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# Water Efficiency and Water-Energy Nexus in Building Construction and Retrofit

IO3. Training Courses Curricula, Contents and e-Learning Platform

*Training materials for the WET's Course*

## TRAINING HANDBOOK Proposal

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***Disclaimer: contents developed in this handbook proposal need to be carefully revised before being used as training materials or directly. Please contact the specific partner teams for any comments, suggestions or enquiries regarding specific modules of this handbook. Also notice that local, national and international standards should be carefully followed and considered.***

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# Contents

# WATER EFFICIENCY TECHNICIAN COURSE TRAINING CONTENTS

## *SUMMARY*

The curriculum for the "Water Efficiency Technician" - WET - consists of a total of six (6) Modules, each of them consisted by 2 to 6 learning Units (2 for Units 3, 4 and 6, 3 for Learning Unit 5, 5 for Unit 2, and 6 for Unit 1), with an overall learning time of **100 hours of learning**. As is shown in the below aggregate table, from the total time of those 100 learning hours, the 40 of them will be spent to the so-called 'contact hours', i.e. the hours during which in-classroom or other type of training (e.g. e-learning) will be provided, 20 hours are foreseen for hands-on training (practicing), i.e. for the practical part of the training (e.g. in special shaped and equipped laboratories or on-site), and 5 for the assessment / examination.

| | Contact hours | Hands-on hours | Self-study hours | Assessment hours | TOTAL |
|---|---|---|---|---|---|
| **Module 1: Hydraulic installations and losses** | 12 | 6 | 11 | 1 | 30 |
| **Module 2: Domestic hot water (DHW) systems** | 8 | 4 | 7 | 1 | 20 |
| **Module 3: Grey water reuse** | 6 | 3 | 5 | 1 | 15 |
| **Module 4: Rainwater harvesting** | 6 | 3 | 5 | 1 | 15 |
| **Module 5: Outdoor installations** | 4 | 2 | 3 | 1 | 10 |
| **Module 6: Communication with customers / consumers** | 4 | 2 | 4 | 0 | 10 |
| **TOTAL:** | **40** | **20** | **35** | **5** | **100** |

It should be stated that the proposed WET course may be ambitious to some of the courses that are usually taken for installers considering water and energy building systems. This was intended, as it should represent an upskilling standard for both starting a career and long lifelong training. It should be highlighted that the current proposal includes the water efficiency dimension, which may be innovative in what regards the existing water and energy building systems curricula.

Regarding module development, Module 1 was developed by CRES, Modules 2 and 5 were developed by ADENE, Modules 3 and 4 were developed by FORMEDIL, and Module 6 was developed by FLC. Please contact the specific partner teams for any comments, suggestions or enquiries regarding specific modules of this handbook.

# MODULE 1: HYDRAULIC INSTALLATIONS AND LOSSES


## *SUMMARY*

A proper hydraulic installation must:

- be characterized by adequate mechanical properties;
- be fire resistant;
- be impermeable and resistant to the impact of external factors;
- be resistant to the fluctuations of pressure and temperature;
- be manufactured with the use of globally approved materials, suitable for any type of application;
- be resistant to wearing down and to changes caused due to strain;
- contribute to the protection of the environment and be constructed using recyclable materials;
- be positive to health protection issues.

A cost-effective and durable installation begins with the judicious selection of the proper materials and equipment. In both domestic cold and hot water systems, the pipe materials and layout, joining methods, hangers, and insulation, all must match the project's needs and will determine the cost as well as the ease of replacement and repair. An economical operating system with reasonable maintenance depends on all these considerations. The location of piping, ease of circulation, bypasses around source and mechanical equipment, adequate valve placement, accessibility, and provisions for the future all are items affecting the operation and maintenance of a system.

This Module of the "WET Course" was designed with the main objective of providing professionals with the specialized knowledge they need to have in order to be able to implement efficient thermo-hydraulic installations in building applications. It is composed by the following Learning Units:

Unit 1: Effective implementation of the thermo-hydraulic installations design

Unit 2: Correct selection and installation of piping materials and components

Unit 3: Correct selection and installation of water-energy efficient appliances and fixtures

Unit 4: Installation and management of smart-meters and other water consumption monitoring equipment

Unit 5: Hydraulic adjustment and balancing of thermo-hydraulic installations

Unit 6: Indoor leakage identification & control and periodic cleaning of hydraulic installations

## *Unit 1: Effective implementation of the thermo-hydraulic installations design*

**Introduction / General description**

In the 1st Unit of Module 1 the principles for an effective implementation of the thermo-hydraulic installations design for adequate performance will be presented to the trainees in order to acquire the necessary knowledge of the operational characteristics of thermo-hydraulic systems components, of the functioning of fittings and other parts of the thermo-hydraulic system, of the methods and/or techniques that may be applied to secure good performance of the thermo-hydraulic system, and of the regulations and standards (local, national, international) applicable to thermo-hydraulic systems, considering water-energy efficiency requirements.

**Scope – Expected results**

After the end of attending this learning unit, the trainees will be able to:

- interpret the thermo-hydraulic system project (and related available manuals) and dimensioning characteristics,
- establish the sequence of pipe installations and the corresponding components,
- limit obstructions and improve the piping network layout, e.g. in respect to reduce pipes lengths,
- provide an estimation of the work to be carried out for the system implementation.

**Key words / basic terminology**

Thermo-hydraulic system, fittings, regulations and standards, pressure drop, flow rate, thermal losses, heating/cooling distribution networks.

## 1.1 Basic calculations for verifying the water network requirements of the facility in study

### *1.1.1 Determination of the demand for domestic hot water (DHW)*

Some common ways of calculating the amount of energy that is needed for the production of the daily domestic hot water (DHW) volume required are presented in the following. It should be mentioned that the information provided herein, in no sense do substitute the task of the designer – engineer, but they do offer a quick way of calculating the required energy amounts (for cross-checking the original calculations made by the designers, e.g. the WEEs).

More specifically, the suggested procedure is as follows:

1. The energy amount required for the production of DHW is calculated taking into account the type of the examined building (use of the building and surface area), the number of occupants, the temperatures (indoor & outdoor), etc.
2. The minimum power of the unit (for the production of DHW) is then determined, having made an acceptance over a "logical" (or "rational") time period needed for the thermal loading of the storage tank.

The amount of energy required for the production of DHW can be calculated with the use of the following equation:

$$Q_{DHW} = V_{DHW} \times \rho_w \times C_{S,w} \times N_{dd} \times (T_w - T_0) \ [1]$$

where:

$Q_{DHW}$ : energy content of the DHW delivered to the user (kJ)

$V_{DHW}$ : daily volume of DHW delivered at specific temperature (lit/day)

$\rho_w$ : water density (kg/m$^3$)

$C_{S,w}$ : specified heat capacity for water (= 4186 J/kg °C)

$N_{dd}$ : number of days considered for the study (for simplicity = 1)

$T_w$ : specified temperature of DHW at tapping point (normally 40 °C)

$T_0$ : temperature of the inlet water from the main supply (normally at 15 °C)

Knowing the "thermal load" of the tank in a specific time period, the minimum required power for the boiler can be determined with the following simple equation:

$$P_{DHW} = {Q_{DHW}}/{t_{RT}} \ [2]$$

where:

$P_{DHW}$: required power for the desired $Q_{DHW}$ (W)

$t_{RT}$: time of operation of the boiler (sec)

For common/usual inlet water temperature values at 15°C and with temperature at tapping point values of DHW production at 40°C, the following are the requirements for the residential buildings (taking also into consideration, in a next step, the proper number of bathrooms and type of control system):

| Floor area of the dwelling ($m^2$) | Required volume of DHW $V_{DHW}$ (lt/$m^2$ per day) | Energy amount (required energy) $E_{DHW}$ (kJ/$m^2$ per day) |
|---|---|---|
| S < 50 | 3 | 314 |
| 50 ≤ S < 120 | 2.5 | 262 |
| 120 ≤ S ≤ 200 | 2 | 210 |
| S > 200 | 1.5 | 157 |

The correction coefficients related to the number of bathrooms and the type of control applied are:

| Number of bathrooms | Correction coefficient $F_s$ |
|---|---|
| 1 | 1 |
| 2 | 1.33 |
| ≥3 | 1.66 |

| Type of control | Correction coefficient $F_d$ |
|---|---|
| Autonomous | 0.9 |
| Non - autonomous | 1 |

Next, an example of calculation with the use of the suggested method is presented below (floor area of the dwelling: 200 $m^2$ with 2 bathrooms and autonomous control)

| Floor area of the dwelling ($m^2$) | $V_{DHW}$ (lt/$m^2$ per day) | $E_{DHW}$ (kJ/$m^2$ per day) | $F_s$ | $F_d$ | $t_{RT}$ (Hours) |
|---|---|---|---|---|---|
| 200 | 2 | 210 | 1,33 | 0,9 | 3 |

↓

| DHW requirements (lt/day) | Energy requirements (kJ/day) | Power of the unit (kW) |
|---|---|---|
| 479 | 50.274 | 4,7 |

The required power shall have to be guaranteed during the "critical" operation hours. It shall be mentioned that the calculated power corresponds to the daily "loading" of the thermal tank. When the system is in an intermittent operation (e.g. during weekends), the time needed for the thermal tank to reach the required water inlet temperature over the system balance temperature will have to be taken into account.

In the below table the energy requirements for commercial buildings, per person and day, are shown:

| Building type | Requirements in $V_{DHW}$ (lt/person - day) | Requirements in $E_{DHW}$ (kJ/person - day) |
|---|---|---|
| Hotel-bathroom with a shower | 60 | 6280 |
| Hotel-bed & bath | 120 | 12600 |
| Hotel-common/shared bath | 50 | 5240 |
| Colleges-other building structures | 50 | 5240 |
| Hospital-shared bath | 50 | 5240 |
| Clinics-in suite bath | 120 | 12600 |
| Offices | 20 | 2100 |
| Building installations with shower | 40 | 4190 |

For the calculation of the final value, two coefficients are used (number of persons and occupancy frequency). In the following example, there are 20 persons in hotel rooms with a bath, the occupancy frequency is 0.8 and the response time is 4 hours.

| Number of persons Nº | $V_{DHW}$ (lt/persons per day) | $E_{DHW}$ (kJ/persons per day) | $F_{\delta\iota\alpha\mu}$ | $t_{RT}$ (Hours) |
|---|---|---|---|---|
| 20 | 120 | 12,600 | 0,8 | 4 |

↓

| DHW requirements (lt/day) | Energy requirements (kJ/day) | Power of the unit (kW) |
|---|---|---|
| 960 | 201,600 | 14,0 |

As already mentioned, the required power must be selected and be guaranteed under critical conditions of operation. The following table offers a general idea regarding the DHW consumption for various applications (based on articles and technical studies of many manufacturers of hot water tanks):

| Type of use/activity | Litres / day | Remarks |
|---|---|---|
| Schools | 5 | Per person |
| Military camps | 30 | Per person |
| Industries | 20 | Per person |
| Offices | 5 | Per person |
| Camping | 30 | Per person |
| Gyms | 35 | Per user |
| Washing machines | 6 | Per kg of clothes |
| Restaurants | 10 | Per meal |
| Bars | 2 | Per drink |

The calculated indicative consumption of DHW for common residential activities is presented in the following table:

| Type of use/activity | Litres (lt) / day | kWh 10-40 ºC |
|---|---|---|
| Hand washing | 2 ÷ 5 | 0,07 ÷ 0,17 |
| Hair washing | 5 ÷ 15 | 0,17 ÷ 0,52 |
| Dish washing (in hand) | 13 ÷ 20 | 0,45 ÷ 0,70 |
| Showers | 30 ÷ 50 | 1,00 ÷ 1,70 |
| Baths | 120 ÷ 150 | 4,20 ÷ 5,20 |

The above table is permitting the calculation of the hot water volume during peak hours, in the case that three (3) persons / members of a family are consecutively taking a bath the one after the other, in a single dwelling.

### *1.1.2 Estimation of losses of heating/cooling distribution networks*

A hot pipe with a temperature higher than the environment temperature is sending heat towards the environment through the mechanisms of convection and radiation. The heat losses per (linear) meter of pipe are a function of the pipe diameter, of the thickness of the external insulation of the pipe and of the thermal conductivity of the insulating material selected for the pipe.

A simplified formula for the calculation of heat losses per pipe meter is given below:

$$U'_{\Sigma} = \frac{\pi}{\frac{1}{2\lambda} ln \frac{d_0}{d_{\Sigma}} + \frac{1}{\alpha_{\Sigma} d_0}} \; [Eq. 1.3]$$

where

$U'_{\Sigma}$ : the linear thermal losses from the pipe in W/(m·°C)

$\lambda$ : the heat conductivity of the insulating material of the pipe

$d_o$ : the outer diameter of the pipe (the insulation included)

$d_{\Sigma}$ : the outer diameter of the pipe without the insulation

$\alpha_{\Sigma}$ : the convection – radiation coefficient of the pipe, equal to 7 W/(m·°C) when insulation exists, and equal to 10 W/(m·°C) when there exists no insulation.

The distribution losses are referring to the central heating piping, which is either placed at the external of the buildings or inside the building but in non- heated spaces. Such spaces might be the basements of buildings, the stairway or the air shaft inside of which the piping is placed vertically. For all parts of the piping that pass through non-heated spaces, the overall distribution losses on a yearly basis are calculated as follows:

$$\dot{A}_{\Delta N} = \sum_{i=1}^{N} U'_{\Sigma,i} \left(T_{\Sigma} - T_{\alpha,i}\right) L_i \; [Eq. 1.4]$$

where

$U'_{\Sigma,i}$: the linear coefficient of thermal losses from the pipe *i* in W/(m·°C)

$T_{\Sigma}$ : the water temperature inside the pipe (°C)

$T_{\alpha,i}$ : the temperature of the non-heated space *i* (°C)

L*i* : the pipe length inside the space *i* (m)

The performance efficiency $\eta_{\Delta N}$ of the distribution system can be calculated as follows:

$$\eta_{\Delta N} = 1 - \frac{\dot{A}_{\Delta N}}{\dot{Q}_{\Delta N}} \; [Eq. 1.5]$$

where $\dot{Q}_{\Delta N}$ is the transferred heat from the distribution network. This can be calculated as: $\dot{Q}_{\Delta N} = \dot{m}\; c\; \Delta T$, where $\dot{m}$ is the hot water flow rate inside the distribution pipe, *c* is the thermal capacity of water [4,187 kJ/(kg °C)] and $\Delta T$ (= 20°C) is the difference between the hot water supply and return from the calorifiers.

The hot water flow rate can be calculated as $\dot{m} = \rho\, \dot{V}$, where $\rho$ is the water density at 60°C (ρ ≈ 980 kg/m$^3$) and $\dot{V}$ is the volumetric flow rate in m$^3$/s, which can be calculated as the product of the water velocity inside and of the pipe diameter (cross section): $\dot{V} = w\, (\pi\, d^2 /\, 4)$. Hereon, based on the common pipes design tactic, it is considered that $w$ = 1.0 m/s. In this way, the transferred heat from the distribution network arises as:

$$\dot{Q}_{\Delta N} = \rho w \frac{\pi\, d^2}{4}\, c\, \Delta T = 980\, \times\, 1{,}0\, \times\, \frac{\pi\, d^2}{4} \times 4{,}187\, \times 20 \cong 64.421\, d^2$$

## 1.2 Basic stages of an efficient hydraulic installation

The hydraulic and drainage installations are addressing the installation of sanitary equipment, of the internal drainage lines until the exterior side of the building wall, of the internal water supply lines and the supply pipe until the external side of the building. The calculation of a hydraulic installation (study to be made by an appropriately qualified engineer) comprises the following stages:

1. Planning of the piping network.
2. Determination of the water flow rate at each branch of the network.
3. Selection of the suitable size of the piping system (pipes size).
4. Calculation of the pressure loss at each branch and based on this, calculation of the pressure loss at the entire network, taking into consideration that this loss should not exceed the minimum available pressure supplied by the city network.

Especially as far as the heating hydraulic installations are concerned, it is necessary to additionally take into account the selection of other elements of the network, as the circulator but also other fittings as the radiators, the boilers, the safety valves, etc.

### *1.2.1 Determination of water flow rate at each branch*

The calculation of the flow rate of water at each branch begins from the terminal branches, which are the branches that are leading the water to the final receptors - fixtures (sinks, wash-basins, bathtubs, etc.) or to the terminal units (radiators, fan coils, etc.), in case we are referring to a heating network. The flow rate of these branches depends on the kind and the size of the intake and it is provided by empirical tables like the one presented below (for copper pipes):

| Intake | Copper pipe diameter (mm) | Flow rate (lt/s) |
|---|---|---|
| Sinks | 15 | 0.125 |
| Wash-basins | 15 | 0.175 |
| Showers | 18 | 0.250 |
| Bathtubs | 18 | 0.175 |
| Toilets | 15 | 0.125 |
| Household appliances | 15-18 | 0.250 |
| Heaters | 15 | 0.175 |
| Urinals | 15 | 0.125 |

In the case of heating networks, the flow rate that is supplied to the calorifiers depends on the size - or, in other words, the “performance” - of the calorifier, the water inflow temperature, and the desired drop in its temperature. Knowing the flow rate values for all the terminal branches, the flow rates of the rest of branches may be calculated, on an opposite than the water flow direction.

More specifically, the water supply of the supply branch at every nod is equal to the sum of the supplies of all branches “leaving” from this nod. Some important remarks are the following:

- The flow velocity concerning such hydraulic installations varies from 1 – 2 m/s should not exceed the value of 3 m/s.
- The flow rate values in litres per second (lt/sec) are approximate.
- The minimum outflow pressure of fixtures is around the value of 1 bar.
- In special cases of calorifiers or heat exchangers, the guidelines of the manufacturers should be followed, both for the flow rate and the operation pressure.

### *1.2.2 Calculation of pressure loss*

The water pressure that is available to the water metering from the central distribution network is varying. The calculation of the losses from the network is considering the minimum value of pressure on the metering and this most of the times corresponds to the value of 4 bar.

The pressure loss ($\Delta P$) in the network is derived taking into consideration the losses:

1) due to altitude difference ($H$),
2) due to the friction of water during its circulation in the pipes ($\Delta P_L$),
3) due to internal friction powers because of the use of fittings, valves and other control devices ($\Delta P_T$).

So: $\Delta P = H + \Delta P_L + \Delta P_T$

Thus, the total drop in the pressure value of the entire network must be lower than 4 bar. The total pressure drop of the entire – or some part of the – network is determined by the sum of the pressure losses of the various consecutive branches that constitute this part of the hydraulic network.

### *1.2.3 Selection of the appropriate piping*

Based on the water consumptions (abstractions), the suitable **pipe diameter** is selected so that the water flow velocity varies between the recommended velocities of 1-2 m/s, while the minimum outflow pressure should be around 1 bar (0.1 bar is equal to the pressure caused by 1 m of water column).

**Example**

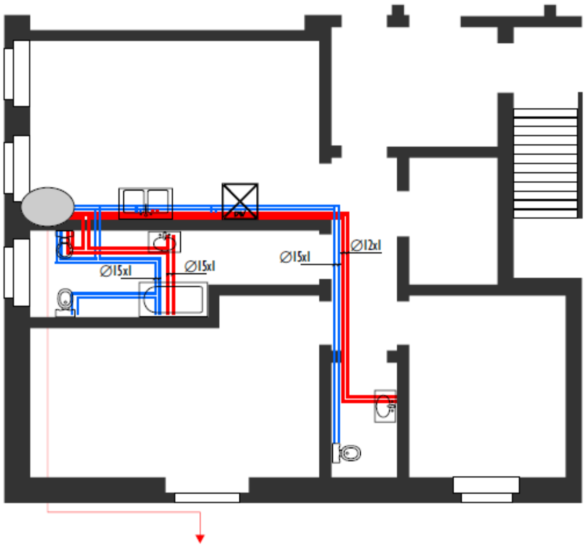
Taking into consideration the short length of the piping of the hot and cold water main pipes at the various abstractions (see the layout in the figure above), as well as the lack of copper and brass fittings throughout the path of the piping (equal to a small pressure drop $\Delta P_T$ of the network), the following cross sections (diameters) of pipes can be used:

- For sinks, wash basins and washing machines, a copper pipe is used: Ø12x1, with a flow rate $G \geq 0.125$ lit/sec (450 lit/h) and a water velocity $U \geq 0.125$ m/s

⇨ From the pressure losses due to friction along the water flow diagram:
$\Delta P_L = 400$ mm $H_2O$ / m

- For baths and toilets, a copper pipe is used: Ø15x1 with a flow rate $G \geq 0{,}22$ lit/sec (800 lit/h) and water velocity $U \geq 1.6$ m/s

⇨ From the pressure losses due to friction along the water flow diagram:
$\Delta P_L$ = 300 mm $H_2O$ / m




**Typical design (layout) of a contemporary hydraulic installation**

As far as the **length of the piping** is concerned, the following are provided:

- Copper pipe Ø12x1 overall for hot and cold water 22 m, for connection to wash basin 2x3 m, for sink 2x6 m and for washing machines 2x2 m.
- Copper pipe Ø15x1 overall for hot and cold water 11 m, for connection to wash basin 2x4 m and for toilet 3 m.

⇨ Thus, the overall/total pressure losses are:
$\Delta P_L$ = 22 m x 400 +11 m x 300 = 12,100 mm $H_2O$

The losses due to fittings and other instruments of the network $\Delta P_T$ are insignificant due to the lack of fittings. In the case of use of rectilinear copper pipes with fittings, for the calculation of the pressure loss because of the fittings $\Delta P_{T,}$ the respective table (for each one of the fittings, e.g. junctions, bifurcations, corners, systolic systems, valves, etc.) is used.

So, the pressure loss in the network, $\Delta P$ is:

$\Delta P = H + \Delta P_T + \Delta P_L$

where:

$H$ = (Elevation pressure difference: 3 m the 1st floor + 3 m the basement) **6,000 mm $H_2O$**

$\Delta P_L$ = **12,100 mm $H_2O$**

⇨ **$\Delta P_L$ = 18,100 mm $H_2O$ = 18.1 m $H_2O$ (1.8 bar)**

With the minimum outflow pressure being around 1 bar and the network pressure loss at 1.8 bar, the operation of the water supply network is judged as satisfactory, based on the supplied pressure from the main public water supply, being usually at 4 bar.

**Note:** In the cases of longer distances or in a classical system of hydraulic installation with the use of rectilinear copper pipes, the above diameters (cross-sections) Ø12x1 and Ø15x1 should respectively become: Ø15x1 and Ø18x1 mm.

## 1.3 Legal requirements for achieving water-energy efficiency

### *1.3.1 Requirements for water-energy efficient thermo-hydraulic systems*

As the population increase is leading to a higher drinkable water demand, the existing water supply cannot meet this increasing demand. A really feasible use of the municipal public water resources cannot be possibly achieved without the introduction of additional improvements for the efficient use of the mains water. On the other hand, most of the water uses inside buildings are explicitly related to the consumption of energy. For example, the supplied (cold) water needs to be heated or chilled, according to the request, and should be further pumped. In the end, after the water is used, the waste is pumped and sent to treatment.

A significant number of initiatives do exist in Europe and/or worldwide aiming at the improvement of the environmental performance of buildings. The initiatives that are related to the water use include a wide range of actions, such as the better control of leakages, the installation of products that are using the water in an efficient way, the reuse or harvesting of water, etc. Furthermore, certain initiatives on European level focus on the development of criteria for the effective use of water in buildings and these criteria could also be used for the scope of an ecological label, or in the green public procurements, or in an ecological design regarding either buildings or products using water. Such initiatives are leading to the elaboration of practices for the effective use of water.

At a European level, the European Commission is since 2007 elaborating a grid of regulatory and non-regulatory actions for the treatment of water scarcity and water saving. According to the relevant explanatory memorandum, a percentage of 21% of the abstractions in Europe relate to water supply, while the 60 – 80% of the water consumption mainly concerns the residential use (35 - 48% is the homes water use in the bathroom). The promotion of technologies and practices that focus at the efficient use of water resources and the enhancement of a culture of water conservation are among the top priorities of the European Commission. Nevertheless, at the EU level, both the legislation and the policy measures promoting the efficient use of water are for the time being limited. [1]

One way for achieving saving of water – and thus energy – is the establishment and implementation of regulations regarding the water consumption of the different network elements (fixtures). The elements that are most commonly addressed are the flushers and the faucets/taps, with the following most "common" limits:

- Flushers: 4.5 – 6 lt/use
- Faucets: 6 - 9 lt/min (in this case, in particular, some other "limits" exist, such as in the USA the 2.2 gpm for the supply of a kitchen faucet or 1.5 gpm for the bathroom's sink faucet)
- Shower heads: 9 - 13 lt/min.

Table 1.1 refers to the use of technologies and devices for effective use of water in the residential sector, and the various possibilities for saving water in households are respectively presented. In the example, savings may sum up to 25% with the improvement of the technological performances of household appliances. These savings may differ under different baseline situations and consumer behaviour patterns.

**Table 1.1: Saving possibilities of the different technologies in households**

| | **Typical dwelling** | | **Dwelling with efficient use of water** | | **Comparison between a typical dwelling and one with efficient water use** |
|---|---|---|---|---|---|
| **Water use per component** | Volume per use (lt) | Per capita consumption (lt/person/d) | Volume per use (lt) | Per capita consumption (lt/person/d) | Water consumption decrease (%) |
| Toilet (flusher) | 6 | 28 | 4 | 17 | 39 |
| Shower | 45 | 25 | 30 | 17 | 32 |
| Bath | 85 | 30 | 80 | 28 | 7 |
| Faucets/taps | - | 12 | - | 10 | 17 |
| Washing machine | 60 | 13 | 40 | 9 | 31 |
| Dish washer | 20 | 8 | 15 | 6 | 25 |
| Garden | - | 6 | - | 5 | 17 |
| **Total (lt/person/day)** | **-** | **122** | **-** | **92** | **Total decrease: 25%** |

Source: *Reference [2]*

### *1.3.2 Existing regulations related to the efficient use of water in thermo-hydraulic systems*

Some indicative examples of the mandatory and voluntary instruments existing at the EU level that regulate water performance requirements for certain water uses are presented in the following paragraphs.

<u>Notice</u>: Whilst these regulations were in-force when this text was written, it is important to check the current standards applied in the respective geographical location at the time that the work / project will be carried out.

<u>Mandatory measures at the EU level</u>

- The Council **Directive 92/75/EEC** of 22 September 1992, on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances: This Directive stipulates the energy labelling requirements of residential washing machines and dishwashers.

- The **Ecodesign Directive 2005/32/EC**: It establishes a framework for the setting of ecodesign requirements for energy using products.

- The **extension of the Ecodesign Directive** to include energy-related products: at the end of March 2009, the European parliament and EU governments reached an agreement on proposals to extend the Ecodesign Directive to energy-related products, including Water use Plans (WuPs), such as taps and showerheads (Directive 2009/125/EC). The rationale behind this step was that less hot water spent by a shower or a tap would also imply less energy required for it to be heated, which would also reduce the total final energy consumption in the EU. Reducing water use would also lead to the reduction of environmental impacts of water supply. Water use Plans such as showers, taps, washing machines and dishwashers all offer households possibilities for water saving, equally diminishing the energy required to heat the water.

In this point, the **Directive 2010/30/EU** on the indication of energy consumption and other resources of household appliances by labelling and providing uniform product information, referring to products that have a direct or indirect impact on energy consumption, needs to be mentioned. The suppliers of these products must place labels on the products they produce, which indicate the energy consumption of the product (A – G, with G being the worst efficient), a brief description of it, the results of the calculations during the design of the product, and related references to allow the presentation of other products. It must also contain the energy classification of the product. This Directive, which applies more to the energy performance rather than that of the water of the product(s), has been in force since 20 July 2011.

Voluntary measures at the EU level

- **European labelling of water-using appliances**: this scheme was designed to promote the products that have a reduced impact on the environment compared to similar ones and to provide consumers with accurate scientifically based information and guidance.

The EU Eco-label has established water consumption criteria for different appliances including dishwashers (Decision of 28 August 2001), establishing the environmental criteria for the award of the EU Eco-label to dishwashers (2001/689/EC), and of washing machines (Commission Decision of 17 December 1999), establishing the environmental criteria for the award of the EU Eco-label to washing machines (2000/45/EC). Water performance standards under the EU Eco-label scheme for washing machines and dishwashers use the same requirements that are specified under the Council Directive 92/75/EEC (presented in the section on mandatory measures at the EU level). It should be noted that Eco-label criteria for dishwashers and washing machines have expired since 30 November 2008 and 28 February 2009 respectively. Plans are underway in the near future to review the criteria to determine whether they will change and whether these products will stay under the Eco-label scheme.

Existing mandatory & voluntary measures in member states

Since a significant volume of water is actually consumed in households due to the use of sanitary products (especially toilets), these products are - no surprisingly - more commonly regulated for. Furthermore, these are often the most commonly purchased water use plans for residential and / or commercial buildings, and thus they may be easier to regulate or test once some efficiency requirements are set. A number of mandatory measures exist in the member states (MSs) nowadays.

Although the existing regulations in MSs present certain differences, some similarities can also be noticed among them. The most significant similarity perhaps is that the member states have set some efficiency requirements for toilets and these requirements are either the same or quite similar between each other (i.e. maximum 6 lt per flush). It is also worth noting that showers and taps are also given similar requirements between the two types of products and they are the 2$^{nd}$ most commonly regulated product. In the following Tables 1.2 and 1.3, the water efficiency requirements as specified in existing either mandatory or voluntary respectively EU and MS schemes are briefly presented.

**Table 1.2: Requirements of existing mandatory EU & MSs water efficiency schemes**

| Measure | MS/EU | Scope | Products covered and water performance requirements | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Toilets | Washing machines | Dish washers | Shower heads | Taps | Car wash |
| Council Directive 92/75/EEC: Labeling | EU | EU level | | < 12 lt/kg | X | | | |
| Ecodesign Directive 2005/32/EC | EU | EU level | | 5.3 - 7 lt/kg | 7 – 10 lt/cycle | X | X | |
| Water supply (fittings) regulations | United Kingdom | National | 6 lt/flush | < 27 lt/kg | <4.5 lt/place setting | | | |
| Ordenanza de Gestión y Uso Eficiente del Agua en la Ciudad de Madrid | Spain | Municipal (Madrid) | 6 lt/flush | | | < 10 lt/min | < 10 lt/min | < 10 lt/min |

**Table 1.3: Requirements of existing voluntary EU & MSs water efficiency schemes**

| Measure | MS/EU | Related standards | Scope | Products covered and water performance requirements | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Toilets | Washing machines | Dish washers | Shower heads | Taps | Car wash |
| EU Eco label | EU | EN 60456:1999 & EN 50242 | EU level | | <12 lt/kg of wash load | | | | |
| Distintivo de garantía de calidad ambiental catalán | Spain | UNE67-001-88 EN 246:2004 | Regional (Catalonia) | <6 lt/min | | | <12 lt/min | <9 lt/min | |
| BMA Water Efficiency | UK | EN 997:2003 & PrEN | National | <4.5 lt/flush | | | <13 lt/min | < 6 lt/min | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Labelling Scheme | | 14055:2007 | | | | | | | |

## *Unit 2: Correct selection and installation of piping materials and components*

**Introduction / General description**

In the 2nd Unit of Module 1 the principles for the correct selection and installation of piping materials and components will be presented to the WET trainees in order to improve their knowledge of selecting the appropriate pipe material, in compliance with the regulations and standards (local, national, international) applicable to building hydraulic water distribution and thermo-hydraulic systems, of the potential for minimization of thermal losses through the piping system, and of selecting the adequate insulating materials that can be used for thermal insulation purposes.

**Scope – Expected results**

With the completion of this Unit, the trainees will be able to:

- accurately implement the building hydraulic water distribution and thermo-hydraulic project proposed,
- correctly apply the most effective and suitable equipment and materials for correct implementation of the system (including thermal insulation),
- efficiently implement the building hydraulic water distribution and thermo-hydraulic system installation,
- deliver to the client an effective thermo-hydraulic system (in line with the client needs and the necessary performance and environmental requests).

**Key words / basic terminology**

Materials for pipes and fittings, pipes diameters, insulating materials, circulation pump, verification of system functioning, tests for leaks.

## 2.1 Hot/cold water distribution systems basics

The provision of hot water is typically the second largest energy consuming procedure in a house (right after space heating and cooling). Thus, one of the primary factors that affect the homeowner/occupant satisfaction is the relative comfort associated with the domestic hot water (DHW) delivery system.

An inefficient hot water delivery system that takes minutes to deliver hot water to the point of use and waste large amounts of energy in the process stands for approximately 10 to 15% of the energy use associated with the hot water delivery system to be wasted in distribution losses. Based on many research studies, the water and energy waste can be reduced by 90% in new homes that are constructed with water-efficient hot water systems addressing plumbing design, pipe insulation, demand recirculation, and drain heat recovery.

It should be noted at this point that, besides the total amount of pipes of a hydraulic installation, i.e. the so called piping or pipeline, a series of fittings/components are also needed as follows:

– juncture of two parts of the same diameter;
– juncture of two parts of different diameter;
– change of direction;
– juncture of two currents for the creation of a third current;
– branch for distribution to various utilization points;
– end of piping;
– adjustment of the flow rate.

Moreover, it is important to notice that a proper hydraulic installation must:

➢ be characterized by excellent mechanical properties;
➢ be fire resistant;
➢ be impermeable and resistant to the impact of external factors;
➢ be resistant to the fluctuations of pressure and temperature;
➢ be manufactured with the use of globally approved materials, suitable for any type of application;
➢ be resistant to wearing down and to changes caused due to strain;
➢ contribute to the protection of the environment and be constructed using recyclable materials;
➢ be positive to health protection issues.

In general, a suitable hydraulic installation must meet (and be evaluated with higher grades) the following requirements characterizing the mechanical properties:

- the installation must receive fewer strains due to the contraction – expansion caused by the fluctuations of temperature (low expansion coefficient);
- the network shall ensure the minimum flow losses due to friction (low friction coefficient – low flow resistance);
- the network must resist to high temperature values, not being burned, not producing any toxic gases and totally respond and meet the fire protection regulations;
- the installation must protect the flow and the quality of water, from external factors and not be harmful as far as the water quality is concerned;
- the size of the pipes and of the various fittings will have to be standardized, regardless of the

manufacturer, the supplier or the kind of the material used;

- the installation must be constructed with the use of environmentally friendly and inexpensive materials, characterized by a long life time cycle.

## 2.2 Selection of the appropriate materials for pipes and fittings

With the implementation of an effective both design and layout of the cold/hot water supply system, the waste of water throughout the long piping paths can at an extent be faced. Nevertheless, as already mentioned before, both the material used for the construction of the pipes and their diameter, do significantly influence the efficiency of the system. In the case of given nominal diameter of the pipe (the diameter is considered as the outer diameter), the inner diameter shall vary depending on the construction material, as the various available materials are characterized by different thicknesses of their wall.

This means that although some DHW supply systems may be identically designed, except for the type of material used, they will finally be able to store different amounts / volumes of hot water into the respective piping. On the other hand, during the evaluation of the piping and of the fittings, the selection of the material is quite crucial for a variety of reasons, including the durability, the required energy and the overall $CO_2$ footprint in product manufacturing.

The water quality may also be affected by the materials, so the health and the welfare of the residents/occupants of the building also have to be taken into account. While there are a variety of materials available, each one of which has its pros and cons, it seems difficult to conclude to a comprehensive, comparative life cycle analysis of plumbing materials which shall allow them to be equally compared. Practically, the newer, lighter and produced by a more efficient process materials, will have as result lower energy and environmental impacts, in comparison to the heavier and more manufacturing – intensive materials. Nevertheless, the endurance in corrosion (corrosion resistance) and the leaching consist of a source of concern for certain products.

### *2.2.1 Piping materials and their applications*

The developers have many available choices to make concerning the material of hot / cold water supply systems pipes. A short overview of the various types of available materials is presented below, as a help to anyone who wants to be able to proceed with his own evaluation of pipes and fittings:

- ***Copper*** is one of the most frequently used materials for pipes manufacturing, in view of its availability and durability. The copper may get corroded if being in contact with water rich in acids and similarly to PVC it may contain lead. In the USA and most specifically in states like California and Vermont, the allowed percentage of lead used in hydraulic systems has been dramatically decreased to below 0.25%.
- ***Galvanized steel*** is not anymore widely used due to its high tendency to corrode and to its short service life. As many dwellings/homeowners and retrofitters can confirm, the galvanized steel often consists of the motivating factor responsible for the change of the entire plumbing systems in old residencies, because of the corroded galvanized piping. Besides the internal corrosion which can lead to restricted water flow, other metals that are used in valves and fittings may be responsible for the more rapid corrosion of the galvanized steel.

- **_Polyvinyl chloride (PVC)_** is a plastic material which is frequently used for the supply of water in residencies from the main, swimming pools and sprinkler drain systems. PVC contains phthalate esters which are controversial as far as the long-term impacts on health are concerned, especially regarding the exposure of infants to them. Although it is somehow not clear whether the use of PVC pipelines might increase the human exposure to phthalate esters in a significant degree, there also exist other issues concerning the PVC. Sometimes lead is also used during the manufacturing phase in PVC, as a hardening agent. Taking also a look at the positive aspects of PVC, chlorinated PVC (CPVC) provides a better endurance to corrosion in cases of high acid water.
- **_Cross-Linked Polyethylene (PEX)_** is a material used for plastic flexible pipes which are extremely resistant to freezing (freeze-resistant) and they allow the use of fewer fittings in comparison to the rigid piping systems. Fewer fittings mean a lower pressure loss which enables the decrease of the size of the pipe, reducing the enclosed volume. PEX is characterized by a big durability and a low corrosion because of its complex molecular formulation. Nevertheless, PEX should be kept away from direct sunlight as the ultraviolet radiation degrades it over time.
- **_Other materials_** involve the polyethylene of raised temperature (PE-RT), which is characterized by a high mechanical stress to pressure and temperature in combination with a large flexibility and easiness in installation without any reticulating process required, the terephthalate polyethylene (PET), as well as the polypropylene (PP or PPR).

Manufacturers and installers shall pay attention to the fact that once copper pipelines are used, there are three basic types of copper that can be used: copper of type M (thin), of type L (medium thickness) or of type K (very thick). Out of the three types, the types L and M are traditionally used in residential hydraulic systems, while the type K pipes, being the thickest of all types, are mainly used for the main supplies and the underground water lines.

Furthermore, it must be highlighted that the selection of a pipe material is directly related – at a certain degree - to the water delivery system type that will be designed and installed in a dwelling / residential building. For example:

- In the *zoned trunk and branch* as well as in the *core* plumbing systems any kind of piping may be used, although the most traditionally used ones are the copper pipes (core systems use less and smaller diameter piping). They can also be made with any type of piping (or multiple types if necessary); copper, CPVC, or cross-lined polyethylene (PEX) are the most common types.
- In the *whole house manifold* systems, also called parallel pipe or home run systems, small diameter, flexible piping (such as PEX - PEX-Al-PEX, PE-AL-PE, ή PEX CTS SDR 9) that run directly to each individual fixture from a central manifold is usually used. The manifold may be constructed of either plastic or metal.
- In the *demand initiated hot water recirculation* systems copper or CPVC pipes are most of the times used, although in some cases PEX pipes can also be used.

In general, the recommended uses of each type (material) of pipe are presented in the following Table. The manufacturers must examine how the material used for the pipes as well as the respective diameters are influencing the hot water supply systems' efficiency. On the other hand, the diameter should not be minimized to such an extent as to endanger the operational ability of the system. The sizing of the pipe diameters must be performed according to the special needs, the design limitations as well as the codes or standards in force.

**Table 2.1: Recommended types of piping for closed loop water networks**

| PIPING USES | TYPE OF PIPE | STANDARD |
|---|---|---|
| Cooling means | Copper pipe<br>Steel pipe | -<br>EN 10216, EN 10217 |
| Cold water | Steel pipe (black or galvanized)<br>Copper pipe<br>Polypropylene | EN 10255, EN 10216, EN 10217<br>EN 1057<br>- |
| Cooling water of water-cooled condensers & Condensates | Galvanized iron or steel pipe<br>Copper pipe<br>Polypropylene | EN 10255, EN 10216, EN 10217<br>EN 1057<br>- |
| Hot water | Iron pipe or steel pipe<br>Copper pipe<br>Polypropylene | EN 10255<br>EN 1057<br>- |

### *2.2.2 Internal volume of various water distribution pipes and delivery time of hot water to a tap*

According to the specifications for "*WaterSense Labeled New Homes"* of the US Environmental Protection Agency, in order for a hydraulic installation to be able to be considered as energy efficient, no more than 1.9 litres of water should be stored as a total to all the piping branches extending from the heater to the hydraulic element. In Table 2.2, the volume of water stored in the different types of pipes, which are used for the DHW supply systems, per foot of the pipe and for a given value of pipe diameter are presented.

**Table 2.2: Inner volume of the different water distribution pipes**

| Ounces of water per foot of hot water piping | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal diameter (in) | Copper M | Copper L | Copper K | CPVC CTS SDR 11 | CPVC SCH 40 | PEX-Al-PEX ASTM F 1281 | PE-AL-PE | PEX CTS SDR 9 |
| ⅜ | 1.06 | 0.97 | 0.84 | N/A | 1.17 | 0.63 | 0.63 | 0.64 |
| ½ | 1.69 | 1.55 | 1.45 | 1.25 | 1.89 | 1.31 | 1.31 | 1.18 |
| ¾ | 3.43 | 3.22 | 2.90 | 2.67 | 3.38 | 3.39 | 3.39 | 2.35 |
| 1 | 5.81 | 5.49 | 5.17 | 4.43 | 5.53 | 5.56 | 5.56 | 3.91 |
| 1 ¼ | 8.70 | 8.36 | 8.09 | 6.61 | 9.66 | 8.49 | 8.49 | 5.81 |
| 1 ½ | 12.18 | 11.83 | 11.45 | 9.22 | 13.20 | 13.88 | 13.88 | 8.09 |
| 2 | 21.08 | 20.58 | 20.04 | 15.79 | 21.88 | 21.48 | 21.48 | 13.86 |

Conversions: 1 gallon - equals 3.8 litres = 128 ounces
1 ounce = 0.00781 gallons (0.0296 litres)

Source: *Modified from 2009 International Plumbing Code Table E202.1, International Code Council.*

The reason for which the inner volume of the different types of water distribution pipes is important, is the fact that in both the residential and the tertiary sector buildings, a common problem arises: when the tap (hot water source) is opened, a long time passes until the water that begins flowing out the faucet (time – to – tap) reaches the desired temperature (hot). In reality, the time – to tap time is quite considerable for the cases of large dwellings including many baths and a long pipeline for DHW. In the following Table 2.3, the (approximate) time required for the hot water to reach the tap/faucet is presented.

**Table 2 3: Delivery time (in sec) of the hot water to a tap depending on the type of pipe**

| Flow rate (lt/sec) | | 0.03 | | 0.1 | | 0.16 | | 0.25 | |
|---|---|---|---|---|---|---|---|---|---|
| **Pipe length (m)** | | ***3*** | ***10*** | ***3*** | ***10*** | ***3*** | ***10*** | ***3*** | ***10*** |
| **Copper pipe** | DN15 | 24 | 81 | 8 | 26 | 5 | 16 | 3 | 10 |
| | DN22 | 46 | 155 | 15 | 52 | 10 | 32 | 6 | 19 |
| **Steel pipe** | DN15 | 61 | 203 | 20 | 68 | 13 | 42 | 8 | 26 |
| | DN20 | 88 | 294 | 29 | 97 | 17 | 58 | 11 | 35 |
| **CPVC pipe** | DN15 | 62 | 206 | 20 | 68 | 13 | 42 | 8 | 26 |
| | DN20 | 92 | 306 | 31 | 103 | 18 | 61 | 12 | 39 |

Source*: ASPE Domestic Water Heating Design Manual*

## 2.3 Selection of the appropriate pipe diameters

The basic characteristics of the pipes are:

- $d_o$ (nominal diameter): it coincides with the outer diameter for large pipes, while it doesn't stand for a real dimension as far as the small pipes are concerned.
- *b*: wall thickness (selected upon the pressure and the allowed tension).
- $N_o$ (series number) is referring to the thickness (a large value of $N_o$ means a large thickness) for copper pipes.
- Inner diameter.
- Outer diameter.

It is worth noting that two pipes with an identical nominal diameter have the same value of outer diameter, regardless of the thickness. Furthermore, the nominal diameter and the series number are usually the characteristics to be defined.

The three quantities/parameters taken into account during the estimations made for the piping networks are:

1) the diameter of the pipes,
2) the velocity of the water and,
3) the value of pressure drop of the water, taking place into the pipes, the devices and the various equipment.

### *2.3.1 Limitations in speed and water pressure drop per pipe length*

To avoid pipe wall noise in the piping network, certain limitations in the velocity of the water and the drop of the pressure of the water per meter of pipe have to be met. The selection of the pressure drop and the dimension of the pipes has to aim at the achievement of the optimum possible solution, among the optimum cost of initial installation (pipes' cross sections) and the optimum operation cost (power range of pumps).

The dimensioning of the pipes is usually performed – and for simplicity reasons – based on diagrams, and by meeting the limitations concerning the water velocity and the water pressure drop. Based on the flow rate (in lt/s or kg/h) that circulates through the respective part of the piping and selecting a medium pressure drop (Pa/m) or water velocity (m/s), the diameter of the pipe and then the correspondent water velocity or pressure drop - per m of the pipe - are estimated (according to the initial selection).

The procedure of calculations for the hot water networks is described as follows:

- The thermal power that is transferred to each part of the piping is determined [in W].
- The hot water supply (hot water flow rate) in every part of the piping is calculated [in kg/h] as:

$$\dot{m}_{HW} = \frac{\dot{Q}_h}{3600 \times c \times \Delta T}$$

  where $\dot{Q}_h$ is the transferred thermal power [kW], $c$ is the specific heat capacity of the water (4,19 kJ/kg K), and $\Delta T$ is the difference between the temperature of water at the tapping point and the inlet water temperature [K].
- The maximum allowed velocity of water [in m/s] or the pressure drop per meter of pipe [kPa/m], are defined, according to the following Table 2.4
- For every part of the piping, an initial cross-section for the calculation is selected (based on the respective diagrams – see the diagram of Figure 2.1 below).
- In case that the criterion of the maximum allowed velocity or of the maximum allowed pressure drop per meter of pipe length is not met, then a larger cross section is selected.

**Table 2.4: Recommended ranges of the water velocity *w* and of the pressure drop *R* in forced circulation heating systems**

| **PIPING POSITION** | **Velocity *w* (m/s)** | **Pressure drop (Pa/m)** |
|---|---|---|
| Inside residential buildings, in secondary branches, in loops and in the heating bodies | 0.5 - 0.7 | 50 -100 |
| Inside residential buildings, in primary branches and in the boiler room | 0.8 - 1.5 | 100 - 200 |
| Outside buildings, in district heating networks | 2 - 3 | 200 - 400 |
| In the industrial buildings, in primary-secondary branches and in the heating bodies | 1 - 2 | 100 - 250 |
| Outside industrial buildings, in supply branches | 2 - 3 | 200 - 400 |

Source: *Buderus Handbuch fuer Heizungstechnik, Beuth Verlag GmbH, 1994*

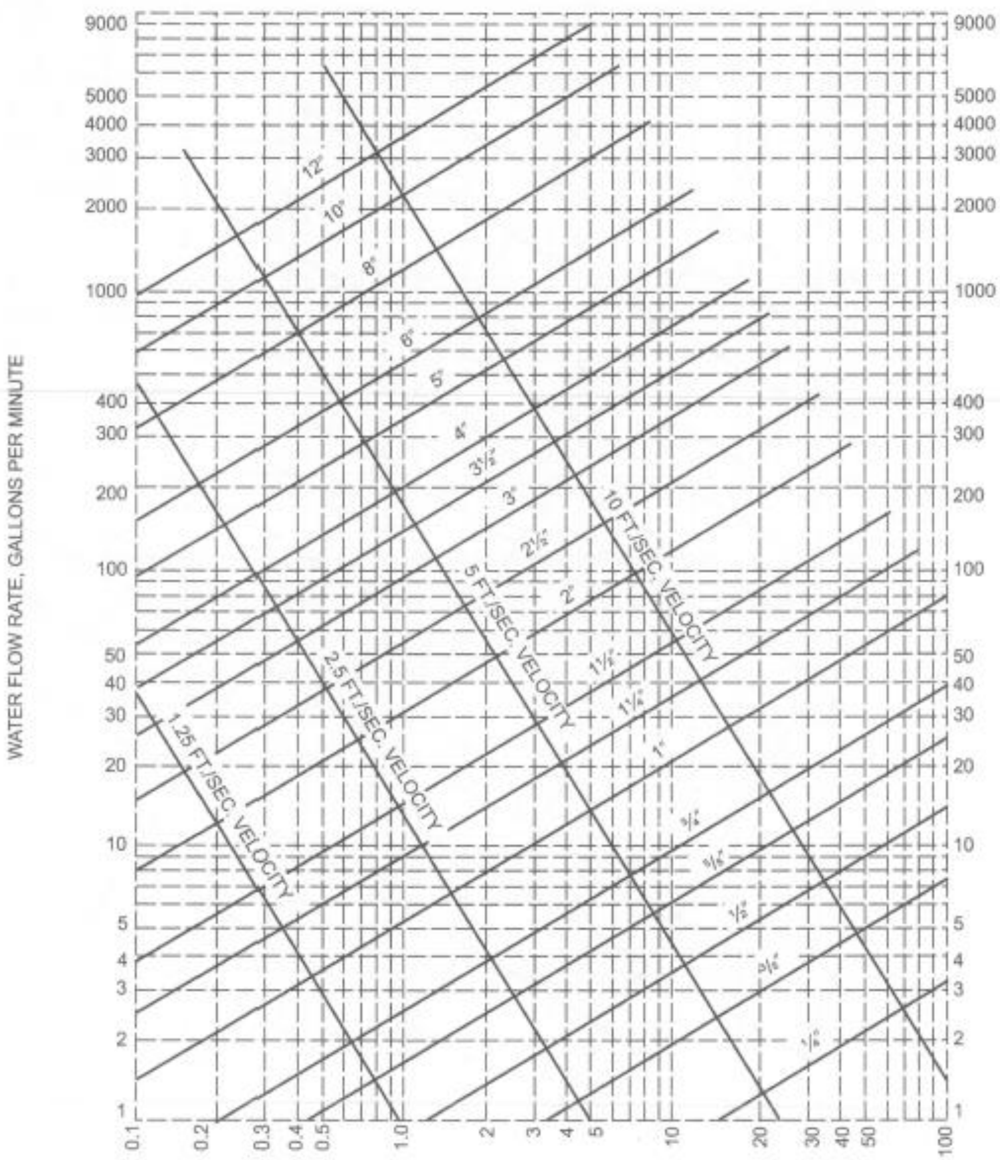



**Figure 2.1: Friction loss in smooth pipe (Type L, ASTM 888 copper tubing)**

[Source: *International Plumbing Code 2015 (IPC 2015), Appendix E Sizing of Water Piping System*]

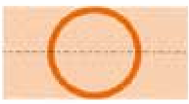
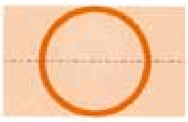
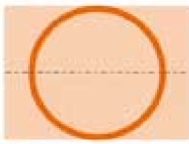
A similar procedure is being followed for the case of the cold water networks, meaning that the transferred cooling power at every part of the piping is being calculated, the flow rate of cold water at every part of the piping is calculated and the maximum allowed water velocity or water pressure drop per meter of the pipe is determined, according to the selection criteria, which in this case are the following:

1. Maximum allowed water velocity for pipes of diameters until 50 mm: $w$ = 1.2 m/s
2. Range of pressure drop: 100 to 400 Pa/m
3. Medium recommended pressure drop: 250 Pa/m
4. Maximum allowed pressure drop for pipes of diameters above 50 mm: 400 Pa/m
5. The velocity of the water may exceed the value of 1.2 m/s in pipes of diameter higher than 50 mm, as long as the limitation of the maximum allowed pressure drop is met.

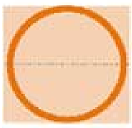
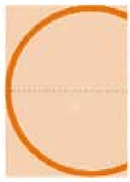
Thus, an initial cross section is selected for every part of the piping and, in case that the criterion of the maximum allowed water velocity or water pressure drop per meter of pipe length is not met, a larger cross section is selected.

### *2.3.2 Proper selection of pipes nominal diameter (according to pipes materials)*

According to what has been mentioned above and the known (from the previous stages of the calculation) flow rate of each branch of the hydraulic installation, the diameter of the pipe that will be placed to this branch can be determined with the help of the suitable Tables – similar to the one presented below concerning the copper pipes – and aiming at assuring that the flow velocity will not overcome the recommended value of 2 m/s but also that the length of the pipe used to the terminal branches won't be lower than the one corresponding to the water consumption for every intake.

| m/s | lt/s | lt/min | lt/s | lt/min | lt/s | lt/min | lt/s | lt/min |
|---|---|---|---|---|---|---|---|---|
| 3.00 | 0.24 | 14.1 | 0.40 | 24.0 | 0.60 | 36.0 | 0.90 | 54.0 |
| 2.75 | 0.22 | 19.9 | 0.36 | 22.0 | 0.55 | 33.0 | 0.87 | 49.5 |
| 2.50 | 0.20 | 11.8 | 0.33 | 20.0 | 0.50 | 30.0 | 0.75 | 45.0 |
| 2.25 | 0.18 | 10.6 | 0.30 | 18.0 | 0.45 | 27.0 | 0.68 | 40.5 |
| 2.00 | 0.16 | 9.4 | 0.26 | 16.0 | 0.40 | 24.0 | 0.60 | 36.0 |
| 1.75 | 0.14 | 8.2 | 0.23 | 14.0 | 0.35 | 21.0 | 0.53 | 31.5 |
| 1.50 | 0.12 | 7.0 | 0.20 | 12.0 | 0.30 | 18.0 | 0.45 | 27.0 |
| 1.25 | 0.10 | 5.9 | 0.17 | 10.0 | 0.25 | 15.0 | 0.38 | 22.5 |
| 1.00 | 0.08 | 4.7 | 0.13 | 8.0 | 0.20 | 12.0 | 0.30 | 18.0 |
| 0.75 | 0.06 | 3.5 | 0.10 | 6.0 | 0.15 | 9.0 | 0.23 | 13.5 |
| 0.50 | 0.04 | 2.1 | 0.07 | 4.0 | 0.10 | 6.0 | 0.15 | 9.0 |
| 0.25 | 0.02 | 1.2 | 0.03 | 2.0 | 0.05 | 3.0 | 0.07 | 4.5 |
| |  | |  | |  | |  | |
| | 12 x 1 | | 15 x 1 | | 18 x 1 | | 22 x 1 | |

| m/s | lt/s | lt/min | lt/s | lt/min | lt/s | lt/min | lt/s | lt/min |
|---|---|---|---|---|---|---|---|---|
| 3.00 | 1.47 | 88.2 | 2.42 | 144.8 | 3.60 | 214.8 | 5.89 | 353.4 |
| 2.75 | 1.35 | 81.4 | 2.21 | 132.7 | 3.30 | 196.9 | 5.39 | 323.4 |
| 2.50 | 1.23 | 74.0 | 2.01 | 120.6 | 3.00 | 179.0 | 4.91 | 294.5 |
| 2.25 | 1.10 | 6.6 | 1.80 | 108.5 | 2.70 | 161.1 | 4.41 | 262.6 |
| 2.00 | 0.98 | 59.2 | 1.60 | 96.5 | 2.40 | 143.2 | 3.92 | 235.2 |
| 1.75 | 0.86 | 51.8 | 1.40 | 84.4 | 2.10 | 125.4 | 3.44 | 206.1 |
| 1.50 | 0.74 | 444.4 | 1.20 | 72.4 | 1.80 | 107.5 | 2.95 | 176.7 |
| 1.25 | 0.61 | 36.8 | 1.00 | 0.3 | 1.50 | 89.5 | 2.45 | 147.2 |
| 1.00 | 0.49 | 29.4 | 0.80 | 48.2 | 1.20 | 71.6 | 1.96 | 117.8 |
| 0.75 | 0.37 | 22.1 | 0.60 | 36.2 | 0.90 | 53.7 | 1.47 | 88.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.50 | 0.25 | 14.7 | 0.40 | 21.1 | 0.60 | 35.8 | 0.98 | 58.9 |
| 0.25 | 0.13 | 7.4 | 0.20 | 12.0 | 0.30 | 17.9 | 0.49 | 29.5 |
| |  | |  | |  | |  | |
| | 28 x 1.5 | | 35 x 1.5 | | 42 X 1.5 | | 54 x 2 | |

Source: *Greek Institute for Copper Development.*

As far as the heating installations are concerned, the marginal maximum velocity is the one presented in Table 2.4 above.

## 2.4 Selection of circulation pump

### *2.4.1 Main features of a circulation pump selection*

The thermal energy produced by the burner - boiler system in a central heating installation has the calorifiers, the air conditioning units, etc. as its final destination. The water, the steam or the air are used as the heat transfer means. For example, in the case of the common radiator/heater, the water is used as the heat transfer means. The movement/circulation of the water can be done in two ways: through natural circulation or using circulators.

The circulators are pumps of centrifugal type aiming at the forced transfer of the hot water from the boiler to the heating bodies/units and they are functioning with electricity. They are usually installed into the boiler room and close to the boiler. Their size depends on the water volume that has to be transferred as well as on the resistances of the network.

The most important characteristics as far as the selection of a circulator is concerned are:

- The water flow rate *G* ($m^3/h$)
- The manometric *H* ($mH_2O$)
- The diameter of the inlet-outlet pipes
- The required power of the motor (Watt or HP)

The circulator flow rate is calculated with the formula:

$$G = \dot{Q}/\Delta T \cdot 1.000$$

where

*G* [$m^3/h$]: the water flow rate.

$\dot{Q}$ [kcal/h]: the power of the boiler.

*ΔT:* the difference between the temperature of water at the tapping point and the inlet water (for the case of a one-pipe heating system the value is equal to 15)

1.000 = constant number.

### *2.4.2 Exemplary calculations*

For the case of simple installations, the flow rate of the circulator *G* can be calculated assuming that each cubic meter of water gives to the heated spaces 15,000 kcal/h. Thus, in the case of a boiler with the characteristics of 50,000 kcal/h, the flow rate of the circulator has to be equal to 50,000/15,000 = 3.33 $m^3$/h.

Initially, the flow rate and the manometric of the required circulator are determined and this is expressed in mWC (metres of water column) and calculated by multiplying the total length (*L* in m) of the drain (hot water) and (cold water) return pipes of the most demanding (bigger in length) heating body of the installation multiplied by 16 (i.e. manometric = $L \cdot 16$). Of course, all the above assume the correct calculation of the pipe diameter, according to the transferred by them thermal load (kcal/h).

## 2.5 Selection of thermal insulation materials and dimensions

### *2.5.1 Effectiveness of the insulation - the R value*

The thermal insulation of water pipes can significantly improve the efficiency of hot water supply system. The insulation of hot/cold water pipes can lead to the decrease of the heat loss rate towards the environment and thus the delivery of water of a higher (or respectively lower) temperature by 2 to 4$^{o}$C is achieved, in comparison to the case of non-insulated pipes. This way, the water temperature is maintained until the final points of the installation, ensuring the homogeneity of heating / cooling. Furthermore, the wearing out due to the condensation or the occurrence of ice is avoided.

