Technical Guide on Technologies for Non Conventional Water Resources Management

Global Water Partnership
Mediterranean

Developed by Global Water Partnership - Mediterranean
in the framework of the Non Conventional Water Resources Programme,
supported by The Coca-Cola Foundation.

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Foreword

Water is a finite resource. In the Mediterranean, water is also a scarce resource. The gap between water availability and demand, in a context of increasing pressures and climate change impacts, dictates the exploitation of non conventional water resources to cover secondary, non-potable uses.

In ancient civilisations, rainwater harvesting was already a standard practice to provide water, also for drinking. From Crete to Northern Egypt and Jordan, as early as in Bronze Age (2200-1200 B.C), local wisdom drove people to build cisterns to collect rainwater, enough to cover the following dry period. Storing water for longer periods of water scarcity became possible during Iron Age (1200-600BC), when plaster was created from mixing locally available earth materials.

Since then, technology advanced, new materials were developed, new techniques were invented. Yet, the principles of rainwater harvesting remain the same: all you need is a catchment surface, conveyors and appropriate storage space to harvest water for the dry season. Options range from traditional cisterns – handcrafted, stone, or concrete – to modern modular tanks. Selecting the most appropriate option to collect and reuse rainwater, depends on both technical and financial factors, as well as time constraints.

Greywater, on the other hand, is largely an untapped resource. It is generated from showers or bathtubs, washbasin and washing machines and is collected separately from the sewage flow. Due to its lightly polluted character, it can be easily treated and reused for secondary uses, like landscaping and toilet flushing. Greywater technologies have evolved in the past years, offering a variety of options from small systems for domestic use to industrial solutions, serving medium and large-scale facilities, such as hotels, sports complexes, etc.

The current publication comprises the technical know-how we acquired throughout the 10-year implementation of the Non Conventional Water Resources Programme (NCWR) in the Mediterranean by GWP-Med and aims to serve as a quick reference guide on rainwater harvesting and greywater recycling systems. The Guide features various types and technologies, outlining selection and design criteria that can be helpful for professionals as well as individuals, who are exploring non conventional water resource solutions at domestic and community level.

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NCWR Programme Coordinator

Contents of the technical guide

i.

Introduction

This technical guide has been developed by GWP-Med to inform and educate practitioners, planners, and engineers to understand commonly available technologies for rainwater harvesting and greywater recycling. This guide also aims to help the selection of suitable technologies according to the desired end water uses and local conditions.
This guide includes a list of most common technologies for rainwater harvesting and greywater recycling. Most of the listed technologies are based on a comprehensive literature review, as well as experience from the "Non Conventional Water Resources Programme in the Mediterranean" and are considered as best practices in different parts of the world.
The technical guide contains information for the technologies and includes:

- Brief description
- Design criteria
- Working principles
- Applicability
- Advantages and disadvantages.

Signs which show applicability of technologies in:

Household Level

Community Level

Rural level

The "Non Conventional Water Resources Programme in the Mediterranean" (www.gwpmed.org/NCWR) is a multi-stakeholder programme designed and implemented by GWP-Med in partnership with the local and national authorities in Cyprus, Greece, Italy and Malta and with the support of The Coca-Cola Foundation. The programme aims at advancing the use of non conventional water resources (NCWR) as a sustainable and cost effective practice for climate change adaptation and water security at local level.

A.

Rainwater Harvesting (RWH)

What is rainwater harvesting?
Rainwater harvesting refers to the collection and storage of rainwater for reuse on-site (usually) rather than allowing it to run off. It is a practice used from ancient times and is suitable for areas with annual average rainfall of more than 400 mm.

Why harvest rainwater?
Modern rainwater harvesting systems – properly managed and maintained – are completely safe and yield good quality water. By using rainwater, one can increase water availability and reduce water demand from the water supply network through its subsequent use for non-potable applications, such as toilet flushing, irrigation, car washing, as well as to increase soil moisture levels for urban greenery, mitigate urban flooding and improve the quality of groundwater.

