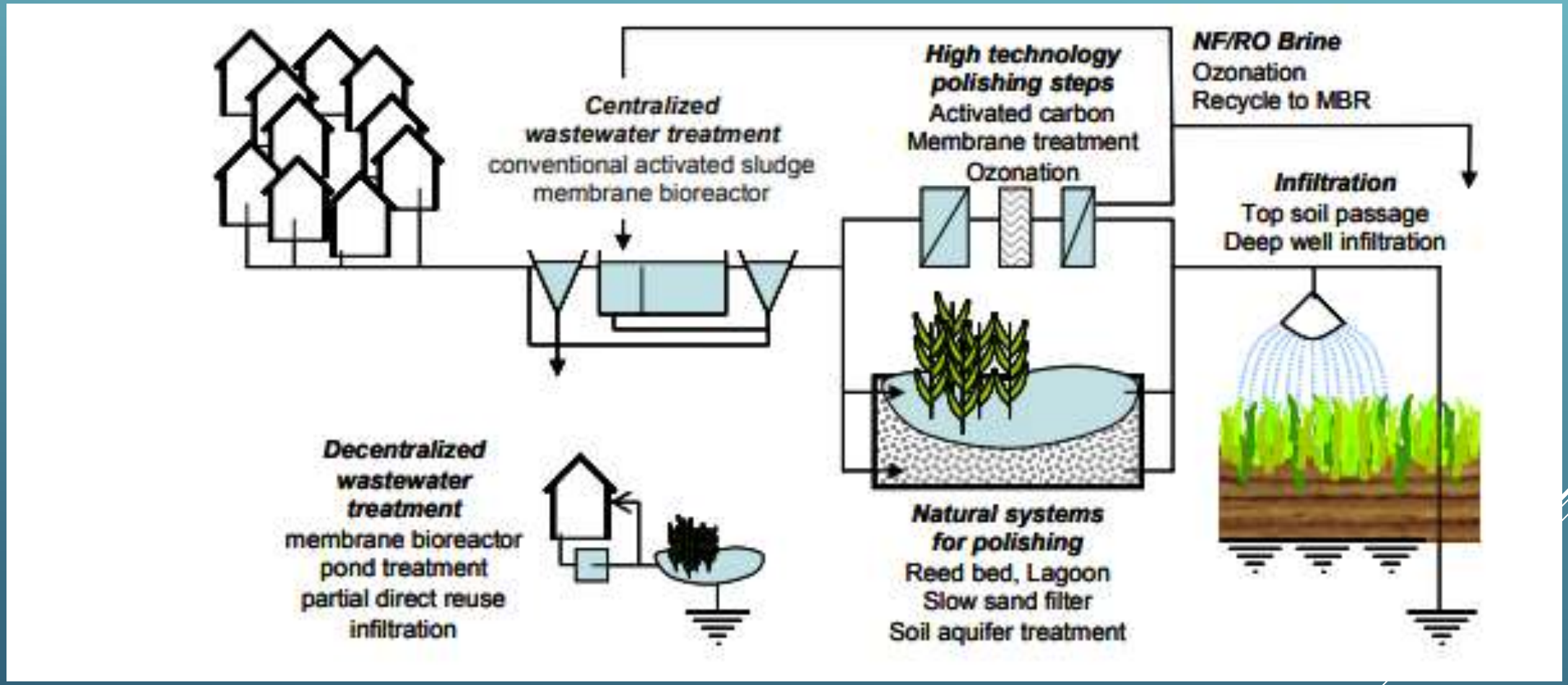
# **REUSE** FOR SMALL SCALE WATER SUPPLY

## TECHNOLOGIES

| | |
|---|---|
| Physical treatment | • Screening<br>• Filtration (membranes)<br>• Adsorption<br>• Ozone<br>• Disinfection |
| Chemical treatment | • Coagulation<br>• Flocculation<br>• Electrocoagulation<br>• Photocatalysis |
| Biological treatment | • Conventional activated sludge<br>• Rotating biological contactor<br>• Biofiltration<br>• Biological activated carbon |
| Advanced technologies | • MBR<br>• Oxidation (H2O2/ozone, UV/H2O2, ect.)<br>• Sub – surface processes |
| Extensive technologies | • Reed beds<br>• Lagoons<br>• Wetlands<br>• Quasi-natural water cycle |