The efficiency of the insulation is expressed as an *R* value (thermal resistance). The more resistant the insulating material to the heat, the higher the R value, thus the more effective the insulation is. For example, the grey insulating material of pipes of 9mm is characterized by a 0.003 R value, while the blue one of 13mm has a 0.035 *R* value (colour coding of insulation). Polyethylene has a high R value, so it is characterized by excellent insulating properties. This specific material is also fire retardant and absorbs the noise (lower noise level in the pipes). Its placement is easy, since it is flexible and easy to cover the pipe and it is not shrinking. The usual materials used for the insulation of the pipes are the fiberglass, the mineral wool and the polyurethane foam.

### *2.5.2 Minimum required insulation thickness and installation basics*

The minimum insulation thickness is determined by the diameter of the pipe and the insulation material. The pipes insulation is made with strips of insulating quilt or with thermal insulating 'pockets' (shells). The inner diameter of the insulating cover must match the diameter of the pipe for a close application. Before the placement of the insulation, the pipes shall get clean. The insulation must be placed around the pipe before the assembling, wherever this is possible, so that the longitudinal junctions are avoided. The insulating strips are added around the pipes with wrapping in a toroid form and covering of their edges. The wrapping must be performed in such a way that air is not trapped.

The insulation must be tied every 30 or 60 cm, with the use of tape, wore or cable, thus contributing to the constant contact of the insulation with the pipe. The insulation must be used through the entire longitude of the pipes, the corners, the junctions and the joints included, but it must be kept at least 15 cm away from the chimney of the water, oil or gas heaters. The insulating quilts require a time-consuming placement procedure, but they are indicated for the case of pipe insulation especially at the junctions' points. The thickness of the insulating shells at the hot water piping must be at least 9 mm.

The insulated piping which are exposed to the solar radiation have to bear an external protection with aluminium foils of a 0.6 thickness. On the other hand, the pipes placed along walls are difficult to be insulated because of the lack of space. What can be alternatively done in this case is the filling of the gaps on the wall with polyurethane foam or mineral wool (stone wool).

## 2.6 Tests for verification of system functioning and for leaks

**Pressure testing** of pipelines is necessary to be carried out for the verification of piping system functioning and ensuring its good performance before its commissioning (as a first 'water & energy efficiency' measure to be taken). It should normally be carried out using water. Only in exceptional circumstances should pneumatic pressure testing using compressed inert gas or air be used, and then only under carefully controlled conditions. The reason for this is because water (as other liquids) is virtually incompressible and only a small quantity of energy needs to be introduced to increase the pressure significantly. Air, however, like all gases is compressible and, as a result, much more energy has to be put into the gas to raise its pressure.

In fact, at the pressure ranges normally used for testing water-piping systems 200 times more energy is stored in compressed gas compared to water at the same pressure and volume. So, should a joint, pipe, or any other component fail under test pressure when using compressed gas, the energy can be released with deadly force! However, where water leakage would cause unacceptable damage to property, a pneumatic leak test (at 5 kPa / 50 mbar) can be used first, followed by a hydraulic leak test.

*Planning for the test*

Before the performance of a pressure test a risk assessment must be carried out. This needs to consider hazards associated with stored energy, the possibility of blast and its effects, potential missile formation and brittle fracture. A safe system of work also needs to be established (this may require a permit-to-work system, training, use of written procedures, suitable venting arrangements, proper tools and equipment, safety restraints and personal protective equipment etc.).

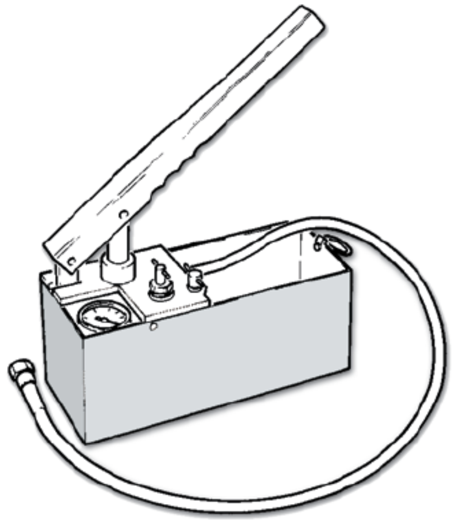
The following factors also need to be considered:

- ✓ Is the specified test appropriate for the service and the building environment?
- ✓ Will it be necessary to divide up the vertical pipework to limit pressures in high-rise buildings?
- ✓ Will a water test leave pockets of undrained water that might cause frost damage or corrosion later?
- ✓ Can the piping, or any in-line fittings and components (valves, bellows, tanks, cylinders, radiators etc.) withstand the proposed test pressure? If not, these need to be blanked-off or removed and 'make-up' pieces of tube inserted.
- ✓ If a water leak occurs what damage might be caused, and could minor faults be checked by carrying out a leak test with air or inert gas at 5kPa (20mbar) before filling with water?
- ✓ Are sufficient people available to keep a progressive check for problems whilst filling the system?
- ✓ Can different services be interconnected temporarily to enable simultaneous testing?

- ✓ How long will it take to fill the system using the water supply available, and what is the best time to start the test bearing in mind the duration and time needed to undertake the necessary preparations?

*Test preparation*

- ✓ Check that all high points have a tap or vent to facilitate removal of air during filling and that these are all closed.
- ✓ Blank, plug or seal any open ends and close all valves at the limits of the test section of the piping.
- ✓ Remove or blank off any vulnerable in-line fittings and components that may be damaged by the test pressure.
- ✓ Open any valves within the enclosed test section.
- ✓ Check that the test gauge is functioning correctly, has been calibrated and has the correct range. Attach the test pump, see Figure 2.2 (fit a separate gauge if necessary, see Figure 2.2 - right) using suitable adaptor fittings.
- ✓ Check that a suitable hose is available for draining the system.



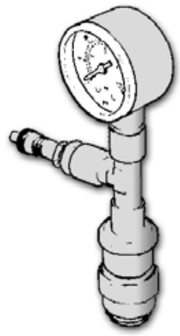


**Figure 2.2: Typical hydraulic test pump (left) and typical pressure gauge (right)**

*Hydraulic pressure test procedure*

1. Start to fill the piping and then 'walk' the route of the piping under test, continuously visually checking for leaks and by listening for the sound of escaping air.
2. Release air from all the high points systematically through the system to completely fill it with water.
3. Once the system is full, raise the pressure to the test pressure and, if a plastics piping system, continue pumping for the specified period.
4. If the pressure falls, check that stop valves are not letting by, then walk the system again for leaks.
5. Once the system is proven sound, have the test witnessed if necessary and obtain a signature on the test certificate.

6. After testing release the pressure. If necessary, ensure that any vents on cylinders, tanks, and pressure-vessels are opened to atmosphere BEFORE draining down and refitting vulnerable items.

If the system has to carry fluids other than water, it may be necessary to dry out the piping internally by passing hot air through it (this can take some time to achieve).

## *Unit 3: Correct selection and installation of water-energy efficient appliances and fixtures*

**Introduction / General description**

In the 3rd Unit of Module 1 the principles of the correct selection and installation processes of water-energy efficient appliances and fixtures will be presented to the participants in the training in order to enhance their knowledge of correctly interpreting the proposed project selecting the adequate appliances and fixtures, in compliance with regulations and standards (local, national, international), of correctly placing all components, appliances and fixtures, in accordance with the proposed project, as well as of performing all required tests to secure the correct functioning of the installed appliances and fixtures.

**Scope – Expected results**

After having finalized this LU, the trainees will be able to:

- recognize the benefits of efficient appliances and fixtures versus the conventional / traditional ones,
- identify the water savings that might result from the use of efficient water appliances and fixtures and to present to the client the water savings derived from the use of efficient appliances and fixtures (in respect to conventional ones),
- accurately implement the appliances and fixtures,
- correctly apply the most effective and suitable techniques and methods for the proper installation of the appliances and fixtures,
- deliver to the client an effective set of appliances and fixtures (in line with the client needs and the necessary performance and environmental requests).

**Key words / basic terminology**

Shower systems, faucets, water saving toilets, dishwashers, clothes washing machines energy label, radiators, fan coils, under-floor heating system.

## 3.1 Available hydraulic equipment (fixtures and other final receptors of water)

As already mentioned, the (hot/cold) water is being used in a number of hydraulic devices / fittings / devices in a household (single and/or multi-family house). By using products that are labelled according to the suitable label/standardization referring to their efficiency (inducing e.g. flow, type of technology in use, low-water behavioural criteria), the efficiency of the entire system is optimized both regarding the energy and the water use, assuring the use of less hot water at the point of (final use). What matters is not just the use of the already heated water but the water use in general.

In the next paragraphs, the fittings / water saving devices and appliances as well as the devices that consume hot water in a dwelling (or a building in general) are briefly described, so that the installer plumber is able to provide the potential customers/clients with the most suitable advices, concerning the use of the most appropriate devices aiming at the decrease of water and energy waste. A large variety of water saving systems for residential use is available in the market, at affordable prices. Next, the available technologies for the direct water saving are briefly described and these include showerheads, bathroom and kitchen faucets and toilets and flashing urinals.

### *3.1.1 Water saving shower systems and devices/appliances*

The showering is - most of the times - the leading "consumer" of water inside a household (as it may represent about 40% of total water use). The volume of the consumed water is defined by the type of the showerhead and the consequent operation, the frequency and the mean time that the shower is being used. There are four main alternatives:

- There are *showerheads using air* thus decreasing this way the water flow and keeping the pressure stable as water is mixed with air. The mixing of water with air is leading to an improvement of the water spraying or else a narrower spraying is produced, offering the feeling of the same amount of water with a lower flow volume.
- Another alternative is the *installation of equipment for the decrease of the flow in the high-volume flow showerheads*. This equipment consists of plastic or metal discs with a hole in the middle, which can be placed in existing showers. Nevertheless, the flow cannot be precisely adapted with the use of those devices, because the flow rate also depends on the water pressure.
- A third alternative is the one of the *showerheads using flow control devices* and these can be adjusted to a specific flow rate, regardless of the specific water pressure. Their operation is based on a disc containing a flexible finger ring of a circular cross section. Under high pressure conditions, the finger ring is levelled and reduces the water flow, while under lower pressure conditions it becomes more relaxed and allows for a higher flow.
- *Showerheads of low pressure* are also available, and these decrease the volume of used water without depriving the feeling of a normal shower.

*Electric showers* also exist, which are directly supplied with cold water while they deliver hot water according to the demand. The water is being heated in site as it passes through an element placed in the shower unit and both the temperature and the water flow are adjusted according to the user preferences. At last, the *mixing showers* also are available, and in this case the hot and cold water are mixed in the shower unit so that the desired temperature is assured. The electric showers may be user-friendly in terms of water usage comfort, but imply energy consumption, so they should be evaluated under the water-energy nexus rationale, i.e. considering the overall savings of water together with energy.

The flow rate of the available in the market showerheads ranges from 7 to 23 lt/min. Their cost varies from 10 to 45 € per item. The saving products are offering a saving potential until 50% without leading to any efficiency decrease. Depending on the baseline situation, the consumer behaviour and the number of people living in the household, paybacks may be of 1-3 years order of greatness. This is important data that the WET professional should consider also when advising the customers.

### *3.1.2 Water saving faucets*

The faucets are divided in two basic categories according to the location they are installed to: the kitchen faucets (installed in the kitchen sink) and the bathroom faucets (installed in the bathroom sinks). Through these faucets, almost 25% of the daily consumption of water consumption in a household is consumed. The water saving faucets are offering the possibility of an important decrease in water consumption in comparison to the conventional ones. A basic measure for the enhancement of the faucets' effectiveness is the fixing of the leakages, as the later consist of one of the most common reasons of water waste in many households.

There are various options for water saving in faucets available in the market:

- *Faucets providing a low water flow*.
- *Faucets* allowing the options *between a large and a low water volume flow,* thus delivering a large volume of water in a small period of time, but also a large volume of water in a short period of time. In this kind of faucets, the water flow is adjusted by a plug inside the tap.
- *Faucets with ventilation devices,* which can contribute to the decrease of water flow, as they are mixing air with water or they decreased the diameter of water outflow at the faucet. These faucets cannot be adjusted to specific flow velocities, since the real flow is dependent on the water specific pressure.
- *Flow control devices* decreasing the flow rate independent of the water pressure. These devices are screwed on the faucet head.
- Small *mechanical devices* placed on the head of the faucet (similarly to the ventilation devices) and adjusting the flow to a specific maximum flow rate. They are available for flow values higher than 1.7 lt (on a scale of 0.5 or 1 lt).

A category of alternative water saving devices (mainly met in public buildings) are the *faucets with metering*, delivering a specified volume of water before the automatic shutoff of water supply of operation. The *faucets that automatically turn off* possess a self-turning off switch and their operation is automatically interrupted once the user releases the switch. Finally, there are *faucets with motion sensor* that start delivering water once the sensor detects a motion right in front of it and terminate the supply of water once the user moves away from the faucet.

The flow rate of the available faucets in the market is characterized by a wide range of values, from 5 to 24 lt/min, while the corresponding cost lies between 20 and 300€ per item. The possibility of water saving may reach the 70%, without any reduction in efficiency. It is worth mentioning that the installation of a device (e.g. a flow restrictor) in an already existing faucet is less expensive than the replacement of the entire unit. Nevertheless, in the case of the kitchen, the installation of a new water saving faucet allowing the option between two different flows (large or small water volume) is much more efficient than the use of water saving devices.

Another device used for energy saving is the *saving nozzles*, which are placed at the end of a faucet assuring a stable flow with a regulated pressure, by introducing air in the water flow. These are categorized according to the flow rate, the use and the type of faucet to which the nozzle is going to be added. Their cost in the market is low ranging from 3 to 20 € per item and depending on their drainage they are offering up to 50% water saving without any reduction of the efficiency.


### *3.1.3 Water saving toilets*

The water consumption accounting for the toilet flushing represents almost 25 to 40% of the total water consumption in a residence. The saving potential lies mainly to the water amount that is used and the number of times used, which is also related with the number of people living in the household. On the other hand, and unlike shower heads and faucets, flushes are not water pressure dependent.

Apart from the case of the toilets with small water tanks (usually using 6 litres of water per flushing, with others using just 4 litres of flushing per flushing in contrast with those using almost 10 litres or more per flushing), the water saving can be achieved through:

- *(Flushing) Cisterns of controlled or dual flow (dual flush system)*, in which the evacuation mechanism offers the possibility of selecting among two buttons: the one of them activates a partial flush (half of the flush), while the other permits the complete evacuation of the tank (full flush). Thus, this dual option allows to the user to either choose a full flushing (4, 6 or 9 litres according to the model) for the case of solid waste, or half of the (partial) flushing (2 to 5 litres) for the case of liquid waste.
- *Water displace devices*, as for example bottles or bricks that can be easily placed in the toilet tank and contribute to water saving by occupying a part of the tank that would else be filled with water. So, the amount of water that is kept in the tank and released during each flushing, is reduced.
- *Early closure flushing devices*, being available in different forms. Once the flushing is activated, the closure can be done earlier with the use of such devices in comparison to the closure done in the case of the initial valve, thus releasing a reduced amount of water. The installation of such a device requires a quite experienced plumber.

The use of dual flushing systems may lead to the achievement of even 50% saving, since the use of the full flushing will only be required one time out of the five times a toilet is being used. The toilet flushing systems offering the option of closure provide a water saving possibility, though their efficiency mainly depends on the user. In the market there are tanks of 6 (3 lt in the case of partial flushing) to 12 litres of storage capacity, with the price ranging from 25 to 200 €, the higher cost corresponding to the embedded systems. It should be noted that the installation of a water displace device obeys to dimensioning and functioning aspects, probably revised by the flush provider, not being the inclusion of something else to reduce reservoir capacity, say, for instance, plastic water bottles.

### 3.2 Household appliances

Two are the major water (either hot or cold) – and, at the same time, energy - using household electrical appliances: the dishwashers and the clothes washers. The consumption of water (end energy) significantly varies among the different models and the available technologies. Nevertheless, the use of the new efficient technology may lead to a significant water and energy saving.

Addressing those appliances, apart from the various guidelines of a "proper behaviour / use", as far as the water and /or energy saving is concerned, a series of labelling also exists so that certain efficiency criteria are met. More specifically, besides the CE typical labelling representing a basic indication concerning the compliance of a product with the European legislation and permitting the circulation of this certain product in the core of the European market, the "Ecolabel" of the EU also exists, addressing the issue of the ecological design of energy products (currently non mandatory), while the majority of these devices also bear the "Energy Star" labelling, also non- mandatory.

The most relevant labelling is the "EU Energy Label". This labelling provides a tool of informing the consumer about the energy efficiency of the home appliances, helping him/her to proceed with the selection of energy efficient equipment as the most cost-effective solution. The labelling also provides additional energy or other resources (e.g. water consumption, volume of the appliance, etc.) related information. The Energy Label of a washing machine (clothes washer) is presented below with an explanation of what each section stands for:

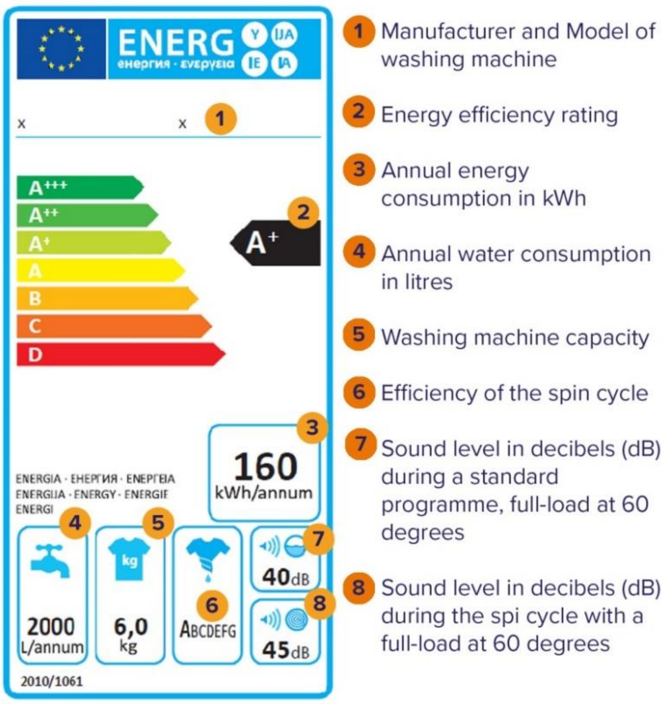



**Figure 3.1: Energy rating information – Example for a washing machine**

- **Washing machines**: Energy ratings can vary from one model to another. Since 2014, washing machines are rated from A – A+++, with models before 2014 rated from D to A+++. Each energy label includes two ratings, one for total energy consumption and one for the efficiency of the spin cycle. For the calculation of the Energy Efficiency (EEI) of a washing machine model of residential use, the weighted yearly energy consumption of the washing machine while operating in the programme of cotton clothing at a temperature of 60°C in full and partial load and while functioning in the same programme at 40°C under partial load, is compared to the typical yearly energy consumption for the same model of washing machine.

For the calculation of the *yearly energy consumption*, the levelized energy consumption, the levelized power in the "off" mode, the levelized power in the "stand-by (left-on)" mode, the levelized duration of the washing programme and the total number of typical washing cycles per year, are taken into account. The energy efficiency ratings are as follows:

| | |
|---|---|
| A+++ | EEI<46 |
| A++ | 46<EEI<52 |
| A+ | 52<EEI<59 |
| A | 59<EEI<68 |
| B | 68<EEI<77 |
| C | 77<EEI <87 |
| D | EEI>87 |

- **Dish washers**: For the calculation of the Energy Efficiency Index (EEI) of a residential use dish washer, the *yearly energy consumption* of the residential dishwasher is compared to the *typical yearly energy consumption* of this model. For the calculation of the *yearly energy consumption*, the energy consumption for the typical cycle, the power in "off-mode" for the typical washing cycle, the power in the "left-on" mode for the typical washing cycle and the total number of typical washing cycles per year are compared. The scheme in force since the 30th of June 2014 is as follows:

| | |
|---|---|
| A+++ | EEI<50 |
| A++ | 50≤ EEI <56 |
| A+ | 56≤ EEI <63 |
| A | 63≤ EEI <71 |
| B | 71≤ EEI <80 |
| C | 80≤ EEI <90 |
| D | EEI≥90 |

In addition to what has been mentioned above concerning the specific electrical appliances, there also exist certain performance criteria regarding the water consumption. Thus, according to the Regulation 1015/2010 regarding the ecological design requirements for residential washing machines, the performance criteria are being defined, the water consumption $W_t$ included: $W_t \leq 5 \times ½\ c + 35$, where *c* is the graduated capacity of the residential washing machine for the normal program of cotton clothing at 40 °C under full load, and for the normal program of cotton clothing at 40 °C under full load, respectively, depending on which one of the two values is lower.

For the case of the dish washers, there is no restraint as far as the water consumption is concerned. However, the Regulation 1016/2010 of the EC regarding the implementation of the Guideline 2009/125/EK about the ecological design requirements for dish washers of residential use include certain benchmarks over the water consumption. More specifically, there is a reference to 9 litres of water per cycle for a dish washer of 12 standard plate settings capacity and 7 litres of water per cycle for a dish washer of 6 standard plate settings capacity. Some more environmental-friendly programs are also available (self-called ‘Eco’ or ‘Economy’), which are using an even lower amount of water.

## 3.3 Heating terminal units

The terminal units are devices that finally transfer the produced heat to the spaces that are meant to be heated. Thus, these are exchangers between the air of the heated space and the heat transfer means, from the production system and though the distribution network towards the spaces to be heated. The terminal units are distinguished depending on their operation temperature to:

a) units of high temperature (water supply at 90°C and water return at 70°C),
b) units of medium temperature (water supply at temperatures form 60°C to 70°C and water return at temperatures from 35°C to 55°C), and
c) units of low temperature (water supply at 30 – 40 °C and water return at temperatures from 25°C to 35°C).

The operation of the heating terminal units is mainly based on two ways of heat transfer: a) convection / conduction and b) radiation, while most of the times both ways are combined. The percentage by which the heat transfer is made on either of the above-mentioned ways depends on the terminal unit type and operation temperature. In the following paragraphs, a short description of the most common heating terminal units is made.

### *3.3.1 Radiators and fan coils*

The **radiators** are the most common type of heating unit where the heat is emitted to the surrounding environment from the thermal surfaces of the unit. Of course, an important part of the heat transfer is also performed through convection due to the – natural – circulation of the heated air around the unit. The radiators are terminal units of high temperatures. The bodies are usually made of steel or aluminium (the cast iron bodies are not used nowadays as they are heavier, while they maintain their temperature for a long time, needing a long time period to become hot). The heating units possess special switches that permit their isolation so that no additional energy is wasted for spaces that are vacant. They also possess ventilation valves for their venting, in cases air is accumulated not allowing the unhindered circulation of water inside of them.

The **forced-circulation air-heating coils** (**fan coils**) are units that operate in both medium and low temperatures and which can immediately heat a space while in combination with the use of the suitable air ducts they can cover the ventilation requirements. In the case of these heating units, there is no mechanism such as transfer through radiation, since the unit consists of a heat exchanger where the circulation is forced (through the respective fan) and characterized by a much higher supply and velocity (rate) than in the case of the natural circulation bodies (radiators).

These units can both be used in conventional heating (boiler) and cooling (chiller) systems and in RES systems (e.g. solar collectors, biomass boilers, etc.). Some common applications of fan coils, except for the residential buildings, with high loads and multiple cold surfaces are the cases of professional and industrial spaces, due to their direct response.

### *3.3.2 Under-floor heating and other integrated heating systems*

During the last years the implementation of "**integrated heating systems**", heating systems that are integrated / placed in wall on the different building elements of the heated spaces, has expanded. These are terminal heating units of low temperature. The most common system of such type is the **under-floor heating**, which in certain countries already consists the main heating system, as it meets the basic demands of contemporary daily life distributing heat evenly and ensuring a comfortable temperature at all times, with no dust clouds. These systems are quite environmentally friendly as well, especially if supported by a solar thermal system.

In an under-floor heating system, hot water at 35-45°C circulates in a circuit of flexible pipes in a meander or snail layout, integrated under the floor, converting the floor itself to a heating unit (Figure 3.2). The maximum temperature of the floor surface must not exceed the 29°C. Only in the case of specific positions with high thermal losses, such as close to narrow external walls, big openings (doors or windows) and in bathrooms, the temperature is allowed to reach the 35°C (this can be achieved by increasing the density of the pipes under the floor).

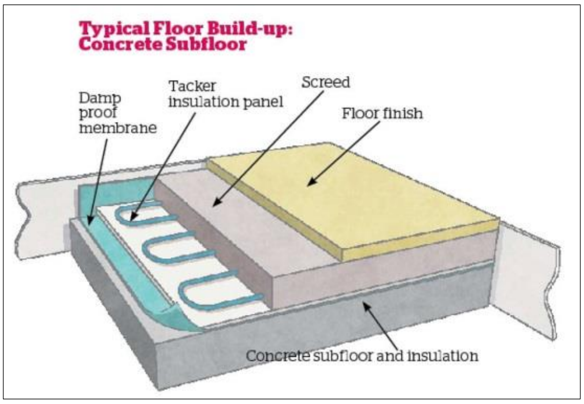



**Figure 3.2: Typical layout (left) and typical intersection (right) of an under-floor system**

[Source: https://www.homebuilding.co.uk/underfloor-heating-guide/]

The integrated pipes usually have a diameter between 16 and 25 mm and they are placed at a distance from each other varying from 80 to 350 mm. Assuming that the floor concrete slab is properly levelled, the total thickness of the under-floor heating system varies between 9 and 11 cm when the final paving is made of tile, or 1.6 cm (max 2 cm) when the final paving is made of wood. The heat transfer is made through radiation from the floor to the heated space, starting from the lower layers towards the higher layers to the entire surface of the heated space and without the presence of any strong currents. In this way, the desired layering of the temperature is achieved, meaning that at the level of the human head, the temperature reaches the values of 18-20°C.

## *Unit 4: Installation and management of smart-meters and other water consumption monitoring equipment*

**Introduction / General description**

The 4th Unit of Module 1 deals with the principles of installation and management of smart-meters and water consumption monitoring equipment, in order for the trainees to acquire the necessary knowledge of correctly selecting the adequate smart-meter and water monitoring equipment, including the adequate fittings, in compliance with the regulations and standards (local, national, international) applicable to thermo-hydraulic systems, of the basic characteristics of the appropriate monitoring equipment and control devices, e.g. for minimisation of water losses, of the benefits from monitoring water consumption in buildings, including the prevention of water losses, and of the regulations and standards (local, national, international) applicable to the monitoring of water consumption.

**Scope – Expected results**

After attending this Learning Unit of Module 1, the trainees will be able to:

- select the suitable water consumption monitoring equipment and control devices,
- properly and correctly install the water consumption monitoring equipment and control devices,
- manage the outputs of smart-meters and control devices (water monitoring equipment).

**Key words / basic terminology**

Water flow meters, smart water meters, data interpretation.

## 4.1 Water metering / smart metering

Water metering in buildings provides information to the user in terms of how much water their building consumes. The user is then likely to become more engaged in monitoring its water use, leading to more efficient water use, but also more active involvement in the identification of leaks.

The metering of water use is in place in many EU Member States (such as Denmark, France, Greece, Spain, Portugal, and Belgium) but is inconsistently applied (e.g. hot water metering for each dwelling and cold water metering for the whole building). Water metering is reported to be also strongly linked to water pricing discussions in Austria, Bulgaria, Belgium, Estonia, Spain, The Netherlands, Sweden and the UK, or that are still under development (Cyprus, Czech Republic, Ireland, Romania, and Slovakia). Water-metering may face technical constraints as individual dwellings and related piping may not allow the installation of individual meters at suitable points of entry.

In general, the benefits of metering are that:

- it allows water metering instead of water consumption estimation,
- in conjunction with volumetric pricing, it provides an incentive for water conservation,
- it helps to manage water consumption areas in the distribution network, thus providing a basis for reducing the amount of non-revenue water,
- it is a precondition for quantity-targeting of water subsidies to the poor.

However, as already mentioned above, there is disagreement as to the effect of metering and water pricing on water consumption. The price elasticity of metered water demand varies greatly depending on local conditions. The effect of volumetric water pricing on consumption tends to be higher if the water bill represents a significant portion of household expenditures.

There is evidence from the UK that there is an instant drop in consumption of some 10% when meters are installed, although in most instances, consumption isn't directly measured prior to meter installation, so the benefits are uncertain. Whilst metered water users in the UK do use less than unmetered users, in most areas metering is not compulsory, so the metered customers are a self-selecting group. In Hamburg, Germany, domestic water consumption for metered flats (112 liters/ capita/ day) was 18% lower than for unmetered flats (137 liters/capita/day) in 1992.

**Table 4.1: Advantages and issues with water metering/smart metering**

| | |
|---|---|
| Advantages | • Raises consumer awareness<br>• Fair pricing can be implemented, based on actual consumption and efforts by consumers |
| Issues | • Costs for implementing meters in areas where they are not used already<br>• May include changes in the tariff scheme |

The implementation of smart water meters, which collect real-time water use information, is also shown to help users address their water uses and help water businesses manage their network more efficiently, by detecting leakages or any other abnormal use efficiently (from the EC public consultation on water efficiency in buildings, 6% of respondents currently use smart water-meters). Given the related costs, the implementation of smart-metering could be restricted to water-stressed areas, as pinpointed by several stakeholders.

## 4.2 Water flow metering devices

### *4.2.1 Typical flow meters and how they work*

A water flow meter is an instrument capable of measuring the amount of water passing through a pipe. Several water flow meter technologies are available for selection depending on the specific water measurement applications, budgetary terms, and maintenance requirements. Each of these water flow meter type has a unique principle of operation, overall cost-of-ownership, and specific application benefits.

There are two common approaches to flow measurement, displacement and velocity, each making use of a variety of technologies. Common displacement designs include oscillating piston and nutating disc meters. Velocity-based designs include single- and multi-jet meters and turbine meters. There are also non-mechanical designs, for example, electromagnetic and ultrasonic meters, and meters designed for special uses.

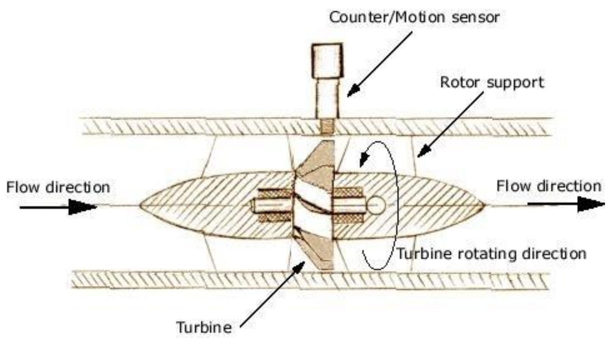
Most meters in a typical water distribution system are designed to measure cold potable water only. Specialty hot water meters are designed with materials that can withstand higher temperatures. Meters for reclaimed water have special lavender register covers to signify that the water should not be used for drinking. The question is what water flow meter should users select for their water flow measurement application?

There are four main (common) types of water flow meters:

1. mechanical (also called turbine) water flow meters,
2. ultrasonic flow meters,
3. vortex volumetric flow meters, and/or
4. magnetic flow meters.

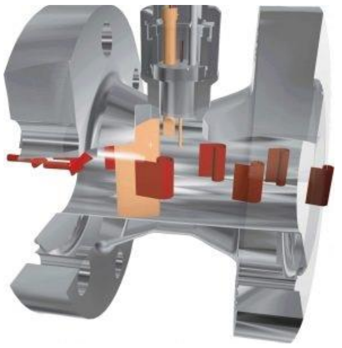
Mechanical flow meters

The mechanical types of water flow meters are the most common and economical type of water flow meters which perform flow measurement through turbine rotation with a shunt, propeller, or paddle wheel design. They work by measuring the speed of water flowing through the pipe that causes a piston or turbine to rotate. Their disadvantage is that they may clog up when the water is dirty or contain larger particles, leading to increased maintenance costs. Mechanical water meters also do not work well when the water flow is low. The proper way of their installation is shown in the figure.



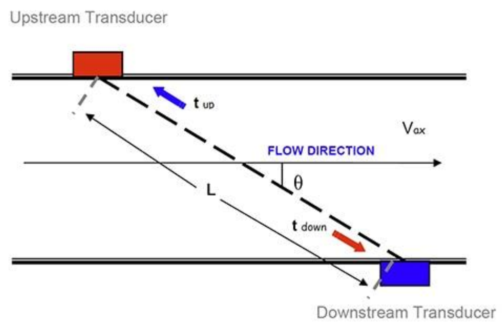
Vortex flow meters

Vortex water flow meters use vortices shed from a sensor immersed in the flow. Vortices are forces of nature, “swirls” produced when a fluid moves past an obstruction, like the wind past a flagpole or water flowing around a rock in a stream. In a vortex meter, a sensor tab flexes from side to side when each vortex flows past, creating a frequency output that is directly proportional to the volumetric flow rate. Multivariable vortex flow meters can measure up to five process variables with one process connection: temperature, pressure, density, mass flow, volumetric flow rate. Insertion vortex meters work well on very large pipes as they can be inserted into the flow by hot tapping with a retractor (see figure).



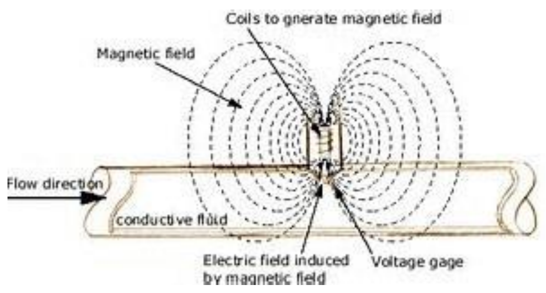
Ultrasonic flow meter

Ultrasonic water flow meters measure the speed of fluid passing through the pipe using ultrasound to measure the volumetric flow. In a transit-time ultrasonic liquid flow meter, an ultrasonic signal is transmitted in the direction of the flowing fluid downstream (see figure), and then another signal is transmitted against the flowing fluid upstream. Then, the time for the sonic pulse to travel downstream is compared to the time for the pulse to travel upstream. Using this differential time, the velocity of the following fluid is calculated. Then the meter calculates the volumetric flow rate in the pipe using this fluid velocity. Clamp-on ultrasonic meters can measure water from outside of the pipe by shooting pulses of sound through the pipe walls, thus having application flexibility and been suitable for water flow measurements in large pipes.




Magnetic flow meter

Magnetic flow meters measure the speed of a fluid passing through a pipe using a magnetic field to measure the volumetric flow. They are based on the principle of Faraday’s Law of Electromagnetic Induction, according to which liquid generates voltage when it flows through a magnetic field (see figure). The voltage produced is directly proportional to the water movement; the voltage signal is processed into the volumetric flow rate by the electronics. Since the magnetic flow meters show an intermediate accuracy, they are not suitable for custody transfer applications and cannot be used to measure pure water as there are no ions to measure.




The ideal water flow meter type is determined by the details of the application, as some flow meters work better than others in certain situations. Water flow meters are generally owned, read and maintained by a public water provider such as a city, rural or private water company. In some cases an owner of a mobile home park, apartment complex or commercial building may be billed by a utility based on the reading of one meter, with the costs shared among the tenants based on some sort of key (size of flat, number of inhabitants or by separately tracking the water consumption of each unit in what is called sub-metering).

#### *4.2.2 Smart water meters as an integral part of an automated water supply system*

As mentioned above, historically, the principal use for meter data is customer billing, with billing as the main driver for meter installation, followed by water conservation. As such, meter readings were only required when a new bill needed to be generated. This low data requirement has meant that many meters are still manually read and only infrequently (often only once a year). A "smart" water meter has the ability to store and transmit a large amount of data that are related to the consumption and the use of water in real time. It is an electromagnetic water meter that is battery powered and which can measure the water flows for many years gathering continuous online information on water consumption.

The advantage of an electromagnetic meter is that there is no loss of pressure inside the water meter and maintenance can be limited. A separate battery supplies electrical power for the wireless system and this enables the user to read the water meter at a distance. The smart water meters are equipped with a chip so that the water consumption is immediately registered through a tele-metering system to the portable devices/appliances of the end users and /or to the data base of the water supply companies. The water meters besides the water volume (water consumption) do also register the time and way (i.e. final use) of consumption.

The smart water meters make part (i.e., are an integral part) of an automated water supply system or, else, of an advanced metering infrastructure (AMI). These systems provide the possibility of measuring and further analyzing information relevant to water consumption and then communicate this information to the consumer / client through the internet. The water supply companies are using the automated water supply systems as part of a wider development initiative called "Smart Grids", also including electricity and natural gas services (consumption measuring).

The AMI technology is a broadening of the already existing advanced measurement reading (AMR). AMR is facilitated by the meters having the capability to send out a data signal, which can be picked up by a meter reader, facilitating passive reading, through drive-by or walk-by. AMI differs by providing a two-way communication and allows the sending of information and commands to the final users for multiple purposes (e.g. use in real time and pricing information, leakage detection or any other improper use identification, exchange of messages on targeted efficient use, measuring changes in water use and even services of distant termination of supply).

The revealed information has the ability to assist in the building operational management as identifying leaks and excessive water consumption. Some of these diagnostic analyses are "low hanging fruits", where a low-cost or no-cost corrective measure yields great water savings and at the same time achieves an efficient control of the building. Data could also be applied to empower the end users. By information and feedback on consumption, improved customer service as well as transparency is achieved, which possibly could lead to positive behavioural change. Daily, weekly and monthly consumption could be presented to the customer as well as social comparisons and alerts for leaks or high consumption.

A goal of processing end user consumption data is to create a better decision basis. By utilizing smart meter data as input and transforming these data through different and purpose dependent analyses, generated outputs are potentially actionable insights to support decisions. Data driven decisions have recognized benefits and pose an efficient tool for improved water management.

## *Unit 5: Hydraulic adjustment and balancing of thermo-hydraulic installations*

**Introduction / General description**

In the 5th Unit of Module 1 the WET trainees will be taught the principles of hydraulic adjustment and balancing of thermo-hydraulic installations works trying to increase their knowledge of the principles of fluid dynamics in pipes, of the possible measures and/or corrective actions for assessing hydraulic imbalances in the thermal-hydraulic system (e.g. pressure drops), as well as of the critical settings that must be met when performing the hydraulic adjustment (specifically to water pressure).

**Scope – Expected results**

Following this LU, the trainees will be able to:

- choose the appropriate tools to secure the proper adjustment of the thermo-hydraulic system,
- perform the necessary tasks for the hydraulic adjustment and balancing of the thermo-hydraulic system,
- efficiently check-out the thermal-hydraulic system installation.

**Key words / basic terminology**

Heating network, hydraulic balancing, static adjustment, dynamic adjustment, balancing valve, Combi valve, operation pressure.

## 5.1 Basics of hydraulic adjustment and balancing

### *5.1.1 Necessity of balancing heating hydraulic networks*

In case a heating network could be compared to an electrical circuit having resistances/resistors in series, the next analogy would exist: in the same way that the current passes through the smaller resistance/resistor, the water follows the path with the smaller resistance/resistor. The pipes, the valves, the bodies and other elements of the heating network are considered as resistances in series, in the correspondent electrical circuit. Thus, the heating bodies that are at a longer distance from the boiler receive a smaller volume of hot water in comparison to the bodies being located closer to it. In other words, in the case of a network containing more than a loop, the ones that are located closer to the circulator are 'stealing' the amount of water.

This situation is illustrated in the following Figure 5.1. As it is clear, the heating bodies that are located higher (i.e. the bodies on the upper floors) are more distant from the boiler in comparison to the heating bodies in the lower floors and this is the reason why they are not sufficiently heated. The same stands for the bodies that are located at the longest distance from the heating source (see circuit at the right of Figure 5.1 - comparison with the bodies located at the left side / closer to the boiler / circulator).

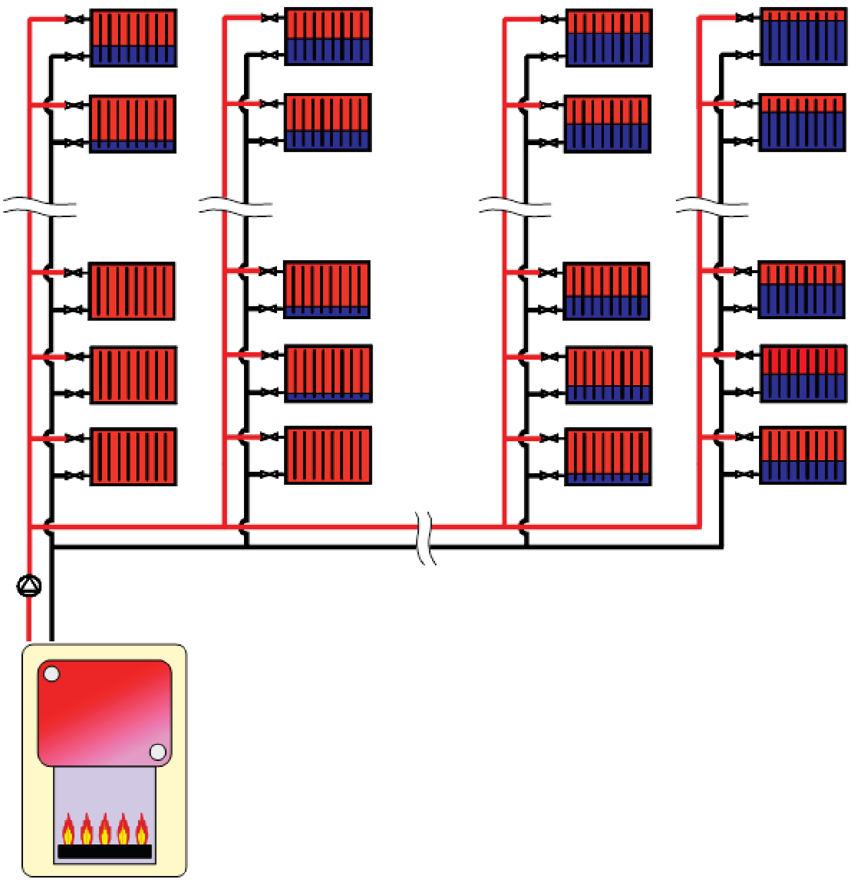


**Figure 5.1: Central heating network without hydraulic balancing**

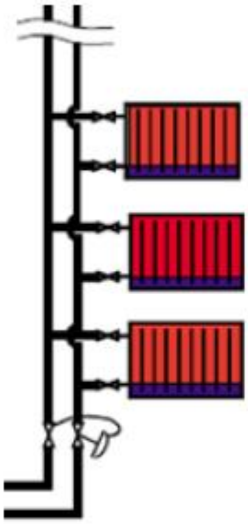
So, the managers of block of apartments or of other building complexes are obliged to start the heating earlier or to preserve a higher temperature at the heating water in order to achieve feasible temperature in all spaces. This status is leading to an important waste of energy due to the overheating of the closer spaces on the one hand and to the early initiation of the heating system operation on the other hand, so that the most remote rooms that are usually

The hydraulic balancing means the “strangulation” of the flow in the nearby bodies so that their resistance increases, and the water flow is optimized, depending on the capacity of each body. In practice, a drop of pressure (an additional “resistance”) is added to each loop so that in all the loops of the network the same pressure drop occurs. This decreases the total water flow and thus the losses in the production and supply heating systems are reduced. An optimized system requires a lower amount of energy for the pumps due to reduced water flow. This also results to electric energy saving. For the achievement of hydraulic balancing, the installation of adjusting valves to some or to all the branches of the delivery network is possible (or necessary).

### *5.1.2 Hydraulic adjustment and balancing methods / techniques*

The hydraulic devices that are used for the hydraulic balancing of the heating networks are the strangulating (throttle) valves of controlled $\Delta P$, the analogue electro-valves and the differential hydraulic controllers. The first of these fixtures requires a manual control and it is suitable only for a static adjustment. The remaining two fixtures are either electrically driven or driven through actuating mechanisms (spring – membrane), both being suitable for both a static and a dynamic adjustment.

In the case of **static adjustment** an autonomous repetitive strangulation process has to be followed, until the flow rates demand is met. In the case of the **dynamic adjustment**, that is the requirement for adaptation of the strangulations to the varying hydraulic characteristics of the network, on the one hand an autonomous procedure of constant strangulation is being followed, but on the other hand it is under discussion whether the required flow rates will be finally achieved. And this is due to the fact that the strangulating layouts / fixtures are characterized by a ΔP range to which they behave in respect and practically operate within, whereas they are unable of responding outside the limits of this range. Finally, we are dealing with the phenomenon of all the dynamic adjusting fixtures experiencing a constant repetitive strangulation procedure.



The proper hydraulic balancing can be achieved through a series of different procedures to new or already existent installations, in the condition that the determination of the required values is performed through a thorough calculation or in some other way/using another way. The target is the punctual adjustment of the flow (rate) in the heating bodies. The indicative required procedures are presented in the following Table 5.1, for both cases of installations (existing and new ones). It should be mentioned that the thermostatic valves of the radiators must be protected against the very high values of differential pressure.

**Table 5.1: Implementation of hydraulic balancing in new and existing installations**

| New installations | Existing installations |
|---|---|
| Determination of the heat demand | Determination of the heat demand |
| Determination of the temperatures in the system | Measurement or determination of the temperatures in the system |
| Design of the heating surfaces | Control of the heating surfaces |
| Calculation of the size of the heating bodies flow | Calculation of the size of the heating bodies flow with the help of the heat demand and of the temperature difference |
| Dimensioning of the piping so that the differential pressure ranges between 30 and 100 Pa/m | Registration of the existing piping for the determination of the pressure drop inside the system |
| Installation of balancing valves, if necessary. Next, performance of the necessary calculations and adjustments. | Installation of balancing valves, if necessary. The pre-selection values have to be determined and the adjustment has to follow. |
| Determination of the pre-selection values for the thermostatic valve of the heating bodies. | Installation of differential pressure adjusters in case the differential pressure inside the piping exceeds the 200 mbar |
| Determination of the pressure drop (manometric) of the circulator | Control of the circulator and replacement if necessary. |
| Installation of differential pressure adjusters in case the differential pressure inside the piping exceeds the 200 mbar | Determination of the pre-selection values for the thermostatic valve of the heating bodies. For helping the calculations a value of the level of 100 mbar may be selected for the valve, as pressure value. |
| Adjustment of the thermostatic valves of the heating bodies | Adjustment of the thermostatic valves of the heating bodies |

## 5.2 Dynamic balancing for dynamic networks

### *5.2.1 Meaning of dynamic balancing of a hydraulic network*

Although the use of pumps and circulators of variable volumetric flow as well as the reduction of the differential pressure of the pump is common, the hydraulic network control keeps on been performed on a large degree through the static control procedure. A common approach is the balancing of the hydraulic networks with the use of static balancing valves, pre-adjusted valves or network control valves. Of course, these interventions are only performed once and only for the specific situation: the design phase under full load.

Nevertheless, the status of operation under full load is rarely occurring while the installation almost always operates under a partial load. So, the question is whether both the pump and the control fixtures must be adjusted to the individual operation status (partial load). In this case, the static hydraulic balancing to a variable installation means the additional introduction of resistances, so that the pressure loss at every path coincides with the less desired for the system resistance when the installation is at the design phase. This is necessary for the unhampered operation of the system under those circumstances.

However, based on the individual use and on the internal and external loads, the less desired flow path is constantly varying. The network behaviour becomes dynamic. In this case the installed static balancing valves are not just useless, but they consist of an important hydraulic “resistance”, which can influence the network control, depending on the use. Given the fact that the hydraulic networks in buildings are almost always operating under partial load, the problem arises when the pump is required to repetitively overpass useless resistances in water installations of variable flow rate and conventional static hydraulic balancing.

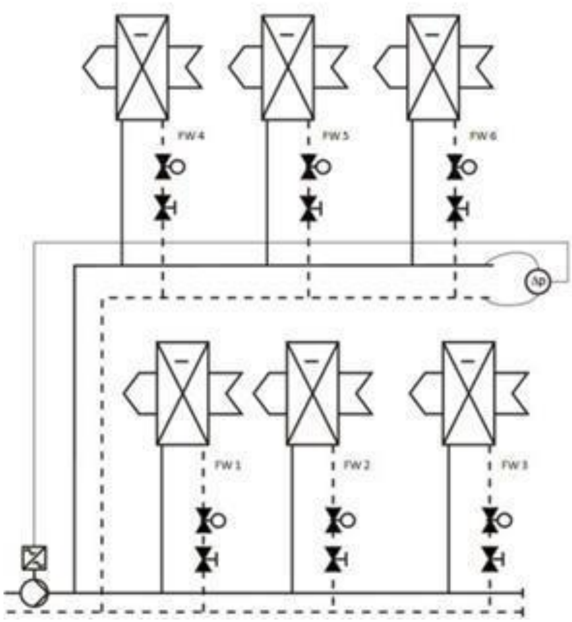



**Figure 5.2: A classic heating network with static balancing**

Figure 5.2 shows a classic thermo-hydraulic (heating) network with static balancing. A partial load condition can be described by an example in which the flow in lanes 2 to 5 is closed and only lane 1 is in operation. While static balancing is designed for the least favourable flow path (i.e. the remote circuit 6), flow path 1 which is in fact the most favourable in this operating state, proves to be the least favourable flow path in the current hydraulic condition. The static balancing valve creates a significant pressure loss in this case, even if it is not necessary. Although there is not always a noticeable underflow, it should however be clear that static balancing in current networks with variable flow rate is not feasible, even from an energy point of view.

### *5.2.2 How the dynamic balancing of a hydraulic network is made*

For a network with a variable volumetric flow to be properly balanced, the dynamic adjustment of the balancing valve is necessary. The solution towards this direction is provided by the automated balancing (Combi) valves. These are constituted by two parts: the first part is the common control valve while the other part is the differential pressure controller, which is connected in series and maintains a stable pressure value through the control valve.

The control valve is activated according to the network requirements (e.g. from a temperature control signal) and modifies/changes the path of the piston with the help of an engine. In the same time, the controller maintains a stable differential pressure to a respective control valve. In view of this combination, the control valve remains independent of the pressure as long a specific minimum differential pressure is maintained.

Due to their dynamic behaviour, the automated balancing valves are able of compensating for small divergences between the design and the assembling in the same installation. Furthermore, it is possible for a hydraulic network to be upgraded relatively easily with the use of pre-adjustable balancing valves, given that these valves are compensating for the new hydraulic parts as well.

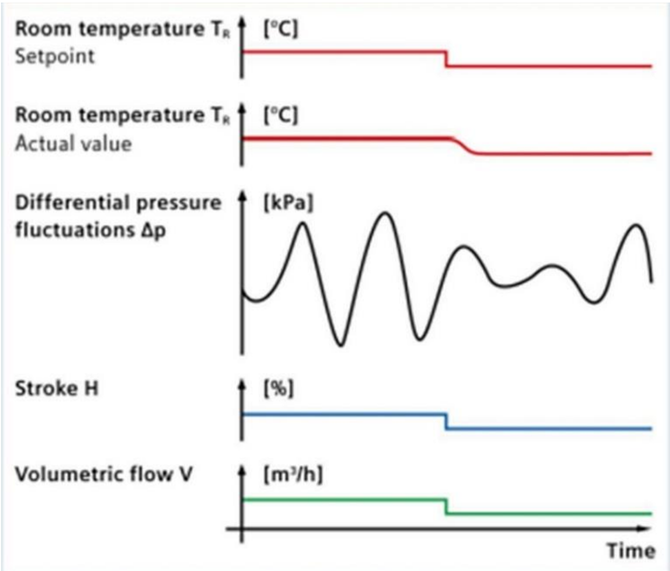



**Figure 5.3: Characteristics of a room controlled by combi valve**

Whichever the case, and despite the drastically reduced amount of design and installation, designing the right network remains essential. The desire for energy efficient hydraulic networks requires well thought out planning. Although the pressure independent (Combi) valves can compensate for many deviations and errors, they should not be misused to compensate for inadequate programming, since a dynamic and economical network with few pressure losses is also inextricably linked to a well-studied topology.

## 5.3 Control of the operation pressure

### *5.3.1 Benefits of controlling the inflow water pressure*

Some “practical” issues that may arise and have to do with water (hot or cold) saving are related to the inflow water pressure. More specifically, the water supply companies (public or private) are using pumps and pumping stations for the enhancement of the inflow water pressure inside the supply networks. In certain cases, the pressure may exceed the value of 200 psi. The majority of hydraulic installations codes require the use of pressure adjustment valves (PRV) in residential systems where the inflow water pressure exceeds the value of 80 psi, as the higher pressure values can lead pipe deterioration and break, also causing serious damage to the fittings.

By assuring that the (incoming) water reaching a hydraulic installation with a pressure value not exceeding the 60 psi (414 kPa), this can lead to important water savings by reducing the amount (volume) of water coming out of the hydraulic element and limiting the possibilities of water leakage from the pipes, form the heaters, as well as the chance of leaking taps and of destructive incidents in case of occurrence of ruptures to the pipes, to the tires or to components of an installation using water. The maintenance of pressure at 60 psi can also contribute to the maintenance of the efficiency of the hydraulic elements, to the reduction of noise from the dishwasher or the washing machine, as well as to the reduction of failure/damage percentage in a hydraulic installation, while the reduction of DHW consumption is contributing to the amount of the energy required for the preheating of water.

### *5.3.2 How the control of the operation pressure is made in hydraulic networks*

The most common type of water pressure reduction valve is the direct operated water pressure reducing valve. These valves gave an iron body construction of sphere type containing a resistant to heat spring diaphragm, connected to the outlet of the valve and which acts on a spring. The water that enters the valve is retracted in the body of the valve and is directed through the internal room which is controlled by an adjustable diaphragm with a spring and a disc. Even in the incident of a fluctuation of the water pressure, the PRV assure a stable water flow at an operation pressure. The minimum flow rate through a PRV must vary between the 10 and the 15% of the maximum desired flow rate.

In general, a controller has to be selected based on the criterion that for this specific controller the operation pressures are dropping to the middle of its nominal operation range and do not depend on the size of the pipe to which it is going to be connected. It is important to mention that the use of a PRV creates a closed system and that the thermal expansion is able of leading to increased pressure values in certain cases. The regional (by site) codes of hydraulic installations must provide guidelines concerning the control of this issue.

## *Unit 6: Indoor leakage identification & control and periodic cleaning of hydraulic installations*

**Introduction / General description**

In the 6th Unit of Module 1 of the WET course, the basics of indoor leakage identification & control and periodic cleaning of hydraulic installations will be showcased to the trainees in order to enhance their knowledge of the procedures for the identification of the leakages in the thermal-hydraulic system, and of the procedures for proper repair, replacement and maintenance of the thermal-hydraulic system.

**Scope – Expected results**

At the end of this Unit, the trainees will be able to:

- identify and / or diagnose the possible leakage occurrence throughout the fixtures and/or other equipment of the hydraulic installation,
- fix the identified problem(s),
- perform the regular maintenance and repair works of the hydraulic installations.

**Key words / basic terminology**

Indoor leakage, leak assessment, identification techniques, periodic cleaning.

## 6.1 System diagnosis for leak assessment

### *6.1.1 Lifetime of main components and identification of those that are more susceptible to leakage*

The detection of leaks from any water using fixtures, appliances or equipment is an ambiguous procedure that has to be regularly followed for the assurance of their efficiency throughout their life time. As an example, it can be mentioned that a typical American home can waste, on average, more than 38,000 litres (10,000 gallons) of water every year due to running toilets, dripping faucets, and other household leaks. The most common likely sources of leaks that can be met in a dwelling include:

- ✓ pipes and fittings running between the utility's water main and the foundation of the home;
- ✓ all connection points in the hot water delivery system;
- ✓ toilet angle valves and connections;
- ✓ toilet flapper valves;
- ✓ hot/cold water connection hoses and valves at kitchen and bathroom faucets;
- ✓ shower arm and showerhead threaded connections;
- ✓ shower diverter in bath/shower combinations;
- ✓ connections and valves to dishwashers, clothes washers, refrigerator ice machines, evaporative air conditioners, water softeners, and drinking water treatment systems, if installed.

A considerable number of various devices and systems are available through which the detection of possible leaks in residential plumbing systems at predetermined locations (e.g. clothes washers, dishwashers, toilets, water heaters, sinks, and pipes that may freeze) can be performed. It is worth mentioning that some of these devices can automatically shut off the water supply to the house or to the specific appliance to reduce the water loss through leaks and/or ruptures. Another category of devices are functioning by sounding a loud alarm for the early water leak detection.

Most of these devices have components that are battery operated and, therefore, they require homeowner maintenance to ensure their performance. If operating correctly, the devices that automatically shut off the water supply are able of contributing to a significant reduction of the amount of water loss through leaks and ruptures. They may also serve as a selling feature of the house due to their potential to reduce or prevent property damage caused by flooding.

The installation of water meters at each single-family home, if not provided by the municipality, is another way for homeowners to check for leaks, in a more indirect way. Water meters can indicate that a leak exists if flow is detected when all fixtures are turned off or through carefully investigation of flow patterns (e.g., night low-flow periods). Furthermore, the residents could also benefit from the installation of a water meter by obtaining a more accurate account of water use for utility billing purposes.

### *6.1.2 Tests, measurements and fault-finding techniques and tools*

To determine if there are any leaks in the home, an inspector (i.e. the WET) must conduct a pressure-loss test. For single-family homes with only one water supply to the home, the inspector will attach a pressure gauge to an outside faucet, take a reading, and then shut off the water supply to the house. After several minutes, the inspector will determine if the pressure has dropped. A loss of pressure indicates a leak that cannot be perceived. For houses with more than one water supply or without an outdoor faucet, inspectors will attach a pressure gauge to the cold water faucet for the washing machine hook-up or other cold water faucet and take the pressure reading. For houses with a separate water supply for irrigation (e.g., reclaimed water), the inspector will check both the outdoor and indoor water supplies for leaks using the approach described above.

The performance of a pressure-loss test in houses of multi-family buildings will vary based on the plumbing system design. Homes that are supplied through a single line with a shutoff can be tested at any point of use within the home. If the home is supplied by multiple supply lines, the inspector will need to coordinate with the builder to ensure that all individual supply systems are tested.

During the inspection, the inspector will check for leaks at all visible water supply connections and valves for water-using fixtures, appliances, and equipment. To check for toilet leaks from the flapper valve, the inspector will remove the tank lid and add some food colouring or a dye tablet to the tank. After about 5 minutes, if the water in the toilet bowl is coloured, the flapper valve is leaking. Flush immediately upon completing the experiment and check to make sure the tank and bowl are both clear of the colouring to avoid any staining.

If such possibility exists, the builder could proceed with the restoring of any identified leaks while the technician is still at the home, and those areas can be immediately re-inspected. Some leaks, such as those from irrigation systems, may be more difficult to immediately fix and may require re-inspection at a later stage.

## 6.2 Periodic cleaning of hydraulic installations

**Heating / cooling systems**

The cleaning and the maintenance of heating and cooling systems is a necessary process for the maximization of the performance of the system and for energy saving purposes. The better the heat distribution throughout the property, the lower household bills will be, the system reliability is increased and, of course, an extended lifetime for the entire system is assured. Some of the most common problems of heating and cooling installations that can prevented if a proper maintenance procedure is regularly implemented are the internal corrosion of the metal in the system by the formation of metal oxides, known as "magnetite mud", the salt deposits & the electrolytic erosion.

On the other hand, the main benefits from the maintenance of a heating system are the fuel economy (oil - gas) or electricity saving, the higher durability of the heating system as well as its increased safety, but also the avoidance of costs for emergency damage. In order to maintain the quality of the heating and cooling network and maximize energy savings, new technologies and products have been developed that offer great durability and increased economy to the systems in which they are applied. One of them is the Magnetic Filter which can be used to face the problems caused by magnetite mud created in heating systems.