How can one harvest rainwater?
Rainwater can be collected from a roof's building or other catchment surfaces. Rainwater is then channeled through gutters and pipes to a storage tank. The tank can be made from a variety of inert materials. The preferred location of the storage tank is below ground, sheltered from daylight, as this minimizes algae growth in the stored water.

A1

Operating components of a RWH system

Basic Operating Principles
A conventional rainwater harvesting system consists of the following basic elements:

a. Catchment surface
b. Conveyance system
c. Storage facility
d. Delivery system

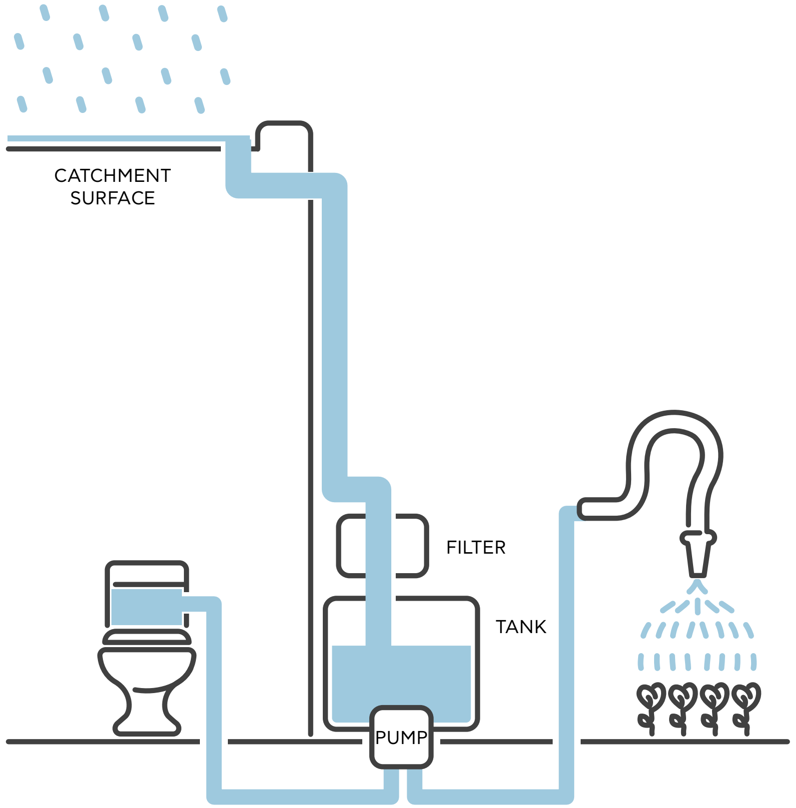

Fig.1: Simple schematic diagram of a catchment surface including conveyance system and storage facilities

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a. Catchment surface:
The catchment surface is the first point of contact of rainwater. The catchment surface area in most cases is the roof of a house or a building. The roof area and the material used in constructing the roof influence the efficiency of rainwater harvesting and the quality of collected water.
Catchment material: Catchment surface should be made of nontoxic material; the smoothest the texture of the area, the more water is collected.
The following materials are recommended:
• Concrete and clay tiles. To reduce water loss, tiles must be painted or coated with a sealant. A special sealant has to be coated on the roof to prevent bacterial growth on porous material.
• Metal roofs. They are always recommended because they easily shed contaminants and their texture is smooth enough for water collection.
• Slate. Its smoothness makes it ideal for a catchment surface for potable use.
• Wood shingle, tar, asphalt, gravel. They are rare roofing materials and the water collected is used only for irrigation.

b. Conveyance system:
Rain gutters are the easiest way to convey rainwater from the rooftop. Rain gutters are typically installed just under the edge of the roofing material and are connected to a downspout that conveys the collected rainwater from the rooftop to the storage area. Chemically inert materials must be used. The most common material used for gutters and downspouts are: PVC, vinyl, seamless aluminum, and galvanised steel. The size of the rain gutters and method of installation depend on the shape of the catchment surface.