# **REUSE** FOR SMALL SCALE WATER SUPPLY

## EXAMPLES



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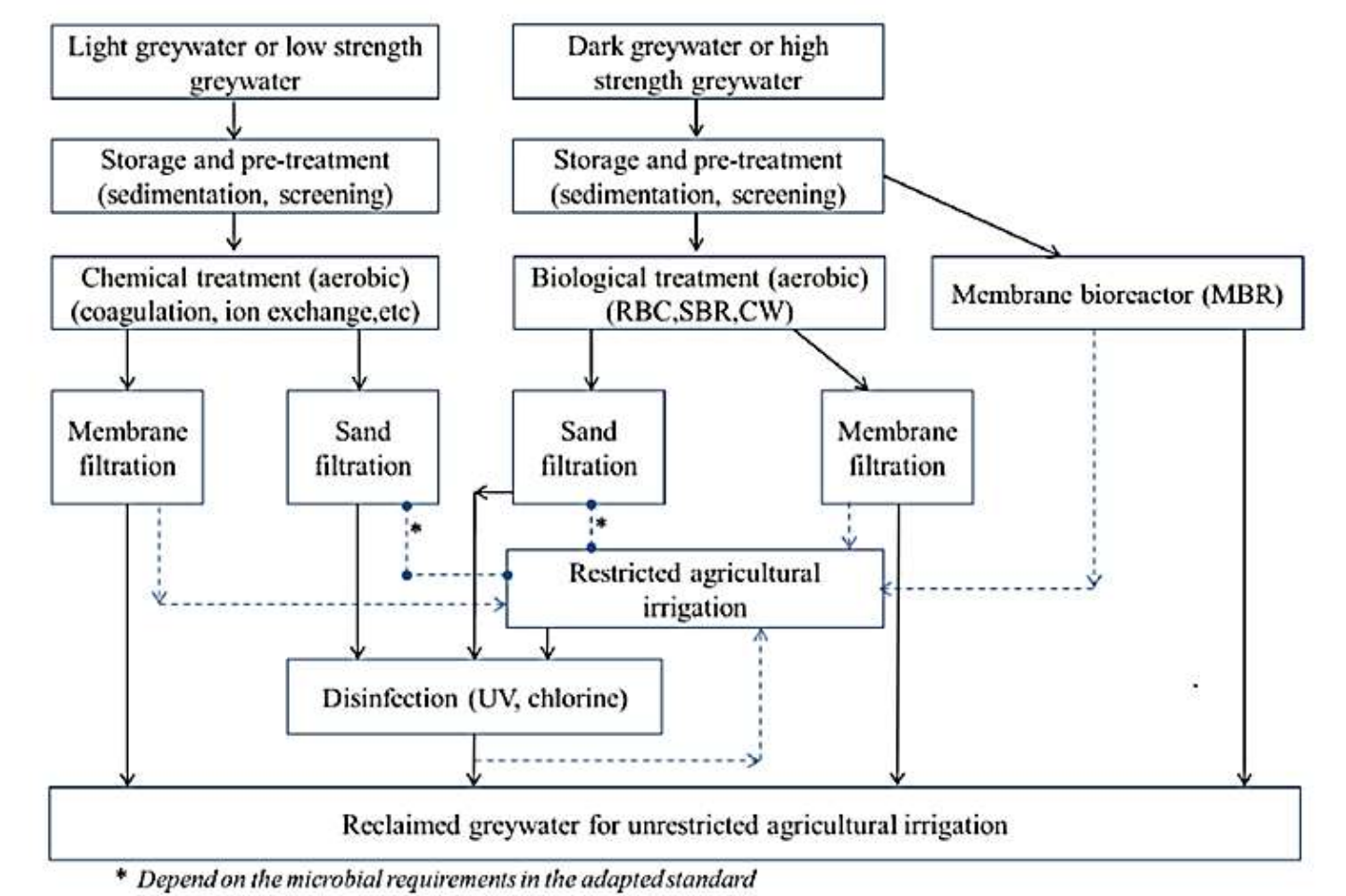