The chemical cleaning (or dynamic rinsing) is the most efficient and effective method for cleaning the central heating system. The fundamental principle is to create a dynamic flow of clean water under controlled conditions to remove sediments from the system. A dynamic rinsing pump and the appropriate products for cleaning and protecting central heating systems are required.

The magnetic softener is another device/tool that is used for the cleaning of the appliances and the pipes: the old pipes are cleaned up and the new ones are free longer. The magnetic softeners are usually indicated for tube cross-section of max 1½ inch (approx. 40 mm). They can be used to face the problems of salt and rust and may be used with any material of metal pipes: iron, copper, stainless steel, galvanized, plastic pipes: PVC, PE, and PP. Furthermore, it is an environmentally friendly solution without salt and chemicals.

A quite popular method for the cleaning of a central heating system is the power-flushing, a method providing a rapid yet comprehensive cleaning. Before proceeding to a cleaning using the power-flushing method, the symptoms verifying the need for cleaning have to be identified: not all rooms are equally heated, the system takes longer time than usual to warm up, one or more radiators are cold at their bottom, the radiators need frequent bleeding, or the boiler is more "noisy" than usual. The tools required for the implementation of the cleaning procedure are a power-flushing machine and a suitable cleaning chemical. This method is further analysed in the following.

*Main steps of the power-flush cleaning*

*1) Preliminary tasks:*

- Prior to the main cleaning procedure the following parameters must be recorded:
  - ✓ temperatures of all the radiators (the most important cold spots must be identified);
  - ✓ settings of any thermostatic radiator valves (TRVs), aiming at the quicker restoration of the system's operation once the power-flush is completed.
- Take a sample of the system water for reference.
- Establish whether the system is open or sealed.
- Turn off all electrical controls and electrically isolate the system and then isolate the cold water supply to the central heating system.
- Manually close any automatic air vents.
- For open-vented systems, cap-off or temporarily join together, the open vent and cold feed to the feed and expansion cistern.
- Mark the position or note the setting of the lock-shield valves, then fully open all valves.
- Remove any TRV heads to ensure maximum flow through each valve.
- Set any diverter or zone valves to their manual, open position.
- Where practical, anti-gravity and non-return valves should be bridged, by-passed or temporarily removed as failure to do so will prevent flow reversal.
- Connect the power-flushing machine to the central heating system following the manufacturer's instructions.
- If a new boiler is being fitted, to prevent damage or contamination, power-flushing should either be undertaken before the boiler is installed or with the new boiler isolated from the rest of the system.

*2) Setting in place and connecting the power-flushing machine*

- Place the unit somewhere within reaching distance of cold feed water and an appropriate drain point.

- Take care of protecting the customer's property form spillages, etc.
- Wherever possible, the power-flushing machine must be connected in the place of the heating water circulator pump for the optimum cleaning result. If not so, then the power-flushing machine could be connected across a radiator, however, this will impair the efficiency.
- Follow the power-flushing machine manufacturer's instructions for hose connections.

*3) Primary Flush*

- Fill the unit with water from the mains and switch on the pump. Let the water circulate for 2-3 minutes.
- Add the cleaning chemical into the power-flushing machine and continue circulating for a further 15 minutes approximately, reversing the flow every 5 minutes or so to improve the initial cleaning process.
- After approximately 15 minutes of cleaning, the hot water circuit and all but one of the radiators should be isolated. Begin with the radiators identified as having cold spots in the initial assessment of the system.
- Circulate the water and cleaning solution through the first radiator, reversing the flow periodically. Vibrating the radiator by banging it with a rubber mallet of the flat of your hand will help to dislodge stubborn debris.
- Once the entire surface of the radiator is clear, move on to the next radiator. Work your way around the system in this way, repeating this process one radiator at a time.
- Once this process has been completed, the secondary flush can begin.

*4) Secondary Flush*

- With a single radiator open, dump the contaminated water, reversing the flow periodically until the water leaving the waste pipe is clear. Isolate this radiator and move onto the next.
- Work your way around the system, repeating this process on each radiator.
- Re-open all radiator valves and flush the system through until the water being dumped to the drain is totally clear.
- Test the water draining from the system.
- Depending on the chemical cleaner, a neutralization may be required at the end of this step.

*5) Following the cleaning procedure (last phase)*

- Add a high quality inhibitor to the power-flushing unit and re-circulate for 10 minutes.
- If necessary, add more inhibitor, re-circulate and test again.
- Once you have confirmed system protection, the power-flush is complete.
- Disconnect the power-flushing unit and replace the circulator pump.
- The system configuration and all components should be returned to their original settings. Remove caps placed on the F&E tank if you were power-flushing an open system.
- Return TRVs to their original positions as recorded at the start of your visit.
- Switch on the boiler and allow the system to come up to temperature. Bleed radiators as necessary and record their temperatures and then compare these with the original readings to

demonstrate the success of the power-flush to your customer.

- Return the boiler and room thermostats to their normal operating temperatures.

**Pipes/water lines**

The water mains have to be regularly inspected and, if necessary, an ambiguous disinfection has to be implemented. It is very important to assure the prevention of various contaminating materials from entering the water mains during storage, construction and maintenance. Such materials must be removed by flushing or other means. The distribution system must be protected from backflow due to pressure test and disinfection procedures by physical separation and/or backflow prevention devices.

Furthermore, chlorination is necessary to negate any residual contamination and flushing and de-chlorinating before disposing of the disinfectant water. Finally, the pH and bacteriological quality have to be determined after flushing the disinfectant water from the mains and then the commissioning of the water mains can be done by connecting to the existing active distribution system. Since particulate matter may contain bacteria it is essential that the water mains and its appurtenances are thoroughly cleaned before the final disinfection by chlorination.

The water mains must also be kept isolated from the distribution system until satisfactory bacteriological results are achieved. It is very crucial that the pipeline is kept clean and that the interior of pipes, valves and fittings is protected against contamination. All possible openings in the water mains have to be closed to safeguard the minimization of the entrance of foreign material, while watertight plugs shall be used to eliminate the entry of groundwater, floodwater from other sources.

Rodent proof plugs may be used during construction when the Site Manager (or equivalent) determines that watertight plugs are not practicable, as long as thorough cleaning and flushing are carried out prior to commencement of the disinfection process. Where contamination has occurred, the area must be thoroughly cleaned and disinfected using a 20 mg/lt sodium hypochlorite solution.

Any kind of dirt that enters the pipes must be cleaned out prior to the disinfection procedure. The cleaning method used shall not force mud or debris into the interior joint spaces. The suggested procedure includes three main stages (preliminary preparation, disinfection and bacteriological testing) that must be followed for the disinfection of the water lines is briefly described below:

*Preliminary Preparation:*

- ✓ During the entire construction period, care shall be taken to keep the inside of pipes, etc., as clean as possible.
- ✓ A suitable service cock or valve within three (3) feet of the supply line shall be installed to introduce the disinfecting agent into the lines. The line(s) to be treated shall be isolated from the rest of the distribution system with cross-connection control devices or other appropriate isolation devices.
- ✓ After final pressure tests and before chlorination, each fixture or outlet shall be flushed until the flow shows only clear water.

*Disinfection:*

- ✓ The system must be full of water and under “Main” pressure.
- ✓ Using injection equipment the disinfectant shall be injected through the service cock at a slow, even, continuous rate until a test at the farthest outlet shows chlorine residual concentration of at least 50 ppm. All other outlets shall be tested for compliance with the 50 ppm residual. The waste chlorinated water must be disposed of properly.
- ✓ All outlets and valves, including service valve at main and injection cock, must then be closed to retain the chlorinated water. Warning signs must be posted at each outlet. This condition must be maintained for at least 24 hours.
- ✓ A test after the 24 hour (or longer) treatment should indicate a chlorine residual of 20 ppm or greater. If it does not, steps 2 through 4 must be repeated.
- ✓ After successful completion of the above test, the system should be flushed until the chlorine residual is 0.5 ppm or equivalent to that of the campus water supply.

*Bacteriological testing:*

- ✓ Final flushing should be completed to proceed with laboratory analyses. After the final flushing completion, representative water samples shall be taken by the water technician for lab tests of coliform presence or absence. A successful test result will indicate the absence of total E. Coli in 100 ml. If coliform is found to be present, the disinfection procedure shall be repeated until the standards are met.
- ✓ Sampling and analysing for other substances to evaluate potability may be required if considered necessary by the water technician.

**Under-floor heating systems**

In general an under-floor heating system, when properly installed is designed to have a long life time and thus it is in principle maintenance free. However, there are some tips (checking points) that should be taken into account:

- ✓ The pressure in the under-floor heating system must be checked on a somehow regular basis. In cases this seems necessary, an under-floor heating system is refilled (e.g. during the beginning of the winter season).
- ✓ Check by means of the manual air bleed valves that the under-floor heating system has been bled of air. A major air bubble can disturb the circulation.
- ✓ In case an increasing need to refill is identified, then a control over potential leakage should be performed. It might also be necessary to tighten the couplings. If there persists a problem of pressure not being able of being maintained nevertheless, it is suggested to carry out a more thorough fault tracing and if necessary the contribution of experts to go through the entire warm water under-floor heating system, might be required.

## *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*


[1] http://ec.europa.eu/environment/water/quantity/water_efficiency.htm#leakagesPDF

[2] T. Dworak, M. Berglund, C. Laaser, P. Strosser, J. Roussard, B. Grandmougin, M. Kossida, Is. Kyriazopoulou, J. Berbel, S. Kolberg, J. A. Rodríguez-Díaz, P. Montesinos (2007). *Water saving potential*. Ecologic - Institute for International and European Environmental Policy. Ιστοσελίδα: ec.europa.eu/environment/water/

[3] Energy Information Administration, Office of Energy Consumption and Efficiency Statistics (2009). *Residential Energy Consumption Survey.*

[4] http://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

[5] FIP-TREET LdV Project (2007), *Renewable Energies & Energy Efficiency Finance Training Guide*. CRES (ISBN 978-960-86907-7-6)

[6] Klein, G. (2004). "*Hot-Water Distribution Systems Part 1.*" Plumbing Systems & Design.

[7] International Code Council (2009). *International Plumbing Code Table E202.1*.

[8] U.S. EPA's WaterSense Program (2012). *Resource Manual for Building WaterSense Labeled New Homes*.

[9] Acker, L., G. Klein (2006). "*Benefits of Demand-Controlled Pumping*." Home Energy.

[10] Home Builders Association of Metro Denver (2007). *Guide to the 2007 Built Green Checklist*.

[11] https://www.ehs.ucsb.edu/sites/www.ehs.ucsb.edu/files/docs/eh/PROCEDURE_FOR_THE_DISINFECTION_OF_WATER_LINES.pdf

[12] https://www.watercorporation.com.au/-/media/files/suppliers/resources/design-standards/disinfection-guidelines-for-water-mains.pdf

[13] https://www.underfloorheatingsystems.co.uk/2011/01/12/underfloor-heating-maintenance/

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 1*

| | | |
|---|---|---|
| 1. | **The speed and efficiency of a hot water system depends on the distribution of the water. Which of the following factors do not affect the efficiency of the distribution system?** | |
| | a. The length of the pipes | |
| | b. The diameter of the pipes | |
| | c. The flow rate of the final user (fixture) | x |
| | d. The pipe insulation | |
| 2. | **In which cases is each of the three types of copper used?** | |
| | a. Types K and L are traditionally used in residential hydraulic systems, while the type M pipe is mainly used for main water supplies and underground water lines | |
| | b. Types K and M are traditionally used in residential hydraulic systems, while type L is mainly used for main water supplies and underground water lines. | |
| | c. Types L and M are traditionally used in residential hydraulic systems, while type K is mainly used for main water supplies and underground water lines. | x |
| 3. | **Identically designed hot water supply systems that use pipes of the same nominal diameter, but of different construction material, store different volumes of hot water within them. The statement is:** | |
| | a. Correct | x |
| | b. Wrong | |
| 4. | **A key requirement of the hot water supply systems specifications is:** | |
| | a. No more than 1.9 liters may be stored in any piping or parallel configuration (manifold) between the hot water source and any hydraulic fixture | |
| | b. No more than 1.9 liters may be stored in any piping or manifold between the hot water source and any hydraulic fixture | x |
| | c. No more than 1.8 liters may be stored in any piping or manifold between the hot water source and any hydraulic fixture | |
| 5. | **What are the advantages of iron pipes over copper cold/hot water supply pipes? (*Choose the correct answer*)** | |
| | a. They do not have high purchase costs | x |
| | b. They do not corrode any other equipment made of iron | |
| | c. They are more difficult to corrode | |
| | d. They are easier to be placed | |
| 6. | **Nominal diameter of a cold water / heating supply pipe is:** | |
| | a. The outer diameter | |
| | b. The inner diameter | x |
| | c. The difference between inner and outer diameter | |
| | d. None of the above | |
| 7. | **In order for a hydraulic system to operate efficiently and economically, there is no need for a change in the volumetric flow of the transported water. This expression is:** | |
| | a. Correct | |
| | b. Wrong | x |
| 8. | **The hydraulic elements used for ………………. are ΔP controlled throttle valves, analog solenoid valves and differential hydraulic controllers.** | |
| | a. external temperature compensation | |
| | b. hydraulic balancing | x |

| | | |
|---|---|---|
| | c. the water heating in the hot water tank | |
| 9. | **The dynamic balancing of the hydraulic networks is achieved by using a ……………………….** | |
| | a. three-way valve | |
| | b. 4-way mixing valve | |
| | c. automatic balancing valve | x |
| 10. | **With insulation of hot water pipes, it can be delivered water that is 2°C to 4°C colder than the non-insulated pipes can deliver** | |
| | a. Correct | |
| | b. Wrong | x |

# MODULE 2: DOMESTIC HOT WATER SYSTEMS

## *SUMMARY*

Water scarcity affects about 1% of the European population and 17% of the European Union territory, whereas it is expected that 45% of the territories to be affected by 2030. Cities may be particularly affected by droughts or floods, representing about 90% of the global risks associated.

Domestic uses of hot water include cooking, cleaning and bathing are considered an essential good to secure people´s daily hygiene and contributes directly to the comfort of families. It is a good which is also directly related to our health although the health issues, related to this precious good, are barely mentioned when people talk about domestic hot water.

Daily use of hot water varies from 40 to 100 litre per person, at 40ºC, depending on the age, health conditions of the person and social status. Another important element that has a considerable impact on the values of the daily hot water consumption has to do with behaviour.

Environmental concern related mainly to the depletion of natural resources, in which water and energy are included, is beginning to play an essential role in people´s decision to reduce the consumption of these resources. The production of domestic hot water is heavily dependent on these resources, which highlights the importance of selecting competent professionals to conceive, design, propose and implement efficient hot water production systems. On the other hand, the production of hot water is greatly improved when local resources are used. This is the case of solar energy and biomass, which due to their proximity to the consumption site, are the most efficient way to use natural resources to produce reliable and secure hot water.

This is the second of the six Water Efficiency Technician (WET) Modules that the WATTer Skills project has produced. This Module integrates five Units:

Unit 1: Correct and effective interpretation of DHW project designs and layouts

Unit 2: Correct selection of efficient technologies and/or equipment for DHW production

Unit 3: Basic concepts and pre-installation checks for DHW systems (focus on SWH)

Unit 4: Installing solar water heating (SWH) systems

Unit 5: Routine service, fault diagnosis and repair work of DHW systems (focus on SWH)

## *Unit 1: Correct and effective interpretation of DHW project designs and layouts*

**General description**

The 1st Unit of Module 2 deals with reading and correct interpretation of DHW project designs and layout, considering the performance of the thermo-hydraulic installations and water efficiency fixtures.

For the use of water in the house, hot water supplies are available to personal hygiene devices: sinks, bathtubs, showers and bidets, as well as to sinks. Although there are cases where hot water is supplied by public distribution networks, this is rather an exceptional fact. Most of the time, water is heated using individual and appropriate devices and, in some cases, in centralized facilities for a whole building of houses or a public building.

The facilities that provide hot water to a single dwelling are called individual facilities. In these facilities the production and supply of hot water can be made independent for each consumer device, but it is common to use a single hot water generator for the entire installation, known as collective installation; denomination that should not be confused with the centralized installation.

The hot water can be produced in the house using different energy sources in devices specially designed for it. The most commonly used energy sources are electricity and fuels (solids, liquids, or gases). At present, the use of solar energy is being extended, especially in isolated homes and public buildings, using more or less complex facilities for collecting and using this energy.

**Scope – Expected results**

At the end of this Unit, the candidate should be able to:

- correctly differentiate the basic characteristics of a hot water system,
- interpret main parts of a project and correctly read schematic system layouts.

This Unit is constituted by 2 lessons.
LO1: General principles and basic characteristics
LO2: Basic layouts of efficient hot water installations

**Key words / basic terminology**

Water heater, boiler, buffer tank, load, instantaneous water heater, electrical heater, heating and hot water.

## 1.1 General principles and basic characteristics

Representations of the most common domestic hot water production systems will be presented and discussed in the following paragraphs. The layouts will present the two elementary parts of hot water production system, the hot water generator and hot water storage, including their positioning in the circuit. The basic tasks of the WET in this case are the following:

- Reading of the entire layout of the proposed project;
- Checking on the proposed piping system for size and placement in the circuit, including proposed joining mechanics;
- Checking on the proposed sitting of the solar thermal collector and the water tank;
- Checking on the rating of the proposed security elements of the system;
- Identifying problems encountered in the hot water distribution networks (stagnant water, prolonged times to receive hot water at the tap).

### *1.1.1 Fundamentals*

Any hot water system is comprised of three fundamental component groups: water heater(s) with or without storage, distribution piping, and an array of hot water-using appliances and faucets. Distribution systems are normally made of a network of insulated piping to reduce heat loss. In large systems or whenever water conservation issues are predominant, a recirculation loop and pump are installed to maintain hot water in the supply lines for faster delivery of hot water to appliances and faucets and reduce the amount of wasted water. Otherwise, it takes minutes for hot water to arrive at its intended temperature at important fixtures such as hand-washing sinks and dishwashers, jeopardizing proper sanitation.

Domestic hot water load of a building can be estimated if some basic elements are provided, and more precisely:

- Building profile: Building geography provides indications of the mains temperature which, in many instances, can be estimated using air temperature. Building profile provides insights on the eventual integration of renewable energy resources and the location of different energy conversion systems.
- Consumer profile: Consumer profile refers to the number of people using the building, daily and hourly consumption, frequency and hot water temperature. In some cases, the age and gender also have an impact on domestic hot water consumption. All these elements are important factors for the safe provisioning of domestic hot water.
- Available energy resources: To select and size hot water production system, it is imperative to know what energy sources are available in the location. It is important to know the history of solar radiation and air temperature for the building location and, the availability of biomass resources.
- Water fixtures and taps technologies: The devices used to consume hot water are also of extreme importance when defining the hot water production system. The selected devices with flow restriction and control have an impact on hot water daily consumption and the energy used to generate hot water.

### *1.1.2 Basic calculations*

Daily energy needs for hot water requirements of a building can be estimated using the occupation number and the number of persons. Depending on the user profile, daily consumption can vary from 20 to 150 litres per person:

$$Q_{Load} = V_{Day} \cdot X_{Persons} \cdot C_P \cdot \Delta T \qquad [1]$$

$Q_{Load}$ - Daily energy quantity for the total hot water supply of the building in J
$V_{Day}$ - Daily hot water consumption per person in litres
$X_{Persons}$ -Total number of people using the building
$C_P$ – Specific heating capacity of water (4187 J⁄(kg ·K))
$\Delta T$ - Temperature difference between hot water and cold water: $\Delta T = T_{HW} - T_{CW}$ (in °C)
$T_{HW}$ - Hot water temperature in °C
$T_{CW}$ - Cold water temperature in °C

The power for a given equipment can be calculated. It relates the load equation with time:

$$P = {Q_{load}}/{t} \qquad [2]$$

$P$ - Power in W
$t$ - Time in seconds

Equation [2] is of extreme importance since it allows the comparison of time to heat a given mass of water. This simple calculation allows us to understand the need to protect the solar system when connecting it to the backup system, since the carbon base systems have lower heating time, depending on their power than solar system that will take 8 hours to heat the water. Whenever connecting solar system to a backup heating system, the solar system must heat the coldest part of the domestic hot water system and the backup system should always be placed to heat the hottest part of the system.

### *1.1.3 Water heater*

Hot water is produced by using an energy source and a piece of equipment that will convert the energy into the water coming from the mains. It can be done instantaneously or through a deposit where hot water is accumulated. The energy source can be conventional, such as natural and LPG, coal and oil-based products, electricity or, renewables, such as solar energy, which is considered a direct conversion system and different forms of biomass.

**Instantaneous heaters**

They generate hot water whenever a hot water tap is opened. For plumbing, the installation of these heaters is really simple, considering a list of available dedicated training courses and the fact that most of them present few connection points, usually no more than 5 plumbing connections.

*Gas fired instantaneous heaters*

In essence, the apparatus consists of a gas burner that heats a copper tube streamer through which the water circulates, which enters cold at one end of the heat exchanger and leaves hot at the opposite end. The heater is equipped with a series of devices that cause the burner to turn on automatically whenever a hot water tap from the installation is opened. The water starts to circulate through the serpentine and stops circulating when the water is closed by a consumer appliance tap.

The device is fixed on the wall by the fixing points provided by the manufacturer, either by hooks or anchor bolts. In each case and for each mole, the manufacturer's recommendations must also be followed. The technological norm indicates that the fixation to the wall must be done by four steel bolts. The water inlet is arranged so that it is connected using a fitting to the cold water supply network and the hot water outlet is connected in the same way at the beginning of the hot water distribution network.

Before installing the appliance, the technician must be sure that its characteristics correspond to those of the water and gas installation requirements. Concerning water, it must be adequate for the pressure and flow of the supply and with respect to gas, the pressure and flow must be sufficient to feed the burners correctly and these must be suitable for the type of gas supplied: liquefied petroleum gas or natural gas.

**Figure 1.1: Instantaneous gas heater**
[Author: ST Spencer]

Being gas combustion appliances, its installation must adapt to the standards required for such a class of appliances, which especially pay attention to the safety in use. Such standards focus especially on the capacity of the enclosure in which they can be installed, the ventilation of the space and the evacuation of the combustion gases.

**Storage heaters**

*Gas fired storage heater*

These devices mainly consist of a tank in which a certain amount of water is stored and heated and kept warm using a gas burner. The water is contained in a metal tank that forms the outlet duct of the hot gases produced by the combustion of the gas in the burner.

To prevent water from cooling through the outer walls of the tank, they are covered by a thermal insulator. Cold water is introduced through the bottom of the tank and hot water is taken from the top. Inside the tank, there is a thermostat that governs the gas supply to the burner, so that it turns off when the water temperature reaches the maximum expected, which is usually set at 85ºC. The cold water enters only when the hot water tap is opened, for which a special valve is available that opens when the pressure in the tank is lower than that of the supply network. This valve is usually combined with the bypass valve that allows the heater to be taken out of service.

On the other hand, the heater is provided with a safety valve, to avoid overpressures, which opens and communicates the tank with the drain when, for any reason, the pressure in the tank becomes excessive. This valve is usually combined with the drain valve that allows the heater to drain if necessary. The fundamental purpose of these devices is to meet a relatively large demand for water at a given time when the installation's gas supply is limited, although continuous.

The installation of gas storage heaters is very similar to that of instant heaters. The connections to the cold water inlet, hot water and gas inlet pipes must be made using rigid fittings and the pipes should be provided with the corresponding wrenches to allow the appliance to be taken out of service when necessary.

One thing to keep in mind when placing these heaters is their considerable weight when they are full of water. Therefore, when hollow brick sections are fixed the wall thickness is an important element to take into consideration and the fixing bolts must be through and joined with metal counter plates. All requirements of the technical standard regarding heaters and concerning the floor, ceiling and other appliances with gas burners are similar to those of instantaneous heaters.

*Storage tank with electrical resistance*

This system is constituted by a metal tank duly heated and adequately insulated to avoid cooling the hot water contained therein. Inside the tank, there is a closed tube (surrounded by water) in which the heating elements are located. In contact with the water, a thermostat is placed that governs an automatic switch that opens (cutting off the passage of the electric current to the resistors) when the water has been heated to the expected temperature, and closes (allowing the passage of the electric current through the resistances) when the temperature of the water drops in the tank, either by cold water inlet when the hot water flows to the consuming devices, or by heat losses from the tank when the water contained in it is used.

The mains water inlet is made through the bottom of the tank and the outlet through the top. A non-return valve is arranged at the inlet, to prevent hot water from entering the cold water supply pipe. The devices are also provided with a safety valve and drain valve. Since the heating in these devices does not depend on the output of hot gases, they can be constructed in different ways, with the reduced height with respect to the diameter, for example, or horizontally, which is quite used for presenting advantages for its placement from the point of view of the available spaces.

**Figure 1.2: Electric water heater**
[Source: Vulcano]

Given the heating system of these devices, their installation does not present restrictions from the point of view of ventilation, however, its installation in bathrooms and toilets are not recommended due to the danger of electrocution that may occur. The installation of the devices is usually done by fixing them on the wall and, due to their weight, the norms and standards are to be strictly followed.

*Mix boiler for heating and hot water*

Mix boiler provides heating and hot water production, which might be instantaneous or through a water tank. Although this system is predominantly used in large installations, it is possible to find a boiler which provides this service for a single dwelling. Both externally and in their operation these devices have a certain similarity with instant heaters although, logically, due to their double function, their controls, their constitution and their installation are more complex.

A single gas burner heats two separate coils, one of them is part of the closed heating circuit and the other provides domestic hot water. A pump integrated into the same device drives the circulation of water through the heating circuit. The burner is provided with automatic valves, safety systems and automatic ignition arranged in such a way that it only burns when there is water circulation in either of the two coils or in both and it automatically shuts off if the circulation stops for both. The heating power of the burner is automatically regulated, when used for heating, generally depending on the return water temperature of the circuit.

**Figure 1.3: Mix gas boiler**
[Author: ST Spencer]

#### *1.1.4 Storage tank*

The generated sanitary hot water can be directly used or stored in a water tank, which complies with very specific requirements. In selecting the storage tank, the professional should consider the daily needs of the property, temperature, distance to different points of water usage, and the period of usage. Other criteria for selecting the storage tank are the following:

- Respond to the needs of the load in pick periods.
- Respond to the needs of the load when the availability of the resource does not coincide with water requirements.

In selecting the hot water storage tank, the technician should also consider the available space for its sitting, the material and corrosion factors (water quality) and maintenance requirements. It is important to consider the available cleaning access devices placed on the water tank and the corrosion protection mechanism. The corrosion protection mechanism should be of easy verification and easy access for any eventual replacement.

Most of the storage tanks are made of low carbon steel. Considering continuous water renovation, any time hot water is used, freshwater will enter the tank, which has to be protected against the particles dissolved in the water and the chemical reaction that will most likely take place when water oxygen reacts with the steel.

### 1.2 Basic layouts of efficient hot water installations

**System types**

Solar thermal systems for domestic hot water (DHW) can be divided in two main groups when the fluid circulation type is the main criteria, thermosyphon and forced circulation:

- ***Thermosyphon***, the system in which the water tank is positioned higher than the collector and the circulation is natural, governed by heat gradients between the water tank and the collector. As the sunrays heat the collector, the fluid gets lighter and moves to upper part of the loop, the water tank, where it leaves the heat and becomes much heavier, forcing it to drop to a lower point, the solar collector, where the process start all over again.
- ***Forced circulation***, the system requires an electric pump to move the fluid within the primary circuit, from the collector where it collects solar energy to the heat exchanger of the water tank where it gives the transported energy to the domestic hot water.

**System main components**

Any solar thermal hot water system is made of three main components, (1) solar thermal collector, (2) water tank, and (3) piping. Solar thermal collector converts sunlight into heat, water tank is used to store the heated water and the piping connects the two previous components to permit the energy to be transported from the hot source to the cold source.

**System layouts**

Simple schematic representations of a hot water system are given in the following with a clear indication of all components.

**System type 1**

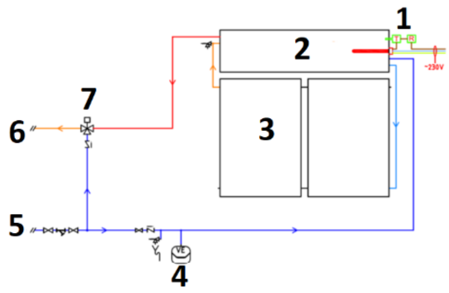



**Figure 1.4: Thermosyphon system with electrical backup system**

1 – Back up system made of electrical resistance, 2 – Storage tank, 3 – Solar thermal collector, 4 – Expansion tank, 5 – Mains entrance, 6 – Domestic hot water, 7 – Three way mixing valve.

*The trainer should provide detailed explanation.*

**System type 2**

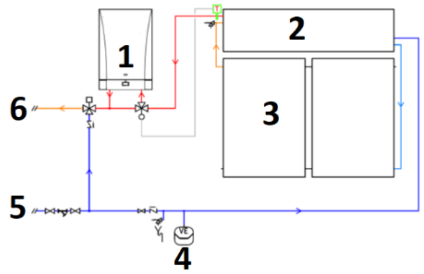



**Figure 1.5: Thermosyphon system with instantaneous gas firing boiler as backup system**

1 – Instantaneous gas firing boiler, 2 – Thermosyphon storage tank, 3 – Solar thermal collector, 4 – Expansion tank, 5 – Mains entrance, 6 – Domestic hot water.

*The trainer should provide detailed explanation.*

**System type 3**

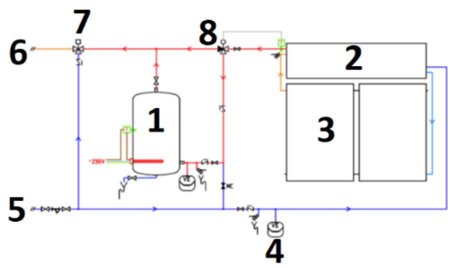



**Figure 1.6: Thermosyphon system with electrical heat placed in a deposit as backup system**

1 – Deposit with electrical resistance, 2 – Thermosyphon storage tank, 3 – Solar thermal collector, 4 – Expansion tank, 5 – Mains entrance, 6 – Domestic hot water, 7 – Three way mixing valve, 8 – Deviation valve.

*The trainer should provide detailed explanation.*

**System type 4**

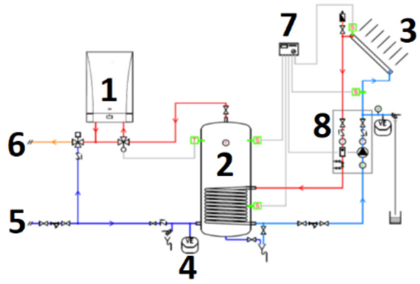



**Figure 1.7: Forced circulation system with gas boiler as backup system**

1 – Gas boiler, 2 – Storage tank, 3 – Solar thermal collector, 4 – Expansion tank, 5 – Mains entrance, 6 – Domestic hot water, 7 – Control unit, 8 – Pump station.

*The trainer should provide detailed explanation.*

## *Unit 2: Correct selection of efficient technologies and/or equipment for DHW production*

**Introduction / General description**

In the 2nd Unit of Module 2 the principles of correct selection and installation of efficient technologies and/or equipment for DHW production and determination of the energy savings resulting from the use of alternative/efficient water heaters are presented.

Correct selection of efficient technology is an important step for the durability and operation of the hot water system. During this phase, it is important to look for certified equipment, certifying entity and norms. During the selection, it is important to consider the place where the equipment will be seated, the distance to the consumption points and any obstructions that might impede regular maintenance of equipment. Selecting quality equipment will most likely reduce the maintenance costs of the selected system and might also contribute to the lowering of any conventional fuel consumption.

**Scope – Expected results**

At the end of this Unit, the candidate should be able to correctly differentiate the basic characteristics of a hot water generator, and to correctly select the appropriate storage and buffer tanks. This Unit is constituted by 4 lessons, based on 4 essential equipment types, plus one more providing the necessary information on the energy savings resulting from the use of alternative/efficient water heaters. A definition of each component is presented, followed by essential selection criteria and position in the circuit.

Unit 2 is constituted by the following five lessons.
LO1: Efficient technologies and/or equipment for DHW production
LO2: Energy savings resulting from the use of alternative/efficient water heaters.

**Key words / basic terminology**

Water heater, boiler, buffer tank, expansion tank, thermosyphon system, efficient technology.

## 2.1 Efficient technologies and/or equipment for DHW production

### *2.1.1 Hot water generators*

The domestic hot water system is made of hot water generator and distribution system. Hot water generator can be a unit of instantaneous equipment, which generates hot water whenever a tap is opened, or a combination of a heat generating source with a deposit to accumulate hot water for later usage. Generators use different energy sources namely solar energy, electricity, LPG, natural gas, biomass, coal and other oil-based products.

Today, hot water generators are very compact units integrating different elements from piping and electrical and electronic components. The gas fired water generators are very common and they can be naturally ventilated or forced ventilated. They can also condense water vapour in the exhaust gases and recover its latent heat of vaporisation which, in the non-condensing boiler, would be wasted. These are classified as very efficient boilers.

In selecting a boiler, it is important to consider user profile, energy source available and the cost of energy source. Carbon base generators are usually installed in a dedicated space, inside the building, respecting product specifications and installation norms. In the case of solar thermal generators, part of the equipment must be placed outside with direct exposure to solar radiation, and another part should be protected from weather conditions.

### *2.1.2 Storage tanks*

The hot water tank is a vessel with specific characteristics to accumulate water for a large number of people or whenever the consumption does not coincide with the availability of the resource, which is the case of solar thermal energy. Whenever hot water is consumed, freshwater enters the vessel carrying particles that might contribute to the degradation of the deposit.

In selecting the deposit, it is important to consider its durability and economic viability:

1. Material – deposits are made of different types of metals, such as low carbon steel or plastic. The selection should consider the water quality, considering a long retention period, and protection against corrosion that might result from the reaction of water oxygen with iron.
2. Corrosion – it is important to know the efficiency of the protection mechanism for the deposit, how easy or difficult it can be verified, its location, considering the time for its replacement.
3. Size – important criteria that determine the economic viability of the system to be acquired. Size should be considered prior to the selection due to the simple fact that the chosen equipment should fit in the available space. The size should meet the hot water requirements of the building.
4. Heat source – when choosing a deposit, one should consider the types of heat sources to be used and its positioning, especially if the deposit should have renewable and carbon-based energy sources.

Types of deposits considering the existence and positioning of the heat exchanger:

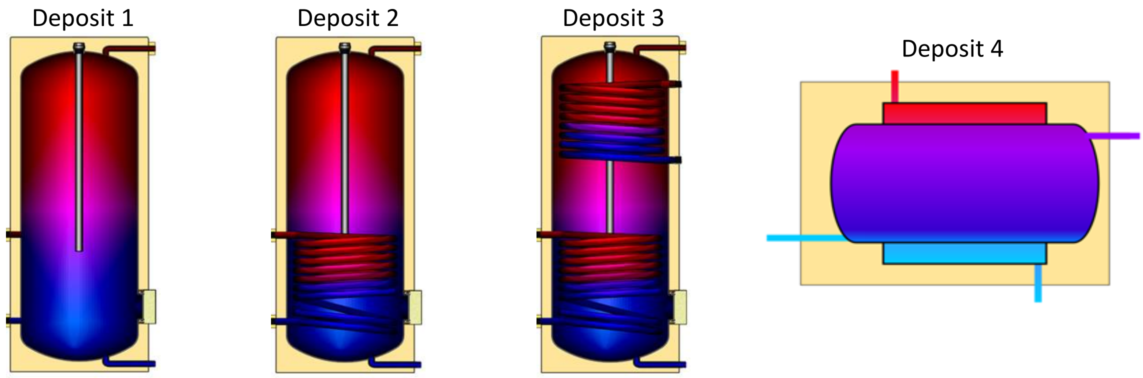



**Figure 2.1: Types of deposits according to the existence and positioning of the heat exchanger**

[Source: *Solar Thermal Systems, Solar Praxis*]

Deposit 1 has no heat exchanger integrated. It would require an external heat exchanger and a second pump to heat the water. Deposit 2 has only one internal heat exchanger placed on its lower part. This deposit should have only one heat source. Deposit 3 has two internal heat exchangers, one placed in the lower part and a second in the upper part. This deposit might have two heat sources. Deposit 4 has an external heat exchanger.

Considering that solar energy is not always available, whenever connecting a deposit to solar system, it is important to give priority to the solar heat. Solar heat should be connected exclusively to the coldest part of the deposit, without the interference of the backup heat, which should be placed on the hottest part.

### *2.1.3 Buffer tanks*

Buffer tanks are energy storage units design to meet the variable load requirements of a building. Buffer tanks can easily cover peak load and store large quantities of renewable energy for later usage, especially whenever the load does coincide with the availability of renewable energy. It is also well suited for low load requirements that otherwise would increase the wear of a conventional boiler.

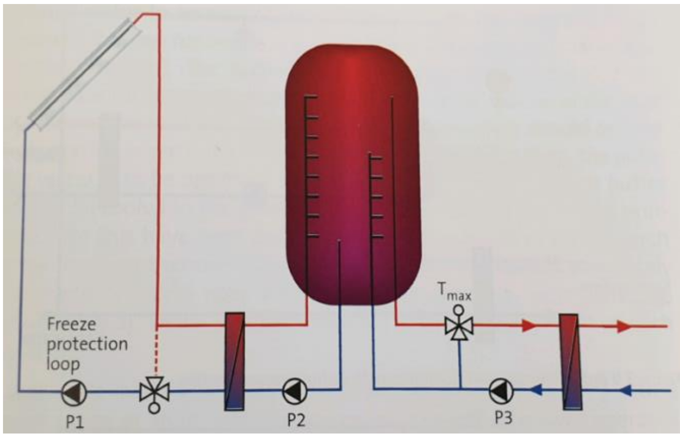



**Figure 2.2: Buffer tank representation**

[Source: *Solar Thermal Systems, Solar Praxis*]

In choosing a buffer tank, one should consider the level of system performance required, the size of a property and usage patterns and the space constraints for its sitting. It is also important to consider the combination of multiple heat sources and the flexibility to heat the water at different times of the day. Buffer tank also allows the displacement of the heating period when cheaper tariffs are valid.

The installation requirements of the buffer tank are not different from those of any pressurized water tank. They are usually equipped with additional inlet and outlet connections, which might be positioned all around the buffer tank, requiring circulating space for the technician during the installation and maintenance.

### *2.1.4 Expansion tanks*

Pressurised circuits with fluctuating energy charging loads, require security equipment that is mainly made of the expansion tank and security valve. It protects the closed loop from excessive pressure. Expansion tank operates by absorbing the pressure fluctuations of heating systems. In the case of a solar thermal system, the membrane of the expansion tank performs different duties:

1. If properly sized and positioned, it absorbs the fluid dilation that will occur during the normal heating process.
2. If properly sized and positioned, it will absorb the fluid expelled from the solar collector during vaporization, especially during stagnation.
3. It might perform the third task, again, if properly sized to be a short reserve for small refilling that the circuit might need.

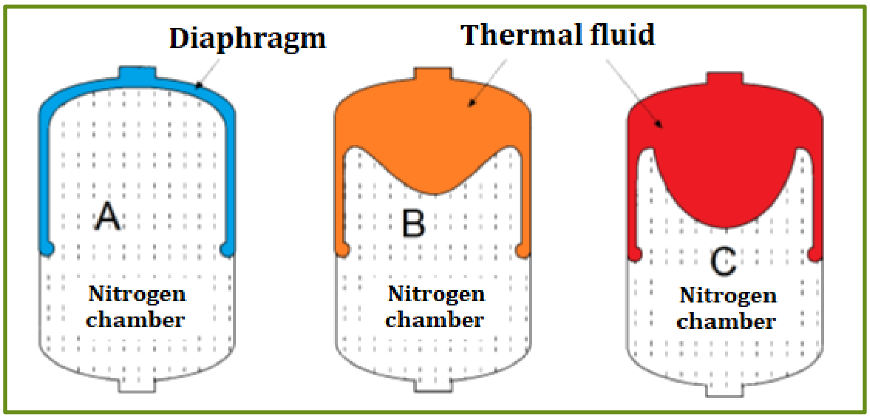



**Figure 2.3: Expansion vessel**

During the selection of the expansion vessel, it is important to evaluate the heat source, the volume of the loop to be protected, the height of the loop, the maximum temperature, the rating of the security valve, and its positioning in the circuit.

The expansion tank should be positioned in accordance with the recommendations of the manufacturer. Generally, it is supposed to be positioned so that it can absorb all dilations that will occur in the circuit. In the case of solar thermal systems, it should be positioned after the check valve so that, during vaporization, at which period the pump is not working, it will be able to absorb all the fluid expelled from the solar collectors. Expansion tanks placed outdoor might suffer from weather exposure and might need to be replaced more frequently.

## 2.2 Energy savings resulting from the use of alternative/efficient water heaters

Today it is clear that using carbon-based sources of energy have a major impact on the environment and on human health. Considering that domestic hot water is used to improve our comfort and health when choosing an efficient water heater, the possibility of using local resources for hot water production should be considered and evaluated. Converting and using energy from the ground, water and air sources, solar and biomass are the most rational and reliable ways to use natural resources and, at the same time, convert energy in a very efficient way.

The efficiency of energy conversion can be evaluated in terms of environmental impact and economics concerns. This lesson will only consider the environmental aspects of energy conversion. The aspects related to the economics of such systems are not the main focus of this lesson, even though when properly considered, with the integration of externalities in the final economic evaluation, renewables resources will always be the best option.

For a long time, gas boilers have been accepted as a comparatively efficient and convenient heating source. However, due to environmental implications resulting from the use of this resource, policymakers and researchers are now strongly focused on how we can move to lower carbon heating systems for our buildings.

When properly selected, installed and maintained, solar thermal systems provide hot water throughout the year, though the backup system will be needed to heat the water further with a boiler or immersion heater during the winter months. Using solar resource reduces energy bills since sunlight is free, so once the initial investment is paid, the hot water costs will be greatly reduced.

| | **Solar thermal energy** | |
|---|---|---|
| **Carbon based resource** | **Fuel bill savings (€/Year)** | **Carbon dioxide savings ($kgCO_2$/Year)** |
| Electricity | | |
| Natural gas | | |
| LPG | | |
| Coal | | |
| Heating oil | | |

*Note: This table will be filled by the trainers when preparing for the training session*

The use of biomass wood fuel is a sustainable process as long as new plants continue to grow to replace those used for fuel. The important aspect is for the fuel to be locally produced to offset the carbon emissions caused by the cultivation and transportation of the fuel. This, of course, in case of biomass fueled boilers for the preparation of domestic how water (DHW) or for space heating.

| | Biomass source of energy | |
|---|---|---|
| **Carbon based resource** | **Fuel bill savings (€/Year)** | **Carbon dioxide savings ($kgCO_2$/Year)** |
| Electricity | | |
| Natural gas | | |
| LPG | | |
| Coal | | |
| Heating oil | | |

*Note: This table will be filled by the trainers when preparing for the training session*

The ground source heat pump is best suited when producing heat at a lower temperature than traditional boilers, which implies that the building must be well insulated and draught-proofed so that the heating system can be effective. Prior to selecting the ground source heat pump system, fuel price must be evaluated to make sure that the replacement is the best option and the system will pay for itself much more quickly.

| | Ground source heat pump as an alternative energy source | |
|---|---|---|
| **Carbon based resource** | **Fuel bill savings (€/Year)** | **Carbon dioxide savings ($kgCO_2$/Year)** |
| Electricity | | |
| Natural gas | | |
| LPG | | |
| Coal | | |
| Heating oil | | |

*Note: This table will be filled by the trainers when preparing for the training session*

## *Unit 3: Basic concepts and pre-installation checks for DHW systems (focus on SWH)*

**Introduction / General description**

In the 3rd Unit of Module 2 the undertaking of site survey of the building for the installation of water heaters systems, including renewable energy sources (RES) based systems will be developed. The pre-installation checks that need to be made for the installation of DHW systems (with focus on SWH systems) will be showcased to the trainees in order to improve their knowledge of the criteria regarding the suitability of a site for the installation of DHW systems, of the way to carry out the necessary pre-installation checks, of the requirements of relevant regulations / standards relating to the installation, testing and commissioning activities for DHW systems, as well as of the applicable regulations to guarantee secure work environment, focusing on SWH systems.

This training content produced in fulfilment of requirements of this project contemplates only custom-build solar thermal installations for hot water.

**Scope – Expected results**

After having finalized this LU, the trainees will be able to:

- recognize the basic concepts of pre-installation checks for the installation of DHW systems,
- develop the capacity to perform pre-installations checks.

Unit 3 integrates 2 lessons:
LO1: Basic concepts,
LO2: Pre-installations checks.

**Key words / basic terminology**

Water heater, boiler, buffer tank, load, instantaneous water heater, electrical heater, heating and hot water.

## 3.1 Basic concepts

Pre-installation checks help the professional match the proposed equipment with the reality of the installation and sitting of the equipment. When doing the pre-installation checks it is important to have a notebook and camera to register all relevant details of the place where the installation will be carried out. The registered details should be used in conversation with the owner and should be a complement in preparing component order. It is a safe way to avoid components that might not fit the requirements of the site. In fact, the first criteria in sizing any hot water system is to evaluate whether the place for its sitting is physically adequate. It is an important form to have more complete planning.

During this phase, it is of extreme importance to study the health and safety regulations that might be different between individual countries. The professional should assess the risks associated to the work to be carried out and make arrangements to eliminate them. Prior to the installation, the delivered material should be checked for possible transport damage. The collector glazing is the most sensible part and must be checked to see whether it is intact. Also checks should be made for the completeness and correctness of the delivery. It is always good to establish the collector position, the piping routes through the building and the location of the water tank must be agreed with the customer. The transport route for the collectors must be established.

**Orientation and tilt of the roof**
Solar hot water collectors (and PV panels) should be oriented geographically to maximize the amount of daily and seasonal solar energy that they receive. In general, the optimum orientation for a solar collector in the northern hemisphere is true south. However, recent studies have shown that, depending on the location and collector tilt, the solar collector can face up to 90° east or west of true south without significantly decreasing its performance.

Also factors such as roof orientation (if it is planned to mount the collector on the roof), local landscape features that shade the collector daily or seasonally, and local weather conditions (foggy mornings or cloudy afternoons) need to be considered, as these factors may affect the solar collector's optimal orientation.

Today, most domestic and small commercial solar electric (PV) and solar water heating collectors are mounted flat on the roof (of course, not in the case of flat roofs). This is more aesthetically pleasing than rack-mounted collectors, which stick up from the roof at odd angles. Thus, most collectors have the same tilt as the roof.

Ideally, a fixed, roof-mounted solar energy system should be at an angle that is equal to the latitude of the location where it is installed. However, pitch angles between 30 and 45 degrees will work well in most situations. Fortunately, the angle of the rooftop has a lower impact on solar collectors' production than the direction the roof faces. However, the roof angle should be taken into account when sizing the system.

**System type**
The system considered in this training material is a forced circulation solar water heating installation, providing hot water in a house, which is a typical installation for the following reasons:

- It is an indirect, closed loop, pumped system.

- The fluid that flows through the collectors is isolated from the potable water, which permits use of antifreeze and anti-corrosive agents, reducing freezing and corrosion problems and, therefore, increases the durability and reliability of the system.
- As the system has pumped circulation, a large part of the system, including the tank, can be installed inside the house, which brings the additional advantage of lower thermal loss and increased durability.
- The auxiliary system is installed in series with the potable water, and as it is an instantaneous water heater, it achieves higher final output with lower consumption. The auxiliary energy is consumed only when needed.

**Custom-built installations**
Custom-built solar heating systems (customized installations) are systems constructed in single block form or assembled from a list of components. In this category, systems are considered to be a set of tested components and the results of the tests are included in a complete system review. The requirements for solar heating systems made to measure their performance are listed in ENV 12977-1:2000, the test methods are specified in prENV 12977-2:2000 and prENV 12977-3:2000.

Custom-built solar heating systems break down into two categories:

- Small custom-built systems are offered by a very small number of companies which provide lists with all components and possible configurations of the systems manufactured by them. Each possible combination of a system configured with components on the list is considered a single customized system.
- Large custom-built systems are designed for specific applications. In general, they are designed by engineers, manufacturers or other experts.

## 3.2 Pre-installation checks

Before proceeding with any installation procedure, the technician should master skills in the following specific areas:

- Reading and interpretation of projects
    - Flow
    - Head losses
- Site survey prior to system installation
    - Take measure of the area where solar collectors are to be installed
    - Collector tilt, orientation and shading
    - Determine the length between collector field and heat exchanger
    - Evaluate the available space for other equipment
- Preparing a competent offer
    - Know the main equipment distributors in the region
    - Check the unit price for the items that will integrate the offer

Also, the technician should be competent in the following specific areas:

- Reading and interpreting collector characteristics:
    - Collector dimension

- Collector stagnation behaviour
- Collector maximum pressure

- ➢ Collector shading.
- ➢ Pipe joining methods and techniques.
- ➢ Pipe insulation.
- ➢ Pump selection for primary circuit.
- ➢ Installing solar hot water tank.
- ➢ Control and command of solar thermal systems.

During the site survey before system installation, the technician should:

- ✓ Check the type of roof and its components/ materials
- ✓ Take measure of the area where solar collectors are to be installed
- ✓ Check for possible collector tilt and orientation
- ✓ Check for objects that can project shading to the solar collector
- ✓ Determine the length between collector field and heat exchanger
- ✓ Evaluate the available space for other equipment.

Other related checks that need to be made:

- authorization for the work to proceed
- verification that the generation capacity of the proposed SHW system installation is appropriate to the hot water system load
- evaluation of the proposed quantities with the installation site dimension
- the availability of appropriate access to all required work areas
- the inspection of existing domestic hot water/heating system installations
- the availability of a suitable electrical input service
- the proposed siting of key internal system components
- the suitability of the building structure in relation to the proposed installation
- the suitability of the proposed location and position of the solar collector panel(s) for optimum collection capacity
- the suitability of the building fabric in relation to the installation of the solar collector panel(s).

## *Unit 4: Installing solar water heating (SWH) systems*

### Introduction / General description

The 4th Unit of Module 2 deals with the principles of installation, testing and commissioning of water heating systems, focusing on Solar Water Heating (SWH) systems, for the trainees to acquire the necessary knowledge of correctly selecting the adequate SWH systems, including the adequate fittings, in compliance with the regulations and standards (local, national, international) applicable to solar thermal systems.

During the installation of a solar thermal system, the team in charge must have a clear plan on where to start, how to start and when to start. These details will help smooth the execution and reduce potential conflicts with other intervenient and the owner. The team might be divided in accordance to their skills and, since part of the installation is to be done outside, the weather factor should also be considered. The availability of different components should also be considered and adequate equipment should be available to the team.

### Scope – Expected results

At the end of this course, the candidate should be able to install, pressurize and commission a small size, force circulation solar thermal system.

This module is constituted by 4 lessons:
LO1: Installing solar thermal collectors
LO2: Solar loop and piping using press-connect joints
LO3: Installing solar pump station
LO4: Pressurising solar thermal system loop

### Key words / basic terminology

Water heater, boiler, buffer tank, load, instantaneous water heater, solar collector, heating and hot water, solar thermal system, solar loop and piping.

### 4.1 Installing solar thermal collectors

This chapter of the training materials for WETs considers solar collectors mounted on-flat roofs. The information provided below does not replace the installation requirements and instructions of the manufacturer. Additional care must be taken to prevent skin roof damage.

**Safety concerns**

Read all the safety regulations, including the regulations about working at heights. Since all roof work is considered hazardous, before undertaking any kind of work, make sure you are acquainted with country´s safety regulations and carry out risk assessments. A safety fence should be mounted and secured firmly to guarantee protection.

**Main tools**

The main tools that are normally used in this type of works are:

- Ladders
- Set of wrenches
- Drill machine
- Tube cutter
- Reamer.

**Collector tilt and orientation**

- How is the angle for solar collectors defined?

If no project or any document defining the project angle exist, the solar tilt angle from the horizontal should be decided according to the latitude of the location.

- Which direction should the solar panel face?

For countries in Northern hemisphere, solar panels should be in South facing direction. Dish anthem can be taken as the reference point.

**Work steps**

- Define the transport path for the collectors from the ground to the location.
- Measure and mark all details of the collector field on the roof, considering the height, width, and orientation.
- Look for surrounding objects that can cause shading
- Layout the building protection mats
- Position and screw collector stand (support structure) on the flat roof
- Transport collectors to the roof
- Place collector on the stand, using all supplied components
- Proceed to make the connections between collector and copper pipe coming from the pump station. This should be done for feed (cold) and return (hot) pipes

- Place the control system hot sensor
- Close any holes in the roof
- Thermal insulate the pipes, leaving no gaps in the insulation

### 4.2 Solar loop and piping using press-connect joints

Prior to selecting the joining system, it is necessary to check on the piping material to assembly the solar loop. Among the materials available in the market, the copper tube offers greater versatility, considering that the number of different tools that can be used to assembly the solar loop.

This lesson provides information in one of the joining techniques, press-connect. People who are not familiar with the other joining techniques should look for additional information.

**Main tools**

- Tube cutter
- Reamer
- Press machine and adequate jaws

**Work steps**

<u>Measuring and cutting</u>

- Correctly measure the length of the tube.
- Avoid excessive length, which introduces unnecessary stress to the joining, with the probability of affecting the durability of the joining.
- If the tube is short, the joining might fail due to the short contact area between the tube and the fitting and excess filling material might accumulate in the fitting.
- When cutting the tube, disc-type tube cutter should be applied to secure the square end. During the cutting process, it is important to avoid deforming the tube to secure proper sitting in the fitting cup.

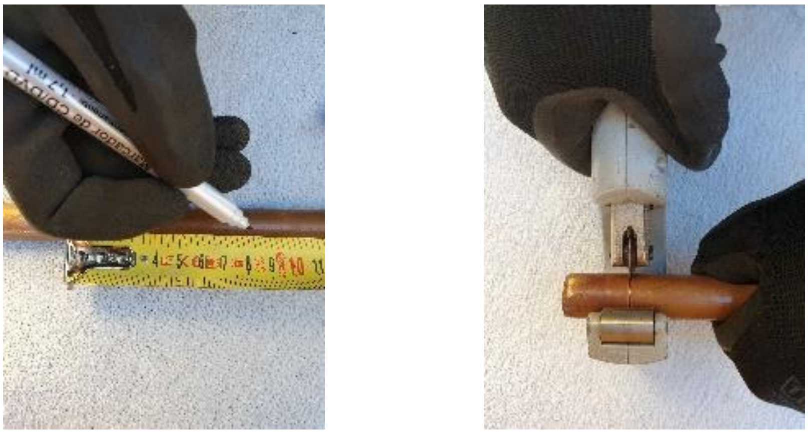


**Figure 4.1: Correct tube measurement (left) & tube cutting (right).**
[Author: ST Spencer]

Reaming

Clear all excess material that will result from the cutting.

To secure that the tube sits properly inside the fitting cup, ream the cut tube and make sure it does not present deformations. Reaming reduces turbulence and potential erosion-corrosion in the join. Properly reamed tube provides a smooth surface for better flow. Burrs removed on the outside of the tube ends ensures proper entrance of the tube into the fitting.

**Figure 4.2: Tube reaming**

[Author: ST Spencer]

Marking

This module considers only press-connect joints. After correct measurement, cutting and removal of any excess material, the fitting must be examined to ensure that the sealing gasket is adequate to high temperature, properly positioned and not damaged. The tube is then introduced into the fitting and marked.

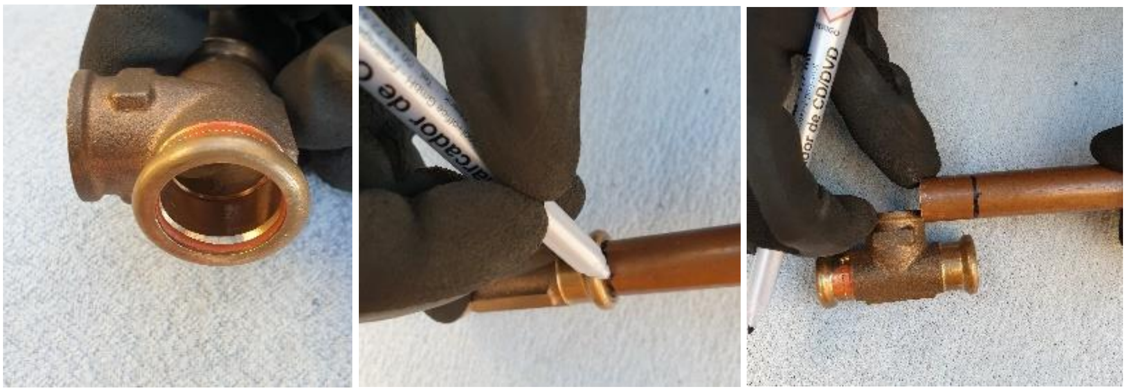


**Figure 4.3: Preparing the tube for press connection**

[Author: ST Spencer]

Pressing

Place the tube inside the fitting and mark its depth of insertion. Remove the tube and measure the marked on the tube to secure the correct length. Insert the tube back into the fitting, select appropriate size of pressing jaw, insert it into the pressing tool. It is extremely important that the tube is completely inserted to the fitting stop (check the previous mark), before applying the pressing jaws onto the fitting. Place the selected jaw over the bead of the fitting, ensuring 90° angle to the centreline of the tube. Press the trigger and do not stop until pressing cycle is completed. Release the pressing jaw and visually inspect the joint to ensure the mark on the tube is square with the fitting. To remove the pressing jaw, press the trigger again and allow the jaw to depress the tube and fitting. Do not change the position of the pressing tool during the pressing.

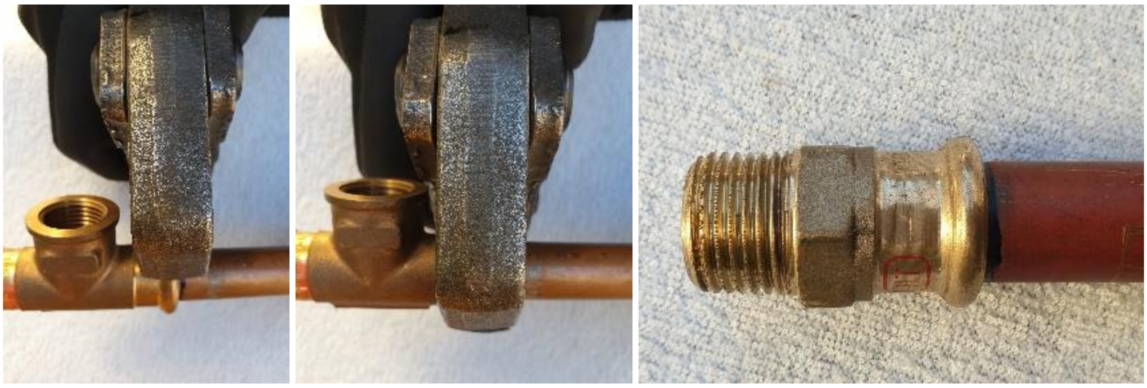


**Figure 4.4: Applying press connection**

[Author: ST Spencer]

### 4.3 Installing solar pump station

**Main tools**

- ✓ Drill
- ✓ Set of wrenches
- ✓ Pipe cutter
- ✓ Pipe reamer.