c. Storage facility:
Rainwater is ultimately collected in a storage tank which may be constructed as part of the building, or may be built as a separate unit located some distance away from the building. The tank should be made of inert materials.
Suitable materials include: reinforced concrete, fiberglass, or stainless steel. For the good operation of the system and the good quality of the water stored, the storage system should also include:

- Solid secure cover
- Coarse inlet filter
- Overflow pipe
- Extraction system that does not contaminate the water; e.g. tap or pump
- Manhole, sump, and drain to facilitate cleaning.

Designing the tanks:
As rainwater supply depends on the annual rainfall, roof surface and the runoff coefficient, the volume of rainwater that can be collected and thus the size of the tank can be calculated using the following formula:

Annual rainwater yield (L)
=
rainfall (mm/year)
x
area (m^2)
x
runoff coefficient.

Typical runoff coefficient values for roof rainwater harvesting depend on the surface material. Examples are supplied below:

Roof material	Typical runoff coefficient value
Metal	0.8 - 0.9
Clay tiles	0.5
Concrete	0.75 - 0.9
Gravel	0.8 - 0.85

d. Delivery system:
The end use of the rainwater is required to be decided in order to install a suitable delivery system. It can be used for a number of secondary uses, as summarised below:
i) Using rainwater outdoors
The most common use for harvested rainwater, with minimal filtering first, is for outdoor water uses:
- Landscape irrigation
- Farming
- Car washing
- Fire suppression & protection
- Yard cleaning

ii) Using rainwater in the house
Rainwater can be filtered to specific standards depending on its use and make a good source of water for indoor secondary uses, such as:
- Washing machines
- Toilets
- Showers and baths

A2
Rainwater Harvesting reservoirs

Design criteria:
Rainwater harvesting reservoirs vary in terms of size and materials used. The selection criteria are the:
a. amount of water to be collected and stored
b. water demand for the specific water source
c. cost for the technology

Most commonly used types of rainwater harvesting storage tanks are:
- Concrete tanks
- Plastic tanks
- Metal tanks
- Rain barrels
- Open water reservoirs
- Modular underground tanks

A2.1

Concrete tanks

Concrete tanks are used both in rural and urban areas. The main characteristic of underground concrete tanks is that they are constructed to collect large volumes of water in land tight for space, where above-ground tanks cannot be accommodated or where a cooler water storage is required. They are mainly used for communities, but can also serve private properties.

The rainwater stored can be used for secondary uses such as:

- Irrigation
- Toilet flushing
- Car washing
- Outdoor washing

Fig.2:
Above: Maintenance of the main municipal water reservoir in Kastellorizo, Greece (source: GWP-Med)
Left: Construction of a concrete reservoir in Astypalea, Greece (source: GWP-Med)

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A2.1a

Advantages and disadvantages of concrete tanks

Advantages

- Underground or overground constructions
- Special treatment for drinking purpose
- Tailormade customisation

Disadvantages

- High building cost
- Long building times
- High maintenance cost
- Stagnant water
- Spatial restrictions
- Building permits

A2.2

Plastic tanks

Plastic tanks are commonly used both in rural and urban areas. The simplicity of their structure allows them to be installed easily. The plastic tanks are ideal for storing rainwater for:

- Emergency backup
- Fire suppression & protection
- Toilet flushing
- Landscape irrigation
- Car washing
- Outdoor washing

Fig.3:
Above: Plastic rainwater harvesting tank installed by UNICEF-Rwanda. (source: E. Dusingizumuremyi, SuSanA Secretariat)
Left: Plastic rainwater harvesting tank installed in Anafora, Cairo (Source: Mariela Antonakopoulou)

A2.2a

Advantages and disadvantages of plastic tanks

Advantages

- Light structure
- Low cost for small sizes
- Quick installation
- Easy transportation
- Easy maintenance
- Suitable for drinking

Disadvantages

- Fragile
- Stagnant water
- High cost for large sizes
- Limitations in pipe connections

A2.3

Metal tanks

Metal tanks are frequently used in rural areas for rainwater harvesting and storm water management. The rainwater is mainly used for farming, washing and other secondary water uses.