Possible greywater recycling scheme for agricultural irrigation reuse purposes

https://www.sciencedirect.com/science/article/pii/S0048969709001594

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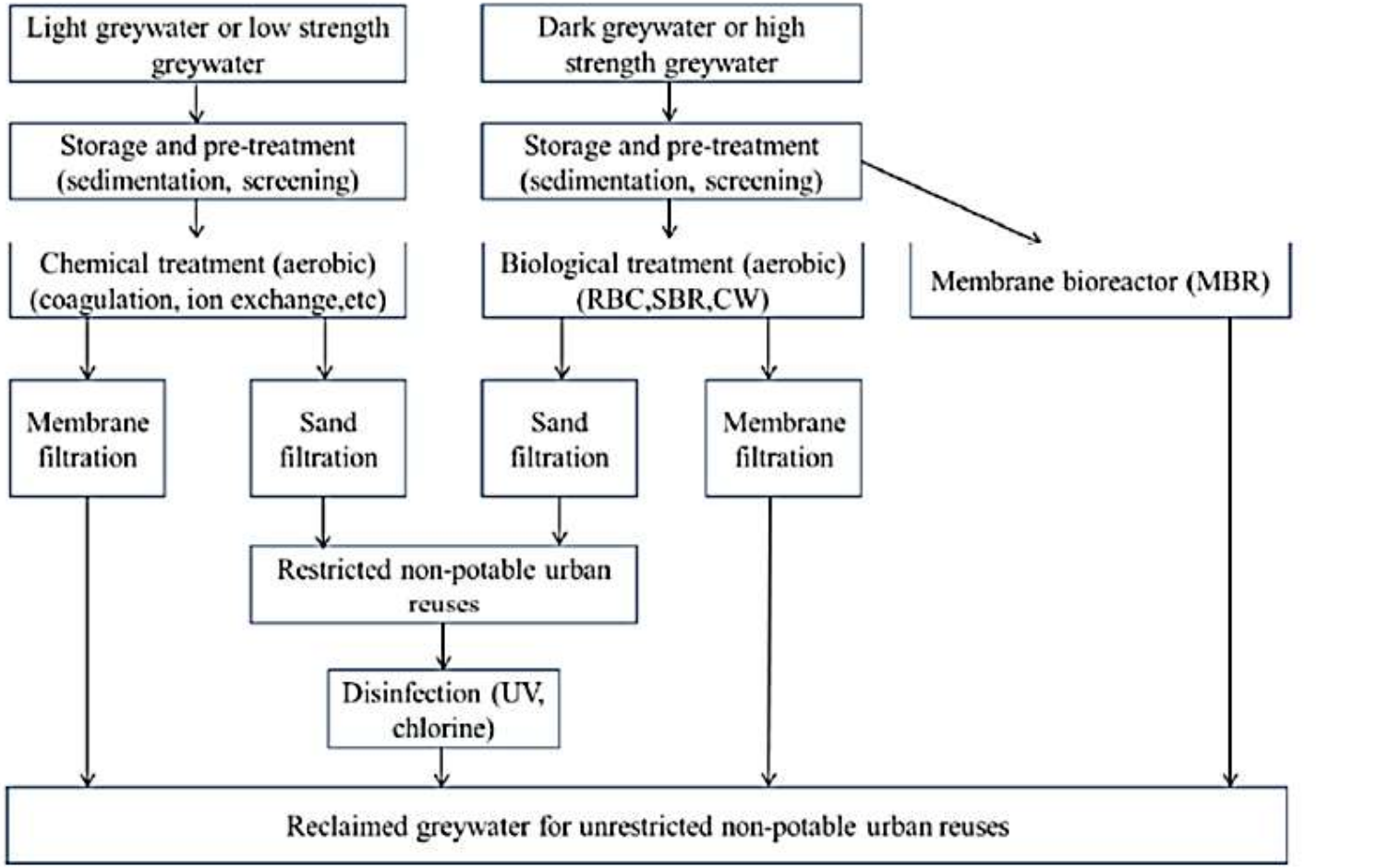