**Preparations**

- ✓ Evaluate pipe diameter and the circuit pressure drop presented in the project or any support documents that provide details of the installation.
- ✓ Check whether the proposed pipe diameter needs any specific adaptation so that it can be directly connected to the solar pump station
- ✓ Check whether you will need threaded components for the connections to be made
- ✓ Select the joining system
- ✓ Read the pressure drop presented in the project and compare it to the pump performance curve. It should be clear whether the equipment you intend to install meets the requirements of the flow and pressure drops presented in the project.
- ✓ Double check all other technical specifications related to height, width and depth of the pump station.
- ✓ In case the selected pump meets the requirements of the project, you can move to the next phase

of work preparation.

- ✓ Identify all the components of the pump station.
- ✓ Know all the functions and parameters of different components of the pump station.

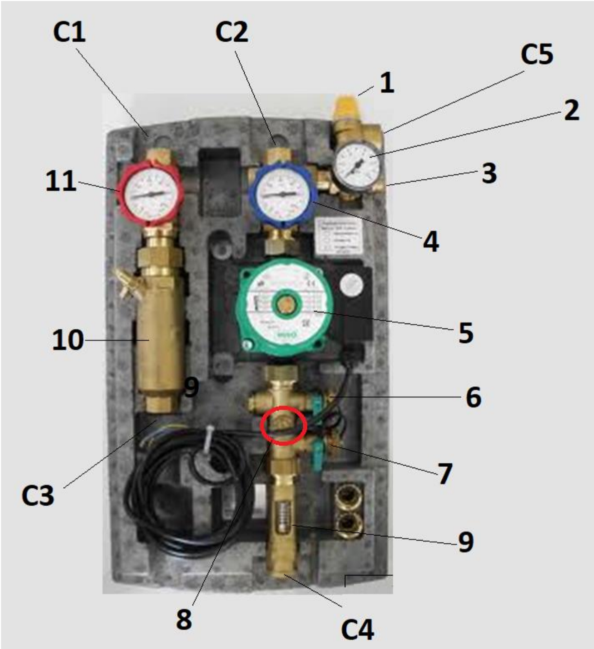



**Figure 4.5: Solar pump station**

[Author: ST Spencer]

Explanations

**1 - Safety valve** also known as **pressure relief valve**, limits the maximum circuit pressure and prevents circuit overpressure. They are adjusted to operate at pressures which are lower than the maximum working pressures of the components in the circuit.

**2 - Pressure gauge** provides circuit pressure reading

**3 - Expansion vessel connection** provides the connection to the expansion vessel. Expansion vessel is a fundamental component since it absorbs all pressure changes and the fluid expelled from the collector field when vaporization occurs.

**4 - Thermometer gauge** on return valve (COLD) provides the cold circuit temperature

**5 - Pump** circulates the fluid between heat exchanger and solar collector

**6 - Filling flow valve** connection to inject water / fluid

**8 - Filling return valve** connection to reject cleaning water

**9 -** Filling **shut-off valve** to flush out the rejected water out of the loop

**10 - Flow meter** helps read and set the circuit flow

**10 - Air separator device** accumulates the air present in the fluid

**11 - Thermometer gauge** on return valve (HOT) provides the hot circuit temperature

The **check valve** is not represented on the pump station. It is located on the pipe beneath component 4. This component prevents convective liquid circulation from taking place in the solar circuit when the circulating pump is switched off, which would withdraw heat from the store and transfer it to the surroundings via the collector field.

The pump station presents **four connections to the solar system**, two connections to the solar collector and two to heat exchanger.

**C1** - Solar loop connection to hot circuit of solar panel

**C2** - Solar loop connection to cold circuit of solar panel

**C3** - Solar loop connection to hot circuit of heat exchanger

**C4** - Solar loop connection to cold circuit of heat exchanger

**C5** - Connection to the expansion vessel

**Work steps**

Positioning and connection of the pump station

- ✓ Determine whether the pump station will be wall fixed or placed in the solar tank
- ✓ Using adequate accessories, connect C1 to the copper tube from solar collector field (hot side). You might use soldering, press fit or any other suitable joining system.
- ✓ Using adequate accessories, connect C1 to the copper tube from solar collector field (hot side). You might use soldering, brazing or any other suitable joining system. However, press-connection is the most commonly used joining option.
- ✓ Using adequate accessories, connect C2 to the copper tube from solar collector field (cold side). You might use soldering, brazing or any other suitable joining system. However, press-connection is the most commonly used joining option.
- ✓ Using adequate accessories, connect C3 to the tube from heat exchanger (hot side). You might use soldering, press fit or any other suitable joining system
- ✓ Using adequate accessories, connect C4 to the tube from heat exchanger (cold side). You might use soldering, brazing, press-connection or any other suitable joining system
- ✓ Using adequate accessories, connect C5 to the expansion tank. You might use soldering, brazing, press-connection or any other suitable joining system

## 4.4 Pressuring solar thermal system loop

**Tools required**

- ✓ Set of wrenches
- ✓ Flushing and filling power pump station

**Work steps**

- Connect the filling pump station to the solar thermal system, using connections 6 and 7 of the pump station.
- Proceed to clean
  - Pump fresh water around the solar loop

   - Drain all water to remove residue
- Fill and pressurize the system using fresh solar fluid.

**Figure 4.6: Circuit filling and pressurizing pump station**

[Author: ST Spencer]

Connections to the equipment

The filling flow and return valves, and the filling/shut off valve (components 6, 7 & 8), are used for flushing and filling the solar thermal installation.

- ✓ Use filling flow valve connection to inject water / fluid.
- ✓ Use filling return valve connection to reject cleaning water.
- ✓ Use filling shut-off valve to flush out the rejected water out of the loop.

Proceed to clean

With all the connections in place, start by injecting fresh water to the loop, using filling flow valve connection. At the same time, the filling return valve connection will be open to make sure that the rejected water will be flushed out of the loop, after passing through different components. During this procedure, the filling shut-off valve will be off. Pump fresh water around for minimum 15 minutes and ensure water is entering all sections. Drain all water to remove residue. The collectors should be shaded during the entire process to avoid overheating.

Once the rejected water presents no residue, the solar loop might be considered clean and might be ready for filling.

Fill the system

For this phase a mixture of water and glycol should be used on a proportion that will prevent freezing.

- ✓ Determine the total volume of the circuit
- ✓ Prepare the fluid for solar circuit, using the correct mixture and the filling station reservoir
- ✓ Connect the hoses to the filling station, using the same connections as the previous to clean the circuit
- ✓ Connect the supply hose to the upper connection on the pump station (connection 6).
- ✓ Connect the return hose to the lower hose connections on the pump station (connection 7), ensuring that it is firmly attached.
- ✓ Open both green valves on the pump station.
- ✓ On the pump station ensure that valve 7 is off.
- ✓ Operate the pump.
- ✓ As the fluid level in the reservoir goes down, add solar fluid, previously prepared.
- ✓ Continue adding fluid until fluid starts coming back and the level no longer goes down.
- ✓ All passage ways must be open, pump stations, or diverter valves, fill all sections.
- ✓ In case you have different groups of collectors, you should ball valves to isolate them so that you can fill one each time. Add more solution to the bucket, if necessary, always making sure to add equal parts of propylene glycol and water.
- ✓ You should see air bubbles coming back into the bucket through the hose connected to valve 7. As the time goes by, the tank will present lesser and lesser fine bubbles and the fluid will become clear and less milky.
- ✓ Pump fluid around for a minimum of 45 minutes depending on system size.

The solar primary circuit is a filled loop with no empty zones. No air should accumulate in the loop. When pumping the solar fluid in the system, a large part of the air is removed by submerging the end hose connected to valve 7 completely in the container liquid. When the movement of fluid on the container becomes smooth and no more air bubbles come out, valve 7 must be closed to star the next phase.

<u>Pressurize the system</u>

- ✓ Continue running the filling pump.
- ✓ Once ready to pressurize the system close the valve 7.
- ✓ Watch the pressure rise and set it to system target pressure.
- ✓ Shut off the valve 6 on the supply hose and immediately shut off the pump.
- ✓ Open valve 8 and check whether the pressure drops.
- ✓ If the pressure drops, check for a leak and, if present, fixed it before refilling the system.
- ✓ If the pressure holds steady, the system is ready to be operated.
- ✓ Turn on the solar pump and observe the flow meter on the pump station. If the indicator pulses noticeably, there is still a significant amount of air in the system that needs to be removed.
- ✓ Dial in the system flow rate to match the number of collectors.
- ✓ See the control unit installation instructions for details.

In <u>setting the system target pressure</u>, please consider:

- ✓ The height of the collector field in relation to pressure relief valve and expansion tank

- ✓ The total circuit pressure drop
- ✓ Collector stagnation temperature

**The system is ready to be operated!**

## *Unit 5: Routine service, fault diagnosis and repair work of DHW systems (focus on SWH)*

**Introduction / General description**

The 5th Unit of Module 2 deals with undertaking the routine service, fault diagnosis and repair work of water heater systems, including solar thermal based systems.

Solar thermal systems are designed and installed to last for, at least, 20 or more years. During this period, regular maintenance should be carried out to secure that the system works properly and fulfils its objectives, which is delivering hot water. Major components such as solar collectors, piping system and water tank are not to be replaced during the lifetime of the system.

Prior to undertaking any maintenance work, it is useful to know some details of the system to be maintained by getting the history of the maintenance work that has been carried out in the past. It is also important which components are most likely to require substitution or refurbishing. It is also important to know hot water consumption pattern of the building.

Systems with well establish preventive maintenance routine will require less corrective maintenance and the costs associated to maintenance will be lower, depending also on the quality of the components.

**Scope – Expected results**

At the end of this course, the candidate should be able to:

- Carry out fault diagnosis of solar thermal systems,
- Plan routine maintenance work in solar thermal systems,
- Make a distinction between planned and unplanned maintenance,
- Describe the routine service and maintenance procedures,
- Carry out repair work for solar thermal systems.

This module is constituted by 2 lessons.
LO1: Requirements for the routine service and maintenance of basic domestic hot water systems
LO2: Diagnose and fault rectification work on basic domestic hot water systems

**Key words / basic terminology**

Water heater, boiler, buffer tank, load, instantaneous water heater, solar collector, heating and hot water, solar thermal system, solar loop and piping.

## 5.1 Requirements for routine service and maintenance of basic domestic hot water systems

Solar thermal systems installed in southern Europe usually experience the phenomenon called collector stagnation, which conditions the routine of the maintenance work to be carried out and the lifetime of the installed systems. Therefore, it is of capital importance to know the details of the solar thermal collector when planning any maintenance work. Professionals should gather information regarding:

- Collector stagnation temperature
- Collector volume
- Collector connection points
- System height
- System and equipment pressure rate
- Applied thermal fluid vapour pressure
- Expansion tank size and position in the circuit
- Control system adjustment parameters.

Professionals should apply Health and Safety procedures during the execution of the work activities. Prior to setting any maintenance work, the professionals should know the safety requirements and gathered adequate equipment to allow for the performance of the tasks with lower risk. Personnel and protective equipment should be correctly identified and used. The work area should be evaluated for any potential hazard. Any potential hazard noticed should be reported before or during completion of the work. This is of extreme importance, considering that part of work is to be carried in height.

Before performing maintenance work on a solar thermal unit, it is very useful to have a concrete knowledge of the system, gathered through the project and all relevant available documents that supported the selection and installation of all major components. A review of the work carried out in the past should be performed. For example, it is important to know whether the system is of thermosyphon or forced circulation type and whether the collector absorber has a selective treatment, which, under stagnation conditions, most likely generates high temperature and pressures in the solar loop, which might be distributed to other components in the loop.

When programming the maintenance, it is useful to divide the system in three basic sections, considering that the time frame, the tools and skills needed for the intervention at different units might be very specific and require specific skills:

1. Energy conversion section which integrates the components that must be placed outside the building, which include, solar collectors and loop, collector support structure, air purge system, hot temperature sensor, flowmeter regulator.
2. Transport unit that covers pipes, valves and pumping unit used to transport the heat generated in the solar collectors to the storage tank. Part of the transport section is placed outside the building and the main components are placed inside the building.
3. Storage unit, used to store solar energy, due essentially to the intermittence of the resource and the fact that it is not permanently available at the same intensity is most of the time located inside the building or with some protection from weather conditions.

Also important is the detailed planning of the maintenance work to be carried out and the assembling of the adequate tools to be used during the maintenance work. Whenever possible, the work should minimize the interference with the regular provision of hot water to the building.

## 5.2 Diagnose and fault rectification work on basic domestic hot water systems

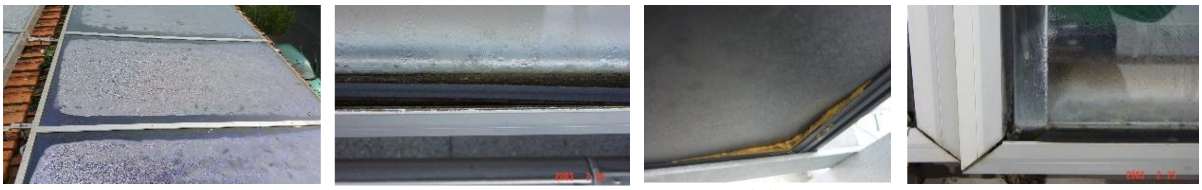
It is common practice to set the steps for the preliminary diagnose of domestic hot water systems:

- System pressure loss
- Discharge from pressure relief valve on the solar primary circuit
- Insulation degradation
- Collector overheating
- Absence of circulation when the parameters are correctly set
- System performance
- System noise and/ or vibration
- Leakages.

For the collector field, regular maintenance should include cleaning of collector units, using water, during period of lower insulation. The frequency of the cleaning depends on the climate zone where the system is installed. Checks of the support structure should indicate whether there is a need to carry out some corrections related to corrosion or structure resistance. Solar collector should be periodically checked visually for deformations, degradation of insulation material, interior condensation and leaks.

All relevant data on the referred items should be reported in a logbook. Flowmeter installed for each collector unit should be evaluated to check its working conditions and the flow value should also be registered in the logbook. Air vent should be checked for eventual air package. Hot temperature sensor should also be checked using, for instance, a cup of water and a thermometer. The sensor is placed inside a cup of water and the registered temperature on the control unit should be compared to the thermometer reading also placed at the same cup of water.

The reporting on the routine inspection findings should include references to the integrity of the collector glazing, fluid or excessive condensation inside the collector, any displacement of collector insulation material, including the high temperature rubber placed between the glass and the frame, corrosion of the frame and deformation of the absorber.



(a) (b) (c) (d)

**Figure 5.1: (a) Internal condensation, (b) rubber sealing deformation, (c) insulation expansion, (d) frame deformation**

[Author: ST Spencer]

The checks on the transport unit includes evaluation of thermal fluid acidity and freezing temperature.

Fluid substitution should be carried out if any of the two parameters are outside the set values. The transport unit should also be frequently checked for leakage. Pipe leak correction should be done using the same pipe material and joining technique. Any leakage should be swiftly corrected. The pump unit should be tested for the flow, noise and body temperature. All values should be registered in the logbook.

The air vent, located at the outlet of the manifold and the drop points, is the component subject to high temperatures, often close to the collector stagnation temperature. Often its degradation occurs in the seating thread, with the rotting of the sealing linen. Another degradation can be seen in the purge valve at the top of the air vent, which can sometimes become calcined. In installations with automatic air vent and with high collector stagnation temperature, it is necessary to check it annually, especially during summer, to allow the correction of the units that show signs of degradation and thus reduce potential problems.


**Figure 5.2: Inadequate air-vent and collector stagnation**

[Author: ST Spencer]

The expansion tank should be checked for leakage and nitrogen chamber pressure level. All insulation material should be evaluated and substituted during the maintenance work. The lifetime of the insulation material depends primarily on the placing of aluminium outer material to reduce its exposition to direct solar radiation.

The check valve should be tested considering that it might be stuck in a fix position. If the check valve is stuck in a permanently open position, there is a great probability that the solar deposit will lose heat during the night, when the tank is at a higher temperature than the collector. If it is stuck in a closed position, the pump might be rotating but there will be no energy transference from the solar collector to hot water deposit. Depending on the material, the heat exchanger needs periodic evaluation and cleaning. Soldered heat exchanger requires different cleaning technique than plate heat exchanger. For plate heat exchanger, pressurise pump can be used for its cleaning.

The high temperature generated in the solar collector and transported to other components through the solar loop determines that the system fluid should be routinely checked, mainly before the winter season. The checks include pH reading to determine fluid acidity, which should be substituted whenever the registered value is below 6. The fluid is also tested for its freezing temperature using a refractometer to determine the concentration of antifreeze within the solar fluid.

**Figure 5.3: Picture of a refractometer**

[Author: ST Spencer]

Water tank maintenance consists of periodic washing, evaluation and substitution of corrosion protection unit, usually made of magnesium anode. Depending on its positioning in the circuit, anode substitution can take a few minutes or hours. Anode positioned at the top of the water tank will take less time to be substituted than the one positioned at the lower part. The water tank should also be checked for leaks, which should be corrected right away. If the tank is equipped with internal heat exchanger, this element should be cleaned whenever the deposit is to be cleaned.

High temperature and low consumption, which occurs mainly in the summer when people leave for vacation, tend to have a wearing effect on the water tank internal treatment. During the maintenance work, a visual inspection should be carried out to check for cracks or any other damages that might occur on the internal treatment of water tanks.

**Figure 5.4: Pictures of water tank interior**

[Author: ST Spencer]

The plate heat exchanger should be periodically checked and cleaned, every 5 years, depending on water quality. High power pumping station can be used to wash the interior of a heat exchanger. However, this tool might not be recommended for plate soldered heat exchanger.

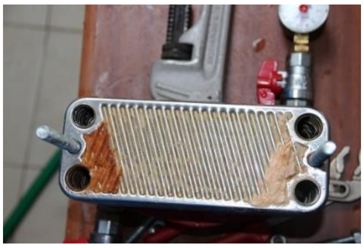


**Figure 5.5: Picture of a plate heat exchanger**

[Author: ST Spencer]

Guidelines: Always complete the relevant service and maintenance records in accordance with industry recognized procedures.

## *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*


[1] James & James, *Solar Thermal Systems, Successful Planning and Construction*, Dr. Felix A. Peuser, Karl-Heinz Remmers, Martin Schnauss.

[2] American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc, 1990, *Guide for Preparing Active Solar Heating Systems, Operation and Maintenance Manual*.

[3] American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1988, *Active Solar Heating Systems Design Manual*.

[4] McGraw-Hill (editor): *Piping Handbook*. Mohinder L. Nayyar.

[5] IDAE, 1983: *Manuales Tecnicos y de Instruccion Para Conservacion de Energia, redes de distribución de fluidos térmicos*.

[6] Blackwell Science, *Plumbing*, R. D. Treloar.

[7] John Wiley & Sons, Inc., *Solar Engineering of Thermal Processes*, John A. Duffie, William A. Backman.

[8] E. & F. N. Spon, *Renewable Energy Resources*, John Twidell and Tony Weir.

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 2*

| | | |
|---|---|---|
| 1. | **Please indicate the main function of an expansion tank in a solar thermal loop.** | |
| | a. Cool the fluid | |
| | b. Treat the fluid | |
| | c. Absorb fluid expansion | x |
| | d. Increase fluid pressure | |
| 2. | **Select all components that are part of the solar thermal loop (*please choose all the correct ones*):** | |
| | a. Heat exchanger | x |
| | b. Pump | x |
| | c. Solar collector | x |
| | d. Radiator | |
| 3. | **Indicate the most suitable fluid to be used in a solar loop to lower freezing temperature:** | |
| | a. Kerosene | |
| | b. Propylene-glycol | x |
| | c. Water | |
| | d. Mercury | |
| 4. | **Indicate the main function of the heat exchanger in a solar loop:** | |
| | a. Lower the freezing temperature | |
| | b. Generate additional heat | |
| | c. Separate the mains water from solar thermal fluid | x |
| | d. Increase solar loop flow | |
| 5. | **When collector stagnation is most likely to occur?** | |
| | a. When heat is removed constantly from the collector field | |
| | b. When the pump stops to function | x |
| | c. When the pump is in high speed | |
| | d. During the night | |
| 6. | **Increasing collector minimum pressure .....** | |
| | a. Reduces the probability of collector stagnation | x |
| | b. Increases the probability of collector stagnation | |
| | c. Does not affect the probability of collector stagnation | |
| | d. Increases solar loop pressure drop | |
| 7. | **What is the main function of pressure relief valve?** | |
| | a. Absorb circuit pressure increase | |
| | b. Protect all components of the solar loop from over pressure | x |
| | c. Control the circulating pump | |
| | d. Control collector freezing temperature | |
| 8. | **Please indicate the correct answer. In a thermosyphon system:** | |
| | a. The tank is placed below the collector. | |
| | b. The tank is placed at the same level as the collector. | |
| | c. The tank is placed higher than the collector. | x |
| | d. The tank is small | |
| 9. | **Please indicate the correct answer. During the lifetime of a solar thermal system:** | |

| | | |
|---|---|---|
| | a. Water tank should be substituted twice during the lifetime of the system. | |
| | b. Water tank should not be substituted during the lifetime of the system. | x |
| | c. Solar collector should be substituted once during the lifetime of the system. | |
| | d. Solar fluid should not be substituted during the lifetime of the system | |
| | | |
| 10. | **What might happen if the check valve is stuck in a permanent open position?** | |
| | a. Circulating pump will stop working. | |
| | b. Circulating pump will increase the flow. | |
| | c. Hot water tank will heat the collector during the night. | x |
| | d. Thermal fluid will be lost. | |

# MODULE 3: GREY WATER REUSE

## *SUMMARY*

Water is only an apparently unlimited resource; in fact, natural water resources are becoming increasingly scarce, due to strong population growth, global climate change, irresponsible human behaviour and the great increase in industrialisation. According to recent United Nations estimates, by 2030 the world will face a water shortage of 40%. In particular, we are talking about conventional water supply resources such as: groundwater from springs and groundwater, surface water from rivers, streams and lakes.

The need for a major change in the way this resource is used, managed and shared emerges. It is mainly a Governance crisis, linked to the ability of nations to guarantee both the supply and the physical-chemical quality of water and the ability to mitigate and manage the problems that could arise from a sudden increase in water demand; rather than a crisis of availability. From a single-family house to a large residential and commercial complex, today it is necessary to take a responsible attitude towards water. Reducing the consumption of drinking water is in our own and collective interest, from which we can obtain great benefits.

An intelligent way to optimise water consumption is to recover grey water. In fact, recovering water means avoiding water waste linked to the use of drinking water even when it could be avoided. Despite this, it should be highlighted that water recovery needs to be carefully studied at the site area and to follow specific and restrict regulation on the required treatment standards. Likewise, the opportunity of conducting a system to recover water should be carefully evaluated together with the public authorities and the water utility operating in the area, and a maintenance plan comprehensively produced, as an attempt to avoid public water contamination. The type of restrictions in place may differ from country to country and, thus, should be carefully revised. In addition, all procedures should be carefully supervised by a water efficiency expert.

This module of the "WET Course" has been designed with the main objective of providing professionals with the specialist knowledge they need to be able to create efficient installations for the recovery and reuse of grey water. The module is divided into 2 units:

Unit 1: Customised method and equipment selection for the reuse of collected grey water

Unit 2: Installation, commissioning and proper maintenance of grey water recycling systems

In Unit 1 the principles of grey water treatment and use and some examples of water recycling will be analysed. In addition, all the components that make up a grey water recycling and storage system will be analysed until the correct sizing of a tank.

In Unit 2 all the steps to be taken for the correct installation of a plant and tanks from the preparation of the area to the excavation (for underground plants) and the correct positioning of the tanks will be analysed. The problem of different types of maintenance will also be addressed. In addition, installation and maintenance costs will be analysed.

## *Unit 1: Customised method and equipment selection for the reuse of collected grey water*

**General description**

In the first Unit of Module 3, trainees will be presented with the principles for carrying out the personalised selection of the method and components for the reuse of collected grey water in order to improve their knowledge of the operational characteristics of grey water system components, the functioning of fittings and other parts of the grey water system, the methods and/or techniques that can be applied to ensure the proper functioning of the grey water system, taking into account the water-energy efficiency requirements and the regulations and standards (local, national, international) applicable to grey water recycling systems. In this way, trainees will improve their ability to recognise the main benefits of grey water systems, identify the water savings that could result from the use of efficient grey water systems and present the water savings resulting from the use of grey water systems to the customer.

**Scope – Expected results**

After the end of attending this learning unit, the trainees will be able to:

- apply the principles and different systems of grey water treatment
- apply techniques for collecting and using grey water
- recognise the components that make up a grey water treatment and storage system
- dimension a collection system, including the storage tank, according to the needs of the applicant
- analyse installation costs.

**Key words / basic terminology**

Grey waters, reuse, recovery plant, distribution of grey water, sizing, phyto-purification, hybrid system, ultrafiltration systems.

## 1.1 Grey waters and their main characteristics

### *1.1.1 Types of grey waters*

Grey water means untreated domestic wastewater that has not come into contact with wastewater (or "black water"). Common sources of grey water in the house include showers, bathrooms, sinks and washing machines. It is water of lesser value that can be recovered, treated and reused for non-drinking purposes. In most of the households, drinking water, taken from the public network, is used for toilet cisterns or for washing food, with a waste of water of superior quality. Most domestic wastewater is recoverable, as it contains organic substances that can be degraded in a short time and a bacterial load that can be easily managed.

It must be mentioned that, wastewater from kitchen sinks and dishwashers tends to have high concentrations of organic matter that encourage the growth of bacteria. This water is sometimes referred to as "dark grey water". Many regions do not have clear regulations or standards regarding the capture and reuse of grey water, but among the regions that have them, many do not allow the reuse of kitchen wastewater. Still, it should be noticed that the management of water supply in households needs to be carefully considered with the public authorities and the water utility.

The grey water is usually composed of only 50% organic substances, nitrogen for about 10% and the remaining part of phosphorus. This is different for the black waters, deriving from the discharges of the WC, in how much their treatment turns out to be more complex and long. In fact, the organic load contained in grey water may be less than half of that in black water, and in few days it is possible to remove even 90% of the substances, twice as much as that obtained with black water. Black water may also contain more pollutants that grey water, apart from the higher organic load.

**Figure 1.1: Typical grey water recovery system**

[Source: https://redi.it/recupero-e-riutilizzo-dellacqua/]

Treated grey water can be reused for non-drinking purposes in different types of buildings. Recognized uses of these waters include the supply of toilets and urinals, fire-fighting systems, the supply of fountains and water tanks, irrigation systems, circuits of air conditioning systems, laundries. Grey water can be reused for purposes that do not require drinking water - such as landscaping, agriculture or sanitation - thus reducing the use of drinking water, under a fit-for-purpose approach. Grey water can also be filtered into the ground to recharge the aquifers and reduce the volume of wastewater to be treated.

Grey water is distinguished from recovered water, which is wastewater (including black water) that is treated by a centralised wastewater treatment plant for drinking or non-drinking reuse. The required levels for grey water treatment depend on the purpose or destination of the recovered water, being public healthy safety the main concern of grey water reuse. Despite the so many possible uses of grey water, any system will need to comply with existing regulations and on-site verification may be conducted to verify the installation matches the required criteria. The involvement of the water utility in any reuse water project design should be considered.

From an environmental point of view, the reuse of grey water, even in private gardens, allows to develop a greater sensitivity in the more responsible use of cleaning products (both in quality and quantity) and strongly discourages the discharge of toxic substances that are not allowed in the sewer. Multiple barriers should be considered in grey water reuse to make sure that public health safety is not compromised.

Advantages:

- Simplicity of treatment.
- Saving of the drinking water resource.
- Saving money.
- Fewer discharges into wastewater treatment plants.
- Irrigation of plants and gardens.
- Nutrient recovery.

Disadvantages:

- Non-potable water network (dual).
- Attention to improper use (signs and posters).
- Use of pumps or pressurization units.
- Periodic maintenance.

#### *1.1.2 Current legislation*

In order to regulate the reuse of wastewater – or grey water, more specifically - a specific regulation that establishes the rules for the techniques for the reuse of domestic, urban and industrial wastewater (grey water) through the regulation of the intended use and the related quality requirements needs to be in place. This, in order to protect the quality and quantity of water resources, limiting the withdrawal of surface water and groundwater, reducing the impact of discharges on the receiving bodies of water and promoting water savings through the multiple use of wastewater.

Reuse must take place in conditions of environmental safety, avoiding alterations to ecosystems, soils and crops, as well as health and hygiene risks for the exposed population and in any case in compliance with current health and safety regulations and the rules of good industrial and agricultural practice. As a result, the possibility of undertaking water reuse systems should be done under the surveillance of the existing public authorities, including water utilities, and comprehensive studies on the potential health risks.

In Italy, in order to regulate the reuse of wastewater, there is a specific regulation, namely Legislative Decree 152 of 3 April 2006, while some regions have issued provisions to reduce water waste in buildings, inviting municipalities to include in their regulations specific provisions to implement on public and private buildings, new construction or subject to renovation, interventions for: the implementation of rainwater and wastewater (grey water) recovery systems and reuse of the same for the discharge of water, irrigation and non- drinking uses.

The technical committee under the ISO TC 282 (water reuse), the viability of reusing water for non-potable uses, such as rainwater for agriculture and landscaping, urbanized systems and industrial uses, is being considered under comprehensive health risk evaluation studies. Under the Water Directive, a guide for the promotion of water reuse has been adopted, as a measure to guarantee the good water quality of water bodies.

### *1.1.3 Definitions and eligible uses*

Water recovery needs to be carefully studied at the site area and to follow specific and restrict regulation on the required treatment standards. Likewise, the opportunity of conducting a system to water recover should be carefully evaluated together with the public authorities and the water utility operating in the site area, and a maintenance plan comprehensively produced, as an attempt to avoid public water contamination. The type of restrictions in place may differ from country to country and, thus, should be carefully revised.

Some useful applicable definitions are the following:

| | |
|---|---|
| **Recovery** | Re-qualification of wastewater (grey water) by appropriate purification treatment to make it suitable for distribution for specific reuses |
| **Recovery plant** | Facilities for the treatment of wastewater (grey water), including any facilities for equalisation and storage of the recovered wastewater (grey water) present within the plant, prior to the introduction of the recovered wastewater (grey water) into the distribution network |
| **Distribution network** | Facilities for the supply of recovered wastewater (grey water), including any facilities for its equalisation, further treatment and storage |
| **Reuse** | Use of recovered wastewater (grey water) of a specified quality for a specific purpose, through a distribution network, in partial or total substitution of surface water or groundwater |

The eligible uses of recovered wastewater (grey water) can be as those shown in the following table:

| | |
|---|---|
| **Irrigated** | For the irrigation of crops intended both for the production of food and feed and for non-food purposes, and for the irrigation of areas used for greenery or for recreational or sporting activities |

| | |
|---|---|
| **Civil** | For street washing in urban centres;<br>for the supply of heating or cooling systems; for the supply of dual supply networks, separated from drinking water, with the exception of the direct use of such water in buildings for civil use, with the exception of drainage systems in toilets |
| **Industrial** | As fire water, process water, washing water and for the thermal cycles of industrial processes, with the exclusion of uses involving contact between recovered wastewater and food or pharmaceutical and cosmetic products |

## 1.2 Grey water treatment and use

### *1.2.1 Aspects to be considered when designing a grey water reuse system*

Grey water reuse is a reliable and efficient technology that, if properly designed and installed, will ensure many years of service with a relatively low level of routine maintenance required. The design of a grey water reuse system must be carried out by a competent person.

When designing a grey water reuse system there is a number of issues that need to be considered, such as:

- information necessary to enable the system to be designed;
- methods for determining the type of system and the requirements for treatment capacity;
- requirements for bypassing the collection pipes;
- requirements to avoid water stagnation;
- requirements for the supply of lids and vents for tanks and reservoirs;
- prevention of contamination and microbial growth;
- requirements for the supply and cessation of overfilling;
- requirements for system pumps;
- requirements concerning the location of the storage tank and the tank;
- the requirement of having a non-interconnection valve, to avoid contamination between the reused water system and the drinking water supply;
- water treatment options and considerations.

The reuse of grey water and the type of treatment to be adopted to make it usable at home and/or for irrigation depends heavily on the quality of the inputs that are fed upstream. In fact, during the activities that involve the use of water at the domestic level, soaps, detergents and various other substances are used that will characterize the quality of the grey water in output from the various processes. In order to avoid having to adopt treatments that are too invasive and that can break down any chemical substances contained in the products used, it is necessary to use suitable and biocompatible detergents. It is therefore advisable to avoid bleaching, water softening products, detergents containing boron or chlorine, sodium hypochlorite (bleach), etc.

Salt and soap residues from washing machines and dishwashers, on the other hand, can be toxic to microbial life and to the life of the plants themselves, but they can be absorbed and degraded by phytodepuration, which is a natural treatment technique that reproduces natural purification processes in a controlled environment and can be carried out, for example, by aquatic plants. The grey water, suitably treated with a certain number of stages of filtration and microbial digestion, can also be used to provide water for washing or toilets, avoiding waste of "white water". Actually, no drinking water is needed for:

**Toilet flush**
**Car wash**
**Cleaning areas outside the house**
**Irrigation**
**Washing machine**

**For these applications, filtered, sanitized and recovered water from grey water and rainwater can be used**

Grey water can be purified more easily than the so called "black waters" as it does not contain suspended solids and, among the main "pollutants", residues of detergents, soaps or various cosmetics used for personal hygiene, home, clothing and dishes can be found. These pollutants are often **degradable** and in any case can be easily eliminated with chemical or mechanical "light" water restoration actions.

The grey water is therefore suitable for recycling through plants of a size calculated on the basis of the use of each individual house, and which mainly involve 5 phases.

- **Phase 1: Coarse filtration**

Eliminates the presence of suspended solids such as lint, textile fibres and hair.

- **Phase 2: Collection of untreated grey water**

After coarse filtration the grey water is collected in a tank.

- **Phase 3: Treatment and disinfection**

From the collection tanks the water is pumped into an ultrafiltration membrane system into one or more bioreactors. Special membranes are used to help eliminate pollutants and any micro-organisms. In some plants, chlorination or UV-c disinfection systems can also be set up.

- **Phase 4: Conservation**

Storage in suitable tanks: adequately oxygenated, cool and dark, generally underground or indoors.

- **Phase 5: Referral to households**

The recovered water will then be sent back to the household through a dedicated system of pipes and separated from that of drinking water. Recycled water can mainly be used for flushing the toilet, for irrigation or for the washing machine. Some more sophisticated purification plants also allow use of water for personal hygiene.

As it has been already stated, all water reuses should be carefully considered based on a fit-for-purpose approach and supervised. The various phases may vary depending on the plant, but this division helps to understand the most important steps for recycling. Among the various options, there would also be recycling by **phyto-purification**. This system involves the use of particular plants. These are species of plants that already in nature act as natural purifiers of the residues typical of grey water.

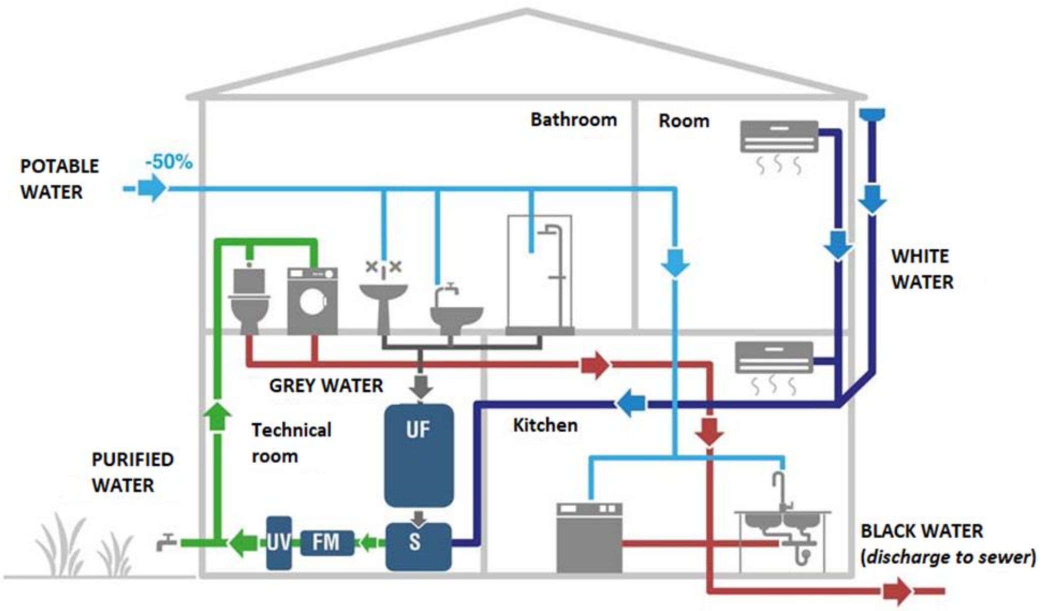
They are used in biological recycling plants that are considered soft. They foresee a collection tank from which the water is passed to a phyto-purification system (in practice a tank containing the plants) that upstream or downstream requires the use of mechanical filters (sand or lava) and / or UV radiation. This is an environmentally friendly approach to be assessed with the help of an expert.

### 1.2.2 *Types of water collection and reuse systems*

There are six main types of grey water reuse systems. Each type is identified and briefly described in the following table.

**Table 1.1: Types of grey water reuse systems**

| Type of system | Description of system |
|---|---|
| **Direct reuse system** | A system that collects the grey water from the equipment and delivers it directly to the points of use without any treatment and minimum or no conservation |
| **Short retention scheme** | A system that includes a basic filtration or treatment technique such as surface skimming and allows the settlement of natural particles |
| **Basic physical/chemical system** | A system that filters grey water before storage and uses chemical disinfectants such as chlorine or bromine to stop bacterial growth during storage |
| **Biological system** | A system that introduces an agent, such as oxygen, into stored grey water to allow bacteria to digest any unwanted organic matter. Pumps or plants can be used to aerate stored water. |
| **Biomechanical scheme** | A system that combines both physical and biological treatment |
| **Hybrid system** | A combination of one of the above systems or a combined rainwater harvesting and wastewater (grey water) reuse system |




**UF:** Primary filter + oxidation + ultrafiltration

**S:** Storage

**FM:** Multi-stage filter + activated charcoal

**UV:** UV disinfection

**Figure 1.2: Example of a grey water treatment plant**

[Source: https://redi.it/recupero-e-riutilizzo-dellacqua/]

### *1.2.3 Grey water for irrigation*

In the case of grey water for irrigation, the low pollution load that characterizes them makes it possible to avoid the adoption of biological treatments, limiting themselves to simple filtration treatments sufficient to meet the required quality levels. The grey water intended for irrigation is then collected in a storage tank with a volume equal to the daily production, in order to avoid inconveniences due to water stagnation. Before it can be used for irrigation, the water passes through a rapid filtration system, generally consisting of one or more layers of material (sand and anthracite), variously supported by a draining bottom and normally crossed from top to bottom.

This system works well when the water is intended for drip sub-irrigation and therefore is not in direct contact with people. A more traditional scheme is that grey water is treated in a septic tank and then slowly filtered. In this way, the organic load is more significantly reduced and the water can also be managed for surface irrigation. However, the type of treatment is strongly linked to the quality of the water to be treated and the conditions of reuse.

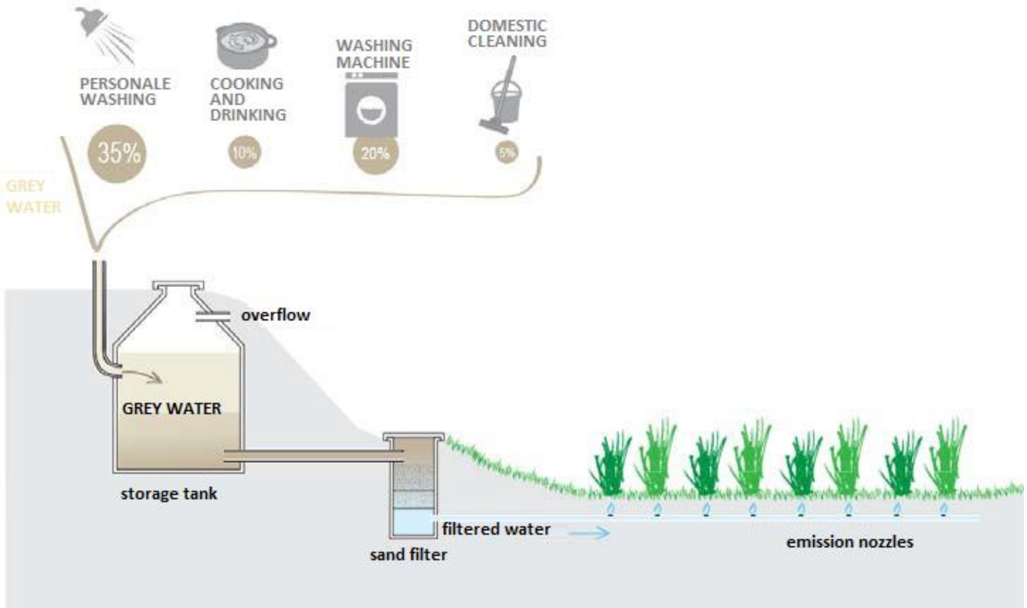



**Figure 1.3: Typical system for the reuse of domestic grey water for sub-irrigation, consisting of a storage tank and a rapid sand filter**

[Source: Visione Sistemica dell'Acqua / Dario Toso (2015)]

### *1.2.4 Grey water recovery for household non-potable applications*

Figure 1.4 provides a schematic diagram of the structure of a typical grey water recovery plant used in households. Grey water from showers, bathtubs and sinks is pre-filtered by a filter before entering the bioreactor. Overflow removes surface dirt. Biodegradation takes place here via the filling bodies, which are aerated with aerators. With the membrane station, the grey water is ultra-filtered inside the tank and pumped into a clean water tank. Sediment is periodically removed from the sludge pump. Water is transferred from the clean water tank to washing machines, toilets, irrigation systems, etc. For added safety, the already ultra-filtered water is subjected to a further step, a phase of UV disinfection.

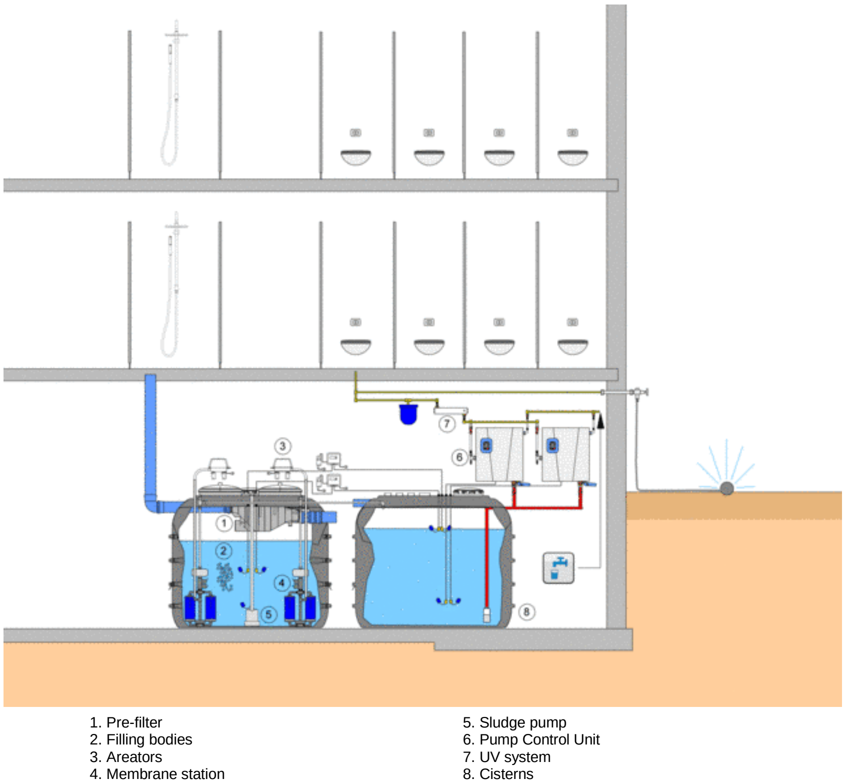
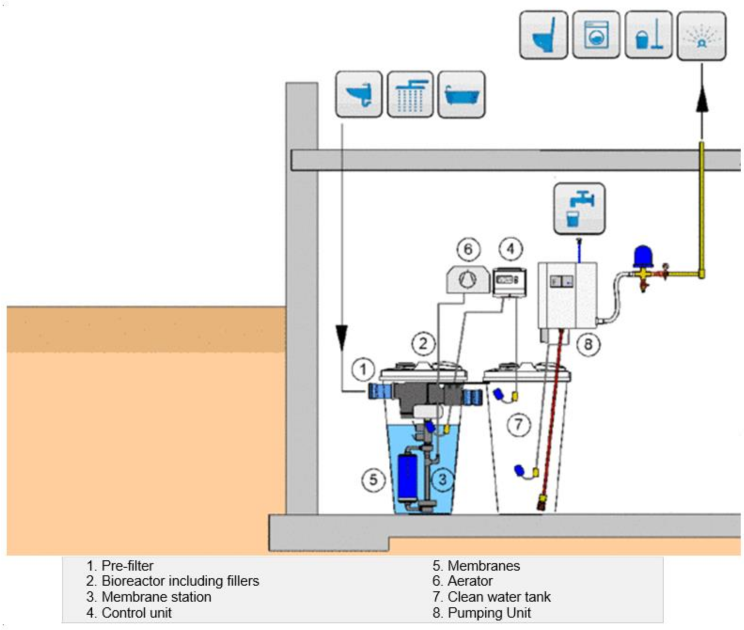



**Figure 1.4: Example of the structure of a grey water recovery plant**

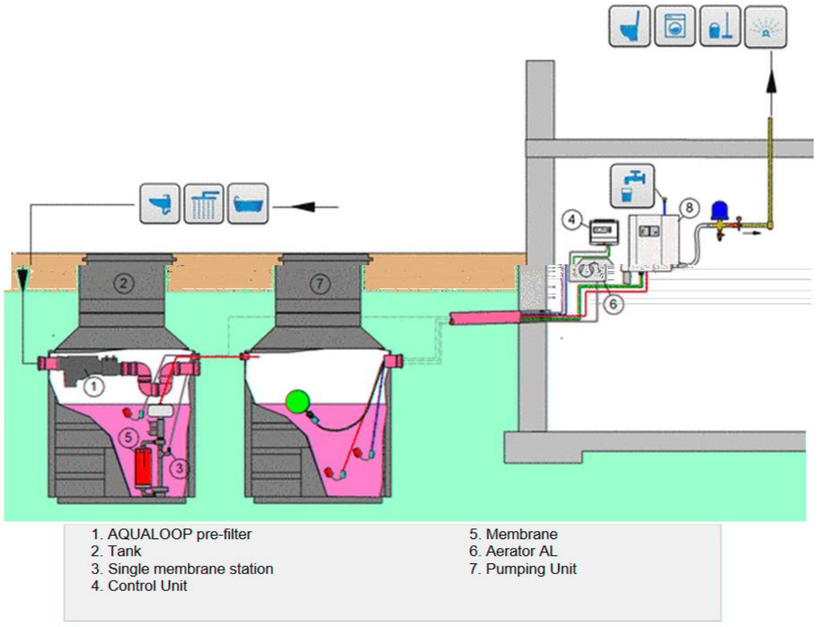
[Source: https://it.intewa.net/]

**Complete system for up to 6 persons with internal tank**




Grey water recycling plants with free-standing storage tanks can be used in most single-family homes due to their small footprint. For a single-family house, two 300-litre tanks are usually sufficient.

**Complete system for up to 6 persons with underground tank**




If there is no space for free-standing storage tanks, underground tanks are a good choice.

## 1.4 Storage of grey water

Water is stored in specially designed waste/grey water storage tanks. The range of tanks varies depending on the material, shape, capacity and location. The position of the tank determines the type of distribution sub-system (with or without pump) and therefore also the uses, the total costs of installation and maintenance, the shape (compact for interior, resistant for burying) and the materials used. Alternatives regarding the location of the tank can be: above ground, inside the building (cellar, garage) and underground.

**Figure 1.5: Waste/grey water system with an above ground tank**

Above ground tanks (Figure 1.5) are generally preferred for the accumulation of water for irrigation (garden, garden, etc.) or for washing cars etc. Where the distribution of the liquid is by gravity without the use of pumps, usually vertical tanks (e.g. to be placed on the building next to or coinciding with the descent of rainwater) or flattened tanks to be located on flat roofs (e.g. on the roof of garages or similar premises) are used.

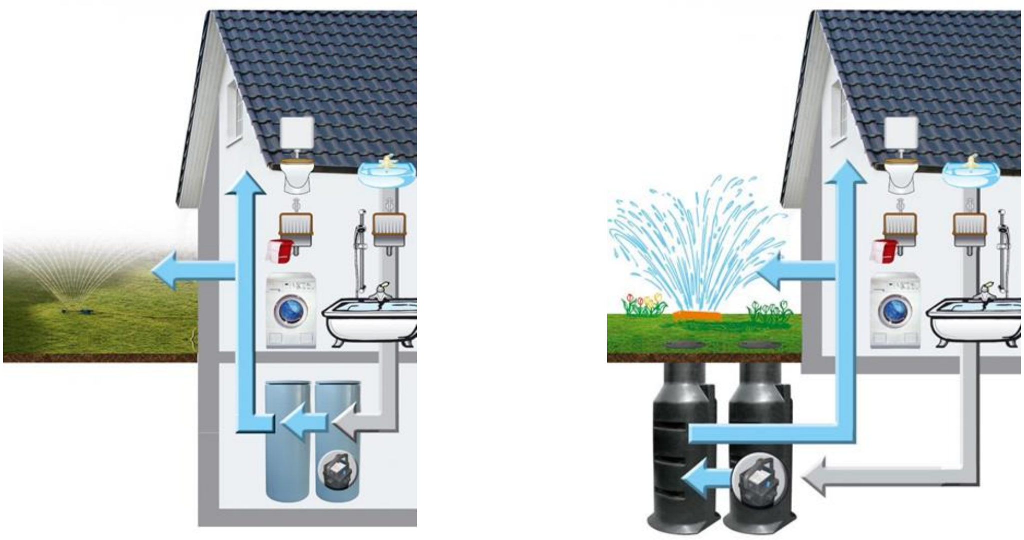


**Figure 1.6: Tank inside the building (left) and in the basement (right)**

When placed inside the building (Figure 1.6), the tank is usually located in rooms located at ground level or underground (garages, cellars, etc.). The choice is usually motivated by the ease of installation, the unavailability of outdoor spaces, difficulties for the burial (rocky ground, surface layers, etc.), the need not to tamper with complex external arrangements and / or damage the radical apparatus of planting of value and / or to contain costs. The development of the tanks is generally vertical to reduce the space required and the size is usually reduced to allow easy introduction into the internal compartments; to increase the capacity, however, it is possible to place more than one in parallel.

The positioning within the ground, even if more expensive, allows to eliminate visible encumbrances not always compatible with the functional and aesthetic needs of the building and allows the installation of even large capacity products. Each tank is equipped with a manhole or a system of access to the tank itself, consisting of a conduit on top of the casing, completed by a manhole, to perform maintenance and control operations. To avoid unwanted opening by strangers or children, it is advisable to use manhole covers with locks.

Once the water has been filtered, it must be introduced into the tank through a stilling pipe or a vertical pipe as high as the tank itself and with a lower end connection bent upwards, so as not to create turbulence that could put any layers of algae or other material deposited on the bottom in suspension. The tank must then be equipped with an *overflow* that allows water to enter the drain system once the maximum tank capacity is reached, and that must be siphoned to prevent the return of unpleasant odours from the disposal system. The overflow outlet can be used in various ways: connected to the sewerage system, connected to a dispersing well, dispersed by means of surface sub-irrigation, discharged onto the ground, discharged into a border dimple, discharged into surface water, discharged to feed natural and/or artificial lagoons.

Finally, the tank must be equipped with a non-return valve, which is essential to prevent contamination of the water stored in the tank. This valve consists of a special device equipped with a self-closing gate valve (manually operated in case of emergency or maintenance) that prevents the backflow of water from the disposal system. Normally the valve is equipped with a grate filter that blocks access to the tank and other components upstream of it, to animals and insects that could go back from the drainage and disposal subsystems.

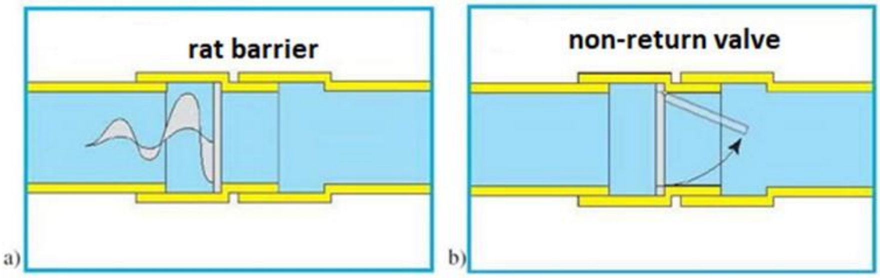



**Figure 1.7: Rat barrier (left) - Non-return valve (right)**

The materials commonly used for the construction of the tanks are high-density polyethylene, concrete and fiberglass. Polyethylene is a very common plastic material, recyclable and compatible with the regulations concerning the storage of water intended for human consumption; it makes it possible to obtain products that are light and resistant to temperature changes and atmospheric agents. It is characterized by resistance to corrosion and stray currents, smooth and easily washable surfaces, easy handling and installation. There are different forms of polyethylene tanks on the market (vertical axis, horizontal axis, bell), and storage capacity ranging from 500 to 15,000 litres. In Europe they are mainly of German manufacture.

The shaping of the casing almost always involves the presence of corrugations, ribs and folds, which act as reinforcement of the fairing. On the bottom of the product can be carved or interlocked, where the forks of the elevators can be inserted and facilitate their movement. For subsequent integrations with other storage tanks, it is possible to use parallel positioning: the installation involves placing the tanks side by side, connected to the base by connecting pipes that allow the simultaneous introduction and extraction of water from all tanks avoiding the negative consequences resulting from stagnation or emptying phenomena.

**Figure 1.8: Polyethylene tank**

Storage tanks can also be made of concrete. Concrete is a good material for tank construction: it is composed of natural raw materials (gravel, sand and cement), is durable over time, withstands the pressure of the ground, the water table and the transit of vehicles and has advantageous costs. The standard range of monolithic parts offers tanks from 1.1 to 8.3 $m^3$ capacity. Larger volumes can be achieved by laying tanks in parallel or by using large tanks, with a usable volume of up to 1000 $m^3$, which can be further extended on several lines serving, for example, large sports centres, nurseries and greenhouses, residential areas and adjoining parks. The advantage of these tanks is that they are inexpensive, but their installation is more complex and therefore more expensive. In the case of new construction, the tank could be integrated, for example, in the patio or in the cellar of the house.

**Figure 1.9: Concrete tank**

There are also tanks made of fiberglass (GRP - Glass-reinforced polyester resin), a thermo-setting composite material, where the fiberglass ensures high mechanical strength and the polyester resin the chemical resistant part. It is a material with very high performance: resistant, lightweight and non-toxic, corrosion-resistant, UV-resistant and easily repairable. These tanks are made of a single block and are then reinforced with box-shaped rings directly welded to the cylinder that ensure maximum resistance to implosion making them perfectly buried and walkable. They can reach high capacities of 60,000 to 70,000 litres. Among the types of tanks analysed here these are the most expensive.

**Figure 1.10: Steel tanks for water storage**

Finally, the tanks can be made of high strength corrugated sheet metal, with a minimum thickness of 2.5 mm to withstand vehicular loads. These tanks are light but very robust and easy to transport and install. They are protected from corrosion by a galvanising process, as required by the regulations. They are generally modular tanks with diameters ranging from DN 2000 mm to DN 3000 mm, for lengths from 4 metres to 15 metres; volumes ranging from 20 to 100 $m^3$, that can be multiplied further by exploiting the modular system and flanking them in line, on several rows or according to requirements, and connecting them with flanges or a suitable elastic joining system.

### 1.5 Distribution of grey water

The filtered and properly stored water is then ready to be taken and reused. As mentioned before, the possible uses are essentially of two types: domestic (non-potable) and irrigation. In the case of simple irrigation use, to draw water from the tank a pump of adequate flow rate and head, which can be immersed in the tank or external, should be installed. It must be equipped with a sampling system at a constant depth, in relation to the level of water in the tank. A special float connected to the draught hose (also equipped with a filter) ensures that it always takes place at a set constant depth, for example -10 cm from the surface, regardless of the level of fluid inside the tank.

If the draught is too close to the bottom, an area in which impurities can accumulate, the pump's activation/deactivation float will remove it and prevent it from draughting until the level of the tank is increased, thus remedying the problem. These necessary measures serve both to guarantee the maximum quality of the fluids taken and to preserve pumps and hydraulic systems from annoying, frequent and costly maintenance and repair.

In cases where the use of the stored water also for domestic purposes is requested, a few more tricks in the implementation of the distribution system should be used. Many companies propose the use of automatic control units in these cases. The control unit has the task of providing the users connected to it with a constant water supply through the automatic management of the traditional hydraulic circuit and the recovery circuit without any kind of waste. For this purpose, the minimum volume below which the stock must never fall must first be determined in order to ensure simultaneous and prolonged use by the connected loads.

To guarantee this volume, a level sensor is installed inside the tank which, when the recovered water falls below the desired quantity, opens the solenoid valve of the drinking water circuit and delivers it, by means of a submersible pump or external, into the tank. It should be noted that the tank will be reintegrated with the traditional water supply exclusively until the required level is reached and maintained (the level determined by the sensor) so as not to frustrate the succession of water input recovered.

In compliance with the applicable health regulations, the traditional hydraulic network and the recovery network must be totally separated without ever coming into direct contact. This guarantee inside the control unit is provided by the solenoid valve that physically separates the two circuits without ever letting them come into direct contact

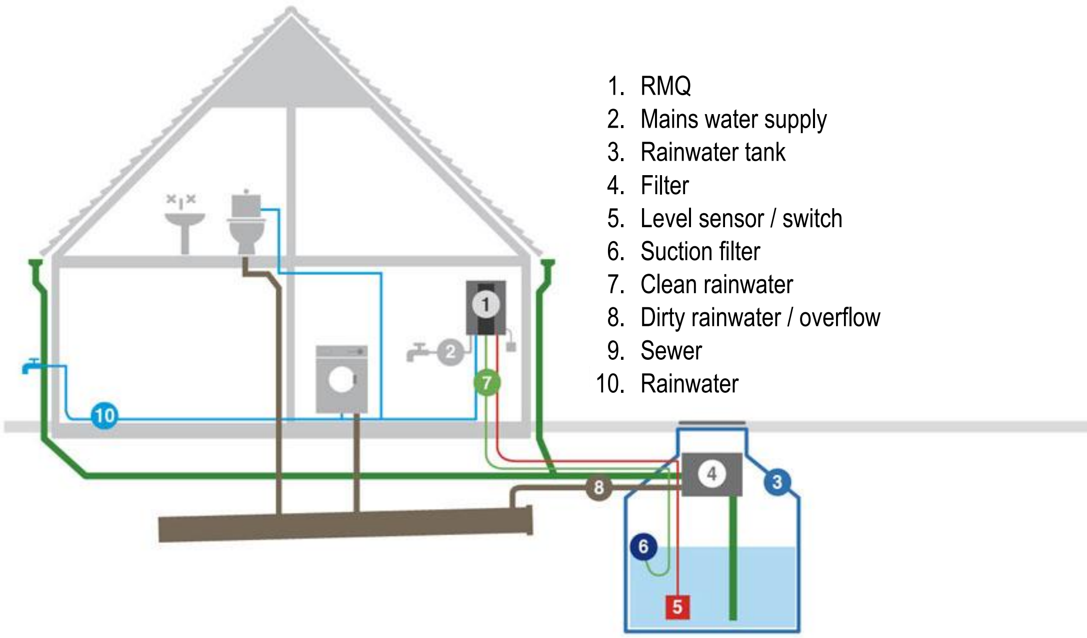



**Figure 1.11: Schematic diagram of a domestic grey water reuse system**

## 1.6 Treatment of grey water

There are numerous methods for grey water treatment (GWT), differing in their characteristics, forms, pollution loadings and treatment procedure. The selection of the suitable technology depends on the quantities of grey water, organic contents, final application and standards acceptance. The treatment processes included preliminary, primary and secondary processes. However, there is no established design for GWT globally, except for in a few countries like Australia and USA, and it is basically designed in relation to the grey water source, quality and quantity, site condition and reuse alternatives. Moreover, the accepted fact is that grey water should be treated with an eco-friendly technology and without chemical additives or toxic by-products. Some of the available options are described in the following paragraphs.