Fig. 4:
Metal tanks have been installed in Ios, Folegandros, Sikinos, Tilos; here the cases of Sikinos (above) and Tilos (below)
(source: GWP-Med)

A2.3a

Advantages and disadvantages of metal tanks

Advantages

- Easy transportation
- Easy and quick installation
- Reasonable cost
- Variety of sizes
- Easy maintenance

Disadvantages

- Water evaporation if not covered
- Stagnant water
- Tank stability
- Salt water sensitivity effects

A2.4

Rain barrels

Rain barrels belong to the category of Low Impact Development (LID) technologies. LID is an approach for land development and retrofit strategy that focuses on protection from flooding through the use of mild interventions which reduce storm water runoff in densely built landscapes. Rain barrels can be used as rainwater infiltration systems, small rain gardens and small reuse systems.
Water may be used as a resource for:

- Recharging groundwater
- Irrigation
- Other household uses.

Fig. 5:
Rain barrel installed in a kindergarten in Andros Island, Greece (source: GWP-Med)

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A2.4a

Advantages and disadvantages of rain barrels

Advantages	Disadvantages
Natural system/ Simple technology	Requires professional expertise
Urban landscaping	Frequent maintenance
Increase of property value	Risk of clogging due to sedimentation
Microclimate improvement	

A2.5

Open water reservoirs

Open water reservoirs are barriers that impound rainwater, stormwater and stream runoff. These reservoirs may be utilised for:

- Water supply
- Irrigation
- Flood control
- Navigation
- Sediment control

The multipurpose of the open water reservoirs is significant for big rural communities, and offer domestic and economic benefits to the population.

Fig. 6:
Above: Open water reservoir of Nisyros island, Greece
Left: Open water reservoir of Astypalea island, Greece
(source: GWP-Med)

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A2.5a

Advantages and disadvantages of open water reservoirs

Advantages

- Large water volume
- Long lifespan
- Multiple water and recreational uses
- Flood and drought protection

Disadvantages

- Water evaporation
- Stagnant water
- Repairing difficulties
- Requires professional expertise and design
- Spatial constrains
- Environmental impact

A2.6

Modular underground tanks

The **modular underground tanks** use surface and underground infiltration techniques to store water that can be reused or allowed to re-enter the natural water system. This can enable urban flood protection as well as groundwater enriching. Mitigating urban flooding and also enriching ground water. The tank comprises of three-dimensional fittings of cubic form units that have a 95% capacity because of the lightweight skeletal structure of each unit. The units are made of recycled polypropylene, a high resistance and sustainable material. The system has a long lifespan of approximately 20 years. Rainwater stored can be used for secondary uses such as:

- Irrigation
- Toilet flushing
- Car washing

Fig. 7:
Above: Installation of a modular tank in Syros Island, Greece. (source: GWP-Med)
Left: Modular tank assembling (source: GWP-Med)

A2.6a

Installation and use of modular underground tanks

Installation begins with site excavation and base preparation. The base is then covered with a layer of thin sand to a depth of 100 mm. A nonwoven geotextile and/or a geomembrane are installed on the base. The modules are assembled to the desired configuration and placed within the excavation. Piping is installed and then the geotextile and/or the geomembrane are wrapped around the installed modules. Clean sand backfill is placed around the sides and above the tank.
The subsurface nature of the modular tanks frees up space for surface landscaping, driveway or parking lot use while meeting the storm water detention requirements of an area.