The greywater recycling scheme for non-potable urban reuse purposes

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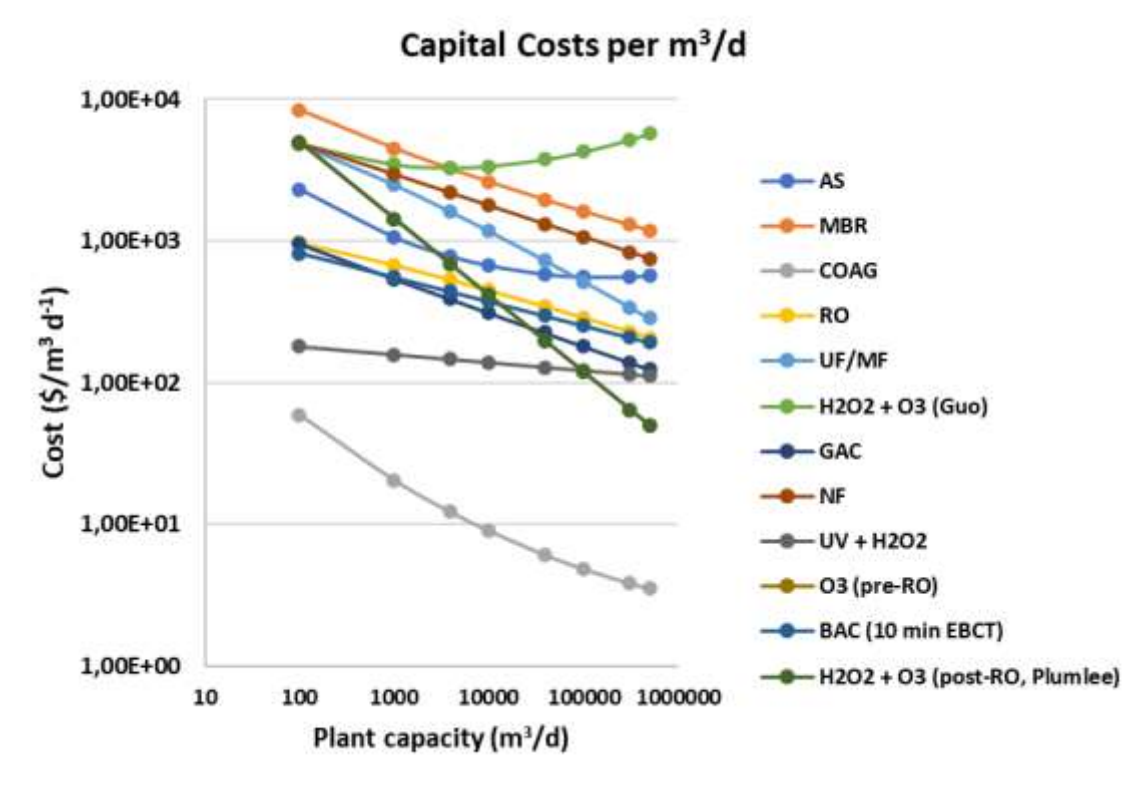
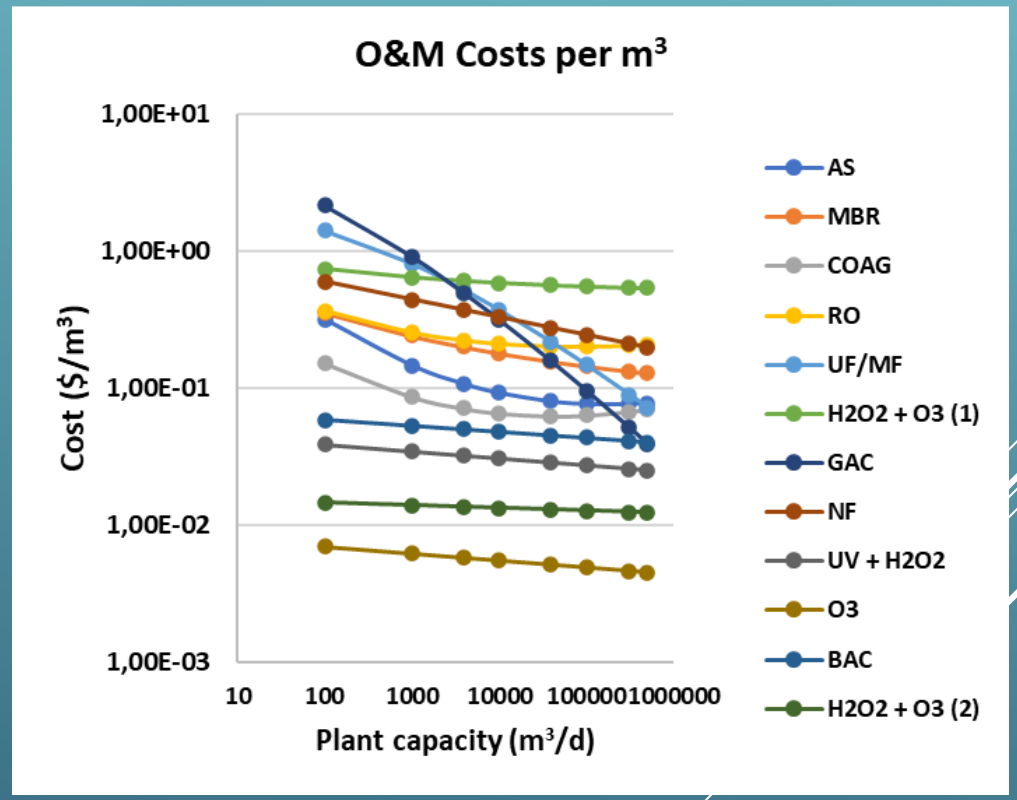
## COSTS