### *1.6.1 Grey water treatment with natural solutions*

A sustainable design choice for the treatment of grey water for re-use must take into account the following factors:

- adaptability to changes in hydraulic and organic input load;
- efficiency in the degradation of organic matter;
- high abatement of the bacterial load;
- simplicity and cost-effectiveness of operation and maintenance.

Phyto-purification techniques represent a type of plant that perfectly adapts to these needs: in particular, at the same hydraulic load treated, their efficiency is greater in reducing the organic load present in the grey water, compared to the case in which there is also black water. As adhesion biomass systems, they are much less affected than traditional activated sludge systems by changes in pollutant concentrations in the grey water.

In addition, they have proven to be highly effective in reducing the bacterial load, which is still present in very limited quantities in grey water. Among the various types of phyto-purification systems, those with submerged flow have marked advantages over those with surface flow: the sub-surface flow strongly limits the risk of odours, the development of insects, and can allow the use of the area used for the plant by the public, thus allowing the inclusion in green accommodation of building complexes.

### *1.6.3 Grey water treatment with compact technical solutions*

There are other systems particularly suitable for the treatment of grey water, characterized by small overall dimensions (generally these are burial systems, but there are some solutions on the market also suitable for installation inside buildings, for example in cellars, also allowing savings in terms of piping outside the buildings). Particularly suitable are the SBR (Sequencing Batch Reactor) systems, which have many advantages, such as high treatment efficiency, compactness, ease of installation and management, silent operation and no production of unpleasant odours. Within the SBR system, water treatment is carried out in several successive time stages that take place in a cyclical manner.


**Figure 1.12: Example of Sequencing Batch Reactor (SBR) system**

The filter is washed periodically and automatically by means of a special pump inside the system, and the residues of the filter cleaning are discharged into the sewage system. Subsequently, the actual biological treatment takes place, with the "batch" operation typical of these systems: the oxidation and sedimentation phases take place within the same compartment at intervals automatically established by means of a control unit. The waste products from the sedimentation phase are automatically expelled at regular intervals and conveyed to the black sewerage system (third stage).

### *1.6.3 Ultrafiltration systems*

Ultrafiltration plants have the objective of separating a dispersed phase, consisting of solid particles, from a continuous phase, i.e. the fluid in question. The suspension is then sent against a filtering membrane, using a difference in pressure called transmembrane pressure, to obtain the passage of the fluid; downstream of the membrane the fluid is collected and is called filtered or permeated.

In the same way, the filtrate is passed through a series of other membranes that together contribute to the completion of the separation process, in particular they are able to retain colloids, bacteria and viruses. During the operating cycle, the membranes are periodically washed to maintain their characteristics intact.

- **System components**

The collection and reuse system consists of the following elements: loading basin with siphoned overflow valve, pre-filtration system, ultrafiltration system, storage tank with non-return valve, siphoned overflow valve, self-priming pump, control unit and inspection chamber. If desired, the storage tank can be the same as the rainwater collection system.

- **Treatment phases**

- Loading dock: the grey water coming from the drains is collected in a dock waiting to be treated.
- Pre-filtration: the water coming from the loading basin is subjected to an initial filtration to retain hair and other coarse materials.
- Ultra-filtration: by means of a low pressure pump, the grey water crosses the membrane which, separating the dispersed phase from the continuous phase, carries out the purification, ensuring that the outgoing water is free of polluting substances.
- Storage and reuse: The water coming out of the ultra-filtration system is stored in a tank, which can also be the same as that used to collect rainwater, to be reused for toilet cisterns, for garden irrigation and for cleaning the building (not for drinking use).

### *1.6.4 Installations with ozone disinfection*

Ozone, among all the disinfectants that can be used for water disinfection, is the one with the highest oxidation power. Thanks to this important property, it acts effectively against bacteria and viruses by eliminating or deactivating their action. Ozone is therefore able to greatly improve the quality of water, among other things by extracting the chloramines that are formed by the reaction between organic compounds and chlorine.

In addition, ozone decomposes during use to form natural oxygen. Ozone is not commercially available, but it can be produced from equipment called ozonizers, which convert the oxygen in the air into ozone, through electrical discharges. A plant that uses this disinfection system also needs a water-ozone mixer in order to facilitate adequate contact time with the grey water to be treated.

- **System components**

The collection and reuse system consists of the following elements: a pre-filtration element, a bio-filtration element, a debacterizer and a storage tank (it can be the same as the rainwater collection system, if any).

- **Treatment phases**

- Pre-filtration: incoming grey water is passed through a filter to remove coarse elements such as hair and other materials.
- Bio-filtration: the pre-filtered waters are passed through a special compartment, inside which are

installed filtering layers, composed of gravel, zeolite, activated carbon. In this way the wastewater undergoes a physical purification.

- Dehydration: during this phase, ozone is dosed in appropriate concentrations inside an accumulation and contact tank; the result is sanitized water that can be used for toilet hunts, irrigation or building cleaning. Drinking use is not permitted.

## 1.7 System components

Apart from the storage tank which is the basic component of a greywater reuse system and for which all the available opportunities have been described in detail in section 1.5, the components actually used in a waste/grey water reuse system vary depending on the type and complexity of the system. The following components can be used in a waste/grey water reuse system:

- Hair traps and pre-filter
- In-line filter
- Air pump
- Membrane filter
- Floating extraction point
- System pump
- Pump control unit
- Float switch
- Pressure vessel
- System Control Unit
- System Module
- Back-up air gap power supply type AA with solenoid control
- Overcharge valve.

**Hair traps and pre-filter**

Depending on the source, grey water may contain hair (e.g. from baths and showers) and/or larger particulate matter such as lint (e.g. from washing machines). In this case, it is a good idea to use hair traps and/or a pre-filter to be used to minimise the pollutants entering the system and to extend the operating life cycle of the filtration integrated into the grey water reuse system. Some pre-filters include a backwash facility.

**Figure 1.13: Point of use hair trap (left), pre-filter (right)**

**In-line filter**

An in-line filter may be used where basic filtration of the greywater prior to a storage tank is required. The in-line filter shown in figure 1.14 includes a pre-filter that is designed to prevent hair and larger organic particles from entering the main filter, thereby prolonging longevity. The pre-filter needs to be cleaned on a regular basis. Once the greywater has passed through the pre-filter it enters the main filter cartridge unit. The main filter cartridge unit features different levels of filtration medium to filter the greywater according to required reuse purpose(s). The main filter cartridge needs to be replaced annually. This type of in-line filter can also be used in rainwater harvesting systems.

Where an in-line filter is used with a greywater reuse storage tank, the system designer will need to assess the risk of contamination of the stored water once it enters the storage tank. A further water treatment arrangement may be required, depending upon the intended use of the stored greywater and the duration of storage before reuse.


**Figure 1.14: In-line greywater filter**

**Air pump**

A greywater reuse system that includes biological treatment of the stored water will typically use an air pump to aerate the stored water. An example of an air pump is shown in the figure below.

**Figure 1.15: Air pump**

**Membrane filter**

Some grey water systems use a membrane filter to remove particles, bacteria and viruses from grey water. An example of a membrane filter is shown in the figure below. The membrane filters must be housed in a special filter module, as shown in the figure, which is then immersed in the grey water.

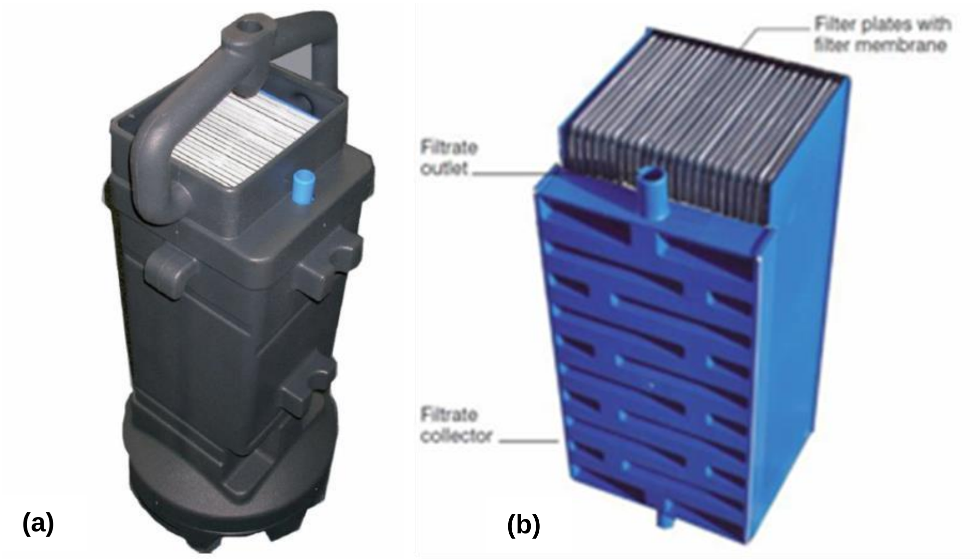



**Figure 1.16: (a) Membrane filter in purpose-made filter module, (b) Membrane filter**

The operating principle of a membrane filter is shown in the figure below. The grey water is drawn in through the membrane of the filter under a pressure of approx. 0.1 bar. Particles, bacteria and viruses are physically blocked by the passage through the filter because of the membrane with a pore size of 0.04 micrometers (µm).

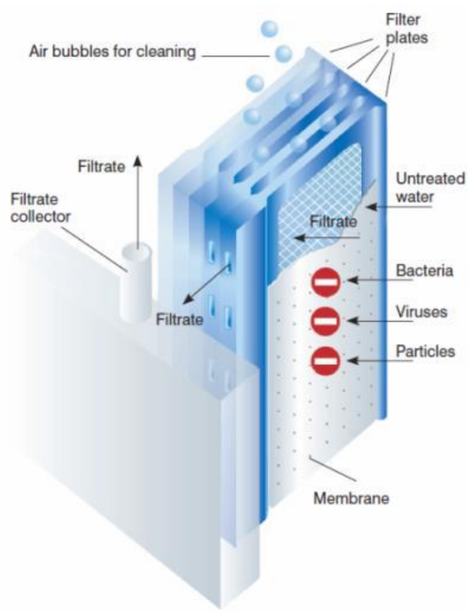



**Figure 1.17: Operating principle of a membrane filter**

**Floating extraction point**

A floating extraction point may be used to enable the stored water that enters the distribution circuit pump to be taken from approximately 100–150 mm below the surface. A floating extraction point is simply a mesh filter with a hose connection that is freely suspended near the surface of the water by means of a polypropylene (or similar material) ball. The grade of mesh filter used depends upon the degree of filtration required. Floating extraction points are available with either fine or coarse mesh filters.


**Figure 1.18: Floating extraction point**

**System pump**

The pump used to distribute the greywater may be one of two types:

- Submersible
- Suction.

**Figure 1.19: Submersible pump with connected floating extraction point and a float switch (left) and suction pump for use outside the storage tank (right)**

Due to the nature of their design and intended use, submersible pumps are mounted inside the storage tank. The suction pumps used in grey water reuse systems are multistage self-priming pumps and can be fitted either outside the storage tank in an enclosure or inside the building, or inside the storage tank in a sealed housing or extraction unit.

An example of the arrangement of a sealed suction unit inside the tank, used in combination with a membrane filter module, is shown in the following figure.

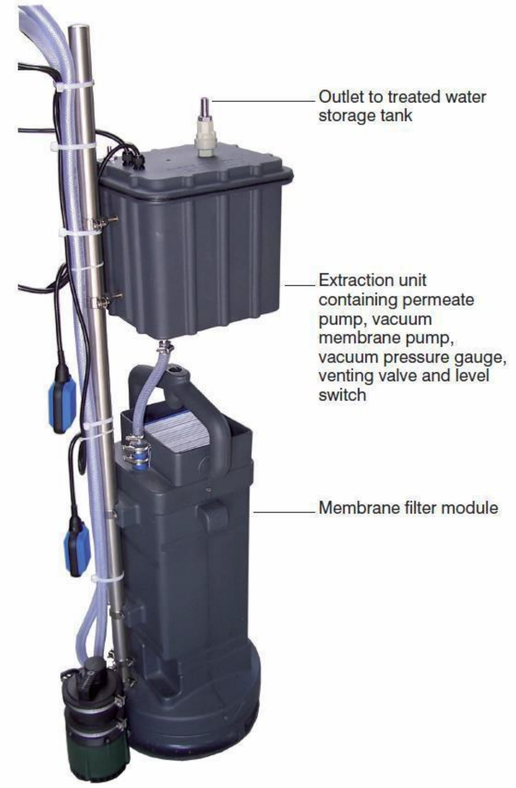



**Figure 1.20: Arrangement of the sealed extraction unit in the tank, used in combination with a membrane filter module**

**Pump control unit**

The system pump should be controlled by a control unit that:

- operates the pump(s) to match demand
- protects the pump(s) from running dry
- protects the motor from overheating and electric overload
- includes a manual override function.

Depending upon the manufacturer, the pump control unit may be a stand-alone unit or integrated with the mains back-up water supply control arrangement as a system control unit. Pump operation will either be pressure-switch controlled or float-switch controlled depending upon the system type.

**Float switch**

A float switch is used in conjunction with the pump control unit to provide dry-run protection to the pump if the storage tank water level drops to a predetermined level. A float switch is also used in conjunction with the backup water supply control arrangement to operate the back-up water supply, to be activated when the storage tank water level drops to a predetermined level. Where a submersible pump is used, a float switch can be mounted on a clamp bracket with a pivot lever to provide a secure and reliable fixing.

**Figure 1.21: Float switch with pump mounting clamp and pivot lever**

**Pressure vessel**

Potable grade expansion vessels are used as a pressure vessel/accumulator tank in some pumped distribution greywater reuse systems with the purpose of maximizing pump life by reducing pump on–off pulsation.

**System control unit**

A system control unit is required to automatically control and monitor the function of the greywater system to facilitate effective operation. The complexity of the system control unit will vary according to the complexity of the greywater reuse system itself. The system control unit will also typically include alarm features to alert the system user of any system malfunction.

**System module**

A system module is a factory assembled greywater reuse component station that contains the following components as a minimum:

- pump (suction);
- pump control with dry run protection;
- back-up water supply connection arrangement with type AA or type AB air gap.

**Back-up air gap power supply type AA with solenoid control**

If the back-up water supply is to be provided via a type AA air gap arrangement, it can be obtained using a factory-assembled component similar to that shown in the figure below. This type of component is suitable for use to provide back-up power directly to an above-ground tank or to an underground tank via a suitable piping arrangement. The solenoid valve is operated by a float switch located inside the storage tank or tank.

**Figure 1.22: Solenoid controlled type AA air gap back-up power supply**

**Anti-surcharge valve**

The UK building regulations require that an anti-backflow device is fitted on any overflow connected to a drain or sewer to prevent contamination of the stored greywater in the event of surcharge in the drain or sewer. This requirement can be met through the installation of an anti-surcharge valve. An example of a surcharge valve is shown in the following figure.

**Figure 1.23: Anti-surcharge valve**

## 1.9 System sizing (example)

Assuming an isolated house consisting of 4 people and having a garden of 450 square meters. It can be said that:

| WATER RECOVERY CALCULATION MODULE | | | | |
|---|---|---|---|---|
| TYPE OF USE | litres/d for person | Number of people | Period in day | YEARLY CONSUMPTION SERVICE WATER |
| WC | 24 | 4 | 365 | 35,040 |
| Washing machine | 14 | 4 | 365 | 20,440 |
| Cleaning | 2 | 4 | 365 | 2,920 |
| Other | 0 | 0 | 0 | 0 |
| TOTAL OF REQUIREMENTS (1) | | | | 58,400 |
| TYPE OF IRRIGATION | | Needs lt sqm/year | Area to be irrigated square meters | YEARLY CONSUMPTION WATER IRRIGATION |
| Garden irrigation | | 60 | | 0 |
| Sports facilities (growing season) | | 300 | | 0 |
| For green areas with light soil | | 450 | 50 | 22,500 |
| For green areas with heavy soil | | 250 | | 0 |
| Other | | | | 0 |

| | |
|---|---|
| TOTALE OF REQUIREMENTS (2) | 22,500 |
| TOTAL REQUIREMENT (1) + (2) (LITRES/YEAR) | 80,900 |

| SYSTEM - GREY WATER RECOVERY | | | | |
|---|---|---|---|---|
| PROVENANCE as of | Water RECYCLED | Number of PEOPLE | DAYS RECOVERY | Total recycled |
| Washbasin | 15 | 4 | 365 | 21,900 |
| Shower | 60 | 4 | 365 | 87,600 |
| Bathtub | 150 | 4 | 12 | 7,200 |
| TOTAL OF LT RECYCLED IN ONE YEAR | | | | 116,700 |

| OVERVIEW | requirements | grey water recovery |
|---|---|---|
| Residential use | 58,400 | 116,700 |

**Cost analysis (estimated metric calculation)**

The following tables list some examples of grey water recovery plants with their prices and quantities with the aim of estimating a total cost for a case study.

- **Tank of 5.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for grey water, reinforced with ribs, to be buried, walkable | 5.000 | 1.854,75 | 1 |
| Grey water filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341,43 | 1 |
| Filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for grey water collection surfaces up to 300 $m^2$ | - | 428,91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3/h$, head from 15 to 40 m, control device with float switch. | - | 1.764,48 | 1 |
| | **Total** | 4.389,57 | 4 |

- **Tank of 6.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for grey water, reinforced with ribs, to be buried, walkable | 6.000 | 2.297,87 | 1 |
| Grey water filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341,43 | 1 |
| Filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for grey water collection surfaces up to 300 $m^2$ | - | 428,91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3/h$, head from 15 to 40 m, control device with float switch. | - | 1.764,48 | 1 |
| | **Total** | 4.832,69 | 4 |

- **Tank of 10.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for grey water, reinforced with ribs, to be buried, walkable | 10.000 | 3.676,79 | 1 |
| Grey water filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341,43 | 1 |
| Filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for grey water collection surfaces up to 300 $m^2$ | - | 428,91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3/h$, head from 15 to 40 m, control device with float switch. | - | 1.764,48 | 1 |
| **Total** | | 6.211,61 | 4 |

## *Unit 2: Installation, commissioning and maintenance of grey water recycling systems*

### General description

In the 2nd Unit of Module 3, trainees will be taught the principles of installation, commissioning and proper maintenance of grey water recycling systems, taking into account the water-energy efficiency requirements and the regulations and standards (local, national, international) applicable to grey water recycling systems. In this way, trainees will improve their ability to interpret the design of the grey water system and the sizing characteristics, taking into account the water-energy efficiency requirements, to establish the sequence of installation of the grey water system, to ensure proper operation, and to provide an estimate of the work to be carried out for the implementation of the system.

### Scope – Expected results

With the completion of this Unit, the trainees will be able to:

- install the various grey water storage and recycling systems
- install the components of the storage system and carry out the excavations in compliance with health and safety regulations
- carry out ordinary and extraordinary maintenance work.

### Key words / basic terminology

Maintenance, hydraulic and electrical connections, excavation, cost analysis, pipework test requirements.

## 2.1 Considerations for installing underground storage tanks

The location and method of installing a below ground storage tank will vary from site to site and should be determined in relation to:

- Manufacturer's instructions
- Ground strength and stability
- Ground water levels
- Proximity of trees
- Proximity to utilities
- Proximity to foundations
- Shading and temperatures
- Access routes.

Installations may need to be surveyed on site, while compliance with regulations need to be verified by public authorities.

**Manufacturer's instructions**

The storage tank manufacturers' instructions should be the first point of reference when planning and undertaking the installation of a storage tank. Some manufacturers produce tanks that can simply be placed into a suitably sized excavation and backfilled, without the need for a base or side support. Other manufacturers require that a specific base is provided and may specify that a certain grade of material is used to backfill the immediate area surrounding the tank. The manufacturers' requirements will primarily be influenced by the type of material that has been used to manufacture the tank.

**Ground strength and stability**

As with above ground storage tanks, it is essential that a below ground storage tank is located in a position that is strong and stable enough to support the load that will be imposed by the storage tank when it is full. Certain ground conditions, such as clay, may not offer suitable strength and stability. Ground conditions where peat is present are unlikely to be suitable due to the compressive properties of peat.

**Ground water levels**

Ideally, a below ground storage tank should be located in a position that is above the normal level of the water table. Where this is not possible and there is no alternative to using a below ground storage tank, the installation method will need to provide protection against the tank floating in the ground when the surrounding water level is higher than the base of the tank. This will normally require the storage tank to be fully encased in concrete.

**Proximity of trees**

Tree roots seek moisture. Therefore, locating a below ground storage tank close to trees is not advisable as this may result in tree roots damaging or entering the storage tank.

**Proximity to utilities**

Some storage tanks are made from materials that may be permeated by substances such as natural gas. Therefore, below ground storage tanks that are susceptible to permeation should not be located adjacent to utilities that pose a hazard of permeating the storage tank and contaminating the stored water. It therefore seems appropriate to maintain at least 350 mm between a below ground storage tank and a gas service pipe unless the tank's manufacturer requires a greater separation distance.

**Proximity to foundations**

The installation of a groundwater harvesting system must not introduce any risk of subsidence to a building. To avoid this risk it is a typical requirement that no excavations for the installation of a below ground tank, or for a drainage pipe supplying the tank, within the area shown in the following figure.

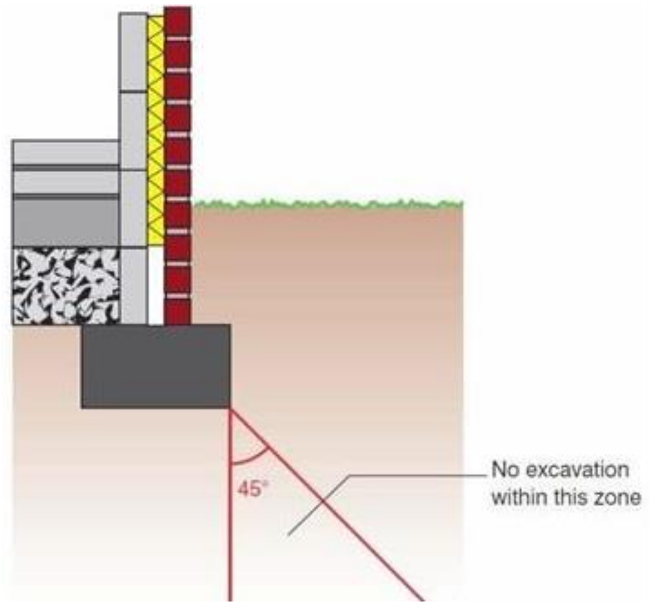



**Figure 2.1: Typical non-excavation zone**

[Source: Aquavet Handbook, CONAIF (2016)]

**Shading and temperatures**

It is important that the rainwater collected is stored at a temperature that does not encourage or encourage the multiplication of legionella. The location of the storage tank in relation to the solar energy path is a key factor affecting the temperature of the stored water. A shady place is preferable.

**Access routes**

There are two considerations relating to access routes:

1. The loading that a below ground storage tank would be subject to if it is located under an access route. Where a traffic load location such as a driveway is chosen, the method of installation and the duty of components such as access covers must be appropriate for the load that will be imposed during the use of the access route.
2. Access to the storage tank for inspection, service and maintenance purposes.

When installing a below ground storage tank access cover, it is important that the access cover is installed flush with or above the ground level and that the area around the access cover is free-draining to prevent surface water entering the storage tank via the access cover.

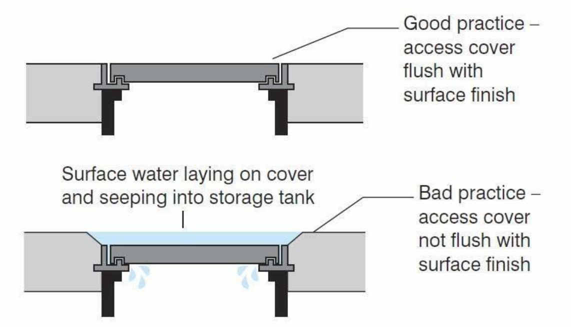



**Figure 2.2: Good and bad practices of access cover installation**

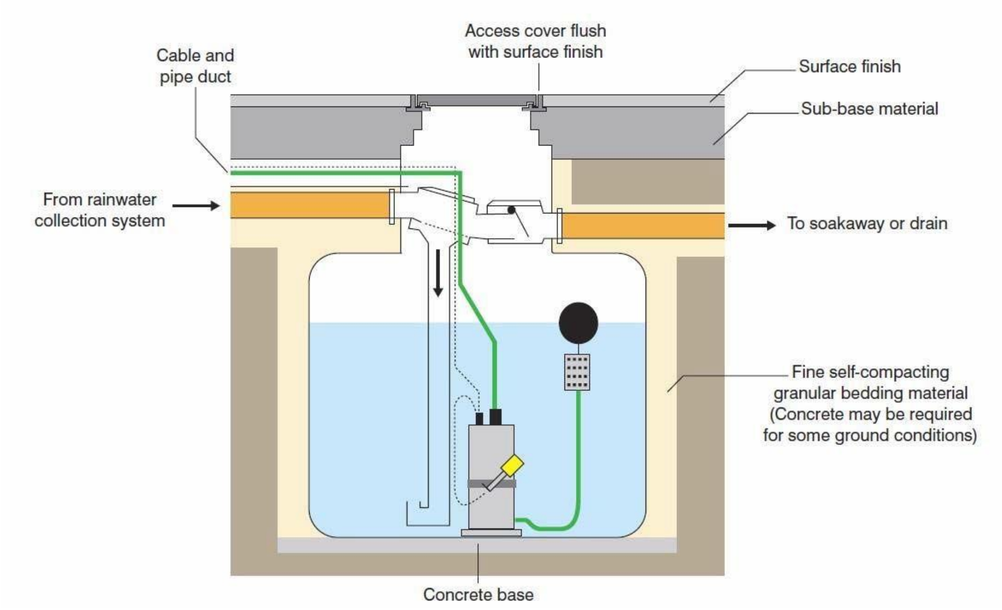



**Figure 2.3: Example of installation of an underground storage tank**

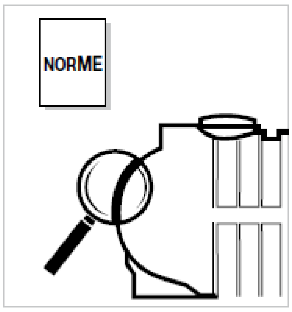
Note: The installation arrangement given in figure 2.3 is not intended, and must not be used, as exemplar installation detail. The installation arrangement used must address any regulatory requirements, component manufacturer's instructions and best suit the features and the constraints of the installation site.

## 2.2 Methods of handling, laying and use of underground tanks

### *2.2.1 Preliminary work*

- **Standards**

During all operations, the safety and hygiene regulations in the workplace and subsequent modifications and integrations on the safety of temporary and mobile work sites must be respected. Before laying, carefully check the integrity of the tank.

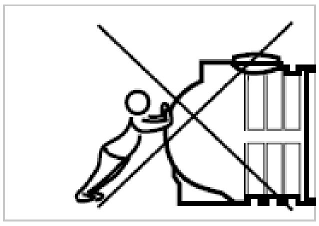


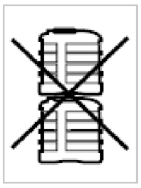

- **Handling and use**

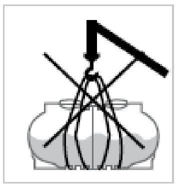
Harness the tank with suitable ropes of adequate capacity, or use the appropriate eyebolts for lifting. The means used for lifting and handling must be of adequate capacity and comply with the regulations in force. Do not place the tank near any heat sources. During the handling work, delimit the affected area with appropriate signs.

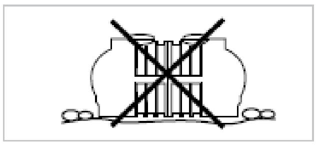
- **Loading and unloading**

The loading and unloading operations must be carried out with care: the tanks must not be thrown or made to crawl on the sides of the vehicle, loading or unloading them from the same, but must be lifted and placed with extreme care. When storing, be careful not to stack tanks that could be damaged.





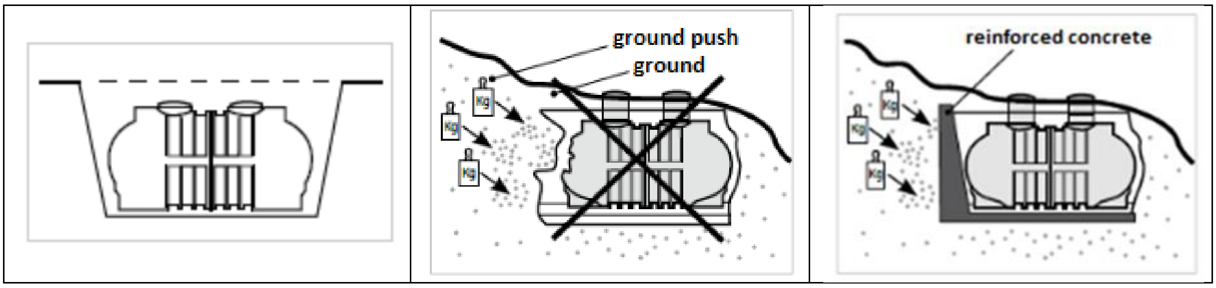




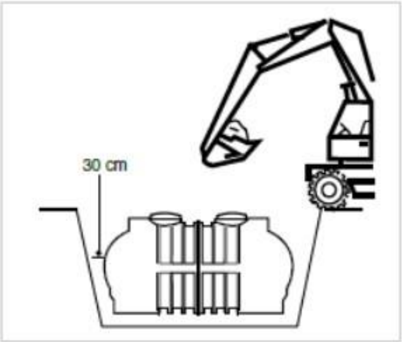
DO NOT HANDLE THE PRODUCT OR PARTIALLY FILL IT.

### *2.2.2 Preparation of excavation and bedding*

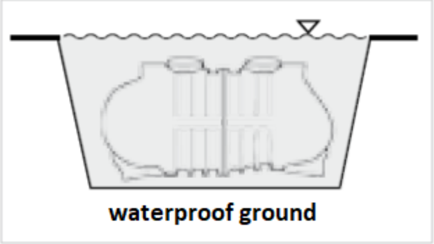
The tanks must never be placed in landslides, on slopes, close to slopes that carry the load on the structures, or in positions subject to rainwater drainage. In such situations, it is absolutely necessary to use a qualified technician to define the most appropriate actions to be taken for a proper solution of the case.




**Excavation dimensions:** Prepare a flat-bottomed hole of suitable dimensions with self-supporting walls, so that a space of about 30 cm remains around the tank.

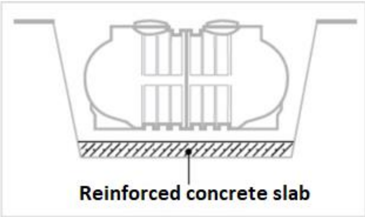



**Drainage:** In the case of impermeable clay and/or loamy soils, in order to prevent the tank from being subjected to different pressures due to the accumulation of water in the excavation during the weather events, it is advisable to provide for a drainage system. If it is not present or not possible to remove the water from the excavation site, follow the instructions in the paragraph "Excavation in the presence of a water table".

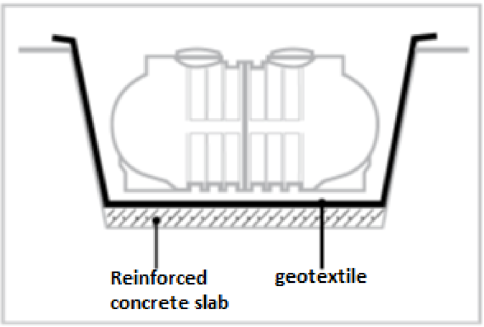



**Type of ground:** In case of non-homogeneous soil, prepare on the basis of the excavation, a distribution slab in reinforced concrete of adequate strength, calculated by a qualified technician.

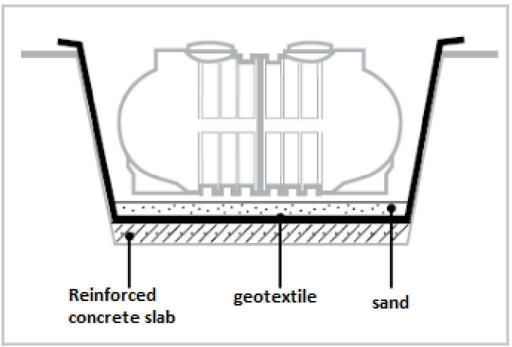
N.B: The reinforced concrete slab must always be made in case of installation of modular and/or ribbed tanks.



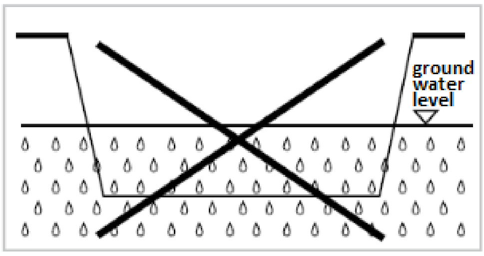

**Coating:** Cover the walls of the excavation with geotextile to avoid dragging the tank backfill material with the formation of vacuum zones that cause different pressures on the tank itself.

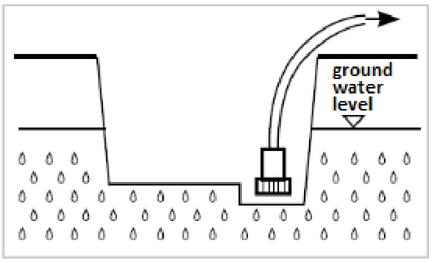



**Laying bed:** Make a sand bed of at least 5 cm on the base of the excavation or above the support slab so that the tank rests on a uniform, compact base and not directly in contact with the base of the excavation or the reinforced concrete plaster.




**Excavation in the presence of groundwater:** During the excavation phase it is essential, in order to be able to work correctly, that the installation site of the tank is in dry conditions; therefore, if there is the presence of water from a shallow water table, it is advisable to eliminate it by using, for example, water pumps.



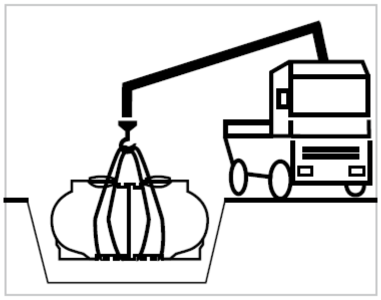




Create a reinforced concrete subfloor suitable for the sub-thrust of the water table.

### *2.2.3 Positioning of the tank and anchoring*

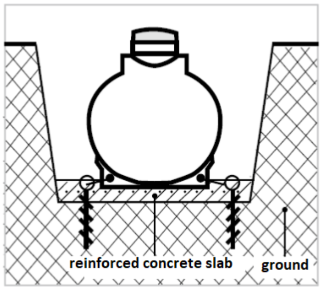
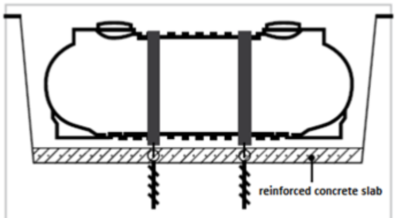
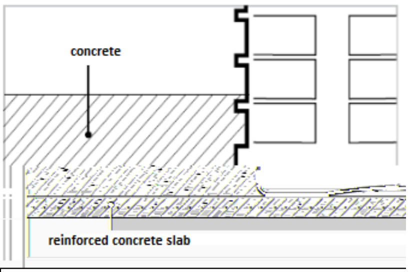
➢ **Tank positioning**

Before laying the tank in the excavation, it is necessary to make sure that the gaskets, pipes and all parts other than the polyethylene present in the tank are suitable for the liquid to be contained.



➢ **Anchorage**

During the construction phase of the foundation, plan and position the underground anchoring points near the tank, according to the overall dimensions indicated in the technical data sheets supplied and taking into account the type of product supplied.

| **Type 1** | **Type 2** | **Type 3** |
|---|---|---|
|  |  |  |
| To anchor these types of tanks it is sufficient to pass a steel tube (Ø 50-60) through the holes in the support feet, and connect it to the anchors already provided in the concrete. | To anchor these types of tanks to the slab it is sufficient to adopt appropriate steel or nylon bands, with a pitch of 2 m, which will be connected with the anchors already prepared in the concrete. | To anchor these types of tanks to the foundation slab it is sufficient to make a layer of concrete to cover the first layer of the structure. |

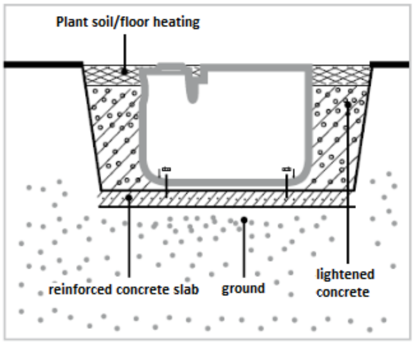
NB: Anchorage is mandatory whenever it is necessary to build the reinforced concrete slab.

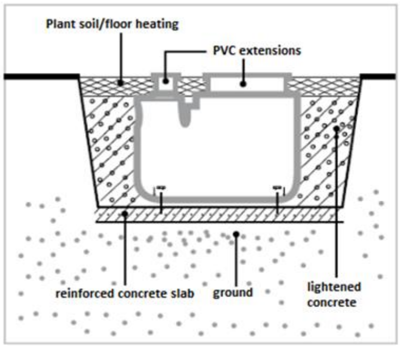
### *2.2.4 Positioning of lifting tanks*

For the operations of handling, transport and positioning of the product, please refer to what has already been mentioned in the previous paragraphs. Pay particular attention to the paragraph "Venting".

## ➢ Anchorage

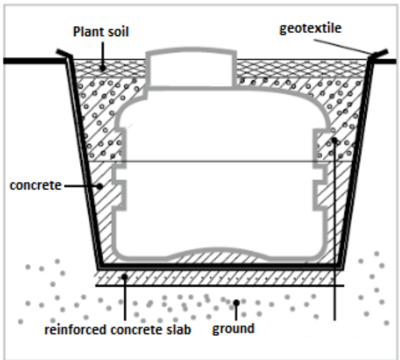
**Smooth bathtubs:** Place the tank on the slab and make holes in the slab in correspondence with the appropriate fixing seats made on the base of the product. Then insert some fisher into the holes made and hook the tank.



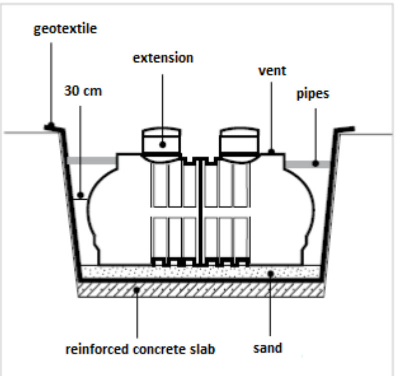

In order to reach the level of the walking surface, it is possible to insert on the lids of the tanks extensions with PVC lids of standard size commonly available on the market (see above figure – right).

**Corrugated tubs:** Make a cement ring connected to the support slab until the first nerve of the product is completely covered from below.



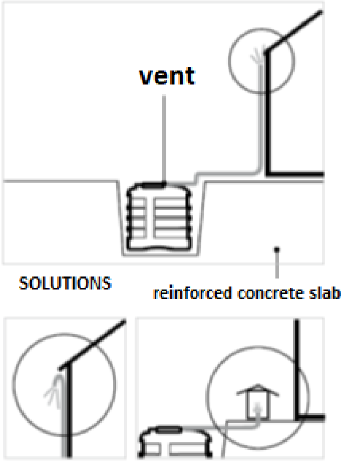

## ➢ Hydraulic connections

Connect and test the connections to the inlet and outlet sockets supplied with the tank. If necessary, place the supplied extensions as recommended accessories at the inspection points, making them integral with the product.



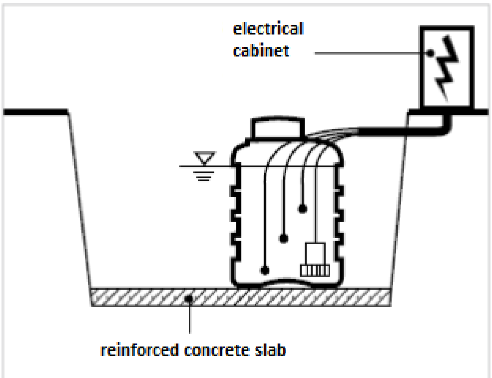
➢ **Venting**

Make sure that the vent is free to prevent the tank from going into vacuum. Connect the tank to the ventilation pipe of the house, i.e. it must be sent to a suitable place where it cannot be blocked; always and in any case at a level higher than the height at which the tank cover is laid.




➢ **Electrical / electromechanical connections**

Before re-inflaming the tanks, according to the methods described in the following paragraphs, for structures in which electromechanical equipment is installed, it is necessary to create wells and sheaths for the protection of electrical cables that will be connected to panels or external equipment, as indicated in the wiring diagrams and in the "use and maintenance manual".



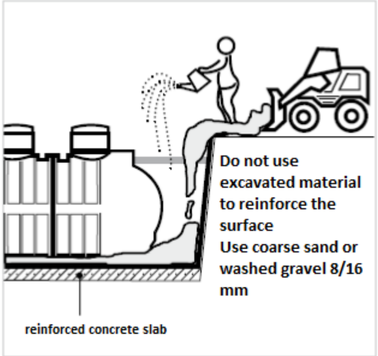

### *2.2.5 Excavation and backfilling of soil*

➢ **General warnings**

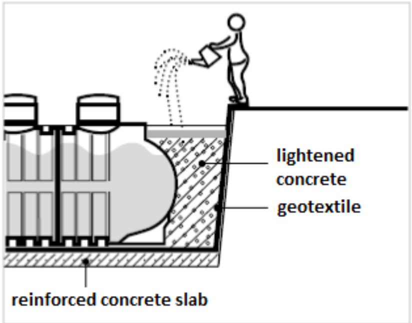
- In order to avoid abnormal deformation on the tanks and inspection towers, during the rhinestones, keep the water level inside always above the rhinestones level.
- Special care must be taken to facilitate the uniform compaction of the backfill material on the total external surface of the product to avoid the formation of air pockets that exert differential pressures on the tank causing it to deform and/or break.
- Covers and plugs may only be removed for the purpose of filling the tank and must be replaced during backfilling operations.

– It is forbidden to fill the tank outside the excavation.
– Never use excavated material to reinforce the surface.

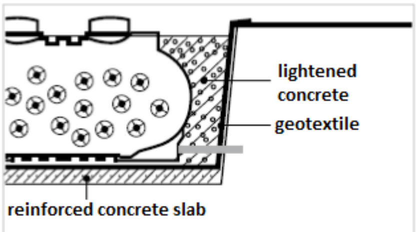
**Always full tanks:** Proceed in successive layers of 15/20 cm, first filling the water tank and then fill in as shown in the figures (use coarse sand or round washed gravel max 8/16 mm). Facilitate the compaction of the backfill material by using a jet of water until the tank cover is reached.



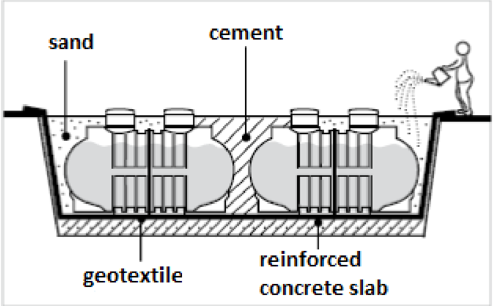

**Bathtubs (also empty) in operation:** Proceed in successive layers of 15/20 cm, first filling the water tank and then fill in as indicated in the drawing with lightened cement or cement mix. It is necessary that the cement used for filling is in the liquid state in order to cover the entire external surface of the tank until it reaches its upper generator.




**Always empty tanks with low outlet:** Reinforce with cement mixed lightened concrete, taking care to insert the filling material slowly and constantly, without creating dynamic stress on the walls of the tank. It is necessary that the cement used for filling is in the liquid state in order to cover the entire external surface of the tank.

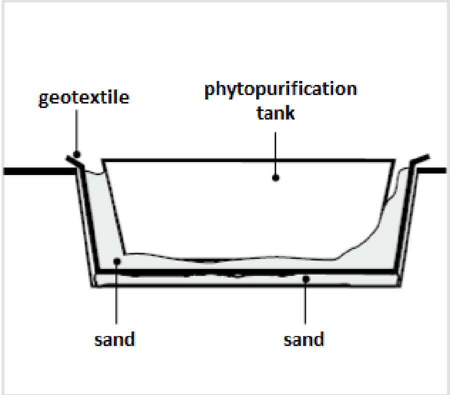



**Multiple tanks in the same excavation:** Proceed in layers of 15/20 cm, first filling the water tanks and then fill in with lightened or cemented mixed cement. The tanks should be filled with washed sand or round gravel (max. size 8/16 mm) mixed with cement or using lightened cement. On the perimeter sides of the excavation, the filler suitable for the use of the tanks themselves (full or empty) must be used. Facilitate the compaction of the backfill material by using a water jet.



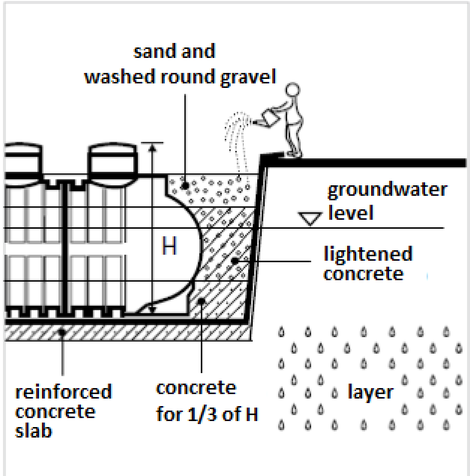

**Phyto-purification tanks:**

- After digging a flat bottom of suitable size, make a bed of 5 cm with a surface at least higher than the base of the tank.
- Cover the walls of the excavation with geotextile.
- Backfill with washed sand or gravel at the same time as filling the tank according to the instructions in the appropriate chapter of the user's manual.

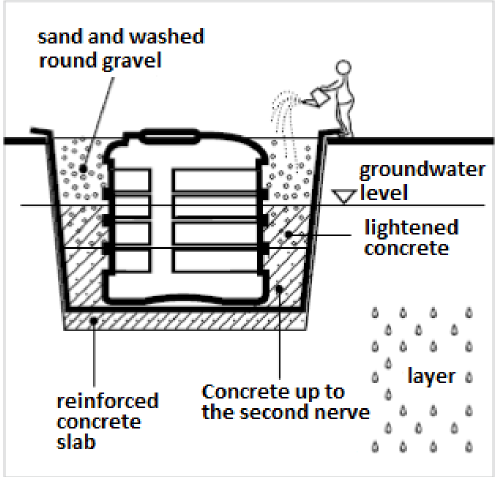



**Reinforcement in groundwater, clayey soil or similar area:**

- **Classic tank -** Once the reinforced concrete slab has been created and the structure anchored, fill the tank with water to a thickness equal to about 1/3 of its height and reinforce it externally with concrete to the same thickness.



➢ **Corrugated tank -** Fill the tank with water until the first layer of water is covered and cover it externally with concrete for the same thickness.

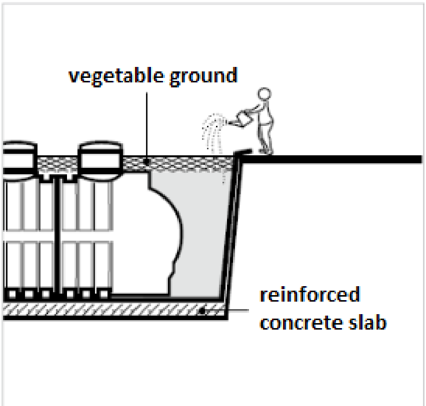



**Filling finish:** After the backfilling with concrete, proceed in successive layers of 15/20 cm, first filling the water tank and then backfilling it with cement mix or lightened concrete, up to a height higher than the maximum level of the water table. It is necessary that the material used for the filling is in the 'liquid' state in order to cover the entire external surface of the tank until reaching the upper generator of tank coverage. Finally, cover the product with a layer of washed round gravel and sand, until it is completely covered.

### *2.2.6 Restoration of excavation, pedestrianization and driveability*

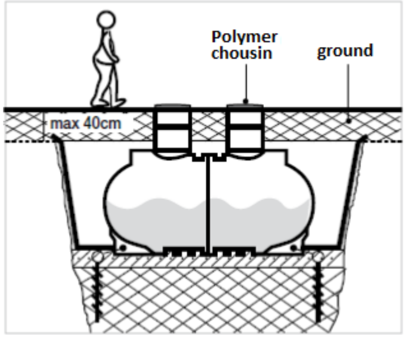
➢ **General information**

Once the tank has been covered, until the upper covering generator is reached, it is possible to proceed with the operation of restoring the excavation with vegetable soil, until the level of footsteps has been reached.



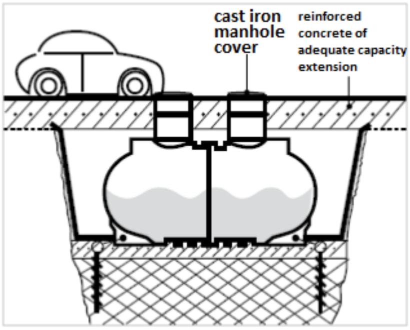

➢ **Walkability of the interrogation zone**

The walkability of the area surrounding the burial of the structures is guaranteed for a maximum depth of 40 cm (carried out according to the methods described in this sheet) from the upper generator of the tank to the finished ground level. If it is necessary to install inspection wells (concrete or cast iron), they must not weigh on the tank.



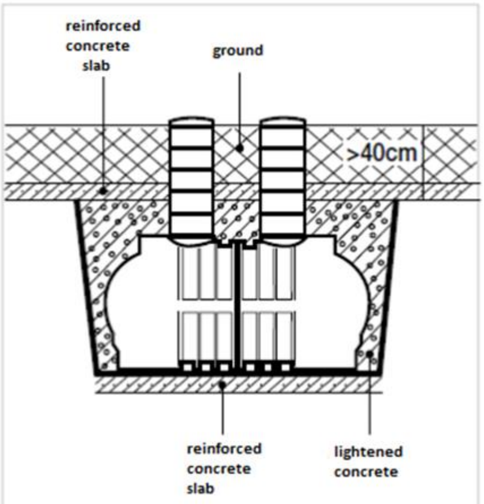

➢ **Driveability of the interrogation zone**

The driveability is guaranteed only in the case of the construction of a special slab covering the tanks that discharges all the pressure into the ground outside the perimeter of the excavation area where the tanks are to be laid. Furthermore, the installation of the cast iron frames and covers for the inspection of the tanks must be integral with the covering slab.




➢ **Laying at a height of more than 40 cm above ground level**

Proceed in successive layers of 15/20 cm, first filling the water tank and then reinvigorating as indicated in the drawing with lightened cement or cement mix. Facilitate the compaction of the backfill material by using a jet of water until the tank cover is reached.

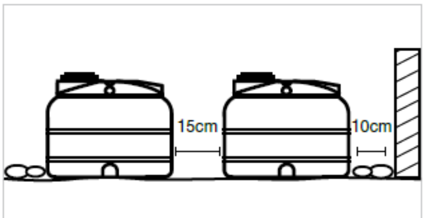


Make a reinforced concrete slab dimensioned and calculated taking into account the loads of the ground above and weighing its loads on the perimeter outside the excavation or on suitable anchorage points (plinths or perimeter walls). Then, complete the filling of the excavation with vegetable soil / reinforced concrete slab, until the level of footsteps is reached according to the requirements of pedestrian mobility.

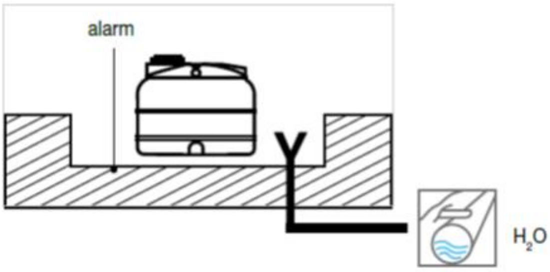
## 2.3 Positioning of communicating tanks

### *2.3.1 Positioning the tanks*

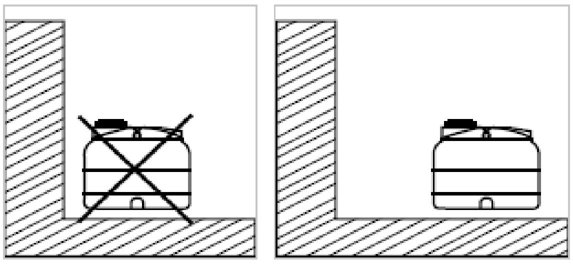
Before positioning the tank, the installation site must be cleaned of any debris that may damage it. Place the tanks on a flat surface (max. slope 4‰), which is stable, smooth, even, clean of waste and resistant to the weight of the full tank. Position the tanks in such a way that they do not come into contact with each other (spaced at least 15 cm apart) or with obstacles (spaced at least 10 cm apart) due to the expansion that the filling and the temperature may cause.



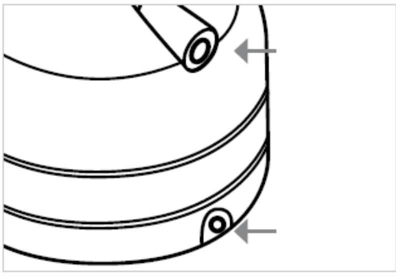

Provide for adequate containment/removal works, with specific leakage detection controls, in the case of use of tanks as a water reserve for autoclaves, containment of liquids other than water and in all cases of use of tanks with automatic filling/emptying systems.




In order to perform normal maintenance, install the product so that it can be easily carried out. Avoid making parts in masonry that would compromise the possibility of carrying out maintenance or replacing the tank itself.

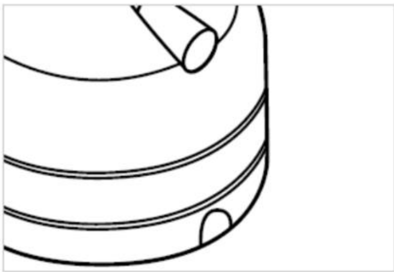


Make sure that gaskets, pipes and all parts other than the polyethylene present in the tank, are suitable for contact with the liquid contained.



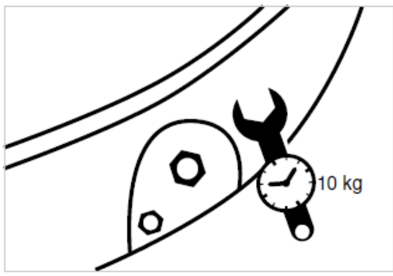
### 2.3.2 Connections

The tanks can be drilled in correspondence of the present flat parts and equipped according to the specific needs. Connect and test the various connections ensuring that the vent is free and sufficient to prevent the tank from operating in pressure / depression.



The connection to brass, plastic or other fittings must be made by means of flexible hoses and, if necessary, by placing pipe supports so that the connection section is not stressed.


In order not to compromise the tightness of the hydraulic connections, do not over-tighten the fittings on the polyethylene, thus yielding the material; as a mere indication, a maximum tightening torque of 10 kg·m will suffice.



## 2.4 Requirements for pre-testing and commissioning

It is industry good practice for the installer of a grey water reuse system to undertake a number of pretesting and commissioning checks before commencing testing and commissioning activities. This is particularly important if the installation has been undertaken by other personnel.

The following table identifies a number of pre-installation control requirements and outlines the key elements to be checked for each requirement. If the installation is commissioned by the same person who carried out the installation, some of the checks indicated in the table may have been carried out in the pre-installation phase and, in this case, it is not necessary to repeat the installation.

**Table 2.1: Pre-testing and commissioning check requirements**

| Check requirement/area | Items to be checked |
|---|---|
| Compliance with the system design and specification | • The correct type and grade of components have been installed<br>• All components are installed in the positions and to the layout given in the system design and specification |
| Compliance with manufacturer's instructions | • All components are installed in accordance with manufacturer's instructions |
| Compliance with regulatory requirements | • The installation is compliant with all relevant aspects of the building regulations and the water regulations/byelaws<br>• No cross connections exist between the greywater distribution system and the wholesome water system<br>• The installation process has not resulted in the building becoming less compliant with the building regulations and the water regulations/byelaws than before the installation work commenced |
| Storage tanks and cisterns | • Adequate base support and, where appropriate, total support in accordance with regulatory requirements and manufacturer's instructions<br>• The tank/cistern installation does not put undue load on the building structure (visual inspection only)<br>• All filters, vents, covers and any insulation are correctly fitted in accordance with regulatory requirements and manufacturer's instructions<br>• All below ground tank access covers are appropriately rated for the load that they will receive<br>• Appropriate overflow arrangement(s) in accordance with regulatory requirements and manufacturer's instructions<br>• Multiple tank/cistern installations are connected to provide through-flow and avoid stagnation<br>• If required, an anti-surcharge valve is fitted<br>• Submersible pump (if fitted) is correctly positioned (visual inspection only) |

| | |
|---|---|
| | • Submersible pump (if fitted) has dry-run protection<br>• Submersible pump (if fitted) immersion depth meets the pump manufacturer's requirements<br>• Submersible pump (if fitted) has a non-return valve and isolating valve to allow pump service and maintenance |
| Greywater collection system | • Collection pipework is free draining or has siphonic action<br>• All filters are correctly positioned, secured and clean |
| A suitable electrical input supply is provided | • Is the supply circuit protected by a residual current detection device?<br>• Does the service have the correct circuit over current protection rating?<br>• Has the safe condition of the service been confirmed?<br>• Is the supply in a location that is readily accessible but also guarded against inadvertent isolation or disconnection of the supply? |
| Flushing of the system | • The installation has been flushed of all installation debris, including flushing of any cleaning product residues |
| Filling of the storage tank | • The storage tank has been filled in accordance with the manufacturer's instructions (Note: some manufacturers may specify a controlled filling process)<br>• Water levels are correct and, where fitted, the water level gauge is functioning correctly |
| Back-up supply arrangement | • A type AA or type AB air gap is provided<br>• The back-up supply is not supplied via a dead leg unless unavoidable<br>• If supplied via a dead leg, a single check valve has been installed adjacent to the back-up supply branch connection |
| Provision of marking and labelling in accordance with water regulation / water byelaw requirements | • All distribution pipework is correctly marked and labelled<br>• All storage tanks and cisterns (or their access covers) and points of use supplied by the greywater reuse system are correctly marked and labelled<br>• The wholesome water supply main stop valve is correctly marked and labelled to identify that a greywater reuse system is installed |

### *2.4.1 Collection of pipework test requirements*

Greywater collection pipework should be air tested to ensure that the system is leak free and that there are no unintentional cross connections. To confirm that the system is leak free, the system should be able to withstand a positive pressure of at least 38 mm water gauge for at least 3 minutes.