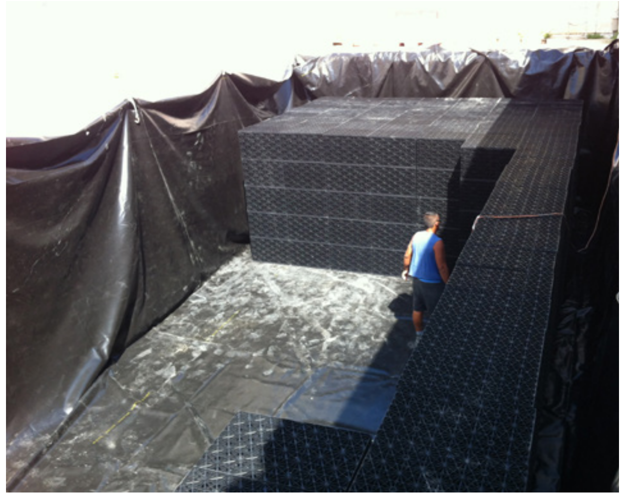

Fig. 8: Installation of a modular tank in Gozo, Malta (source: GWP-Med)

A2.6b

Advantages and disadvantages of modular underground tanks

Advantages

- Easy transportation
- Quick and flexible installation
- Overcomes spatial constraints
- Ideal for integrated urban water management
- Creation of green areas
- Low installation and maintenance cost
- Ideal for retrofitting in buildings

Disadvantages

- Variety of dimensions and shapes
  Not easily accessible
- Installed and repaired by experts
- Maintenance / repair may require excavation

B.

Greywater recycling

What is greywater recycling?

Greywater recycling is the practice of reusing wastewater generated from residential, commercial and industrial bathroom sinks, bath tub and shower drains, and washing machine equipment drains for secondary uses in households, communities and industries. Greywater recycling is a sustainable approach for water resources management and can be cost-effective in the long term.

Why recycle greywater?

Recycling greywater helps to increase water availability, reduce water demand from municipal water supply and decrease wastewater load of sewerage systems. Also, recycling and reusing water on site or nearby, reduces the energy needed for water and wastewater transportation and for pumping groundwater.

How can greywater be treated?

Depending on the end use of the treated greywater, one has to select a treatment process. Greywater can be treated with **physical, chemical or biological processes**. Most treatment units reported in the literature are based on physical processes (i.e. sedimentation and disinfection), while the more advanced ones incorporate chemical and biological treatment. More advanced greywater treatment technology developed is based on **membrane bioreactors**. Only a few off-the-shelf systems are commercially available and few are tested on full scale for long time periods.

B1

Physical greywater treatment

Physical greywater recycling systems consist of compartments for water settling and different gravel filter bed units with a plant/grass cover on top. These systems are mainly used in household level in rural environments. It is recommended the water is only used for secondary water uses.

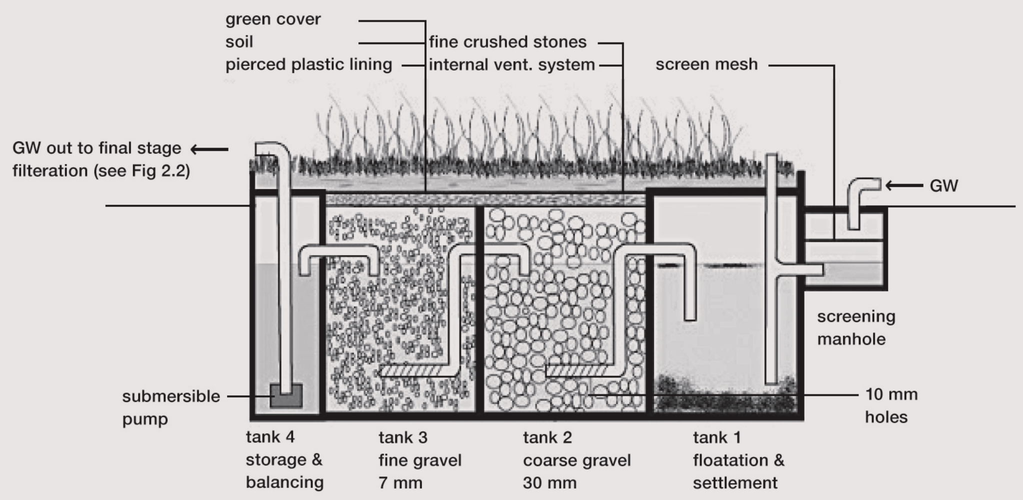

Fig.9:
Physical greywater recycling system (Original source: Physical greywater treatment system used in Qebia Village, Palestine (Source: Burnat and Eshtayah, 2010)