*RO = reverse osmosis, UF/MF = ultrafiltration/microfiltration, MBR = membrane bioreactor, AS = activated sludge, COAG = coagulation, H2O2 + O3 (1) = peroxone, and GAC = granular activated carbon.9 From Plumlee et al.: NF = nanofiltration, UV + H2O2 =ultraviolet + hydrogen peroxide, O3 = ozone, BAC = biologically activated carbon, and H2O2+O3 (2) = peroxone*
*All costs adjusted for inflation to 2021.*

https://pubs.acs.org/doi/10.1021/acsestengg.1c00258

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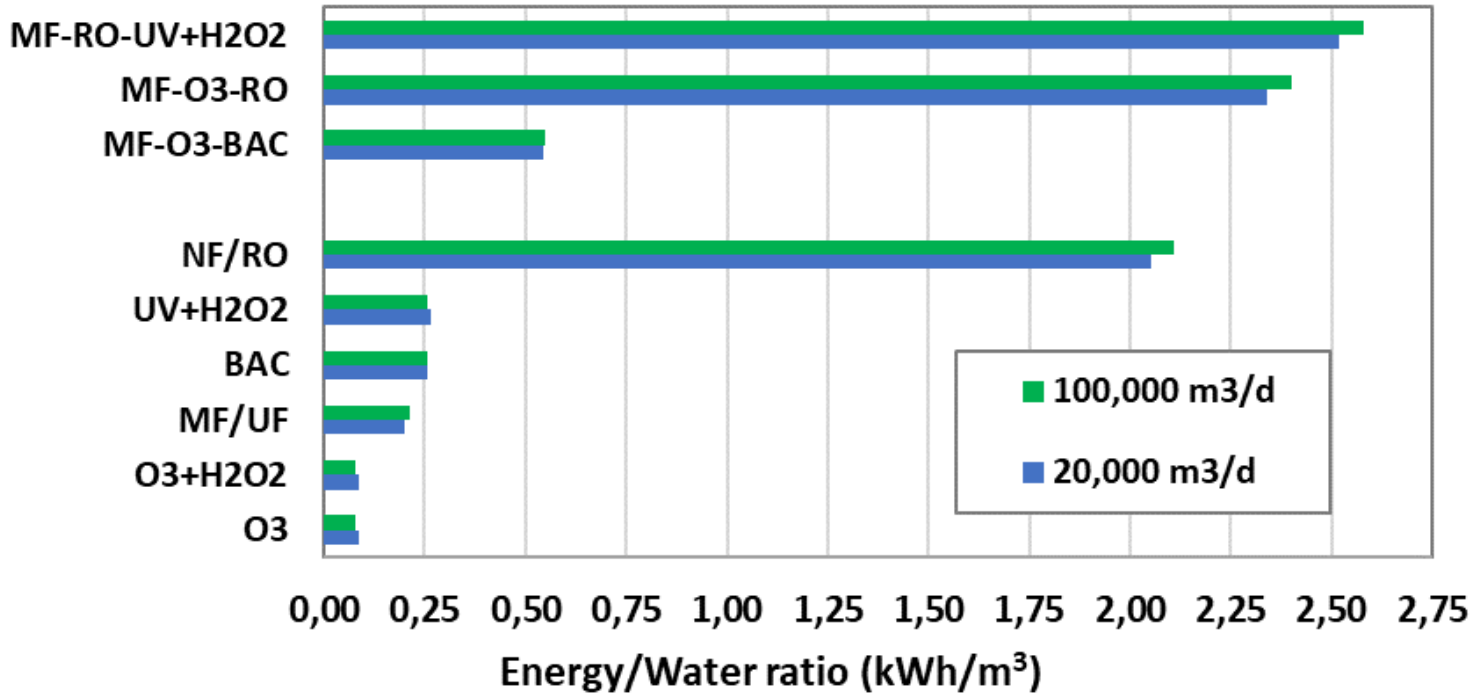


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# TECHNOLOGIES APPLICABLE IN INTEGRATED WATER MANAGEMENT FOR SMALL SETTLEMENTS AND REUSE

## CONCLUSIONS

Membrane technologies are proven to be a highly effective method for removal of various pollutants from contaminated drinking water of small settlements, but reduction in cost and energy is a challenge.

Ion exchange is a competitive solution where applicable.

Biological methods are promising.

The combination of aerobic biological process with physical filtration and disinfection is considered to be the most economical and feasible solution for water recycling.

MBR and BAC are another very attractive solution for small settlements.

Regardless of technology excellence, the implementation of IWRM and reuse starts with changing the attitude of all stakeholders towards water.

# THANK YOU FOR YOUR ATTENTION !