### *2.4.2 Requirements and procedure for transverse connection tests*

A dye test should be carried out to ensure that there are no cross connections between the rainwater harvesting system and the wholesome water system pipework. It is recommended that the local water supply undertaker is contacted prior to the cross-connection dye test being carried out as they may wish to witness the test. The following items are needed to undertake a cross-connection dye test:

- two pumped test units
- dye/colouring.

A pumped test unit is simply a unit with a storage container large enough to hold the required amount of test fluid and a pump to circulate the test fluid. The cross-connection colouring test is usually performed using a bright food colouring such as cochineal E124.

The cross-connection dye test procedure is given below:

1. Temporarily disconnect the system at the point where the internal distribution pipework begins and temporarily cap off the distribution pipe at the point of entry.
2. Connect pumped test unit 1 to the distribution pipework using a temporary connection. Add water containing a suitable dye to the test unit.
3. Temporarily disconnect the mains wholesome water supply at the point where the internal distribution pipework begins.
4. Connect pumped test unit 2 to the mains wholesome water supply pipework using a temporary connection. Add wholesome water to the test unit.
5. Open all in-line service valves on both pipework systems.
6. Draw water through all outlets and check for a dyed water discharge. Where the system supplies a washing machine, the connection hose should be temporarily disconnected from the machine before water is drawn through.
7. Draw water through all wholesome water outlets and check for a clear wholesome water discharge.

If the dyed water from pumped test unit 1 is discharged through any wholesome water outlets, the cause must be investigated and rectified.

#### *2.4.3 Start-up requirements*

All testing and commissioning activities must be carried out in accordance with the manufacturer's instructions. The requirements for commissioning vary depending on the type of system. The water quality check is not normally carried out as part of the commissioning process, as grey water reuse systems are generally filled with mains water and, therefore, it is unlikely that the water quality is representative of the water quality during normal plant use (i.e. when it is filled with grey water).

The first water quality test is normally performed as part of the first routine maintenance inspection. However, where there is increased human exposure to grey water, for example in public buildings, or where users of the system are particularly vulnerable when exposed to contact with contaminated water, a water quality test may be required after the first significant period of use.

#### *2.4.4 Requirements for registration of the start-up*

All activities of commissioning the wastewater reuse system must be recorded and the recording must be transmitted to the end user as part of the delivery process. Some manufacturers of packaged wastewater reuse systems may provide a commissioning log as part of the installation and commissioning instructions. There is currently no standardised wastewater reuse system for pro forma industry record commissioning.

#### *2.4.5 System delivery requirements*

Before starting the delivery of a grey water recovery system, the following actions/controls must be carried out:

- all testing and commissioning activities have been satisfactorily completed
- the component covers removed during installation and/or testing and commissioning have been replaced correctly
- all system components are clean and undamaged
- the area of the site is clean and undamaged
- the delivery documentation package is complete and available
- if the customer has special needs to be met or covered during the delivery process.

The technician who will make the delivery to the customer is fully aware of the installation and delivery requirements and is competent to make the delivery. The delivery of a grey water recovery system should include a package of documents for delivery, as well as verbal information and demonstrations relating to the operation and use of the system.

**Package of documents for delivery**

There are currently no standardised industrial requirements for the contents of a delivery package for water collection and grey water reuse systems. In the absence of a standardised industrial requirement, the following content is recommended:

- all documents relating to the manufacturer's instructions and guarantees relating to the equipment installed
- a single "as fitted" plan of the hydraulic and electrical system, which illustrates in detail all the operating elements of the system up to the point of integration with the existing collection and distribution systems
- any documents relating to safety advice
- the system commissioning logbook
- guidelines on restrictions on the use of water collection and grey water reuse systems and the obligation not to introduce any cross-linking between the rainwater collection system and the healthy water system in the future.
- guidelines on actions to be taken in the event of a system failure
- guidelines on measures to be taken in the event of poor or suspected poor water quality
- detailed information on the routine maintenance checks to be carried out by the user
- an indication of the maintenance intervals required when maintenance is to be carried out by a competent technician
- contact information for the installer and manufacturer of the system.

**Verbal information and demonstration concerning the operation and use of the system**

All information and verbal indications must be provided in a language and terms that the customer/end user will understand. Verbal information and demonstration guidelines are provided below, as a minimum suggested:

- an explanation of the content of the delivery documentation, including an explanation of customer-friendly schematic diagrams
- identification of the location and purpose of key system components
- the importance of labelling and marking of the system and the reasons why it should not be removed
- how to set/operate any user control
- detailed information on any controls or components that should only be touched by a competent person
- any symptom/condition that would require a call from a competent person
- the actions to be taken in the event of a system failure
- guidelines on measures to be taken in the event of poor or suspected poor water quality.

## 2.5 System maintenance

### *2.5.1 Routine/programmed maintenance*

Ordinary maintenance means all the activities and services necessary to maintain the good working order and conservation of every part of the plant. This maintenance is properly planned by the owner and the installer technician, carefully assessing the parameters relating to the systems (such as: verification of the state of cleanliness, integrity of the pipes and tanks, etc.), the frequency (monthly, bimonthly, half-yearly, annual, etc.) and the methods of execution (inspection, removal of foreign elements, cleaning, etc.).

The addresses to follow for cleaning the components of the water supply network, according to the different types of system, are as follows:

- Clean the filter once a month by removing the cover and removing it using the appropriate handles, so as to remove any debris deposited on the grids, using sponges or nylon brushes
- Check the surface of the water inside the tanks. The water should be slightly opalescent. If there are solids inside, they must be removed immediately and a maintenance technician must be contacted. It is advised to check the transparency of the water coming out every 2-3 months.
- Empty the tank and clean it completely (purge sediment at the bottom) whenever necessary
- Periodically remove the pump to clean the suction filters every 3/4 months.
- Check the condition of the gaskets and verify their proper functioning every 3/4 months.

### *2.5.2 Extraordinary maintenance*

Extraordinary maintenance includes all interventions aimed at the conservation, enhancement and implementation of interventions necessary to ensure an adequate service collection of grey water, the replacement of plants and / or equipment, or parts of distribution networks, the construction of new networks or new collection systems, as well as the implementation and integration of technological services for the regulation, monitoring of the quality and quantity of water.

### *2.5.3 Analysis of maintenance costs*

The following table lists the maintenance costs expected for a period of twenty years (hypothetical useful life of the plant), taking into account the indications of the Italian UNI/TS 11445.

- **Interventions at ten-years intervals (M1)**

| Service description | U.M. | Quantity | Price | Amount |
|---|---|---|---|---|
| **Special hydrodynamic tanker rental for emptying and washing of rainwater tank** | €/H | 1 | 90.00 | 90.00 |
| **Special van rental equipped for interventions in confined spaces** | €/H | 1 | 75.00 | 75.00 |
| **Specialised labour force appointed operator** | €/H | 1 | 30.00 | 30.00 |
| **Preparation of vehicles/ personnel** | €/CAD | 1 | 195.00 | 195.00 |
| **Transport to authorised plant** | €/CAD | 1 | 115.00 | 115.00 |
| **TOTAL M1** | | | | **505.00** |

- **Annual maintenance costs (M2)**

| Service description | U.M. | Quantity | Price | Amount |
|---|---|---|---|---|
| **Operator manpower supervisor** | €/H | 1 | 30.00 | 30.00 |
| **Preparation means/staff** | €/CAD | 1 | 95.00 | 95.00 |
| **TOTAL M2** | | | | **125.00** |

- **Total maintenance costs (M3)**

| Service description | U.M. | Quantity | Price | Amount |
|---|---|---|---|---|
| **M1** | €/CAD | 2 | 505.00 | 1,001.00 |
| **M2** | €/CAD | 18 | 125.00 | 2,250.00 |
| **TOTAL M3** | | | | **3,260.00** |

## 2.6 Case study

The case study concerns the renovation of the condominium in Via Sassetti in Milan (see Figure 2.4).

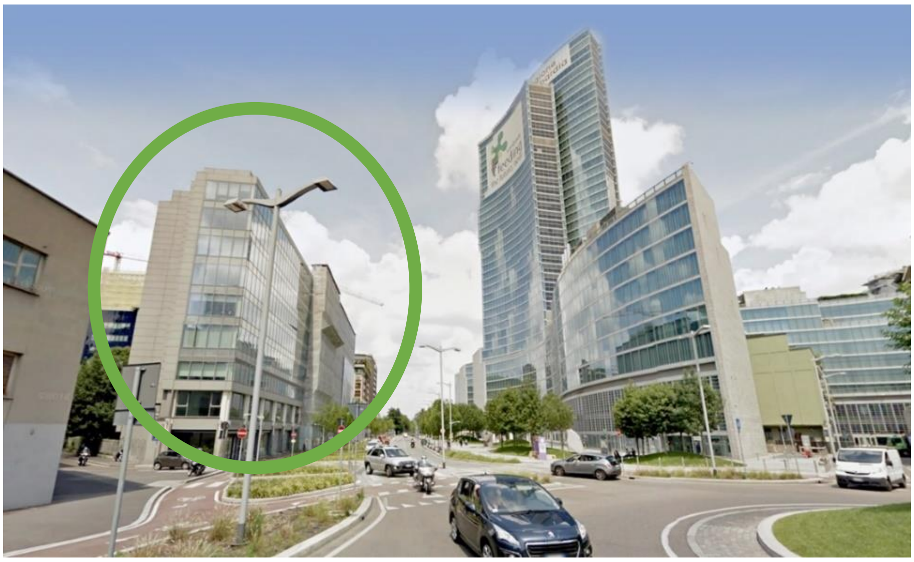


**Figure 2.4: The case study place in the "new" Milan**

[Source: https://www.google.com/maps/]

The renovation represents an intervention of **real estate redevelopment** in an area of great prestige (in front of the new building of the Region and next to the registry office of the municipality of Milan). The condominium has been renovated following the **philosophy of energy saving** and to reduce the consumption of drinking water has been installed a water recovery system

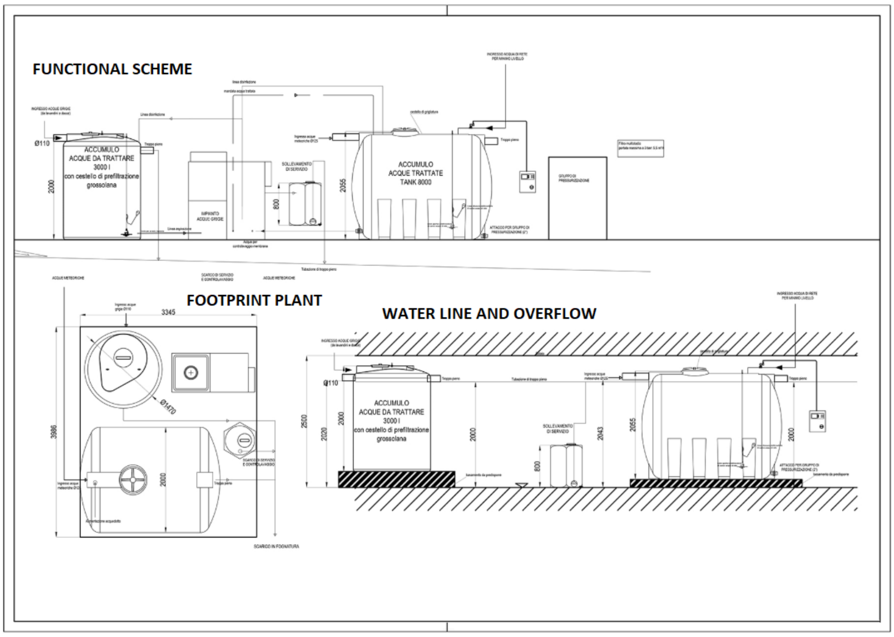



**Figure 2.5: Diagram of the storage system**

[Source: https://redi.it/condominio-di-via-sassetti-milano/]

To reduce water consumption, a system has been installed to recover grey and white water: water from showers, washbasins and bidets, and rainwater. The system consists of a water storage tank, an ultrafiltration membrane treatment station, a lifting station to relaunch the sanitized water. Recovered water can be used for flushing toilets, washing cars, cleaning areas outside the home, irrigation and washing machines.


**Figure 2.6: Technical compartment in which the recovery system has been installed**

[Source: https://redi.it/condominio-di-via-sassetti-milano/]

The grey water reuse system requires that the water coming from the wash basins of the bathrooms, through different levels of **filtration** and **sterilization** is cleaned of pollutants, returning to a state suitable for subsequent reuse as for the discharge of the toilet. The **filtration** process is **biological-mechanical** and does not require any chemical additives. Together with the collection and reuse of rainwater, it saves about 50% of a building's drinking water consumption.

The biological-mechanical filtration process does not require any chemical additives. With the system of reuse of both white and grey water there is a 50% reduction in the consumption of drinking water. The system is designed for **very low maintenance**, and operating costs are very low, thanks to the automatic backwashing system with easy access for maintenance.

The technology used for fine filtration (**ultrafiltration**, in vessels with microtubules filters) allows a **longer life of** the filtering capacity and the maintenance of the flow rates. The positioning of the serviceable parts is accessible and easy to check. Pumping systems are managed with inverters to improve performance and reduce consumption. All this to ensure a constant supply of recycled water without complicated management and performance losses, as happens with other types.

**Figure 2.7: Pumping systems**

**Pumping systems** are managed with inverters to improve performance and reduce consumption. All this to ensure a **constant supply of** recycled water without complicated management and performance losses, as happens with other types of plant.

## *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*


[1] Commission of the European Communities, Communication from the Commission to the European Parliament and the Council, Tackling the problem of water scarcity and drought in the European Union, 18/07/2007

[2] D.Lgs 11 maggio 1999, n°152, Disposizioni sulla tutela delle acque dall' inquinamento e recepimento della direttiva 91/271/CEE concernente il trattamento delle acque reflue urbane e della direttiva 91/676/CEE relativa alla protezione delle acque dall'inquinamento provocato dai nitrati provenienti da fonti agricole

[3] Nuvole e sciacquoni. Edizioni Ambiente - Conte, G.,

[4] Franek, A., Koncagul, E., Connor, R., Hunziker, D., L'acqua per un mondo sostenibile, fatti e cifre, Rapporto 2015 delle Nazioni Unite sullo sviluppo delle risorse idriche mondiali, UN water, 2015

[5] Murad, A.A., Al Nuaimi, H., Al Hammadi, M., Comprehensive assesment of water resources in the United Arab Emirates (UAE), Water resour. Manag.21, 1449-1463, 2007

[6] Mari, L., Rubinetti a secco a Roma, ecco il "cervellone" Acea per gestire l'emergenza acqua, La Repubblica di Roma, 31/08/2017

[7] Fanizzi, L., (2008). Gli impianti urbani per lo sfruttamento dell'acqua meteorica di dilavamento. L'Ambiente, n. 1, Ed. Ranieri, Milano.

[8] Freni, G., Mannina G., Torregrossa M., Viviani G., (2007). Sistemi localizzati di riuso delle acque reflue e meteoriche in ambiente urbano. V Giornata di studio sul drenaggio, urbano sostenibile, riuso e risparmio acque reflue e meteoriche, 13 Dicembre 2007, Genova.

[9] AA. VV., (2002). Acqua. Sistemi e dispositivi per il risparmio e il riuso. EdicomEdizioni.

[10] Aquavet Handbook – Attività 03-A4 – Conaif (July 2016)

[11] ISTAT, Censimento delle acque per uso civile, Statistiche Report Istat, 2017

[12] http://ga.water.usgs.gov

[13] www.archiexpo.it

[14] www.arpaitalia.it

[15] www.et-studio.it

[16] www.euroambiente.info

[17] www.genitronsviluppo.com

[18] www.inderst.it

[19] www.iridra.com

[20] www.iseagroup.com

[21] www.planiplastic.it

[22] www.pozzolineutra.com

[23] www.rainharvesting.co.uk

[24] www.rainharvesting.com

[25] www.vemar.net

[26] www.redi.it

[27] https://www.intewa.de/it/

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 3*

| | | |
|---|---|---|
| 1. | **What are the main steps for the correct recycling of grey water?** | |
| | a. Coarse filtration, Collection of untreated grey water, Treatment, Storage, Return to domestic use | |
| | b. Coarse filtration, Collection of untreated grey water, Treatment and filtration, Storage, Return to households | |
| | c. Coarse filtration, Collecting untreated grey water, Treatment and disinfection, Conservation, Return to home use | x |
| | d. Coarse filtration, Collection of treated grey water, Treatment and purification, Conservation, Return to domestic users | |
| | | |
| 2. | **How much does feeding toilet flushing with recycled water alone reduce the overall domestic water demand?** | |
| | a. about 10% | |
| | b. about 20% | |
| | c. about 25% | |
| | d. about 30% | x |
| | | |
| 3. | **What is grey water?** | |
| | a. Grey water means untreated domestic wastewater that has not come into contact with wastewater (or "black water"). | x |
| | b. Grey water means treated domestic wastewater which has not come into contact with wastewater (or 'black water'). | |
| | c. Grey water means any type of treated or untreated water originating from domestic use. | |
| | d. Grey water means all wastewater | |
| | | |
| 4. | **For a single-family house consisting of 6 people it is usually necessary to install storage tanks for a total of** | |
| | a. 400 lt | |
| | b. 600 lt | x |
| | c. 800 lt | |
| | d. 1000 lt | |
| | | |
| 5. | **If 2 or more tanks have to be installed, what is the minimum distance to be respected?** | |
| | a. 5 cm | |
| | b. 10 cm | |
| | c. 15 cm | x |
| | d. 20 cm | |
| 6. | **In order to avoid the risk of a building collapsing, excavations for the installation of an underground tank, or an exhaust pipe feeding the tank, must not be carried out within an area forming an angle of ........ with the foundation** | |
| | a. 10° | |
| | b. 20° | |
| | c. 40° | |
| | d. 45° | x |
| | | |
| 7. | **What is the space required to leave the tank intact when carrying out a flat-bottomed excavation with self-supporting walls?** | |

| | | |
|---|---|---|
| | a. about 50 cm | |
| | b. about 20 cm | |
| | c. about 40 cm | |
| | d. about 30 cm | x |

| | | |
|---|---|---|
| 8. | **Phytopurification is a system that involves the use of a species of plants that already in nature act as natural purifiers of residues typical of grey water.** | |
| | a. Correct | x |
| | b. Wrong | |

| | | |
|---|---|---|
| 9. | **What is a direct reuse system?** | |
| | a. A system that collects grey water from appliances and delivers it directly to the points of use without any treatment and with little or no conservation | x |
| | b. A system that collects grey water from appliances and delivers it after purification to the points of use with little or no conservation. | |
| | c. A system that collects grey water from appliances and delivers it directly to the points of use without any treatment. | |

| | | |
|---|---|---|
| 10. | **In order not to promote the multiplication of legionella it is advisable to install the tank in a ...........** | |
| | a. sunny | |
| | b. shaded | x |
| | c. semi sunny | |
| | d. indifferent. Legionella multiplies only by other factors | |

# MODULE 4: RAINWATER HARVESTING

## *SUMMARY*

Another intelligent way to optimise water consumption is rainwater harvesting. This is the process of accumulating and storing rainwater for on-site use instead of allowing it to run off. Rainwater provides an independent and free water supply that offers several ways the water can be used. The following are 5 advantages of harvesting rainwater:

1. Harvesting rainwater can reduce erosion around downspouts and in gardens. It can also control stormwater run-off. The collection of rainwater may reduce flooding in certain areas as well.

2. Rainwater harvesting will not only help individuals save on their water bills but can cut costs for entire communities. Having a source of water can also reduce dependence on municipal sources in case the water becomes contaminated. Rainwater can be used as the primary source of water or as a backup source when needed.

3. Sources of groundwater are increasingly being strained in many areas throughout the world. It only makes sense to use sources of rainwater whenever possible. Harvested rainwater can be stored and then used during times of drought and when the groundwater supplies have been depleted.

4. Everything from washing clothes and dishes to bathing and flushing toilets requires large amounts of water. Rainwater can be used for all of these things. It can also be used for washing vehicles, bathing pets, and nearly all cleaning that uses water.

5. Harvested rainwater is generally free from several types of pollutants and man-made contaminants. Rain is also free from chlorination. Using water that is clean and healthy for plants and trees can save money on overall property maintenance and landscaping needs.

While regular maintenance is required, simple collection systems can be constructed that most people can easily build and maintain. Rainwater harvesting and storage can be incorporated in both rural and urban areas and provides many benefits to individuals, communities, and the environment.

This module of the "WET Course" has been designed with the main objective of providing professionals with the necessary specialist knowledge to build efficient plants for the recovery and reuse of rainwater. The module is divided into 2 units:

Unit 1: Customized method and components selection for efficient rainwater storage and treatment

Unit 2: Installation, commissioning and proper maintenance of rainwater collection systems

In Unit 1 the principles of rainwater treatment and use and some examples of water recycling will be analysed. In addition, all the components that make up a rainwater recycling and storage system will be analysed until the correct sizing of a tank.

In Unit 2 all the steps to be taken for the correct installation of a system and tanks will be analysed, from the preparation of the area to the excavation (for underground systems), the measures to be taken on roofs and eaves, and the correct positioning of the tanks. The problem of the different types of maintenance to be carried out will also be addressed. In addition, installation and maintenance costs will be analysed.

## *Unit 1: Customized method and components selection for efficient rainwater storage and treatment*

**General description**

In the 1st unit of module 4, the trainees will be presented with the principles to make a personalised selection of the method and components for efficient rainwater storage and treatment in order to improve their knowledge of water efficiency concepts and corresponding savings, and the relationship between water saving and efficient use of rainwater harvesting systems. In this way, trainees will improve their ability to recognise the main benefits of rainwater harvesting systems, to identify water savings that could result from the use of efficient rainwater harvesting systems and to present to the customer the water savings that could result from the use of rainwater harvesting systems.

**Scope – Expected results**

After the end of attending this learning unit, the trainees will be able to:

- apply the principles and different rainwater treatment systems
- apply techniques for the collection and use of rainwater
- recognise the components that make up a rainwater treatment and storage system
- dimension a collection system, including a storage tank, according to the place of installation and the needs of the client.

**Key words / basic terminology**

First rainwater, rainwater recovery, reuse, distribution network, hybrid system, ultrafiltration systems, rainwater distribution, sizing.

## 1.1 Basic concepts of rainwater collection and reuse systems

### *1.1.1 Existing regulations – the case of Italy*

As regards the national legislation in force on the subject, in the following paragraphs what stands for Italy is described. So, the accumulation of rainwater in reservoirs and tanks serving agricultural land or individual buildings for civil or industrial use is free and does not require a licence or concession to divert water, although the construction of the relative structures remains regulated by the laws on construction, construction in seismic areas, dams and weirs and by other special laws (paragraph 4, art. 96, Legislative Decree no. 152 of 3 April 2006).

Legislative Decree 152/06 takes up the concept of quantitative protection of water resources introduced by Legislative Decree 152/99: Part Three, Chapter III, Article 95, paragraph 1: "the quantitative protection of the resource contributes to the achievement of quality objectives through a planning of water uses aimed at avoiding repercussions on the quality of the same and to allow sustainable water consumption".

Article 98 (water saving) states that "those who manage or use water resources shall take the necessary measures to eliminate waste and reduce consumption and to increase recycling and reuse, including through the best available techniques". The reuse of rainwater is allowed according to the indications contained in the Ministerial Decree 02/05/2006 n.93.

The eligible uses identified are irrigation, civil and industrial. Specifically:

- Irrigated reuse means the irrigation of crops intended both for the production of food for human and animal consumption and for non-food purposes, as well as for the irrigation of areas intended for greenery, recreation or sports; rainwater is used only for irrigation purposes, arrives at the tank after being filtered and from there is sent to the point of withdrawal by means of a submerged pump located in the tank (but a self-priming pump outside can be also used), equipped with a filter on the suction. At a slightly lower level than the inlet pipe, an overflow should be provided to convey the excess water to a dispersion well.
- Civil: for street washing in urban centres; for the supply of heating or cooling systems; for the supply of dual supply networks, separated from drinking water, with the exception of the direct use of such water in buildings for civil use, with the exception of drainage systems in toilets;
- Industrial: as firewater, process water, washing water and for the thermal cycles of industrial processes, with the exclusion of uses involving contact between recovered wastewater and food or pharmaceutical and cosmetic products.

Subject to the limits imposed by the Annex to DM 93/2006, many existing technological systems on the market with regard to the reuse for flushing cisterns of toilets are sized to meet the quality requirements imposed by the Presidential Decree of 24 May 1988, n.236 (quality of water intended for human consumption) or by the German guidelines FBR 1999 (requirements of the indicative sheet H 201, German Professional Association for the use of industrial water and rainwater). In view of this, it should be noted that, to date, there is no Italian law regulating the design and installation of systems for the exploitation of rainwater.

At the European level, only in December 2000 did the E DIN 1989-1 standard appear in Germany, which technically regulates the plants for the exploitation of rainwater (planning, execution, activities and maintenance). It is a complete standard, i.e. in a single process the development of the system is followed from design to installation, defining measures to be maintained and checks to be carried out. This standard is divided into four sections: the first provides guidance on the design, installation and maintenance of the entire system.

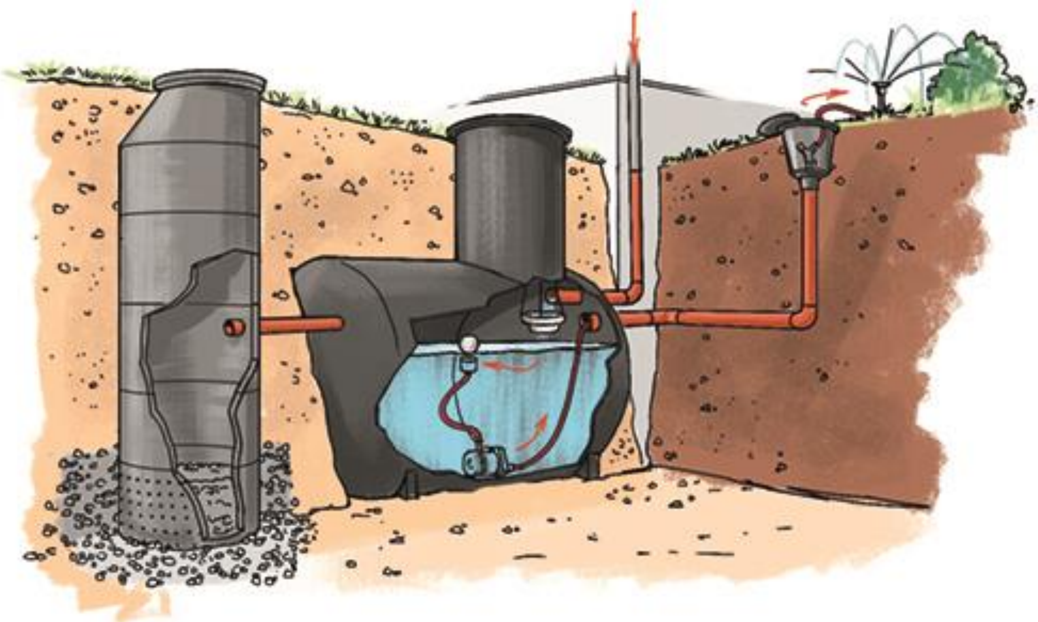


**Figure 1.1: Example of rainwater recovery for irrigation use**

[Source: www.bricoportale.it/wp-content/uploads/2014/04/recupero-acqua-piovana-10.jpg]

As far as the design is concerned, the safety and functionality of the system is at the forefront, making specific requests, for example for ease of maintenance and the guarantee that the drinking water does not come into contact with the rainwater for any reason. Equally important are the quality constraints on the harvesting areas. The second part is entirely dedicated to filters and provides their classification and criteria for verifying their operation and efficiency.

The third part contains all the provisions concerning tanks, from the materials for their construction to the conditions of installation (pedestrian tanks, driveways, etc.). It also lists the checks that the tanks must meet in order to be introduced into the project, especially with regard to the waterproofing requirements. The fourth and last part concerns the accessories for the management and monitoring of the plant.

The interception, collection and evacuation system (consisting of collection surfaces, gutters, showers, downspouts, manholes, drainpipes, separate collectors and drainage works) is regulated by UNI EN 12053-3 and UNI 9184 standards. Finally, the DIN 1988 standard regulates the dimensioning of the supply pipes (dual network) of the service water (other than drinking water), at the withdrawal points (which must provide for the affixing of specific signs bearing the wording "non-drinking water", according to the standards E DIN 4844 and ISO 3864) and the colour with which these must be clearly marked (specifically, the green RAL 6032 is the chromaticity to be assigned to the water supply pipes according to the UNI 5634- 97 standard).

***1.1.2 Definitions, eligible uses and quality requirements***

According to statistics, about half of the drinking water fed into water networks is used for purposes other than drinking, personal hygiene and food preparation. Being able to reuse rainwater is therefore a clear benefit, since in this way the waste of drinking water is avoided, but it is not to be ignored even the significant savings in the bill that can be achieved by using the water recovered from the rains.

Some useful definitions regarding the corresponding eligible sources and destinations of use of rainwaters (redrafted by the Italian Legislative Decree of 2 May 2006) are the following:

**Table 1.1: Eligible destinations of use of rainwaters**

| TYPOLOGY | DEFINITION |
|---|---|
| **STORMWATER** | Uncontaminated rainwater from rainfall |
| **REFLUE WATER** | Use-contaminated water and all water entering the sewer system, including rainwater, if discharged into the wastewater sewer system |
| **FIRST RAIN WATER** | These are considered to be those corresponding for each meteoric event to a precipitation of 5 mm uniformly distributed over the entire drainage surface served by the drainage network. For the calculation of the relative flow rates it is assumed that this value occurs in a period of time of 15 minutes. |
| **SECOND RAIN WATER** | The rainwater from the drainage surface served by the drainage system and sent for discharge into the receptor body at a later time than that defined for the calculation of the first rainwater (after 15 minutes) |
| **WASHING WATER** | Water in any case supplied (drawn or recovered) used for washing drainage surfaces and any other water not of meteoric origin that directly or indirectly affects these surfaces |
| **DRAINING SURFACE** | The set of roads, courtyards, yards, loading and unloading areas and any other uncovered surface (waterproofing) |
| **PLUVIAL WATERS** | Rainwater from runoff of roofs, canopies and terraces of buildings and installations |

Water recovery needs to be carefully studied at the site area and to follow specific and restrict regulation on the required treatment standards. Likewise, the opportunity of conducting a system to water recover should be carefully evaluated together with the public authorities and the water utility operating in the site area, and a maintenance plan comprehensively produced, as an attempt to avoid public water contamination. The type of restrictions in place may differ from country to country and, thus, should be carefully revised.

Rainwater in some ways is preferable to drinking water as it does not contain limestone and is very low in mineral salts, so it can be safely used for appliances and flushes without damaging them, to water the garden without harming the plants or to do domestic cleaning without any contraindication. Evidently, rainwater must be properly treated and its use restricted in specific areas in order to be reused.

The following table shows the quality requirements for rainwater and wastewater contained in the Italian Decree of 2 May 2006 "Technical standards for the reuse of wastewater”. The parameters are divided into chemical-physical and microbiological.

| | PARAMETER | UM | LIMIT VALUE |
|---|---|---|---|
| CHEMICAL-PHYSICAL PARAMETERS | pH | | 6-9,5 |
| | SAR | | 10 |
| | Coarse materials | | 0 |
| | Total suspended solids | mg/l | 10 |
| | BOD5 | mgO2/l | 20 |
| | COD | mgO2/l | 100 |
| | Total phosphorus | mgP/l | 2 |
| | Total nitrogen | mgN/l | 15 |
| | Ammoniacal nitrogen | mgNH4/l | 2 |
| | Electrical conductivity | µS/cm | 3 000 |
| | Aluminium | mg/l | 1 |
| | Arsenic | mg/l | 0,02 |
| | Barium | mg/l | 10 |
| | Beryllium | mg/l | 0,1 |
| | Boron | mg/l | 1,0 |
| | Cadmium | mg/l | 0,0005 |
| | Cobalt | mg/l | 0,05 |
| | Total chrome | mg/l | 0,1 |
| | Chrome VI | mg/l | 0,005 |
| | Iron | mg/l | 2 |
| | Manganese | mg/l | 0,2 |
| | Mercury | mg/l | 0,001 |
| | Nickel | mg/l | 0,2 |
| | Lead | mg/l | 0,1 |
| | Copper | mg/l | 1 |
| | Selenium | mg/l | 0,01 |
| | Pond | mg/l | 3 |
| | Thallium | mg/l | 0,001 |
| | Vanadium | mg/l | 0,1 |
| | Zinc | mg/l | 0,5 |
| | Total Cyanides | mg/l | 0,05 |
| | Sulphides | mgH2S/l | 0,5 |
| | Sulfites | mgSO3/l | 0,5 |
| | Sulphates | mgSO4/l | 500 |
| | Active chlorine | mg/l | 0,2 |
| | Chlorides | mgCl/l | 250 |
| | Fluorides | mgF/l | 1,5 |
| | Animal/vegetal fats and oils | mg/l | 10 |
| | Mineral oils | mg/l | 0,05 |
| | Total phenols | mg/l | 0,1 |
| | Pentachlorophenol | mg/l | 0,003 |
| | Total aldehydes | mg/l | 0,5 |
| | Tetrachloroethylene, trichloroethylene | mg/l | 0,01 |

| | | | |
|---|---|---|---|
| | Total chlorinated solvents | mg/l | 0,04 |
| | Trialomethanes | mg/l | 0,03 |
| | Total organic aromatic solvents | mg/l | 0,01 |
| | Benzene | mg/l | 0,001 |
| | Benzo(a)pyrene | mg/l | 0,00001 |
| | Total organic nitrogen solvents | mg/l | 0,01 |
| | Total surfactants | mg/l | 0,5 |
| | Chlorinated pesticides | mg/l | 0,0001 |
| | Phosphorous pesticides | mg/l | 0,0001 |
| | Other total pesticides | mg/l | 0,05 |
| **MICROBIOLOGICAL PARAMETERS** | **PARAMETER** | **UM** | **LIMIT VALUE** |
| | Escherichia coli | UFC/100ml | 10% |
| | Salmonella | | 0 |

### *1.1.3 Types of rainwater collection and reuse systems*

A modern rainwater harvesting system is basically based on three elements:

- the interception system, i.e. the net that collects the water from the drained surface and filters it before introducing it into the tank;
- the tank;
- the water lifting and distribution system for its intended uses.

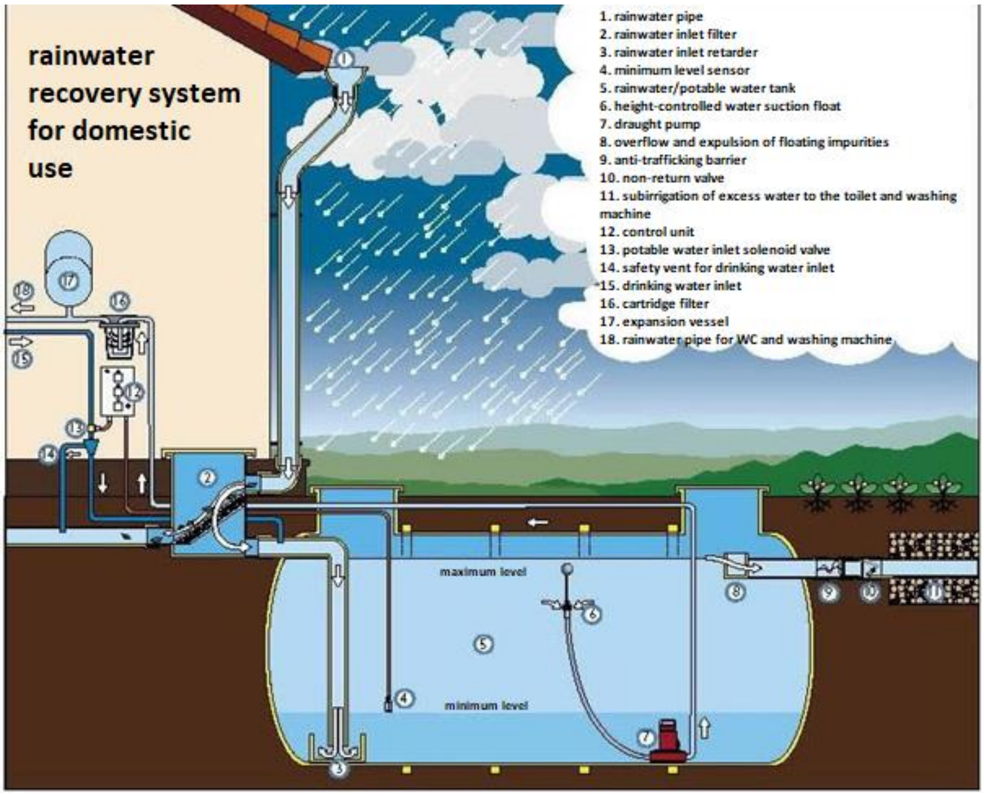



**Figure 1.2: Rainwater recovery system for domestic use**

The interception system, whose function is to select and filter the water destined for storage in the appropriate tanks, consists of the collection surface (i.e. the roof) on which the rainwater flows, the gutters and descendants that carry the water from the roof to the tank, the first rain water diverters and filters. The distribution system, on the other hand, is to all intents and purposes a hydraulic system that serves to take water from the tank and distribute it to the appliances that use it, which must therefore be connected to a double system that allows the differentiated withdrawal in relation to consumption and availability of reserves. In order to avoid any risk of contamination, the pipes and terminals of the recycling plant must be clearly marked and the words "non-potable water" must be clearly displayed at the sampling points (taps, etc.).

There is a wide range of system options, including packaged kits and custom systems using individual components. As discussed above, storage tanks can be positioned either internally or externally. External tanks can be self-supporting, partially underground or completely underground. Several tanks can be connected together. Integrated approaches considering the water-energy nexus should be studied, in order to avoid an extensive energy use despite of the more efficient use of water.

Regardless of whether the system is packaged or custom-made, a rainwater harvesting system will typically be one of the following basic types of system:

- water collected in a storage tank and fed by gravity to the point or points of use
- water collected in a storage tank and pumped directly to the point or points of use
- water collected in a storage tank and pumped into an intermediate tank and fed by gravity to the point or points of use.
- water collected in a storage tank and fed by gravity to the point or points of use.

In the following layout, the rainwater storage tank is located below the rainwater source and above the appliances to be supplied with the collected rainwater. No pump is required, as rainwater is discharged into the gravity tank and water is distributed to the equipment by gravity. This type of system is not as common as pumping systems.

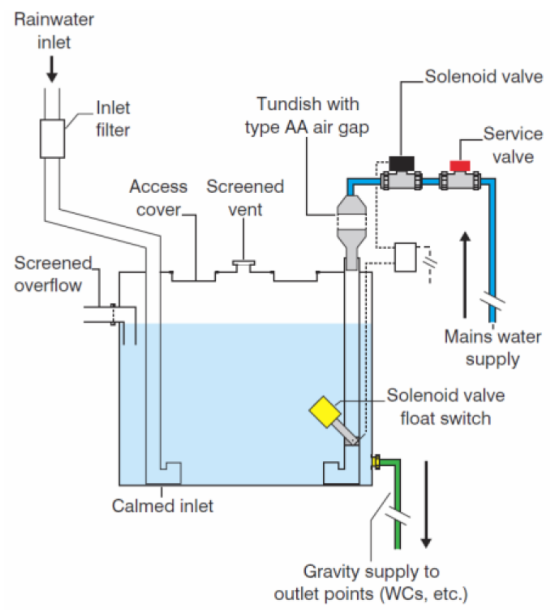



**Figure 1.3: Example of water collected in a storage tank and fed by gravity to the point(s) of use**

In the layout of Figure 1.4 (water collected in a storage tank and pumped directly to the point or points of use) a system module is used which includes an above-ground suction pump.

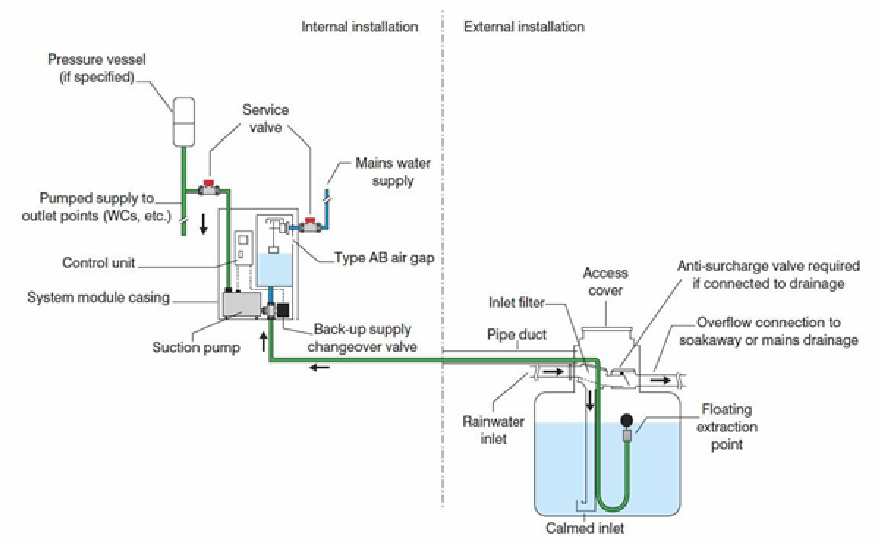



**Figure 1.4: Example of water collected in a storage tank and pumped directly to the point(s) of use**

In the following layout a submersible pump is used. The backup water supply is represented as a type AA air gap arrangement with solenoid valve. Alternatively, an intermediate tank with overflow can be used to provide an AB type air gap.

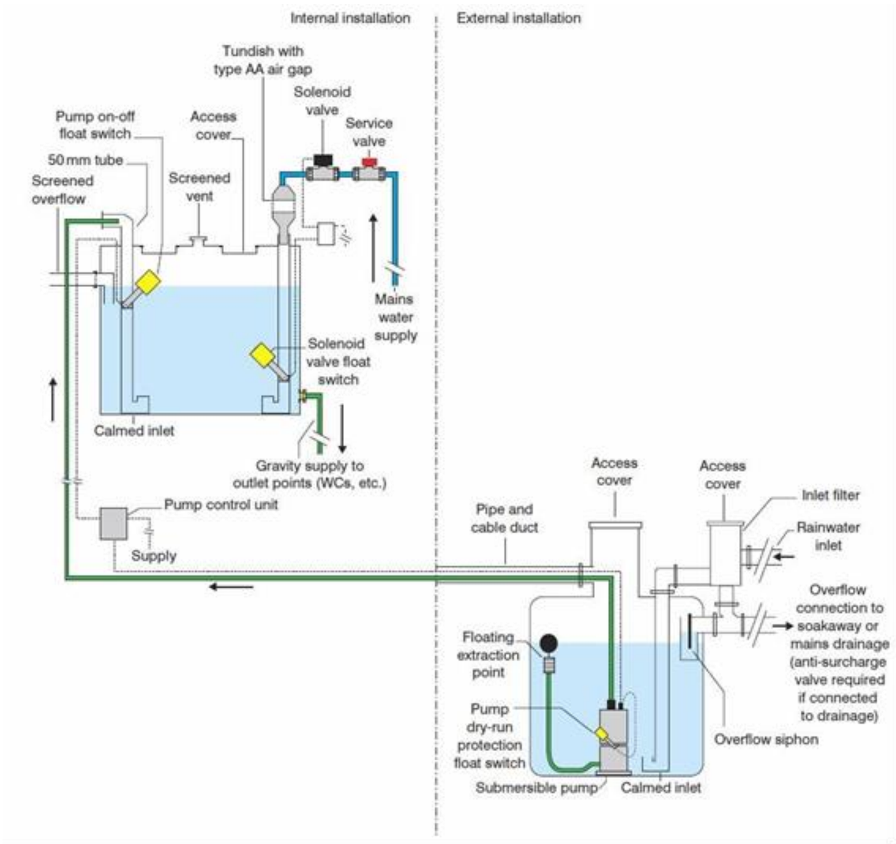



**Figure 1.5: Example of water collected in a storage tank and pumped into an intermediate tank and fed by gravity at the point or points of use**

It must be noted that the above layouts are not intended and should not be used as exemplary installation diagrams. Some of the indicated provisions or components may not be appropriate and/or necessary for all installations of the system. The design of the system must take into account all the regulatory requirements, the instructions of the manufacturer of the components and best meet the needs of the customer in relation to the type and size of the system, the construction characteristics and constraints of the place of installation.

### 1.2 Principles of rainwater recycling

The operation of a rainwater recovery system takes place in the following phases:

**A - Rainwater harvesting:** All waterproof surfaces are suitable as rainwater catchment areas: roofs, terraces, balconies, sidewalks, squares, roads, etc. For this type of system, the waterproof air-termination surface is the roof of buildings, pergolas, verandas and balconies.

**B - Conveyance and transport of rainwater:** The rainwater is conveyed through the gutter channels or by those who perform the same function for them. Once the water enters the conveying systems, it is confined to the filter by means of rainwater and/or suitably prepared piping networks.

**C – Rainwater filtration:** Before rainwater enters the tank, it must be flushed. The filter must be located upstream of the tank and can be installed at different points in the system. It can be installed for this type of system:

- Directly on the downpipe.
- Basement.
- Inside the tank.

**D – Storage of rainwater:** Water is stored in specially designed rainwater storage tanks. For this type of system, underground or outdoor tanks are used, with characteristics that vary according to requirements.

**E – Rainwater harvesting and treatment:** The accumulated rainwater can be withdrawn by means of a self-priming pump or a submersible pump and stored in a special 350-litre tank containing the second stage of filtration called ultrafiltration.

**F – Collection and reuse of rainwater:** The accumulated rainwater can be withdrawn by means of a self-priming pump or a submersible pump and stored in a special 350-litre tank containing the second stage of filtration called ultrafiltration.

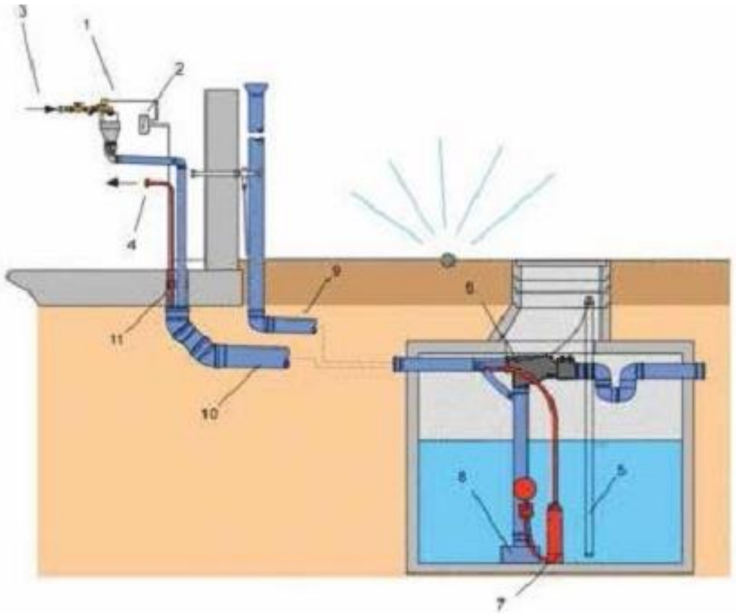
**G – Re-use of rainwater for drinking purposes:** The ultra-filtered water undergoes a reverse osmosis treatment that allows its purification.

**H – Disposal of excess rainwater:** Once the tank is full, the water is automatically diverted to the drain. For this type of system, the water can be disposed of in public sewerage or by means of a special drainage system.

### *1.2.1 Rainwater recovery for outdoor use*

A rainwater harvesting system for outdoor use only is ideal for:
- Irrigate public, condominium and private green areas.
- Wash paved areas.
- Wash vehicles.

**Example of system with underground tank and submersible pump**



Legend:
1. Solenoid reintegration valve
2. Digital level control unit
3. Connection to the main water supply
4. Plant delivery pipe
5. Level sensor
6. Self-cleaning filter for internal tank
7. Submersible pump
8. Calm bathtub
9. Rainwater pipeline
10. Technical piping for the passage of the hydraulic and electrical system
11. Watertight wall pass-through connection (if water pipes serving the irrigation system pass inside the building)

### *1.2.2 Rainwater recovery for external and domestic non-potable uses*

This type of plant allows to recover and reuse rainwater for outdoor and domestic uses that are not drinking water. It is more articulated but it pays for itself quickly, and is optimal for:

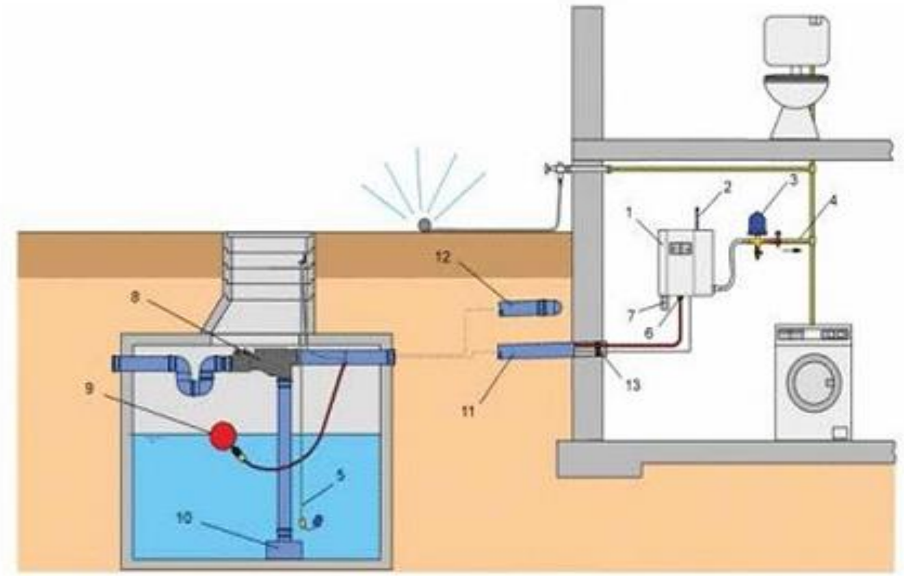
NON-POTABLE USES INSIDE THE BUILDING

- Water supply for toilet flushes and urinals;
- Foods for washing machines and dishwashers;
- Washing floors, walls and glass.

NON-POTABLE USES OUTSIDE THE BUILDING

- Irrigation of public, condominium and private green areas;
- Washing of paved areas;
- Washing of vehicles.

**Example of system with underground tank and automatic pumping unit**



Legend:

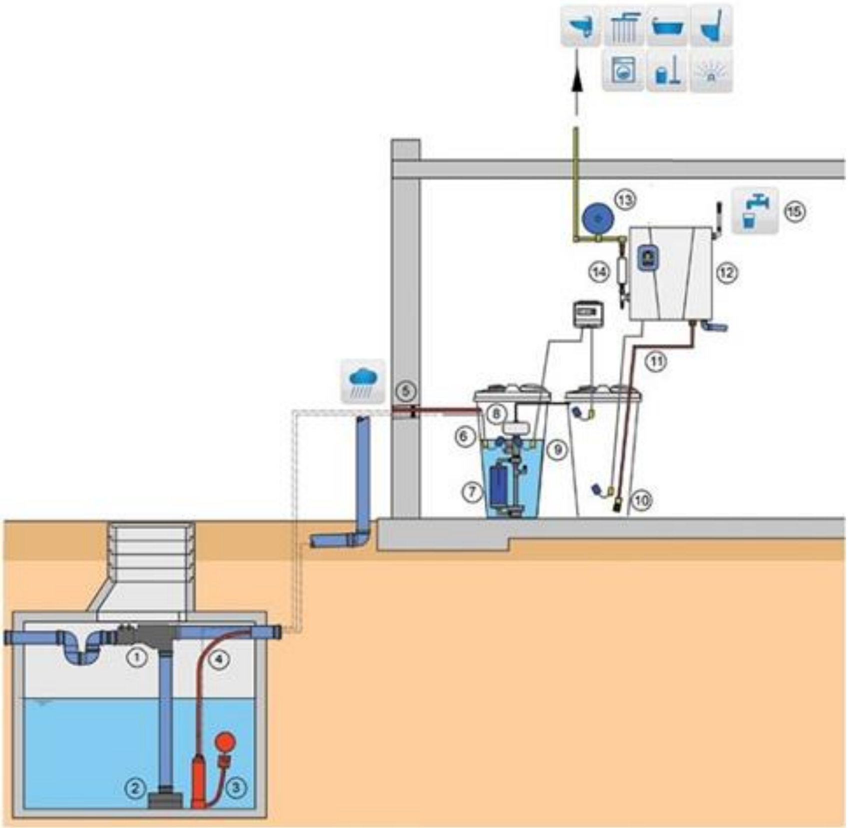
1. Automatic pumping unit
2. Connection to the national water mains;
3. Expansion tank
4. System delivery pipe
5. Level sensor with float;
6. Suction of rainwater
7. Overflow pumping unit
8. Self-cleaning filter from inside the tank;
9. Suction filter with float
10. Calm tank
11. Technical piping for the passage of the hydraulic and electrical system
12. Rainwater piping
13. Watertight pass-through connection

### *1.2.3 Rainwater recovery for outdoor and domestic water and sanitation uses*

This type of plant allows to recover and reuse rainwater for all uses that require drinking water, such as:

- Washing hands.
- Showering.
- Wash dishes by hand or with a dishwasher.
- Hygiene in general.

**Example of system with underground tank**



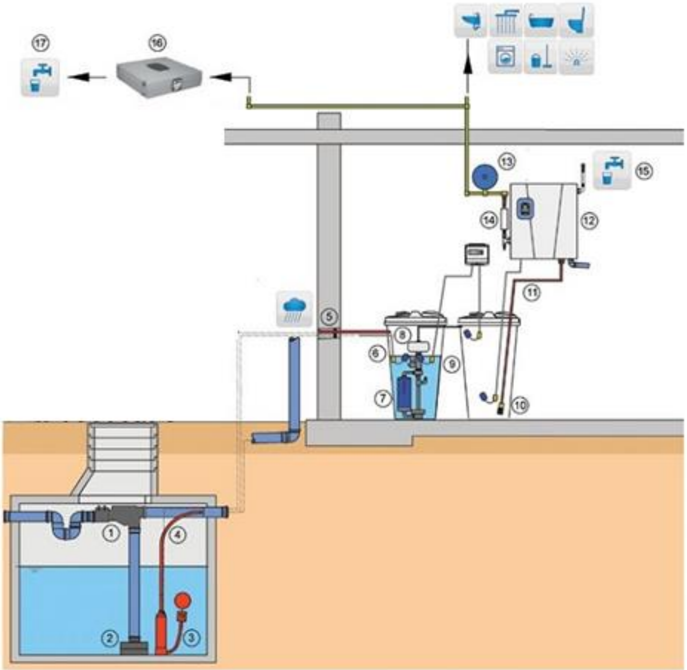
Legend:

1. Self-cleaning filter from inside the tank;
2. Calm tank
3. Submersible pump
4. Rainwater delivery pipe
5. Watertight wall pass-through connection
6. Level sensor
7. Filtering membrane
8. Pumping station
9. Technical tank
10. Suction filter
11. Treated water suction
12. Automatic pumping unit
13. Expansion tank
14. UV sterilizer
15. Public water supply system

### *1.2.4 Rainwater recovery for outdoor and domestic use water, and sanitation and drinking water*

This type of plant takes the water treated with the previous system and subjects it to a second physical treatment, making it suitable for drinking and cooking. For this last step it is normally necessary to have the treated water analyzed by an authorized analysis laboratory in order to verify compliance with the chemical-physical parameters required by the applicable law.

**Example of system with underground tank**



Legend:
1. Self-cleaning filter from inside the tank
2. Calm tank
3. Submersible pump
4. Rainwater delivery pipe
5. Watertight wall pass-through connection
6. Level sensor
7. Filtering membrane
8. Pumping station
9. Technical tank
10. Suction filter
11. Treated water suction
12. Automatic pumping unit
13. Expansion tank
14. UV sterilizer
15. Reintegrating from public aqueduct
16. Osmosis
17. Kitchen sink tap

## 1.3 Rainwater collection

All waterproof surfaces not subject to vehicle transit are suitable as collection areas: roofs, terraces, balconies, sidewalks. The calculation of the cross-sections of gutters, gullies, downspouts, drainage shafts and collection pipes must take into account the climatological data (quantity and duration of rainfall) and the geometric data (sum of the areas that can receive precipitation). The materials and components must comply with the corresponding product standards and resist the chemical action of air pollutants and the mechanical action of atmospheric agents such as hail, wind, snowfall, etc.

Among the innovations aimed at solving the frequent problem of clogging of the gutters and downspouts, caused by accumulations of leaves and other residues that fall on the roofs, we must point out particular gutters prepared for the collection of water equipped with systems that in practice close the upper part of the gutter itself. The water passes through the drainpipes with grid, or through slits along the entire length of the channel or through networks that form a single body with the channel itself.

**Figure 1.6: Gutters designed for pre-filtration of water from coarse bodies**

During the collection phase, it is necessary to adopt measures regarding the first rain water, which is the surface flow water that flows in the first moments of a precipitation event; in fact, this water, known by the name of first flush, is characterized by high concentrations of pollutants. As a rule, first rainwater is considered to be water corresponding, in the first part of a meteoric event, to a precipitation of 2.5 - 5 mm of water.

The sources of contaminants in the water collected can be: substances present in the atmosphere that are associated with the water during the rain (e.g. acid rain); substances released from the materials that make up the water collection and/or storage systems (e.g. lead in converse, hydrocarbons and polymers in impermeable sheaths, dust and fragments from tiles, tiles, slabs, etc.); parasites, bacteria and viruses derived from the dung of birds and animals that have access to the roof and to the collection surfaces. Inside the rainwater collection system, the problem is solved with the installation in the downpipe of a first rainwater diverter also called first flush diverter, whose function is essentially to reduce the peak pollutant by retaining the first part of the meteoric event.

There are different types of diverters, for example the roof washer, a blind rainwater pipe at one end that is adjacent to the one that connects the gutter channels to the storage tank. The configuration of the two pipes is such that the water coming from the roof can flow to the tank only when the roof washer is completely full. A variant that can be found on the market is the roof washer with ball valve, designed so that once filled the space for the first rain water, the floating ball valve obstructs the passage of water that will then flow to the collection tank.

There are also diverters with manual or automatic operation that are installed on the final section of the rainwater and obstruct the section, causing the diversion of rainwater to a drain or to the tank. However, the quality of first rain water is highly dependent on the specificity of the site in question and in particular on the hydrological, climatic and morphological characteristics of the area (frequency and intensity of rainfall, type of surface, etc.).