B1.a

Physical greywater recycling systems – Operating components

Design Criteria

The design of a physical greywater recycling system depends on the:

- Quality and quantity of the greywater to be treated
- End use of the treated greywater

Main operating principles & components:

a) Collection tank of greywater

Greywater and black water pipelines have to be separated. The greywater is collected in a special water storage tank before its treatment process. The size of the tank depends on the water treated.

b) Main treatment process

Physical treatment.

c) Storage facilities

Treated greywater is ultimately stored in a tank ready to be reused. The size of the tank depends on the amount of water treated.

d) End uses

Recycled water can be used for:

Surface irrigation of orchards and vineyards, non-food crop irrigation, groundwater recharge of non potable aquifer, wetlands, wildlife habitat, stream flow augmentation, industrial cooling processes.

B1.b

Advantages and disadvantages of physical greywater recycling systems

Advantages

- Built and repaired with local material
- No chemical and electricity needed
- Lifespan of over than 5 years
- No flies or odors if used correctly
- Low capital and operation costs

Disadvantages

- Frequent monitoring
- Low reduction in pathogens, solids and organics
- Low public acceptance
- Limited water end uses

B2

Chemical greywater treatment

Greywater recycling systems are coupled with chemical treatment when used for outdoor urban irrigation where there is a chance of human exposure, such as green roofs or gardens and other household secondary uses. The chemical greywater recycling systems consist of storage tanks, filters, pumps and also incorporate activated carbon, clay filters and disinfection (e.g. chlorination, purification with ultraviolet radiation).

Fig. 10:
Above: Chemical greywater recycling system installed in Malta (source: GWP-Med)
Left: Chemical greywater recycling system installed in Cyprus (source: GWP-Med)

B2.a

Chemical greywater recycling systems – Operating components

Design Criteria

The design of a chemical greywater recycling system depends on various parameters, and most importantly on:

- Quality and quantity of the greywater to be treated
- End use of the treated greywater.

Main operating principles & components

a) Collection tank of greywater

Greywater and black water pipelines have to be separated. The greywater is collected in a special water storage tank before its treatment process. Size depends on the water treated. The material should be resistant to commonly used chemicals (e.g. chlorine).

b) Main treatment process

Chemical treatment.

c) Storage facilities

Treated greywater ultimately is stored in a tank ready to be reused. Size depends on the water treated.

d) End uses

Recycled water can serve as a source for secondary water uses with a possibility of human exposure, such as: food irrigation, toilet flushing, car washing, landscape and sports field irrigation, recreational areas and also for groundwater recharge.

B2.b

Advantages and disadvantages of chemical greywater recycling systems

Advantages

- High reduction in pathogens, solids and organics
- No flies or odors if used correctly
- Moderate operating cost depending on operating level

Disadvantages

- Expert designers
- Frequent monitoring by experts
- Low public acceptance
- High cost
- Special chemicals and electricity needs

B3

Biological greywater treatment with MBRs

Greywater recycling treatment with membrane bioreactors (MBRs) is a consolidated technology for biological treatment of greywater. The MBR combines biodegradation with membrane filtration for solid liquid separation. Due to its relatively low content of pollutants, greywater is easy to treat with MBRs. The pollutants are decomposed by the bacteria of the activated sludge tank. The treated greywater is then of high quality standards. The MBR is an innovative technology for greywater treatment due to its process stability and its ability to successfully remove pathogens.