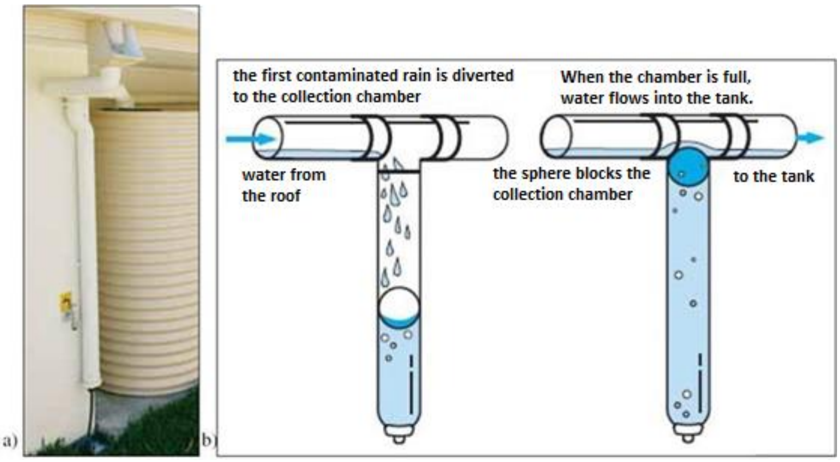



**Figure 1.7: a) Roof washer; b) Roof washer with ball valve**

The next step is to filter the rainwater. The filtration system assumes a particular importance in the economy of the entire technological line because it is required to avoid the introduction into the tank of debris and foreign bodies collected by rainwater in its path, which, by sedimentation, would lead to a deterioration in the quality of water and the risk of clogging of the pipelines and the pumping and pressurization system. The importance of this system is also demonstrated by the fact that an entire section of the E DIN 1989 standard is dedicated to it.

The filter located upstream of the storage tank, however, may be:

- installed in different points of the system (on rainwater, above ground, underground, integrated in the tank, etc.);
- designed according to different principles of material interception;
- equipped with automatic rinsing devices to eliminate the intercepted material which, by stratifying, would decrease its efficiency.

For small plants, where the rainwater is collected by one or a few rainfalls, the filter is inserted on the pipe of the rainwater by replacing a short section of the same. It consists of a casing having the same section of the pipe that can be easily connected and removed for periodic maintenance, and of an internal interception element generally consisting of a metal grid (with holes with a diameter of less than 2 tenths of a millimetre) shaped like a truncated cone, tapered downwards and capable of retaining residues of various kinds (mosses, lichens, leaves, sand, dust, etc.).

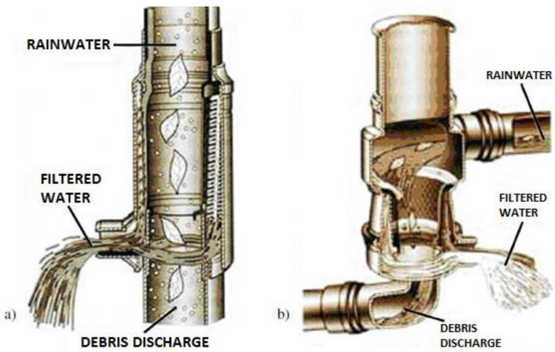



**Figure 1.8: a) Filter integrated with the downpipe; b) Centrifugal filter**

The portion of water that penetrates through the filter is diverted outside the downpipe and sent to storage while the residues intercepted and washed away by the remaining water are conveyed to the disposal system. There are also centrifugal filters, in which the speed at the inlet of the water (tangentially introduced into the filtering chamber) is exploited by intercepting and separating any suspended bodies through a peripheral grid on which the incoming liquid is projected; the filtered water collects in the perimeter cavity and is then conveyed towards the tank.

Another type of filter is the so-called chamber filter, in which water is passed through a well containing inert material of different grain sizes, which acts as a trap for coarse bodies. The inside of the well is divided into chambers (2 or 3) equipped with baskets or removable pockets, each of which must be filled with gravel of decreasing grain size in the direction of water flow (for example: Ø 80-35 mm / 35-25 mm / 25-15 mm). The operation foresees that, even if the inlet and outlet of the water are placed on the same level, the liquid carries out an obligatory path so as to pass through all the chambers and allow the suspended substances to remain trapped in the mixtures of filtering material. If the filter is obstructed or there is an exceptional influx of water, an overflow hole ensures that the excess liquid is disposed of in the drainage system or in a losing well.

Finally, there are gravity filters: this type of device, to be installed both on the surface and underground and in some cases inside the storage tank, operate by gravity and provide for the capture of unwanted material by means of fabric filters. The water passes through the filter and mostly runs through the area below, depositing the impurities on the mesh of the sieve; the remaining amount of water, precisely because it is prevented from filtering by the presence of the intercepted residues, produces a leaching effect on the latter, dragging them towards the drainage connected to the sewage system.

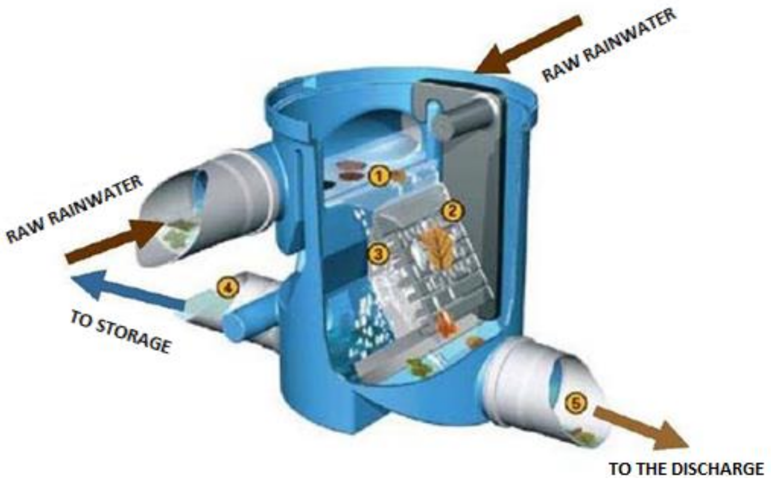



**Figure 1.9: Example of underground filter made of black linear high-density polyethylene (recyclable)**

The efficiency of the system depends to a large extent on the periodic cleaning of the filter, which can be accessed through the cover of the manhole cover. To overcome this problem, some models (self-cleaning filters) are equipped with a backwashing unit, i.e. a device similar to a rotating arm sprinkler which, when operated manually, cleans the filter with a jet of mains water sprayed in the opposite direction to that of the fall.

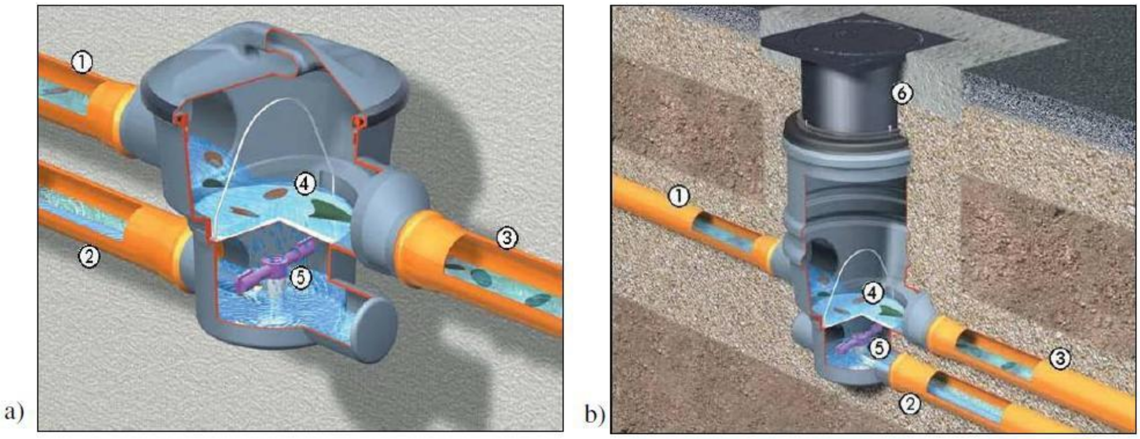


**Figure 1.10: a) Self-cleaning filter produced by Kessel; b) Example of underground installation**

Legend: 1) Rainwater inlet; 2) Rainwater filtered to the tank; 3) Rainwater remaining or containing suspended bodies sent to the dispersion or to the sewer system; 4) Filter cartridge; 5) Backwash unit; 6) Height-adjustable telescopic manhole cover.

## 1.4 Storage

Water is stored in specially designed rainwater storage tanks. The range of tanks varies depending on the material, shape, capacity and location. The position of the tank determines the type of distribution sub- system (with or without pump) and, therefore, also the uses, the total costs of installation and maintenance, the shape (compact for interior, resistant for burying) and the materials used. Alternatives regarding the location of the tank can be above ground, inside the building (cellar, garage), and underground.

**Figure 1.11: Examples of a) an above-ground 750-litre polyethylene tank, positioned on the cover of a box-garage; b) tank for minimum encumbrance; c) tank for irrigation use**

Above ground tanks are generally preferred for the accumulation of water for irrigation (garden, garden, etc.) or for washing cars and the like, where the distribution of the liquid is by gravity without the use of pumps, usually vertical tanks (e.g. to be placed on the building next to or coinciding with the descent of rainwater) or flattened tanks to be located on flat roofs (e.g. on the roof of garages or similar premises).

When placed inside the building, the tank is usually located in rooms at ground level or underground (garages, cellars, etc.). The choice is usually motivated by the ease of installation, the unavailability of outdoor spaces, difficulties for the burial (rocky ground, surface layers, etc.), the need not to tamper with complex external arrangements and / or damage the radical apparatus of planting of value and / or to contain costs. The development of the tanks is generally vertical to reduce the space required and the size is usually reduced to allow easy introduction into the internal compartments. However, to increase the capacity it is possible to place more than one in parallel.

**Figure 1.12: Indoor tank with capacity of 1500 litres, which can be increased by connecting several tanks in series, made of recyclable and non-deformable polyethylene**

The positioning within the ground, even if more expensive, allows to eliminate visible encumbrances not always compatible with the functional and aesthetic needs of the building and allows the installation of even large capacity products. Each tank is equipped with a *manhole* or a system of access to the tank itself, consisting of a conduit on top of the casing, completed by a manhole, to perform maintenance and control operations. To avoid unwanted opening by strangers or children, it is advisable to use manhole covers with locks.

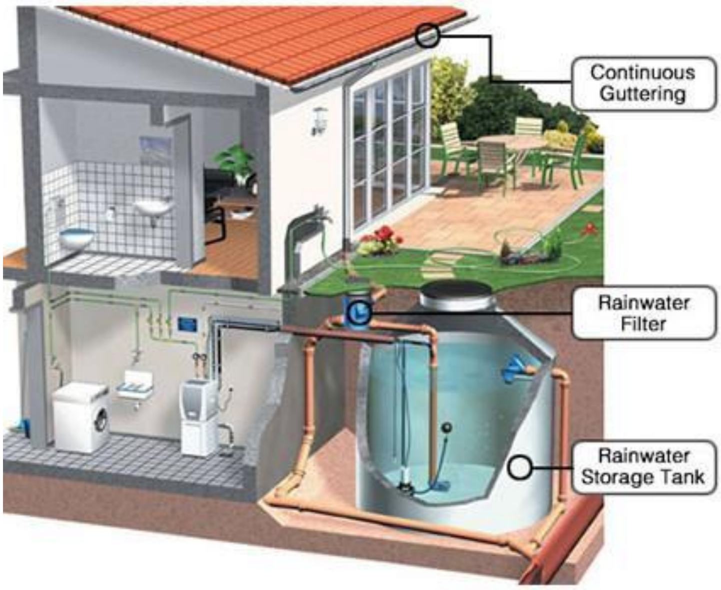



**Figure 1.13: System example with underground tank**

Once the water has been filtered, it must be introduced into the tank through a stilling pipe or a vertical pipe as high as the tank itself and with a lower end connection bent upwards, so as not to create turbulence that could put any layers of algae or other material deposited on the bottom in suspension. The tank must then be equipped with an overflow that allows water to enter the drain system once the maximum tank capacity is reached, and that must be siphoned to prevent the return of unpleasant odours from the disposal system.

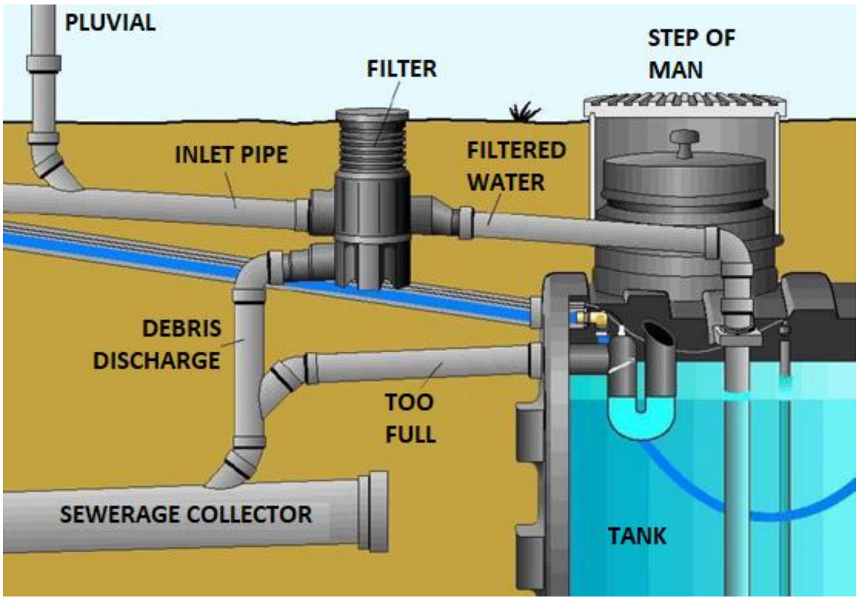



**Figure 1.14: Connection diagram for a rainwater storage tank**

The overflow outlet can be used in various ways: connected to the sewerage system, connected to a dispersing well, dispersed by means of surface sub-irrigation, discharged onto the ground, discharged into a border dimple, discharged into surface water, discharged to feed natural and/or artificial lagoons.

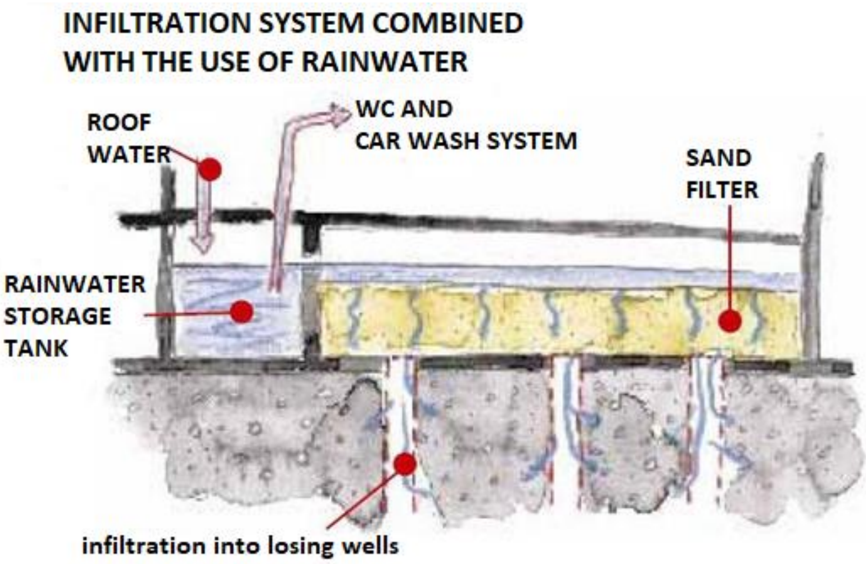



**Figure 1.15: Diagram of a possible system for the disposal of excess rainwater**

Finally, the tank must be equipped with a non-return valve, which is essential to prevent contamination of the water stored in the tank. This valve consists of a special device equipped with a self-closing gate valve (manually operated in case of emergency or maintenance) that prevents the backflow of water from the disposal system. Normally the valve is equipped with a grate filter that blocks access to the tank and other components upstream of it, to animals and insects that could go back from the drainage and disposal subsystems.

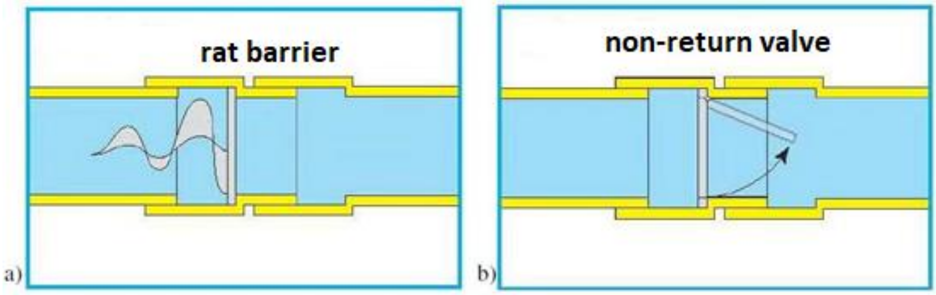



**Figure 1.16: a) Rat barrier; b) non-return valve**

The materials commonly used for the construction of the tanks are high-density polyethylene, concrete and fiberglass. Polyethylene is a very common plastic material, recyclable and compatible with the regulations concerning the storage of water intended for human consumption; it makes it possible to obtain products that are light and resistant to temperature changes and atmospheric agents. It is characterized by resistance to corrosion and stray currents, smooth and easily washable surfaces, easy handling and installation. There are different forms of polyethylene tanks on the market (vertical axis, horizontal axis, bell), and storage capacity ranging from 500 to 15,000 liters. In Europe, they are mainly manufactured in Germany.

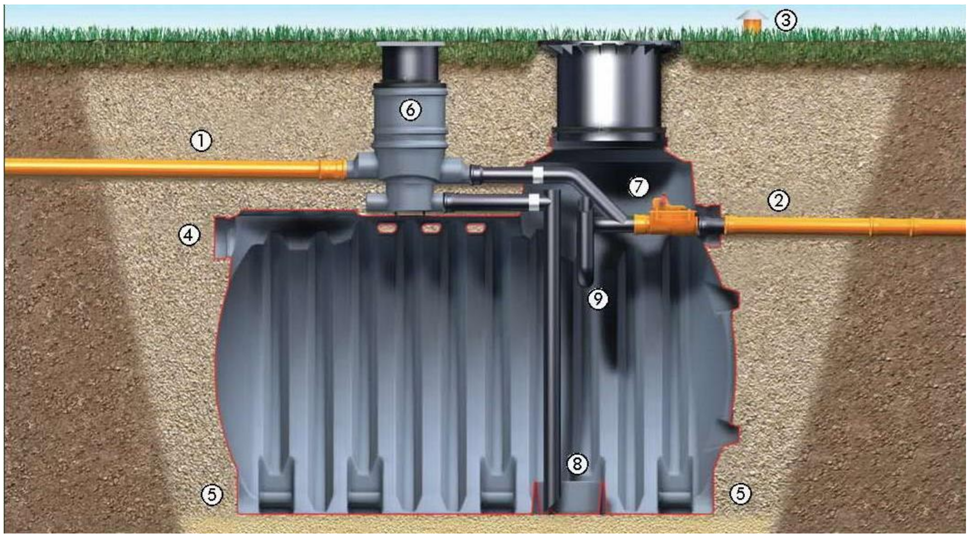



**Figure 1.17: Example of a polyethylene rainwater tank (burying depth: 50 cm / 100 cm; useful volume 3000, 4500 or 6000 litres)**

Legend: 1) rainwater inlet; 2) sewer/dispersion outlet; 3) Ventilation; 4) surface to be drilled for ventilation; 5) Connection of surface to be drilled; 6) rainwater filter; 7) backflow preventer; 8) jet stop; 9) overflow siphon

The shaping of the casing almost always involves the presence of corrugations, ribs and folds, which act as reinforcement of the fairing. On the bottom of the product can be carved or interlocked where the "forks" of the elevators and facilitate their movement can be inserted. For subsequent integrations with other storage tanks, it is possible to use parallel positioning: the installation involves placing the tanks side by side, connected to the base by connecting pipes that allow the simultaneous introduction and extraction of water from all tanks avoiding the negative consequences resulting from stagnation or emptying phenomena.

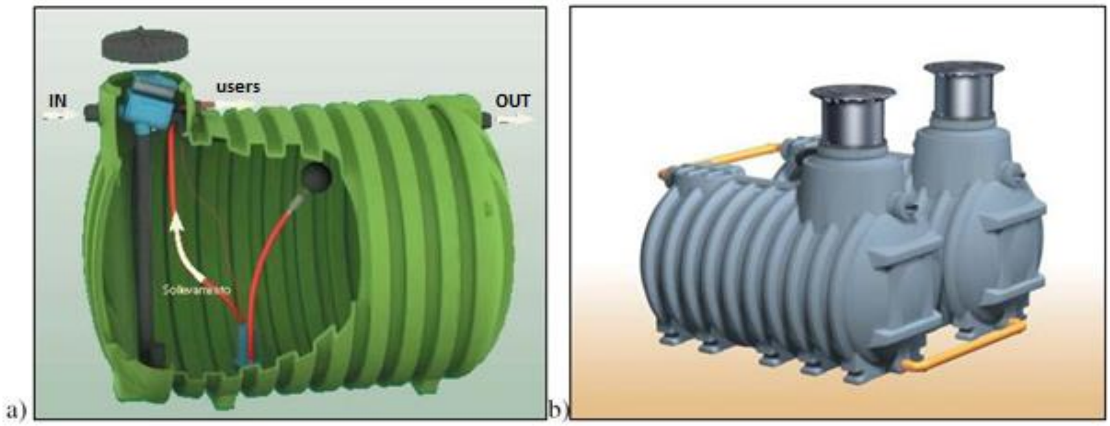



**Figure 1.18: a) Polyethylene tank with litre inside the tank and self-priming pump; b) larger useful volume with parallel positioning of several tanks**

Storage tanks can also be made of concrete. Concrete is a good material for tank construction: it is composed of natural raw materials (gravel, sand and cement), is durable over time, withstands the pressure of the ground, the water table and the transit of vehicles and has advantageous costs. The standard range of monolithic parts offers tanks from 1.1 to 8.3 capacity. Larger volumes can be achieved by laying tanks in parallel or by using large tanks, with a usable volume of up to 1000, which can be further extended on several lines to serve, for example, large sports centers, nurseries and greenhouses, residential areas and adjoining parks. The advantage of these tanks is that they are inexpensive, but their installation is more complex and therefore more expensive. In the case of new construction, the tank could be integrated, for example, in the patio or in the cellar of the house.


**Figure 1.19: Concrete tank**

[Source: www.Ecorain.it]

Tanks made of fiberglass (GRP - Glass-reinforced polyester resin), a thermosetting composite material, where the fiberglass ensures high mechanical strength and the polyester resin the chemical resistant part, are also available in the market. It is a material with very high performances: resistant, light and non-toxic, resistant to corrosion, resistant to UV rays and easily repairable. These tanks are made of a single block and are then reinforced with box-shaped rings directly welded to the cylinder that ensure maximum resistance to implosion making them perfectly buried and walkable. They can reach high capacities of 60,000 to 70,000 litres. Among the types of tanks analyzed are the most expensive.

**Figure 1.20: Fiberglass tank produced by Vemar and its installation**

Finally, the tanks can be made of steel. Made of high strength corrugated sheet metal, with a minimum thickness of 2.5 mm to withstand vehicular loads, they are light but very robust and easy to transport and install. They are protected from corrosion by a galvanising process, as required by the regulations. They are generally modular tanks with diameters ranging from DN 2000 mm to DN 3000 mm, for lengths from 4 metres to 15 metres; volumes ranging from 20 to 100 can be further multiplied by exploiting the modular system and flanking them in line, on several rows or according to requirements and connecting them with flanges or a suitable elastic joining system.

**Figure 1.21: Steel tanks for storing rainwater**

## 1.5 Distribution

The filtered and properly stored water is then ready to be taken and reused. As mentioned before, the possible uses are essentially of two types: domestic (non-potable) and irrigation. In the case of simple irrigation use, to draw water from the tank just install a pump of adequate flow rate and head, which can be immersed in the tank or external. It must be equipped with a sampling system at a constant depth, in relation to the level of water in the tank. A special float connected to the flexible draught pipe (also equipped with a filter) ensures that it always takes place at a set constant depth, for example -10 cm from the surface, regardless of the level of fluid inside the tank. If the draught is too close to the bottom, an area in which impurities can accumulate, the pump's activation/deactivation float will remove it and prevent it from draught until the level of the tank is increased, thus remedying the problem.

These necessary measures serve both to guarantee the maximum quality of the fluids taken and to preserve pumps and hydraulic systems from annoying, frequent and costly maintenance and repair. In cases where it is wanted to use the stored water also for domestic use, a few more tricks in the implementation of the distribution system must be used. Many companies propose the use of automatic control units in these cases. The control unit has the task of providing the users connected to it with a constant water supply even in periods of long drought through the automatic management of the traditional hydraulic circuit and the recovery without any kind of waste.

For this purpose, the minimum volume below which the stock must never fall must first be determined in order to ensure simultaneous and prolonged use by the connected loads. To guarantee this volume, a level sensor is installed inside the tank which, when the rainwater falls below the desired quantity, opens the solenoid valve of the drinking water circuit and delivers it, by means of a submersible pump or external, into the tank. It should be noted that the tank will be reintegrated with the traditional water supply exclusively until the required level is reached and maintained (the level determined by the sensor) so as not to frustrate the next weather event.

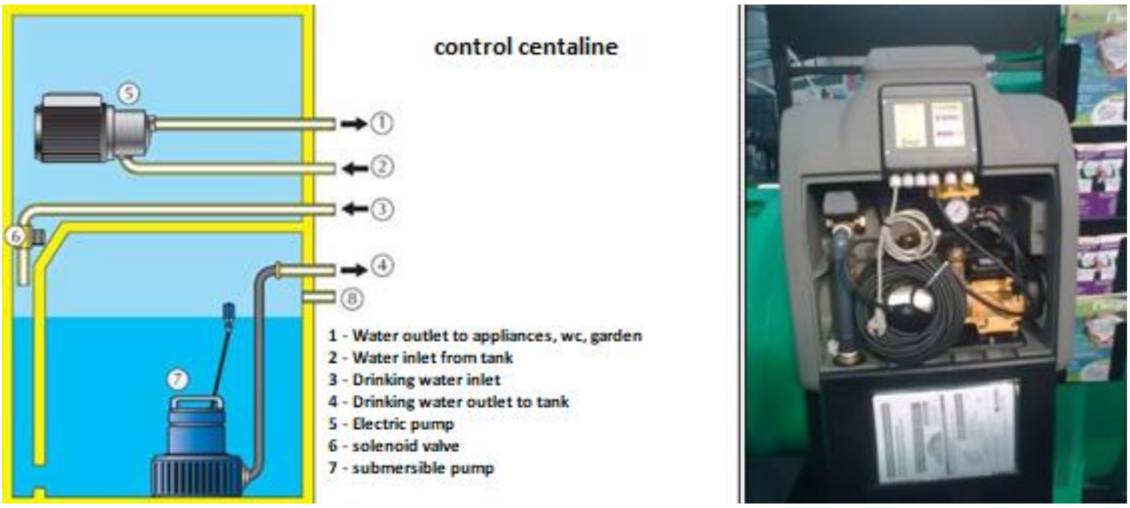



**Figure 1.22: A typical electric pump (right) and its functioning in the circuit (left)**

According to the above figure, the electric pump (5) takes the liquids inside the tank and then redistributes them under pressure to all the users connected to the control unit (toilets, washing machines, irrigation systems, etc.). The traditional water circuit (3), used to replenish the minimum supply, is separated by a solenoid valve (6) so that it never comes into direct contact with the recovery circuit. The submersible pump (7) sends the drinking water to the tank

In compliance with the various national health regulations, the traditional hydraulic network and the recovery network must be totally separated without ever coming into direct contact. This guarantee inside the control unit is provided by the solenoid valve that physically separates the two circuits without ever letting them come into direct contact.

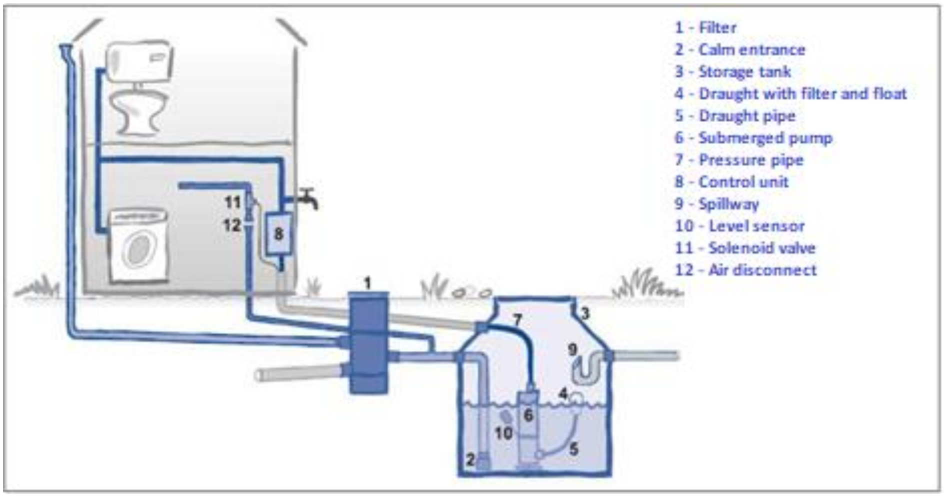



**Figure 1.23: Diagram of a submersible pump system**

## 1.6 Treatment

Before reaching the final users, the water collected in the tank must be treated in order to eliminate any risk to human health during use. The treatment generally consists of filtration and disinfection processes. In a first step, filtration is carried out to remove any suspended solids, using cartridge, sand, activated carbon or membrane filters. Subsequently, in order to eliminate any microorganisms present, the disinfection phase is carried out, which is usually carried out with an ultraviolet (UV) debacterizer, or through chemical treatments based on chlorine or ozone.


**Figure 1.24: Typical treatment system with a 5 µm cartridge filter, a 3 µm active carbon filter and ultraviolet light debacterizer (left), and ultraviolet debacterizer (right)**

A typical treatment system consists of two in-line filters, a 5 micron cartridge filter followed by a 3 micron carbon filter followed by the ultraviolet debacterizer. The disinfection system must be placed after the autoclave or after the pump. It is important to note that filter cartridges must be replaced regularly. Otherwise, the filters themselves may cause the bacteria to proliferate. The 5 micron filter mechanically removes suspended particles and dust, while the 3 micron filter mechanically traps microscopic particles; the smallest organic molecules are absorbed by the active carbon present in the filter itself. In cases of higher water flow, in order to obtain an adequate filtration, the filters can be arranged in parallel, i.e. two 5 micron filters are stacked in a single cartridge followed by two 3 micron active carbon filters in another cartridge.

The ultraviolet (UV) debacterizer must also be adjusted to the volume of water to be treated. Using special quartz-based materials, UV lamps are able to generate the exact wavelength of UV light required for disinfection. A specially designed power supply system and electronic controls manage and control these lamps for best performance. The system uses the technology of these UV lamps in specially designed stainless steel disinfection chambers, ensuring that UV energy is effectively distributed when water passes through the unit. The result is that every harmful organism in the water is subjected to a lethal dose of UV energy.

The result is an effective destruction of the dangerous organisms that may be present in the rainwater that washed the collection surface, and that can survive up to the storage tank and overcome filtration. UV rays have no effect on the taste, smell and clarity of water and no residual substances or chemicals should be added to the water. It is a system that can be easily installed in the water line of a house and the lamps need to be replaced only after more than a year of use; the system also requires less energy than a normal house lamp.

### 1.7 System components overview

This section covers the following components:

- inlet filter;
- calmed inlet;
- overflow siphon;
- floating extraction point;
- anti-surcharge valve;
- system pump;
- pump control unit;
- float switch;
- expansion vessel;
- water level gauge;
- solenoid controlled Type AA air gap back-up supply;
- system module;
- desander.

**Inlet filter**

All water entering a rainwater harvesting storage tank needs to be filtered to remove leaves, dirt particles, etc. The type and number of filters used will typically depend upon the intended use of the harvested rainwater (internal or external use), the size of the installation and the local conditions (for example, the number of trees, condition of surfaces that are catching the rainfall, etc.).

There are three main types of inlet filter:

- downpipe filter
- in-line mesh filter
- vortex filter.

***Downpipe filter***

Downpipe filters are typically suitable to filter rainwater collected by a roof area of up to 100 $m^2$ per downpipe. The filter shown in the following figure uses a two-stage filtration process where large or coarse particles such as leaves and moss are filtered via a cascade process and then small or fine particles are filtered via a stainless steel mesh.

**Figure 1.25: Downpipe filter**

***Inline mesh filters***

In-line mesh filters are typically suitable to filter rainwater collected by a total roof area of up to 350 $m^2$. There are various designs of in-line mesh filter available, some using a flat mesh filter as shown in figure 1.26, others using a cylindrical mesh filter. The filter shown uses a filtration process where large or coarse particles such as leaves and moss pass across the filter surface and go to drainage or soak away, and the small or fine particles are filtered out by the water passing through the mesh filter before it enters the storage tank. In a cylindrical mesh filter, rainwater from the roof enters the filter housing and flows over the cylinder-shaped filter mesh. Mesh filters are effective in being self-cleaning due to the continual flow of water and the provision for debris to be washed through to drainage or soakaway.


**Figure 1.26: In-line mesh filter**

### *Vortex filters*

In a vortex filter, rainwater is sucked through the vertical mesh walls of the filter and then conveyed through the outlet to the storage tank. Solids and dirt particles are washed in the drain with residual water. Typically, 90-95% of the rainwater entering a vortex filter reaches the storage tank as long as sufficient capacity is available. As rainwater passes through the filter, the flow of the vortex contributes to enriching the water with oxygen. This process helps to achieve good water quality inside the storage tank. The vortex filters are available in various sizes and, depending on the size installed, can generally cope with an inflow from roof areas up to 3000 $m^2$.

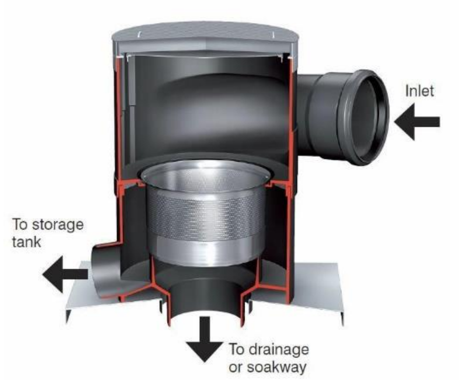



**Figure 1.27: Vortex filter**

### Calmed inlet

After the harvested rainwater has passed though the inlet filter it enters the storage tank though a calmed inlet located at the base of the storage tank. Some of the very fine particles which pass through the inlet filter will settle on the base of the storage tank. The design and purpose of the calmed inlet is to prevent swirling that could lead to the disturbance of the fine particles on the bottom of the tank and to oxygenate the water. This helps to maintain clear and odourless stored water and minimises the risk of stagnation of the stored water.

**Figure 1.28: Calm input**

### Overflow siphon

Although the inlet filter and the calmed inlet are effective in helping to maintain clear and odourless stored water, it is inevitable that some low density fine particles such as flower pollen will rise to the surface of the stored water and form a surface layer of fine debris.

The use of an overflow siphon enables the surface layer to be removed due to a 'skimmer effect' occurring when the tank overflows. At the same time the siphon keeps away undesirable smells as well as small animals, which is particularly important when a mains drainage overflow connection is used. Some overflow siphons also include additional features such as a grille to prevent vermin entry and an anti-backflow feature as shown in the Figure 1.29.

**Figure 1.29: Overflow siphon (left) and overflow siphon with an anti-backflow feature (right)**

**Floating extraction point**

Most rainwater harvesting systems make use of a floating extraction point to enable the stored water that enters the pump to be taken from approximately 100–150 mm below the surface. This is where the water is most likely to be at its cleanest. A floating extraction point is simply a mesh filter with a hose connection that is freely suspended near the surface of the water by means of a polypropylene (or similar material) ball.

The grade of mesh filter used depends upon the degree of filtration required. Floating extraction points are available with either fine or coarse mesh filters. Where the rainwater has been filtered on entry to the tank, a coarse mesh filter is normally used at the point of extraction.

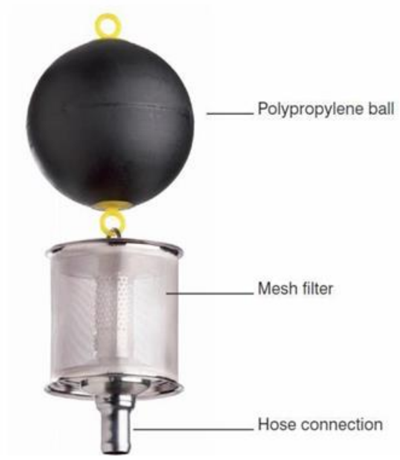



**Figure 1.30: Floating extraction point**

**Anti-surcharge valve**

Building regulations require that an anti-backflow device is fitted on any overflow connected to a drain or sewer to prevent contamination of the stored rainwater in the event of surcharge in the drain or sewer. This requirement can be met by using an overflow siphon that includes an anti-backflow feature or through the installation of a separate anti-surcharge valve as shown in the next Figure

**Figure 1.31: Anti-surchage valve**

**System pump**

Pumps used to distribute the harvested rainwater may be one of two types:

- submersible
- suction

By the very nature of their design and purpose, submersible pumps are fitted within the storage tank. Suction pumps used in rainwater harvesting systems are self-priming, multistage pumps and are fitted outside of the storage tank either in a purpose made enclosure or inside the building.

**Figure 1.32: Submersible pump shown with floating extraction point connected and float switch (left), Suction pump (right)**

**Pump control unit**

The system pump should be controlled by a unit that:

- operates the pump(s) to match demand
- protects the pump(s) from running dry
- protects the motor from overheating and electric overload
- includes a manual override function.

Depending upon the manufacturer, the pump control unit may be a stand-alone unit or integrated with the mains back-up water supply control arrangement as a system control unit. Pump operation will either be pressure-switch controlled or float-switch controlled depending upon the system type

**Float switch**

A float switch is also used in conjunction with the back-up water supply control arrangement to operate the back-up water supply. This is activated when the storage tank water level drops to a predetermined level. Where a submersible pump is used, a float switch can be mounted on a clamp bracket with a pivot lever to provide a secure and reliable fixing.

**Figure 1.33: Float switch with pump mounting clam and pivot lever**

**Expansion vessel**

Potable grade expansion vessels are used as a pressure vessel/accumulator tank in some pumped rainwater harvesting systems, with the purpose of maximising pump life by reducing pump on–off pulsation.

**Water level gauge**

A system water level gauge may be included in the installation where the end user wishes to be able monitor the volume of stored water. Both analogue and digital pneumatic water level gauges are available.


**Figure 1.34: Analogue pneumatic water level gauge with manual pump**

The gauge shown in Figure 1.34 works by measuring the hydrostatic liquid pressure acting upon a pressure membrane located at the bottom of the tank. The pressure membrane is connected to the gauge by means of a capillary tube. To obtain a reading, pressure must be built up in the capillary tube by operating the manual pump incorporated in the gauge. When the pressure within the capillary tube is equivalent to the hydrostatic pressure acting upon the bottom of the tank, the gauge dial displays the liquid height as a percentage.

**Solenoid controlled Type AA air gap back-up supply**

Where the back-up water supply is to be provided via a Type AA air gap arrangement, this may be achieved by use of a factory assembled component similar to that shown in the next figure. This type of component is suitable for use to provide the back-up supply directly into an above ground tank or cistern or into a below ground tank via a suitable pipework arrangement. The solenoid valve is operated via a float switch located within the storage tank or cistern.

**Figure 1.35: Solenoid controlled Type AA air gap back-up supply**

**System module**

A system module is a factory assembled rainwater harvesting component station that contains the following components as a minimum:

- pump (suction)
- pump control with dry run protection
- back-up water supply connection arrangement with Type AB air gap.

A system module may also contain components such as a water level gauge. An example of a system module is shown in the next figure.

**Figure 1.36: System module**

**Desander**

Desanding consists in the separation of the water to be treated, whether primary or waste, from the sandy, mineral, clayey, etc., substances which, in addition to creating deposits in the pipes, could damage pumps or other equipment of the subsequent treatment plant. The separation takes place in a tank where the incoming water decreases in speed and remains for a sufficient time to sediment the sand contained in it.

**Figure 1.37: Desander configurations**

## 1.8 First Rain Basins

More and more frequently, designers and/or clients ask us for the difference between Continuous or Discontinuous First Rain Plants or Bathtubs (Storage and relaunch). It is very easy to come across very general titles and descriptions such as "first rain systems" without an explanation of the difference. In the following, it will be tried to explain in simple words the difference in these types of rainwater treatment.

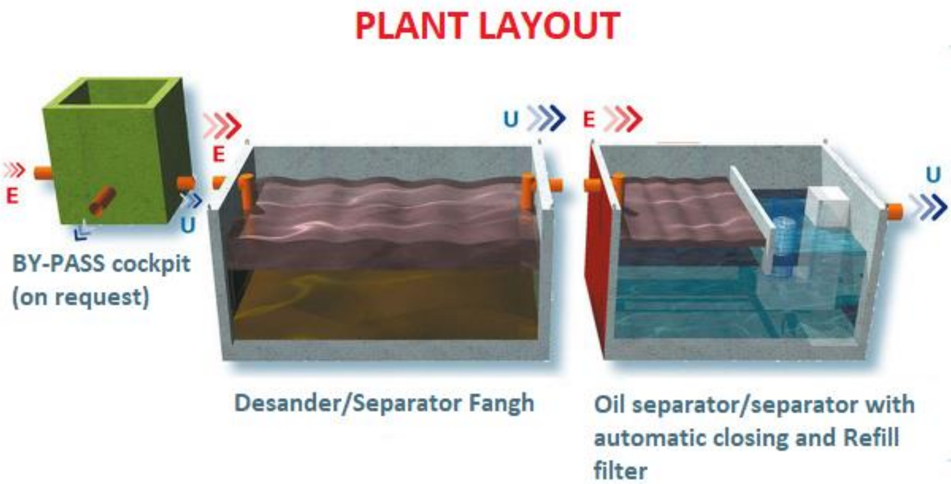



**Figure 1.38: Example of a Continuous First Rain System**

***Continuous First Rain System***

This type of first rain system provides for a "continuous" treatment and therefore in a constant manner throughout the duration of the meteoric event, is sized and designed always starting from the surface of the yard, but, in this case, the flow rate is the data that determines the size and volume of the prefabricated tanks. The calculation of the size of the plant is therefore the ratio between the surface area, the intensity of rain (which determines the flow rate of first rain of the first 15 minutes) and time of sedimentation separation oils (retention time).

***Discontinuous First Rain System***

Discontinuous systems, i.e. with spillway, "accumulation and relaunch" to the oil separator, are the traditional systems of first rain as described in most of the national, regional and provincial laws and guidelines. The characteristics that distinguish this system from the continuous one with by-pass are that the size of the first rain accumulation basin is established by the square meters of the waterproof surface of roads or parking lots multiplied by 5 mm, the result of this calculation is exactly the volume of first rain to be stored and retained before relaunching it to the gravimetric physical treatment with static separator (complete with coalescence filter and lamellar packs).

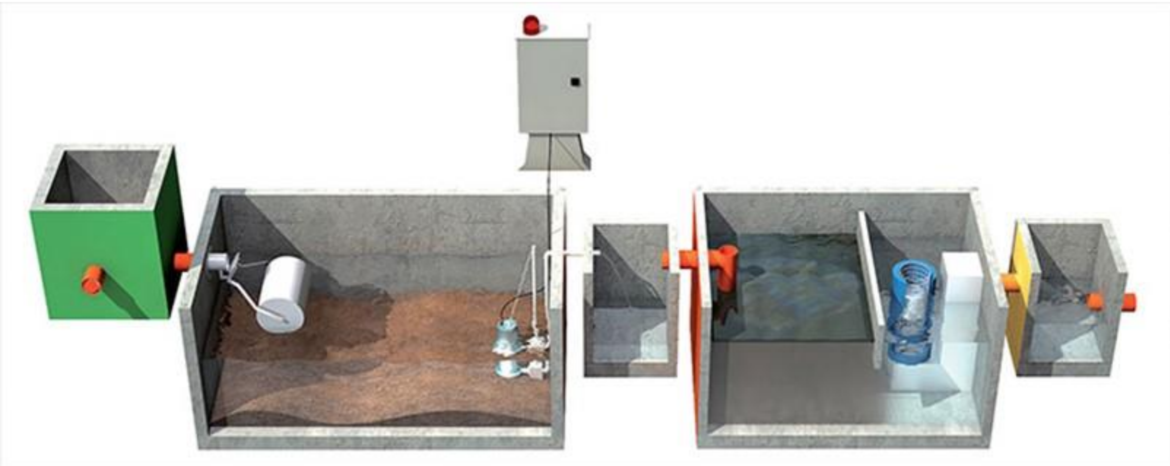


**Figure 1.39: Example of a Discontinuous type First Rain System**

## 1.9 System sizing

The design of a collection system consists in estimating the amount of water that can be obtained according to the available collection surfaces and the volume required to store them, which depends on the average distribution of rainfall and variations in use in different periods. It is necessary to take into account periods with little or no rainfall and from this point of view it is clear that the Mediterranean countries, where in summer periods of 60-80 days can occur without rainfall, are disadvantaged compared to countries in central and northern Europe.

In practice, for the same water consumption, a rain collection system in Italy requires a much larger storage tank than that required in countries with more regular rainfall distribution. In these cases it is possible to build a tank of certain dimensions, able to supply water for non-drinking uses for 8-10 months and, when it does not rain for long periods, to supply the tank with water from the aqueduct.

The sizing of rainwater tanks depends substantially on two factors:

- the net contribution of rainwater, i.e. commensurate with the intensity of precipitation, the receiving surface (for sloping roofs, only horizontal projection is considered) and the runoff coefficient;
- the need for service water, depending on the type of user, the number of users and the specificity of the services required. The amount of rainwater available should be used as much as possible to minimise integration with drinking water.

The standard contains the general requirements for the design, construction, operation and maintenance of systems for the recovery of rainwater for uses other than human consumption, in residential and similar; it is explicitly stressed that the distribution network of these waters must be absolutely separate from the distribution network of water for human consumption. Finally, it is specified that the water collected can be used for irrigation of gardens, the discharge of toilets, the washing systems of the relevant surfaces, and other non-drinking uses allowed by current legislation.

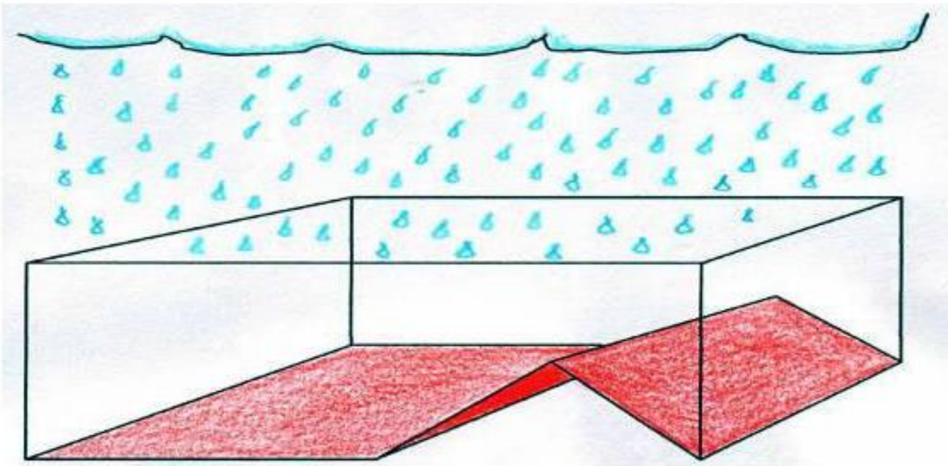


**Figure 1.40: Horizontal projection of the pitched roof**

The **maximum annual amount of theoretically cumulative rainwater is** calculated according to the following formula:

$$V= \varphi \cdot S \cdot P \cdot \eta$$

where:
$V$: maximum cumulative volume of rainwater [litres/year]
$S$: sum of the precipitation collection areas in horizontal projection [$m^2$]
$\varphi$: flow coefficient [%]
$P$: annual amount of precipitation [mm or litre/$m^2$]
$\eta$: filter efficiency [%] - it is necessary to use the indications given by the manufacturer concerning the fraction of the actually usable water flow downstream of the filter interception.

The flow coefficient considers the difference between the amount of precipitation falling on the surfaces of the collection system and the amount of water that actually flows to the storage system; it depends on the orientation, slope, alignment and nature of the collection surface, its values are shown in the following table:

**Table 1.2: Flow coefficient associated with various surface types**

| Type and nature of surfaces exposed to rain | Value of the flow coefficient φ (%) |
|---|---|
| **Inclined roofs with tiles, plastic corrugated, plastic or metal sheets; Flat roofs covered with plastic material or metal sheet.** | 90-100 |
| **Flat roofs with concrete or similarly paved slabs; Flat roofs covered with asphalt** | 80 |
| **Flat roofs with gravel coating** | 60 |
| **Intensive green roofs** | 30 |
| **Extensive green roofs** | 50 |

The **average annual demand** must then be calculated, using average values or by means of data sheets provided by system manufacturers, which, depending on the number of users, the type of equipment used and the intended irrigation use, allow the average annual quantity of service water to be established.

| Action | Water requirements (litres/inhabitant- day) | No. of habitants | Time (dd) | Water requirements (litres/year) |
|---|---|---|---|---|
| **WC rinsing** | 24 | 4 | 365 | 35,040 |
| **Washing machine** | 10 | 4 | 365 | 14,600 |
| **Cleaning** | 2 | 4 | 365 | 2,920 |
| **Summation of annual requirement (litres/year)** | | | | **52,560** |

| Irrigation use | Specific annual requirements (litres/m²) | Surface area (m²) | Water requirements (litres/year) |
|---|---|---|---|
| **Garden** | 60 | 100 | 6,000 |
| **Green areas with light soil (garden)** | 200 | 200 | 40,000 |
| **Total annual water requirement (litres/year)** | | | **46,000** |

**Total annual water requirement = 52,500+46,000= 98,500 Litres/year**

At this point, the average dry time is calculated, i.e. the number of weeks or days during which there may be no meteoric precipitation. This value can be derived from the analysis of rain data or evaluated by the following expression

$$T_{SM} = \frac{(365 - F)}{12}$$

where $T_{SM}$ is the average dry time [d], and *F* the frequency of rain, represented by the number of rainy days in a year [d].

The analytical determination of the storage volume is given, finally, by the following equation:

$$V_R = T_{SM} \cdot \frac{(Average\ annual\ needs)^*}{365}$$

where $V_R$ is the reserve water volume [litres].

**If the annual rainwater supply is higher than the total annual requirement, the latter is taken into account for the calculation of the tank volume, otherwise the average value between the cumulative annual volume of rainwater and the total annual requirement is used*.

***Example of dimensioning***
The calculation method is applied to the case of a single-family house with a flat roof of 250 m$^2$ of air-termination area, in tiles, located in Bologna, with an average annual inflow of 795 mm. It is considered a family nucleus made up of 4 people and having an open green area of property of 150 m$^2$, of which 50 m$^2$ for the vegetable garden and the remaining part for the garden.

Calculation of the annual rainwater supply (maximum quantity of water theoretically cumulable):

$$V = \varphi \cdot S \cdot P \cdot \eta = 0.9 \cdot 200 \cdot 795 \cdot 0.95 = 135{,}945 \text{ litres/year}$$

Calculation of the annual service water requirement:

- Toilets: 8,760 litres/year per user - 4 users = **35,040** litres/year
- Washing machine: 3,650 litres/year per user - 4 users = **14,600** litres/year
- Cleaning: 730 litres/year per user - 4 users = **2,920** litres/year
- Vegetable garden irrigation: (60 litres/year - m$^2$) - 50 m$^2$= **3,000** litres/year
- Garden irrigation: (200 litres/year - m$^2$) - 150 m$^2$= **30,000** litres/year

**Annual service water requirement = 85,560 litres/year**

Since the annual supply of rainwater (169,931 litres) is higher than the required water requirement (85,560 litres), the requirement is taken into account for the following calculations as a value of *V*. The dry weather that is considered is 24 days (the average for Bologna) with a return period of one year.

Calculation of the volume required for the water supply:

$$V = T_{SM} + \frac{V_{MC}}{365} = 24 \cdot \frac{85{,}560}{365} = 11{,}173 \text{ litres}$$

The optimal size of the tank to be used for rainwater storage is therefore 11.5 m$^3$.

The method described above does not seem entirely satisfactory, in fact it does not go into some aspects that need to be taken into account when designing a new plant. It does not allow, in fact, to determine the efficiency of the system, an important parameter in order to assess the convenience of the construction of a rainwater collection system. Furthermore, the assessment of water needs does not start from a realistic consumption analysis, but from predetermined values, which may deviate from actual consumption by a great deal.

**Cost analysis (estimated metric calculation)**

The following tables list some examples rainwater recovery plants with their prices and quantities with the aim of estimating a total cost for a case study.

- **Tank of 5.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for rainwater, reinforced with ribs, to be buried, walkable | 5,000 | 1,854.75 | 1 |
| Rainwater filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341.43 | 1 |
| Rainwater filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 428.91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3$/h, head from 15 to 40 m, control device with float switch | - | 1,764.48 | 1 |
| **Total** | | 4,389.57 | 4 |

- **Tank of 6.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for rainwater, reinforced with ribs, to be buried, walkable | 6,000 | 2,297.87 | 1 |
| Rainwater filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341.43 | 1 |
| Rainwater filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 428.91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3$/h, head from 15 to 40 m, control device with float switch | - | 1,764.48 | 1 |
| **Total** | | 4,832.69 | 4 |

- **Tank of 10.000 lt**

| Description | Volume [l] | Price [€] | Quantity |
|---|---|---|---|
| Polyethylene storage tank for rainwater, reinforced with ribs, to be buried, walkable | 10,000 | 3,676.79 | 1 |
| Rainwater filter to be installed in outdoor drains. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 341.43 | 1 |
| Rainwater filters to be buried in the ground, with continuous height and level compensation manhole cover and cover plate. Made of polyethylene, filter mesh 0.2 mm, for rainwater collection surfaces up to 300 $m^2$ | - | 428.91 | 1 |
| Pumping unit with centrifugal pump and control unit, automatic supplementary drinking water supply, overflow connection with manhole cover, pressure switch, pressure gauge and dry run protection. Complete with fixing and connecting material. Max flow rate 4 $m^3$/h, head from 15 to 40 m, control device with float switch | - | 1,764.48 | 1 |
| **Total** | | 6,211.61 | 4 |

## *Unit 2: Installation, commissioning and maintenance of rainwater collection systems*

**General description**

In the 2nd Unit of Module 4, the techniques applied for the installation, commissioning and proper rainwater harvesting, taking into account the water-energy efficiency requirements, the operation of accessories and other parts of the rainwater harvesting system, the methods and/or techniques that can be applied to ensure the proper operation of the rainwater harvesting system, as well as the rules and standards (local, national, international) applicable to rainwater harvesting systems will be presented to the trainees. Therefore, the trainees will improve their ability to interpret the design of the rainwater harvesting system and the sizing characteristics, taking into account the water-energy efficiency requirements, to establish the sequence of installation of the rainwater harvesting system, to ensure proper operation and provide an estimate of the work to be carried out to implement the system. Maintenance of rainwater harvesting systems will be presented to the trainees in order to improve their knowledge of the operational characteristics of the components of the collection system.

**Scope – Expected results**

With the completion of this Unit, the trainees will be able to:

- install the various rainwater storage and recycling systems
- install the components of the storage system and carry out the excavations in compliance with health and safety regulations
- carry out ordinary and extraordinary maintenance work
- analyse maintenance costs

**Key words / basic terminology**

Maintenance, Hydraulic and electrical connections, Drainage, Excavation, Cost analysis, pipework test requirements.

## 2.1 Considerations for installing underground storage tanks

The location and method of installing an underground storage tank will vary from site to site and should be determined in relation to:

- manufacturer's instructions
- ground strength and stability
- ground water levels
- proximity of trees
- proximity to utilities
- proximity to foundations
- shading and temperatures
- access routes.

**Manufacturer's instructions**

The instructions of the manufacturers of storage tanks should be the first point of reference for planning and installing a storage tank. Some manufacturers produce tanks that can simply be placed in an excavation of adequate size and filled, without the need for a base or side support. Other manufacturers require the supply of a base and may specify that a certain type of material is used to fill the area immediately surrounding the tank. Manufacturers' requirements will be influenced mainly by the type of material used to manufacture the tank.

**Soil strength and stability**

As with above-ground storage tanks, it is essential that an underground storage tank is located in a sufficiently strong and stable position to support the load that will be imposed by the storage tank when it is full. Some soil conditions, such as clay, may not offer adequate strength and stability. It is unlikely that the soil conditions in which the peat is present are suitable due to the compressive properties of the peat.

**Groundwater levels**

Ideally, an underground storage tank should be placed in a position that is above the normal groundwater level. In cases where this is not possible and there is no alternative to using an underground storage tank, the installation method shall provide protection against the tank floating in the ground when the surrounding water level is higher than the tank base. This normally requires the storage tank to be completely embedded in the concrete.

**Proximity of trees**

The roots of the trees are looking for moisture. Therefore, it is not recommended to place an underground storage tank near the trees, as this could cause damage to the roots of the trees or entry into the storage tank.

**Proximity to utilities**

Some storage tanks will be made with materials that can be permeated by substances such as natural gas. Therefore, underground storage tanks that are susceptible to permeation should not be placed in the vicinity of users that pose a risk of permeation of the storage tank and contamination of the stored water. It seems appropriate to keep at least 350 mm between an underground storage tank and a gas service pipe, unless the manufacturer of the storage tank requires a greater separation distance.

**Proximity to foundations**

The installation of an underground rainwater collection system must not entail any risk of a building collapsing. To avoid this risk, it is a typical requirement that no digging is carried out for the installation of an underground tank, or an exhaust pipe feeding the tank, within the area shown in Figure 1.2.

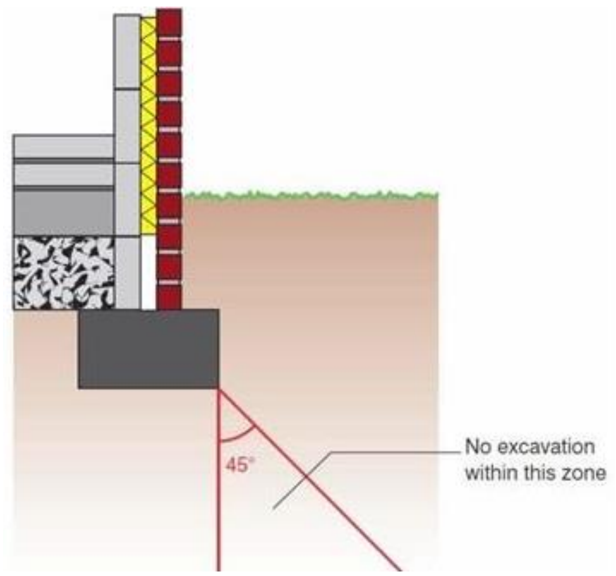



**Figure 2.1: Typical non-excavation zone**

[Source: Aquavet Handbook, CONAIF, July 2016]

**Shading and temperatures**

It is important that the rainwater collected is stored at a temperature that does not encourage or encourage the multiplication of legionella. The location of the storage tank in relation to the solar energy path is a key factor affecting the temperature of the stored water. A shady place is preferable.

**Access routes**

There are two considerations regarding access routes:

1. The load that an underground storage tank would be subject to if it were located under an access road. When choosing a traffic loading location, such as a driveway, the method of installation and the function of components such as access covers must be adapted to the load that will be imposed during the use of the access road.
2. Access to the storage tank for inspection, service and maintenance.

When installing an access cover to the underground storage tank, it is important that the access cover is installed flush with or above ground level and that the area around the access cover is free draining to prevent surface water from entering the storage tank through the access cover.