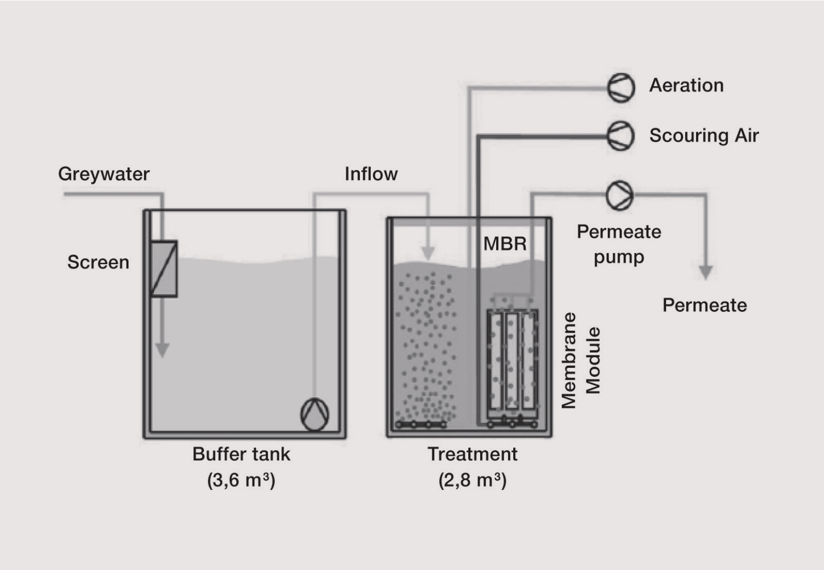

Fig.11:
Above: Scheme of greywater recycling system with MBR technology (source: Catalogue of Technologies for Integrated Urban Water Management, 2014)
Left: Greywater recycling plant with MBR technology, in Malta (source: SYSTEMA AZUD, S.A.)

B3.a

Greywater recycling systems with Membrane Bioreactors (MBRs) – Operating components

Design Criteria
The design of greywater recycling systems with MBRs depends on the:
- quality and quantity of the greywater to be treated
- purpose of the end use of the treated greywater.

Depending on the above, further criteria are taken into consideration:

- the type of low pressure membrane filtration used: microfiltration (MF) or ultrafiltration (UF) is used to separate effluent from activated sludge. Microfiltration (MF) or ultrafiltration (UF) membranes provide a higher degree of suspended solids and microbial removal. Especially UF membranes are effective for virus removal.

- MBR configurations: Internal/submerged membranes or external/sidestream circulation. The submerged are more often used in domestic wastewater treatment.

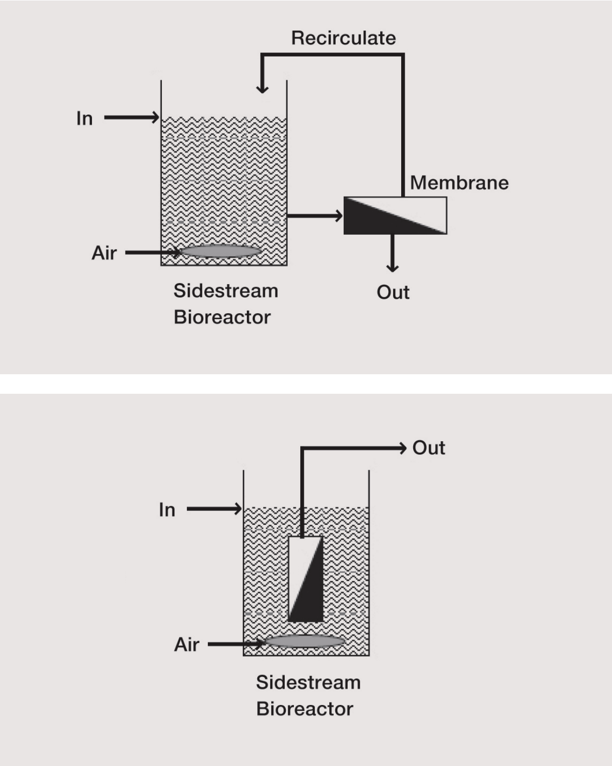

Fig. 12:
Scheme of greywater recycling system with MBR Types: Sidestream (top) and Submerged (bottom) (source: Catalogue of Technologies for Integrated Urban Water Management, 2014)

B3.a

Greywater recycling systems with Membrane Bioreactors (MBRs) – Operating components (continued)

Main operating principles & components

a) Collection tank of greywater

- Greywater and black water pipelines have to be separated. The greywater is collected in a special raw water storage tank before its treatment process. The size depends on the amount of greywater which will be treated.
- Material used : FRP tanks (Fiberglass Reforced Polyester) or other material resistant to commonly used chemicals (e.g. chlorine).

b) Main treatment process

Use of Membrane Bioreactors (MBRs)

c) Storage facilities

- Treated greywater ultimately is stored in a tank the size of which depends on the amount of greywater treated.
- Material recommended: FRP tanks (Fiberglass Reforced Polyester) or other material which resists to chlorine.

d) End uses

Recycled water can be used for secondary uses where there is a possibility of human exposure. It can be reused for: food and urban irrigation, toilet flushing, car washing, landscape and sports fields irrigation, recreational areas and for groundwater recharge.

B3.b

Advantages and disadvantages of MBRs

Advantages

- Small footprint and small reactor volume
- Decreased sludge production
- Good quality of effluent
- Effective removal of bacteria and viruses
- Lower sensitivity to peak contaminant loads
- Adaptation to any membrane configuration
- Improved effluent quality
- Easy maintenance of membrane
- Reliable control of membrane fouling parameters evolution together with biological process parameters

Disadvantages

- High installation and maintenance cost
- Sophisticated control systems
- Requires professional expertise and design
- Potential of sludge during the decant phase
- Frequent fouling and clogging of bioreactor
- Limitations imposed to meet membrane tolerance
- Few suppliers worldwide
- Very few trained maintenance technicians

Keywords / Rainwater Harvesting

Concrete tanks
- Underground / Overground concrete tanks
- Concrete water tank construction

Plastic tanks
- Plastic water storage tanks
- RWH plastic cisterns

Metal tanks
- Metal water storage tanks
- RWH stainless steel water tanks

Rain barrels
- Rain barrels
- Rainwater collection barrels
- Clay rain barrels

Open water reservoirs
- Open water reservoirs
- Pond reservoirs
- Pond liners and seal

Modular underground tanks
- Modular underground tanks
- Modular rainwater harvesting tanks
- Geotextile
- Polypropylene plastic liner

Complementary equipment
- Gutter
- Filter
- Downspout
- Diverter
- Trash and debris filter
- Overflow pipe
- Reuse / Suction pump

Keywords / Greywater Recycling

Physical
- Physical greywater recycling systems
- Cartridge filter
- Sedimentation
- Activated carbon filter
- Sand filter
- Disinfection

Chemical
- Chemical greywater recycling systems
- Electro-coagulation
- Coagulation/Filtration
- Coagulation (with aluminum salt)
- Magnetic ion exchange resin treatment

MBRs
- Membrane bioreactors (MBRs) for greywater recycling
- Compact MBR greywater treatment system
- Ultrafiltration

Complementary equipment
- Greywater piping
- Greywater filter
- Greywater storage tank
- Treated water tank
- Submersible pump
- Reuse hose
- Reuse piping

If this guide inspired you to explore the application of Non Conventional Water Resources, please share your projects at **secretariat@gwpmed.org** or on our Facebook page **https://www.facebook.com/NCWRProgramme/**

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Online Resources

- Non Conventional Water Resources Programme in the Mediterranean, http://www.gwp.org/en/GWP-Mediterranean/GwpMed-in-action/List-of-Programmes/Non-Conventional-Water-Resources-Programme-in-the-Mediterranean/
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- http://www.demeaumed.eu/index.php/inno

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