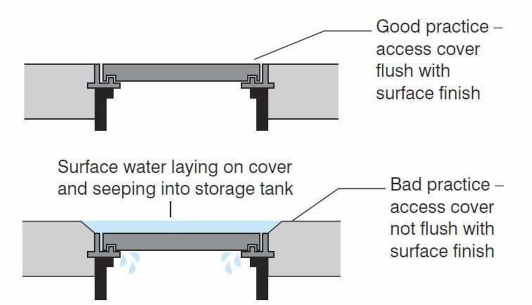



**Figure 2.2: Good and bad practices of access cover installation**

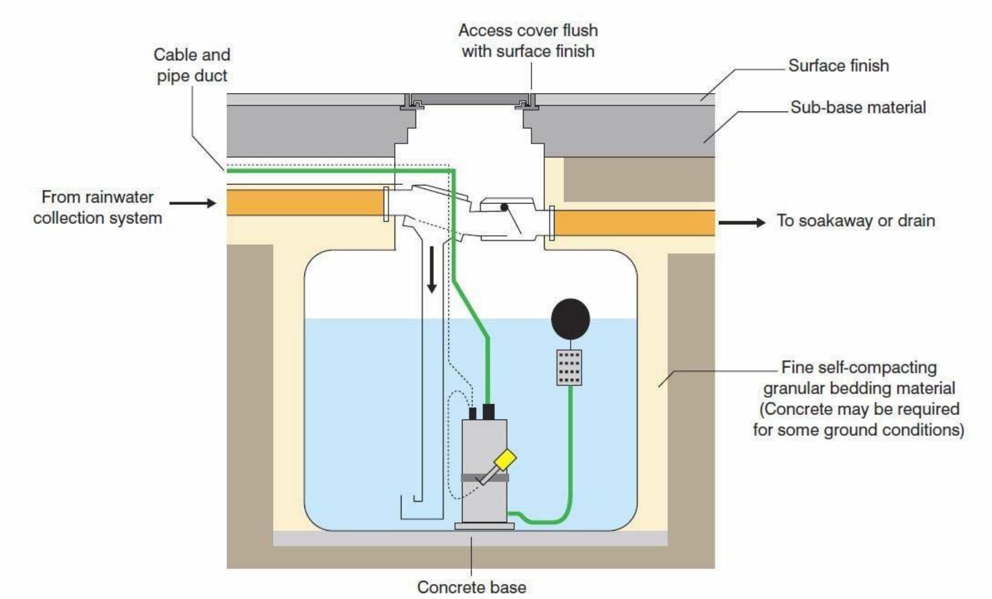


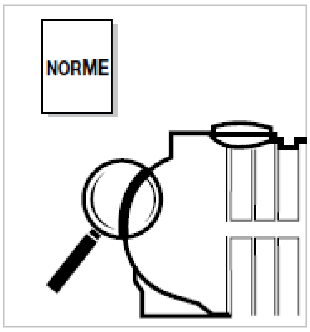

**Figure 2.3: Example of installation of an underground storage tank**

Note: The installation arrangement shown in Figure 2.3 is not intended and should not be used as an example of installation detail. The installation layout used must take into account all regulatory requirements, the instructions of the manufacturer of the components and adapt as best as possible to the characteristics and constraints of the installation site.

## 2.2 Methods of handling, laying and use of underground tanks

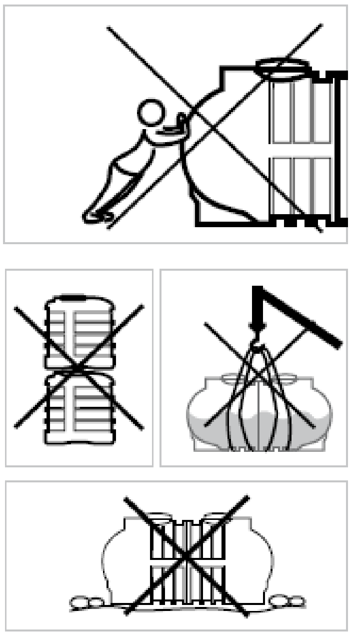
### *2.2.1 Preliminary work*

- **Standards:** During all operations, the safety and hygiene regulations in the workplace and subsequent modifications and integrations on the safety of temporary and mobile work sites must be respected. Before laying, carefully check the integrity of the tank.




- **Handling and use:** Harness the tank with suitable ropes of adequate capacity or use the appropriate eyebolts for lifting. The means used for lifting and handling must be of adequate capacity and comply with the regulations in force. Do not place the tank near any heat sources. During the handling work, delimit the affected area with appropriate signs.

- **Loading and unloading:** The loading and unloading operations must be carried out with care: the tanks must not be thrown or made to crawl on the sides of the vehicle, loading or unloading them from the same, but must be lifted and placed with extreme care. When storing, be careful not to stack tanks that could be damaged.

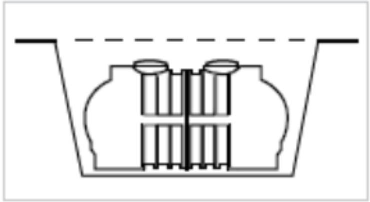


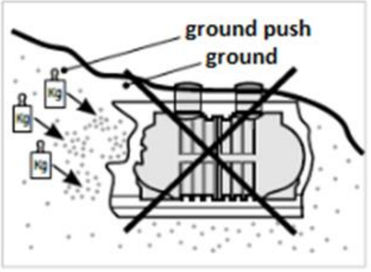
DO NOT HANDLE THE PRODUCT OR PARTIALLY FILL IT.

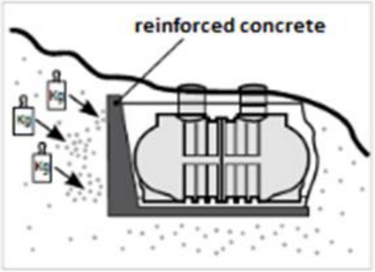
### *2.2.2 Preparation of excavation and bedding*

➢ **Preparation of excavation and bedding**

The tanks must never be placed in landslides, on slopes, close to slopes that carry the load on the structures, or in positions subject to rainwater drainage. In such situations, it is absolutely necessary to use a qualified technician to define the most appropriate actions to be taken for a proper solution of the case

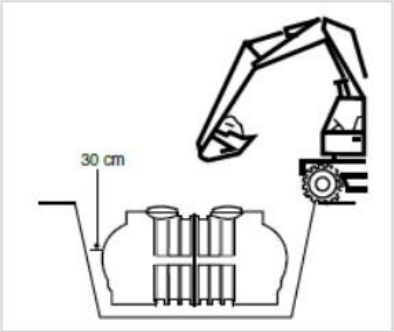




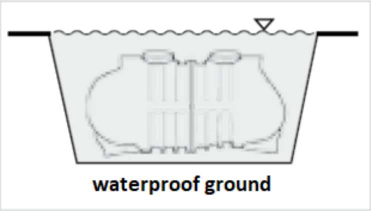




➢ **Excavation**

**Excavation dimensions:** Prepare a flat-bottomed hole of suitable dimensions with self-supporting walls, so that a space of about 30 cm remains around the tank

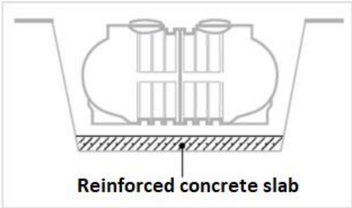



**Drainage:** In the case of impermeable clay and/or loamy soils, in order to prevent the tank from being subjected to different pressures due to the accumulation of water in the excavation during the weather events, it is advisable to provide for a drainage system. If it is not present or not possible to remove the water from the excavation site, follow the instructions in the paragraph "Excavation in the presence of a water table".

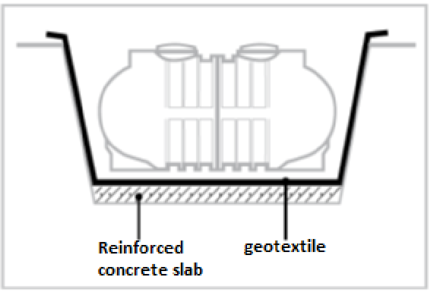



**Type of ground:** In case of non-homogeneous soil, prepare on the basis of the excavation, a distribution slab in reinforced concrete of adequate strength, calculated by a qualified technician.

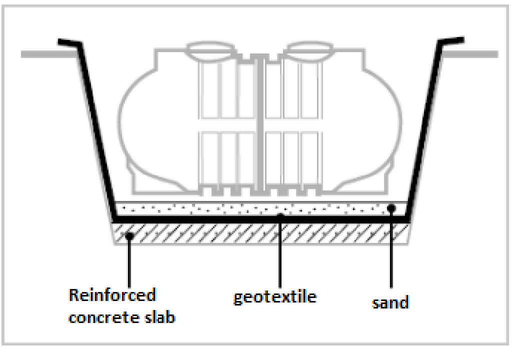
N.B: The reinforced concrete slab must always be made in case of installation of modular and/or ribbed tanks



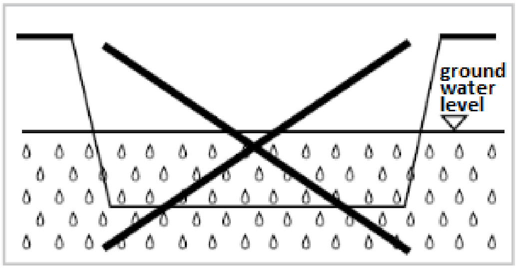

**Coating:** Cover the walls of the excavation with geotextile to avoid dragging the tank backfill material with the formation of vacuum zones that cause different pressures on the tank itself.

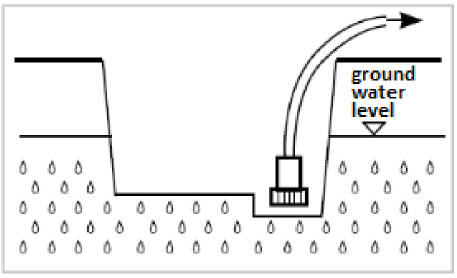



**Laying bed:** Make a sand bed of at least 5 cm on the base of the excavation or above the support slab so that the tank rests on a uniform, compact base and not directly in contact with the base of the excavation or the reinforced concrete plaster.




**Excavation in the presence of groundwater:** During the excavation phase it is essential, in order to be able to work correctly, that the installation site of the tank is in dry conditions; therefore, if there is presence of water from a shallow water table, it is advisable to eliminate it by using, for example, water pumps. Create a reinforced concrete subfloor suitable for the sub-thrust of the water table.

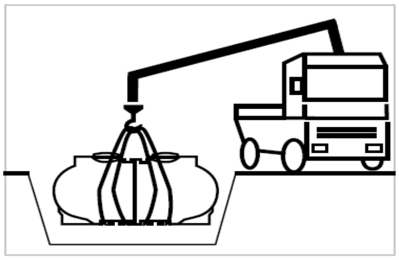


### *2.2.3 Positioning the tank and anchoring*

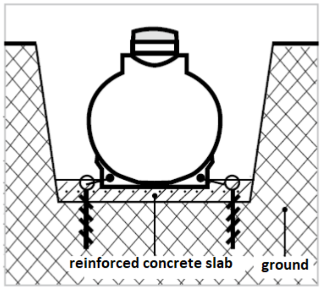
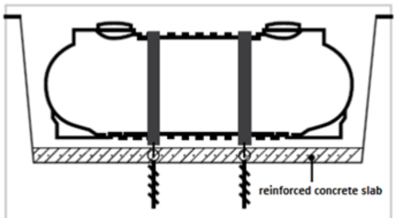
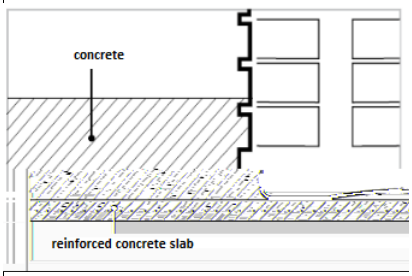
- **Tank positioning**

Before laying the tank in the excavation, it is necessary to make sure that the gaskets, pipes and all parts other than the polyethylene present in the tank are suitable for the liquid to be contained.



- **Anchorage**

During the construction phase of the foundation, plan and position the underground anchoring points near the tank, according to the overall dimensions indicated in the technical data sheets supplied and taking into account the type of product supplied.

| **Type 1** | **Type 2** | **Type 3** |
|---|---|---|
|   |   |   |
| To anchor these types of tanks it is sufficient to pass a steel tube (Ø 50-60) through the holes in the support feet, and connect it to the anchors already provided in the concrete. | To anchor these types of tanks to the slab it is sufficient to adopt appropriate steel or nylon bands, with a pitch of 2 m, which will be connected with the anchors already prepared in the concrete. | To anchor these types of tanks to the foundation slab it is sufficient to make a layer of concrete to cover the first layer of the structure. |

NB: Anchorage is mandatory whenever it is necessary to build the reinforced concrete slab.

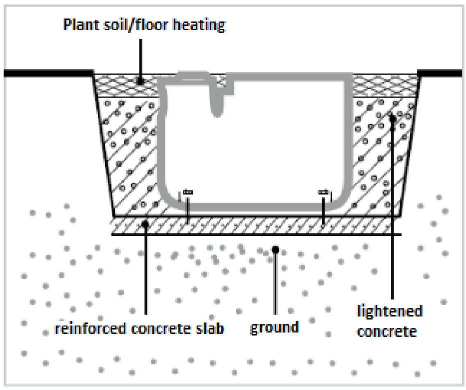
### *2.2.7 Positioning of lifting tanks*

**Preliminary remarks**

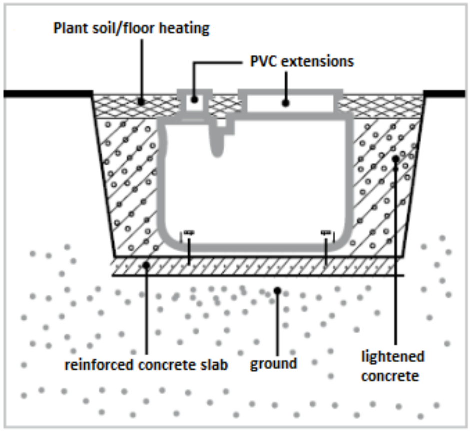
For the operations of handling, transport and positioning of the product, please refer to what has already been mentioned in the previous paragraphs. Particular attention should be paid to the paragraph related to "Venting".

➢ **Anchorage**

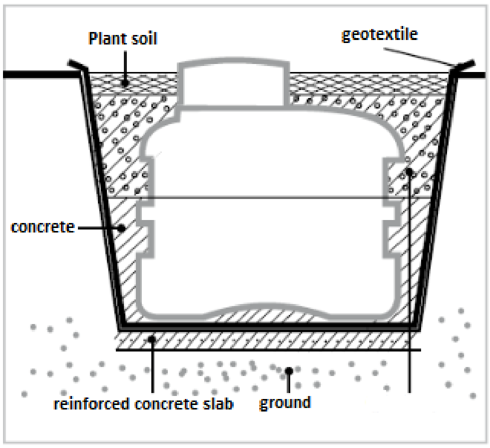
**Smooth bathtubs:** Place the tank on the slab and make holes in the slab in correspondence with the appropriate fixing seats made on the base of the product. Then insert some fisher into the holes made and hook the tank.




In order to reach the level of the walking surface, it is possible to insert on the lids of the tanks extensions with PVC lids of standard size commonly available on the market.



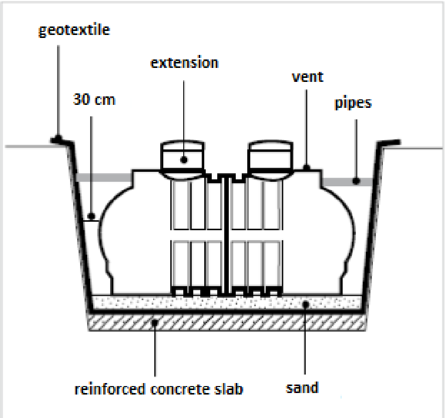

**Corrugated tubs:** Make a cement ring connected to the support slab until the first nerve of the product is completely covered from below.




### *2.2.7 Hydraulic and electrical connections*

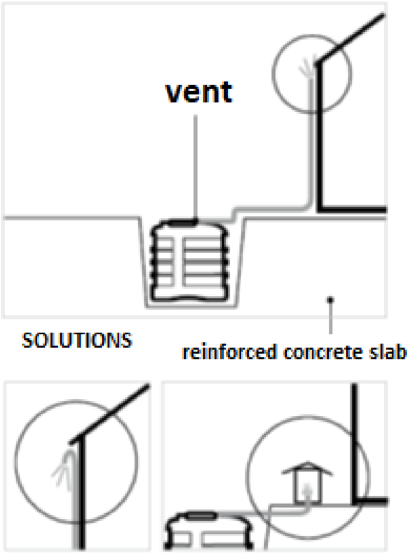
➢ **Hydraulic connections**

Connect and test the connections to the inlet and outlet sockets supplied with the tank. If necessary, place the supplied extensions as recommended accessories at the inspection points, making them integral with the product.



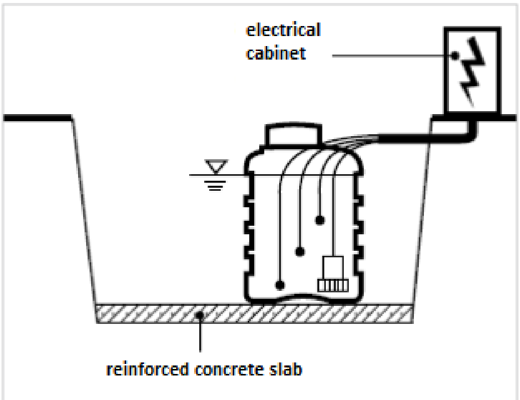

➢ **Venting**

Make sure that the vent is free to prevent the tank from going into vacuum. Connect the tank to the ventilation pipe of the house, i.e. it must be sent to a suitable place where it cannot be blocked; always and in any case at a level higher than the height at which the tank cover is laid.




- **Electrical / electromechanical connections**

Before re-inflaming the tanks, according to the procedures described below, for structures in which electromechanical equipment is installed, it is necessary to create wells and sheaths for the protection of electrical cables that will be connected to panels or external equipment, as indicated in the wiring diagrams and in the "use and maintenance manual".



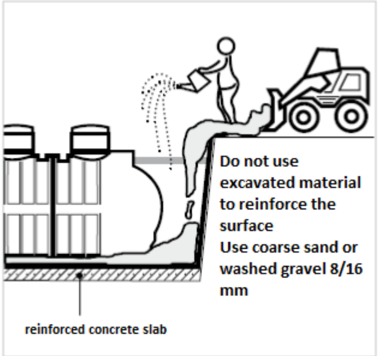

### *2.2.7 Excavation and backfilling of soil*

- **General warnings**
  - In order to avoid abnormal deformation on the tanks and inspection towers, during the rhinestones, keep the water level inside always above the rhinestones level.
  - Special care must be taken to facilitate the uniform compaction of the backfill material on the total external surface of the product to avoid the formation of air pockets that exert differential pressures on the tank causing it to deform and/or break.
  - Covers and plugs may only be removed for the purpose of filling the tank and must be replaced during backfilling operations.
  - It is forbidden to fill the tank outside the excavation.

– NEVER use excavated material to reinforce the surface.

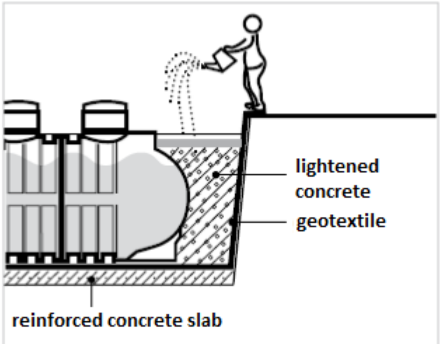
➢ **Always full tanks**

Proceed in successive layers of 15/20 cm, first filling the water tank and then fill in as shown in the figures (use coarse sand or round washed gravel max 8/16 mm). Facilitate the compaction of the backfill material by using a jet of water until the tank cover is reached.



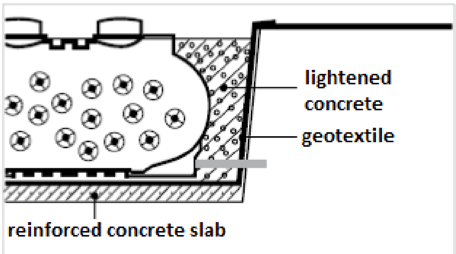

➢ **Bathtubs (also empty) in operation**

Proceed in successive layers of 15/20 cm, first filling the water tank and then fill in as indicated in the drawing with lightened cement or cement mix. It is necessary that the cement used for filling is in the liquid state in order to cover the entire external surface of the tank until it reaches its upper generator.



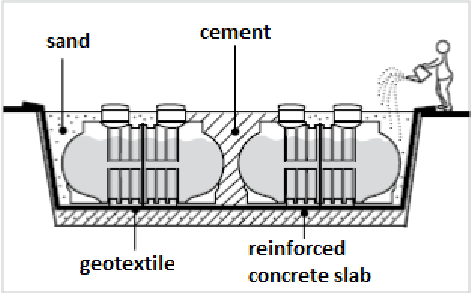

➢ **Always empty tanks with low outlet**

Reinforce with cement mixed lightened concrete, taking care to insert the filling material slowly and constantly, without creating dynamic stress on the walls of the tank. It is necessary that the cement used for filling is in the liquid state in order to cover the entire external surface of the tank.



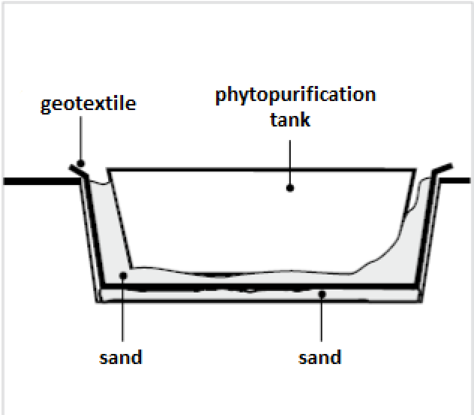
- **Multiple tanks in the same excavation**

Proceed in layers of 15/20 cm, first filling the water tanks and then fill in with lightened or cemented mixed cement. The tanks should be filled with washed sand or round gravel (max. size 8/16 mm) mixed with cement or using lightened cement. On the perimeter sides of the excavation, the filler suitable for the use of the tanks themselves (full or empty) must be used. Facilitate the compaction of the backfill material by using a water jet.



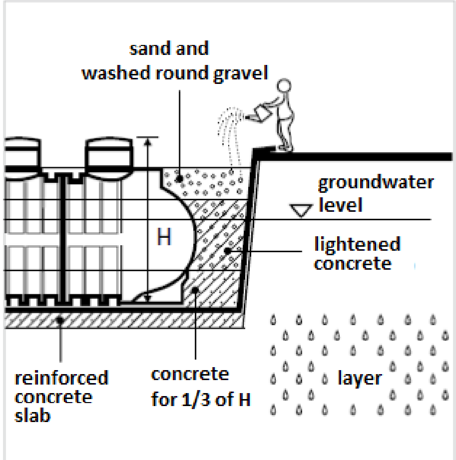

- **Phytopurification tanks**

After digging a flat bottom of suitable size, make a bed of 5 cm with a surface at least higher than the base of the tank. Cover the walls of the excavation with geotextile. Backfill with washed sand or gravel at the same time as filling the tank according to the instructions in the appropriate chapter of the user's manual, biological treatment.

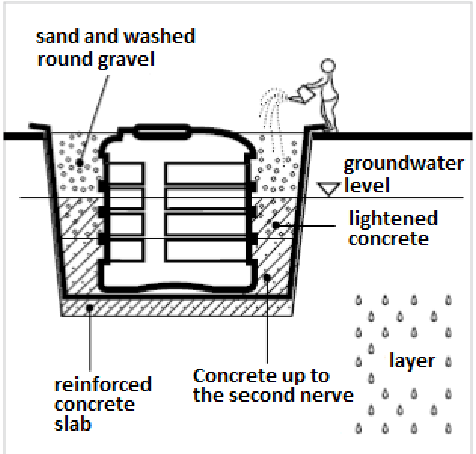



- **Reinforcement in groundwater, clayey soil or similar area**

**Classic tank:** Once the reinforced concrete slab has been created and the structure anchored, fill the tank with water to a thickness equal to about 1/3 of its height and reinforce it externally with concrete to the same thickness.




**Corrugated tank:** Fill the tank with water until the first layer of water is covered and cover it externally with concrete for the same thickness.



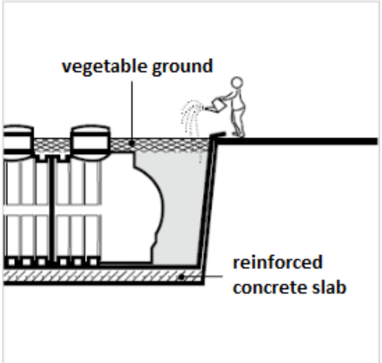

- **Filling finish**

After backfilling with concrete, proceed in successive layers of 15/20 cm, first filling the water tank and then backfilling it with cement mix or lightened concrete, up to a height higher than the maximum level of the water table. It is necessary that the material used for the filling is in the 'liquid' state in order to cover the entire external surface of the tank until reaching the upper generator of tank coverage. Finally, cover the product with a layer of washed round gravel and sand, until it is completely covered.

### *2.2.7 Restoration of excavation, pedestrianization and driveability*

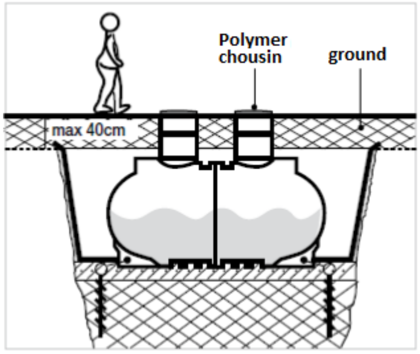
- **General information**

Once the tank has been covered, until the upper covering generator is reached, it is possible to proceed with the operation of restoring the excavation with vegetable soil, until the level of footsteps has been reached.



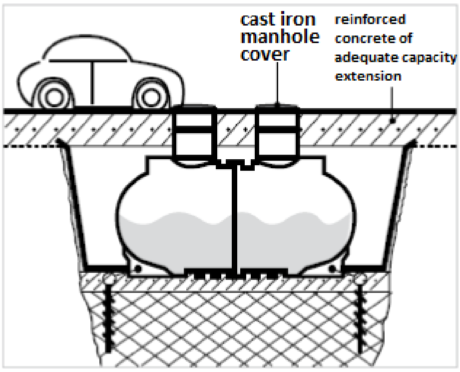

- **Walkability of the interrogation zone**

The walkability of the area surrounding the burial of the structures is guaranteed for a maximum depth of 40 cm (carried out according to the methods described in this sheet) from the upper generator of the tank to the finished ground level. If it is necessary to install inspection wells (concrete or cast iron), they must not weigh on the tank.



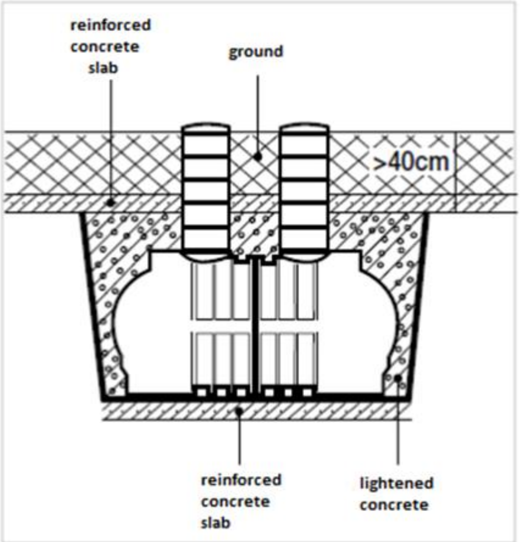

- **Driveability of the interrogation zone**

The driveability is guaranteed only in the case of the construction of a special slab covering the tanks that discharges all the pressure into the ground outside the perimeter of the excavation area where the tanks are to be laid. Furthermore, the installation of the cast iron frames and covers for the inspection of the tanks must be integral with the covering slab.



➢ **Laying at a height of more than 40 cm above ground level**

Proceed in successive layers of 15/20 cm, first filling the water tank and then reinvigorating as indicated in the drawing with lightened cement or cement mix. Facilitate the compaction of the backfill material by using a jet of water until the tank cover is reached. Make a reinforced concrete slab dimensioned and calculated by a qualified technician who takes into account the loads of the ground above and who weighs its loads on the perimeter outside the excavation or on suitable anchorage points (plinths or perimeter walls). Complete the filling of the excavation with vegetable soil/reinforced concrete slab, until the level of footsteps is reached according to the requirements of pedestrian mobility.



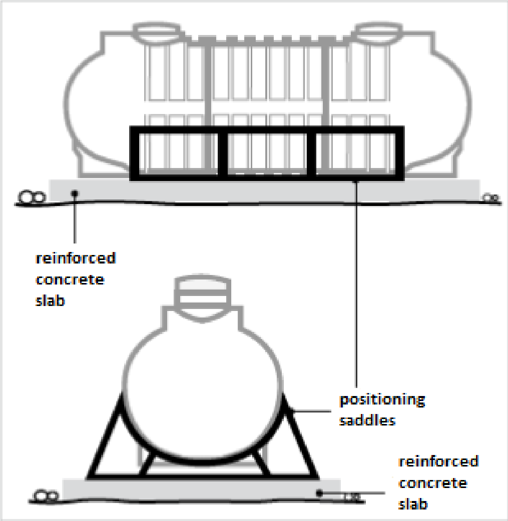

## 2.3 Above ground tank positioning

➢ **General information**

For handling and transport, reference should be made to the information already mentioned in the specific paragraphs.

➢ **Installations for tanks type**

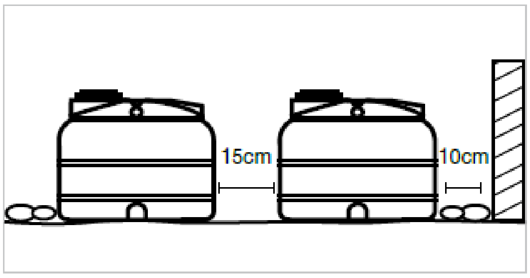
Make a suitably levelled reinforced concrete support slab, designed for the loads pertaining to it and for the type of ground in which the structure is installed, and position the tanks on top of it with the relative support saddles.



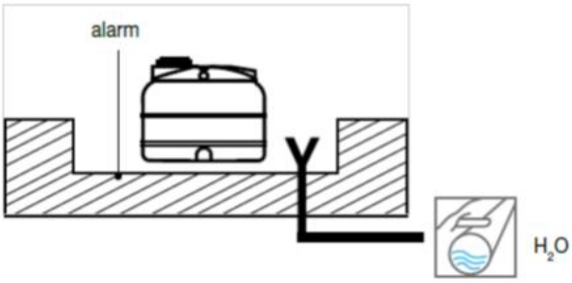

## 2.4 Positioning of communicating tanks

### *2.4.1 Positioning the tanks*

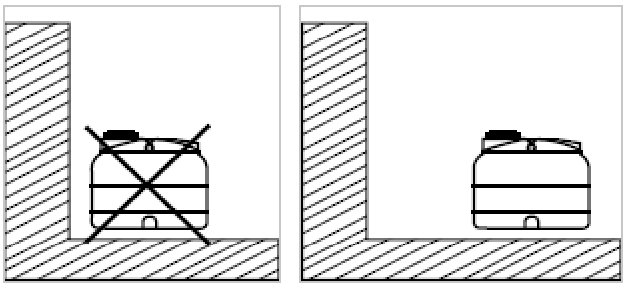
Before positioning the tank, the installation site must be cleaned of any debris that may damage it. Place the tanks on a flat surface (max. slope 4‰), which is stable, smooth, even, clean of waste and resistant to the weight of the full tank. Position the tanks in such a way that they do not come into contact with each other (spaced at least 15 cm apart) or with obstacles (spaced at least 10 cm apart) due to the expansion that the filling and the temperature may cause.



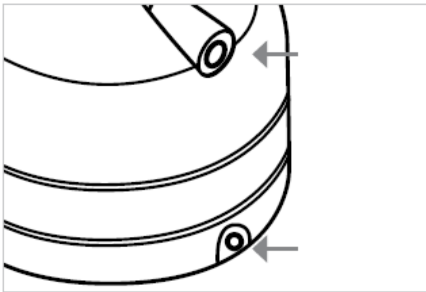

Provide for adequate containment/removal works, with specific leakage detection controls, in the case of use of tanks as a water reserve for autoclaves, containment of liquids other than water and in all cases of use of tanks with automatic filling/emptying systems.




In order to perform normal maintenance, install the product so that it can be easily carried out. Avoid making parts in masonry that would compromise the possibility of carrying out maintenance or replacing the tank itself.

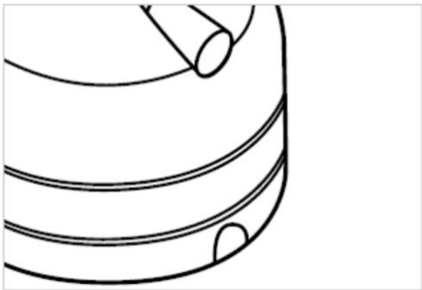


Make sure that gaskets, pipes and all parts other than the polyethylene present in the tank, are suitable for contact with the liquid contained.

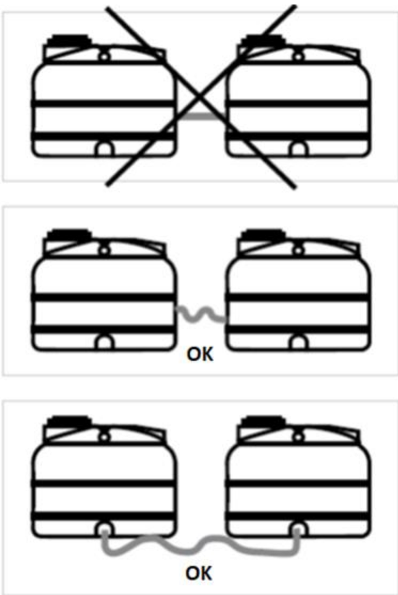


### *2.4.2 Connections*

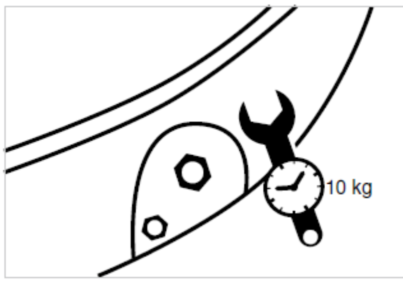
The tanks can be drilled in correspondence of the present flat parts and equipped according to the specific needs. Connect and test the various connections ensuring that the vent is free and sufficient to prevent the tank from operating in pressure / depression.



The connection to brass, plastic or other fittings must be made by means of flexible hoses and, if necessary, by placing pipe supports so that the connection section is not stressed.




In order not to compromise the tightness of the hydraulic connections, do not over-tighten the fittings on the polyethylene, thus yielding the material; as a mere indication, a maximum tightening torque of 10 kg·m will suffice.




### 2.5 Pre-installation checks

For the installer of a rainwater harvesting system, it is good industrial practice to carry out a series of pre-installation checks before starting work on site. This is particularly important if other personnel have undertaken the system design and/or initial site inspection.

| **Control requirement** | **Elements to be controlled** |
|---|---|
| Has the necessary authorisation been obtained for the start of work? | Has the installation been notified to the competent water company and its authorisation to the installation been granted?<br>Do I need planning permission or building permission?<br>If so, have they been obtained? |
| Is there adequate access to all required work areas? | Are there secure pedestrian access and exit routes?<br>Is vehicular access required? If so, is there a safe route available?<br>Are there any equipment available for access at height in relation to the dangers and risks? |
| Is the storage capacity | A basic cross-check, using the simplified approach, that |

| | |
|---|---|
| Appropriate for the installation situation? | Storage capacity is relevant in relation to roof area, average annual rainfall and number of occupants. (Residential projects with tiled roof inclined only for the collection of tiles). |
| Are the structure of the building and the fabric suitable for the installation of the system? | Is the structure considered solid and suitable for any load that will be imposed by the installation (visual inspection only)?<br>Are the building conditions adequate, in particular the conditions of existing roofs and existing rainwater systems? |
| Is the existing water system suitable? | Are all identified supply points suitable for rainwater supply?<br>Is there a suitable location for connecting the backup power supply? |
| Is the existing rainwater gutter suitable? | Are the conditions of the existing plant adequate?<br>Do the installation layout and processing standard support free drainage to the storage tank without the risk of water stagnation? |
| Is a suitable electrical input service available or has a suitable electrical input service been specified? | Is the service suitable?<br>Does the service have the correct degree of overcurrent protection for the circuit?<br>The security status of the service has been confirmed<br>Is the power supply in an easily accessible location but also protected by unintentional isolation or disconnection of the power supply? |
| Is the proposed location of the key components of the internal system appropriate? | Does the proposed location of the components meet the standards, the manufacturer and, if applicable, any customer requirements? |

## 2.6 Pre-testing and commissioning requirements

The development of knowledge and skills for the testing, commissioning and delivery of rainwater is best covered through practical and/or demonstration activities. Therefore, this section focuses on some specific testing, commissioning and handover topics to complement practical training and/or demonstration activities. This section deals with the following:

- requirements for pre-testing and commissioning;
- requirements for hydraulic tests;
- requirements and procedures for cross-linking tests;
- requirements for commissioning;
- requirements for registration of commissioning requirements for system delivery.

All testing, commissioning and delivery work must be carried out in accordance with regulatory requirements, manufacturer's instructions and with due diligence in relation to existing health and safety risks.

### *2.6.1 Requirements for pre-testing and commissioning*

It is good industrial practice for the installer of a rainwater harvesting system to undertake a series of preliminary tests and commissioning checks before starting testing and commissioning activities. This is particularly important if the installation was carried out by other personnel. The following table identifies a set of requirements for pre-installation checks and outlines the key elements to be performed for each check requirement.

If the installation is commissioned by the same person who carried out the installation, some of the checks listed in the table may have been carried out in the pre-installation phase and, in this case, it is not necessary to repeat the installation.

**Table 2.1: Requirements for pre-testing and commissioning control**

| **Control requirement** | **Elements to be controlled** |
|---|---|
| Compliance with system design and specifications | • The correct type and grade of components were installed correctly<br>• All components are installed in the positions and layouts specified in the design and system specifications |
| Compliance with manufacturer's instructions | • All components are installed according to the manufacturer's instructions |
| Regulatory compliance applicable | • Installation complies with all relevant aspects of building codes and water standards/regulations<br>• There are no cross-links between the grey water distribution system and the healthy water system<br>• The installation process did not lead to the building becoming less compliant with building regulations / water regulations than before the start of installation work |
| Tanks and cisterns | • Adequate basic support and, where appropriate, full support in accordance with the manufacturer's instructions and regulatory requirements and/or the technical guides of each country.<br>• The installation of the tank does not lead to an excessive load on the structure of the building (only visual inspection)<br>• All filters, vents, lids and any insulation are properly installed in accordance with the regulatory requirements, manufacturer's instructions and / or technical guides of each country<br>• All access covers to the underground tank are appropriately classified according to the load they will receive<br>• Appropriate overflow devices comply with the regulatory requirements, manufacturer's instructions and/or technical guides of each country<br>• Multiple installations of tanks/reservoirs are connected to provide a continuous flow and avoid stagnation<br>• If necessary, an anti-overload valve is installed.<br>• Submersible pump (if installed) is correctly positioned (visual inspection only)<br>• Submersible pump (if present) has dry run protection<br>• The immersion depth of the submersible pump (if installed) meets the requirements of the pump manufacturer<br>• The submersible pump (if present) has a non-return valve and a shut-off valve to allow service and maintenance of the pump. |
| An adequate electrical input the supply is provided | • Is the power supply circuit protected by a residual current detector?<br>• Does the service have the correct degree of overcurrent protection for the circuit?<br>• Has the security status of the service been confirmed?<br>• Is the power supply in an easily accessible location but also |

| | |
|---|---|
| | protected by unintentional isolation or disconnection of the power supply? |
| Plant washing | • The system has been rinsed or will be rinsed of all system debris, including the rinsing of any residual cleaning agent. |
| Filling the storage tank | • The storage tank has been filled according to the manufacturer's instructions.<br>(Note: some manufacturers may specify a controlled filling process)<br>• The water level is correct and, if installed, the water level gauge works correctly. |
| Ready for backup power supply | • A type AA or AB air gap is provided<br>• The backup power is not supplied through a dead leg unless it is inevitable<br>• If fed by a dead foot, a single non-return valve has been installed adjacent to the connection of the spare supply branch. |
| Provision of marking and labelling in accordance with water regulation / water byelaw requirements | • All distribution pipes are correctly marked and labelled<br>• All storage tanks and tanks (or their access lids) and points of use provided by the wastewater reuse system are correctly marked and labelled.<br>• The main shut-off valve of the saltwater is correctly marked and labelled to identify the installation of a rainwater reuse system. |

### *2.6.2 Requirements and procedure for cross-connection tests*

A dye test should be carried out to ensure that there are no cross connections between the rainwater harvesting system and the wholesome water system pipework. It is recommended that the local water supply undertaker is contacted prior to the cross-connection dye test being carried out as they may wish to witness the test. The following items are needed to undertake a cross-connection dye test:

- two pumped test units;
- dye/colouring.

A pumped test unit is simply a unit with a storage container large enough to hold the required amount of test fluid and a pump to circulate the test fluid. The cross-connection colouring test is usually performed using a bright food colouring such as cochineal E124.

The cross-connection dye test procedure is given below:

1. Temporarily disconnect the system at the point where the internal distribution pipework begins and temporarily cap off the distribution pipe at the point of entry.
2. Connect pumped test unit 1 to the distribution pipework using a temporary connection. Add water containing a suitable dye to the test unit.
3. Temporarily disconnect the mains wholesome water supply at the point where the internal distribution pipework begins.
4. Connect pumped test unit 2 to the mains wholesome water supply pipework using a temporary connection. Add wholesome water to the test unit.
5. Open all in-line service valves on both pipework systems.
6. Draw water through all outlets and check for a dyed water discharge. Where the system supplies a washing machine, the connection hose should be temporarily disconnected from the machine

before water is drawn through.

7. Draw water through all wholesome water outlets and check for a clear wholesome water discharge.

If the dyed water from pumped test unit 1 is discharged through any wholesome water outlets, the cause must be investigated and rectified.

### *2.6.3 Commissioning requirements*

As stated at the start of this section, all testing and commissioning activities should be undertaken in accordance with manufacturers' instructions. The commissioning requirements will vary according to the system type. Table 2.2 identifies some typical commissioning activities and check requirements.

**Table 2.2: Commissioning requirements**

| Control requirement | Elements to be controlled |
|---|---|
| Collection pipework | • No signs of leakage and/or dampness (post-test visual inspection only)<br>• An air test has been carried out to confirm that the system is leak free<br>• Collection pipework is free draining or has siphonic action<br>• All filters are correctly positioned, secured and clean |
| Distribution pipework and System | • Check and record pressure vessel charge pressure (if fitted)<br>• A hydraulic test has been carried out in accordance with national legislation<br>• A cross-connection test has been carried out<br>• Flow rates at all supply points are acceptable |
| Back-up water supply | • The back-up water supply operates correctly (functional test) |
| Whole system | • All manufacturer's commissioning requirements have been carried out<br>• Installation is compliant with manufacturer's requirements<br>• The installation is compliant with all relevant regulations<br>• System alarms and warning devices operate correctly<br>• Water levels are correct and, where fitted, the water level gauge is functioning correctly<br>• System controls are set for efficient operation |

Water quality testing is not normally undertaken as part of the commissioning process as systems are generally filled with mains water and therefore the water quality is unlikely to be representative of the water quality during normal system use, i.e. when the system is filled with rainwater.

The first water quality test is normally carried out as part of the first routine maintenance inspection. However, where there is greater human exposure to the harvested rainwater such as in public buildings, or where the users of the system are particularly vulnerable if exposed to contact with contaminated water, a water quality test may be required after the first significant period of rainfall.

### *2.6.4 Commissioning record requirements*

All commissioning activities should be recorded and the record passed to the end user as part of the handover process. Some manufacturers of packaged rainwater harvesting systems may provide a commissioning record as part of the installation and commissioning instructions. There is currently no standardised pro forma industry commissioning record for rainwater harvesting systems.

### *2.6.5 Pre-handover check requirements*

Prior to commencing handover of a rainwater harvesting systems the following actions/checks should be undertaken:

- all testing and commissioning activities have been satisfactorily completed
- any component covers removed during installation and/or testing and commissioning have been correctly replaced
- all system components are clean and undamaged
- the site area is clean and undamaged
- the handover documentation pack is complete and available
- if the client has any special requirements to be met or covered during the handover process
- the person who will undertake the handover to the client is fully conversant with the system installation and the handover requirements, and is competent to undertake the handover.

The handover of a rainwater harvesting system should involve provision of the following:

- a handover document pack
- verbal information/demonstration relating to system operation and use.

**Handover document pack**

There is currently no standardised industry requirement relating to the content of a handover pack for rainwater harvesting/greywater reuse systems. In the absence of a standardised industry requirement, the following content is recommended:

- all manufacturer's instruction documents and warranties relating to any installed equipment
- an 'as fitted' single line schematic plan of both plumbing and electrical systems – detailing all functioning components of the system up to the point of integration with the existing collection and distribution systems
- any safety advice documents
- the system commissioning record
- guidance on the limitations of use of rainwater harvesting/greywater reuse systems and the requirement that any future works must not introduce a cross-connection between the rainwater harvesting system and the wholesome water system
- guidance on what action to take in the event of system failure
- guidance on what action to take in the event of (or suspected) poor water quality
- details of routine maintenance checks to be undertaken by the user
- details of required maintenance intervals when the maintenance must be carried out by a competent engineer
- contact details for the installer and the system manufacturer.

**Verbal information and relating to system operation and use**

All verbal information and guidance should be provided using language and terms that the client/end user will understand. The following is provided as suggested minimum verbal information / demonstration guidance:

- ➢ an explanation of the contents of the handover documentation pack including a client-friendly explanation of the schematic diagrams

- identification of the location and purpose of key system components
- the importance of the system labelling and marking and why it must not be removed
- how to set/operate any user controls
- details of any controls or components that must only be touched by a competent person
- any symptoms/conditions that would require a competent person to be called
- action to take in the event of system failure
- guidance on what action to take in the event of poor water quality or suspected poor water quality
- details of system service and maintenance requirements, including frequency, details of and demonstration of any maintenance activities that the client may need to undertake
- guidance on any checks and practices that could reduce or increase maintenance requirements.

## 2.7 System maintenance

### *2.7.1 Routine/programmed maintenance*

Ordinary maintenance means all the activities and services necessary to maintain the good working order and conservation of every part of the plant. This maintenance is properly planned by the owner and the installer technician, carefully assessing the parameters relating to the systems (such as: verification of the state of cleanliness, integrity of the pipes and tanks, etc.), the frequency (monthly, bimonthly, half-yearly, annual, etc.) and the methods of execution (inspection, removal of foreign elements, cleaning, etc.).

The addresses to follow for cleaning the components of the water supply network, according to the different types of system, are as follows:

- Clean the filter once a month by removing the cover and removing it using the appropriate handles, so as to remove any debris deposited on the grids, using sponges or nylon brushes.
- Check the surface of the water inside the tanks. The water should be slightly opalescent. If there are solids inside, they must be removed immediately and a maintenance technician must be contacted. It is good practice to check the transparency of the water coming out every 2-3 months.
- Empty the tank and clean it completely (purge sediment at the bottom) whenever necessary.
- Periodically remove the pump to clean the suction filters every 3/4 months.
- Check the condition of the gaskets and verify their proper functioning every 3/4 months.

### *2.7.2 Extraordinary maintenance*

Extraordinary maintenance includes all interventions aimed at the conservation, enhancement and implementation of interventions necessary to ensure an adequate service collection of grey water, the replacement of plants and / or equipment, or parts of distribution networks, the construction of new networks or new collection systems, as well as the implementation and integration of technological services for the regulation, monitoring of the quality and quantity of water.

### *2.7.3 Analysis of maintenance costs*

The following table lists the maintenance costs expected for a period of a hypothetical useful life of the plant of twenty years (taking into account the indications of the Italian UNI/TS 11445).

- **Interventions at ten-yearly intervals (M1)**

| Service description | U.M. | Quantity | Price | Amount |
|---|---|---|---|---|
| **Special hydrodynamic tanker rental for emptying and washing of rainwater tank** | €/H | 1 | 90.00 | 90.00 |
| **Special van rental equipped for interventions in confined spaces** | €/H | 1 | 75.00 | 75.00 |
| **Specialised labour force appointed operator** | €/H | 1 | 30.00 | 30.00 |
| **Preparation of vehicles/ personnel** | €/CAD | 1 | 195.00 | 195.00 |
| **Transport to authorised plant** | €/CAD | 1 | 115.00 | 115.00 |
| **TOTAL M1** | | | | **505.00** |

- **Annual maintenance costs (M2)**

| Service description | U.M. | Quantity | Price of | Amount |
|---|---|---|---|---|
| **Operator manpower supervisor** | €/H | 1 | 30.00 | 30.00 |
| **Preparation means/staff** | €/CAD | 1 | 95.00 | 95.00 |
| **TOTAL M2** | | | | **125.00** |

- **Total maintenance costs (M3)**

| Service description | U.M. | Quantity | Price of | Amount |
|---|---|---|---|---|
| **M1** | €/CAD | 2 | 505.00 | 1,001.00 |
| **M2** | €/CAD | 18 | 125.00 | 2,250.00 |
| **TOTAL M3** | | | | **3,260.00** |

## *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*


[1] Commission of the European Communities, Communication from the Commission to the European Parliament and the Council, Tackling the problem of water scarcity and drought in the European Union, 18/07/2007

[2] D.Lgs 11 maggio 1999, n°152, Disposizioni sulla tutela delle acque dall' inquinamento e recepimento della direttiva 91/271/CEE concernente il trattamento delle acque reflue urbane e della direttiva 91/676/CEE relativa alla protezione delle acque dall'inquinamento provocato dai nitrati provenienti da fonti agricole

[3] Franek, A., Koncagul, E., Connor, R., Hunziker, D., L'acqua per un mondo sostenibile, fatti e cifre, Rapporto 2015 delle Nazioni Unite sullo sviluppo delle risorse idriche mondiali, UN water, 2015

[4] Murad, A.A., Al Nuaimi, H., Al Hammadi, M., Comprehensive assesment of water resources in the United Arab Emirates (UAE), Water resour. Manag.21, 1449-1463, 2007

[5] Mari, L., Rubinetti a secco a Roma, ecco il "cervellone" Acea per gestire l'emergenza acqua, La Repubblica di Roma, 31/08/2017

[6] Fanizzi, L., (2008). Gli impianti urbani per lo sfruttamento dell'acqua meteorica di dilavamento. L'Ambiente, n. 1, Ed. Ranieri, Milano.

[7] Rainwater tank capacity and potential for potable water savings by using rainwater in the residential sector of southeastern Brazil. Elsevier Ghisi, Lapolli Bressan, Martini.

[8] Rainwater utilisation in Germany: efficiency, dimensioning, hydraulic and environmental aspects. Urban Water, Volume 1, Issue 4, - Herrmann T., Schmida. U., (2000).

[9] Freni, G., Mannina G., Torregrossa M., Viviani G., (2007). Sistemi localizzati di riuso delle acque reflue e meteoriche in ambiente urbano. V Giornata di studio sul drenaggio, urbano sostenibile, riuso e risparmio acque reflue e meteoriche, 13 Dicembre 2007, Genova.

[10] AA. VV., (2002). Acqua. Sistemi e dispositivi per il risparmio e il riuso. EdicomEdizioni.

[11] Aquavet Handbook – Attività 03-A4 – Conaif (July 2016)

[12] ISTAT, Censimento delle acque per uso civile, Statistiche Report Istat, 2017

[13] http://ga.water.usgs.gov

[14] www.archiexpo.it

[15] www.arpaitalia.it

[16] www.et-studio.it

[17] www.euroambiente.info

[18] www.genitronsviluppo.com

[19] www.inderst.it

[20] www.iridra.com

[21] www.iseagroup.com

[22] www.planiplastic.it

[23] www.pozzolineutra.com

[24] www.rainharvesting.co.uk

[25] www.rainharvesting.com

[26] www.vemar.net

[27] www.redi.it

[28] https://www.intewa.de/it/

[29] www.sciencedirect.com

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 4*

| | | |
|---|---|---|
| 1. | **Routine/programmed maintenance is properly established by the owner and the installer technician by carefully evaluating the following parameters** | |
| | a. parameters referring to the plant (cleanliness, integrity, etc.), type of plant (underground or above ground) and execution mode (inspection, cleaning, etc.) | |
| | b. parameters referring to the installations (cleanliness, integrity, etc.), frequency (monthly, half-yearly, etc.) and type of installation (underground or above ground) | |
| | c. parameters referring to the plants (cleanliness, integrity, etc.), type of plant (underground or above ground) and frequency (monthly, half-yearly, etc.) | |
| | d. parameters relating to the installations (cleanliness, integrity, etc.), frequency (monthly, half-yearly, etc.) and method of execution (inspection, cleaning, etc.) | x |
| 2. | **The calculation of the maximum cumulative annual quantity of rainwater shall take into account** | |
| | a. Total harvesting area - runoff coefficient - quantity of annual rainfall - effectiveness of the filter - rainy days ($V= \phi \cdot S \cdot P \cdot \eta \cdot d$) | |
| | b. Total harvesting area - run-off coefficient - quantity of annual precipitation - filter efficiency ($V= \phi \cdot S \cdot P \cdot \eta$) | x |
| | c. Average of the harvesting area - runoff coefficient - quantity of annual precipitation - effectiveness of the filter ($V= \phi \cdot Ms \cdot P \cdot \eta$) | |
| | d. Total harvesting area - runoff coefficient - average annual precipitation - filter efficiency ($V= \phi \cdot S \cdot Mp \cdot \eta$) | |
| 3. | **What is meant with the expression "first rain waters"?** | |
| | a. These are considered to be those corresponding for each meteoric event to a precipitation of 10 mm evenly distributed over the entire draining surface served by the drainage system. For the calculation of the relative flow rates, it is assumed that this value occurs within a time period of 15 minutes. | |
| | b. The flow rates shall be considered to be those corresponding for each meteoric event to a precipitation of 10 mm evenly distributed over the entire drainage surface served by the drainage system. For the calculation of the relevant flow rates, this value shall be assumed to occur within a time period of 30 minutes. | |
| | c. The corresponding values for each meteoric event shall be those corresponding to a precipitation of 5 mm evenly distributed over the entire drainage surface served by the drainage system. For the calculation of the relevant flow rates, this value shall be assumed to occur within a time period of 30 minutes. | |
| | d. These shall be considered to be those corresponding for each meteoric event to a precipitation of 5 mm evenly distributed over the entire drainage surface served by the drainage system. For the calculation of the relative flow rates, it is assumed that this value occurs within a time period of 15 minutes. | x |
| 4. | **First rain systems can only be of the type** | |
| | a. continuous | |
| | b. discontinuous | |
| | c. both | x |
| | d. none of the above | |
| 5. | **The analytical determination of the storage volume is given, finally, depends on** | |
| | a. $\mathbf{T_{SM}}$ (average dry weather [d]) – Rain frequency – 365 days $V_R = T_{SM} \cdot \frac{(\text{Rain frequency})}{365}$ | |

| | | |
|---|---|---|
| | b. **T**$_{SM}$ (average dry weather [d]) – Rain frequency – 12 months $V_R = T_{SM} \cdot \frac{\text{Rain frequency)}}{12}$ | |
| | c. **T**$_{SM}$ (average dry weather [d]) – Average annual requirement – 12 months $V_R = T_{SM} \cdot \frac{\text{(Fabbisogno medio annuo)}}{12}$ | |
| | d. **T**$_{SM}$ (taverage dry weather [d]) – Average annual requirement – 365 days $V_R = T_{SM} \cdot \frac{\text{(Average annual requirement )}}{365}$ | x |
| 6. | **In order to avoid the risk of a building collapsing, excavations for the installation of an underground tank, or an exhaust pipe feeding the tank, must not be carried out within an area forming an angle of ........ with the foundation** | |
| | a. 10° | |
| | b. 20 | |
| | c. 40° | |
| | d. 45° | x |
| 7. | **What is the space required to leave the tank intact when carrying out a flat-bottomed excavation with self-supporting walls?** | |
| | a. about 50 cm | |
| | b. about 20 cm | |
| | c. about 40 cm | |
| | d. about 30 cm | x |
| 8. | **If 2 or more tanks have to be installed, what is the minimum distance to be respected?** | |
| | a. 5 cm | |
| | b. 10 cm | |
| | c. 15 cm | x |
| 9. | **A modern rain collection system is basically based on a few elements. Which ones?** | |
| | a. interception system - tank - lifting and distribution system | x |
| | b. purification system - tank - lifting and distribution system | |
| | c. interception system - filtration system - lifting and distribution system | |
| 10. | **What is meant by first rainwater?** | |
| | a. Rainwater runoff from the draining surface served by the drainage system and discharged into the receptor body after the time defined for the calculation of first rainwater (after 10 minutes). | |
| | b. Rainwater runoff from the draining surface served by the drainage system and discharged into the receptor body after the time defined for the calculation of first rainwater (after 15 minutes). | x |
| | c. Rainwater runoff from the draining surface served by the drainage system and discharged into the receptor body after the time defined for the calculation of first rainwater (after 20 minutes). | |
| | d. Rainwater runoff from the draining surface served by the drainage system and discharged into the receptor body after the time defined for the calculation of first rainwater (after 30 minutes). | |

# MODULE 5: OUTDOOR INSTALLATIONS


## *SUMMARY*

Outdoor water uses are a considerable part of water consumption in houses and as the systems present in those areas are exposed to rougher conditions they tend to degrade faster so it is of the most importance to have proper maintenance in these systems and to be able to identify, repair and optimize possible issues.

Unit 1 of Module 5 provides the principles for the correct interpretation of outdoor and irrigation drawings, including the methods used by system designers to ensure that the whole system is compatible, and it ensures the required performance for the plants of each location. These methods will showcase to WET trainees the water savings opportunities in such systems and will provide knowledge regarding the identification operation characteristics of an outdoor system. In Unit 1 also provides the definition of two common misuses of water in an outdoor system, runoff and overspray. Trainees will learn how to minimize or completely eliminate these issues and promote the optimal water use for each system.

Unit 2 of Module 3 provides the principles for a correct selection, installation and maintenance of components for an outdoor and irrigation system. Selecting the correct pipe material, emitter and fitting for an irrigation system considering water-energy efficiency requirements will be taught to WET trainees, enabling to accurately implement a project and deliver to the client an effective irrigation system, in line with client needs and environmental good practices. Unit 2 also includes the methods for optimizing the irrigation scheduling, improving performance by taking into account climatic variables and other factors that influence system performance and increase evaporation losses.

Unit 3 of Module 5 describes the methods used for the identification and repair of leaks in the different components of an irrigation system. WET trainees will enhance their abilities to evaluate the current condition of irrigation systems and to maintain the systems with the highest water efficiency, providing guidance to the owners for the most appropriate technologies and equipment to fix the system and to maintain a regular performance.


This is the fifth Water Efficiency Technician (WET). It integrates three Units:

Unit 1: Correct interpretation of outdoor landscape design and application of techniques to minimise water from irrigation runoff or overspray

Unit 2: Correct selection, installation and maintenance of outdoor water use systems, including scheduling for optimal irrigation performance

Unit 3: Detection and repair of outdoor systems leaks

## *Unit 1: Correct interpretation of outdoor landscape design and application of techniques to minimise water from irrigation runoff or overspray*

**General description**

In the 1st Unit of Module 5 the basics for the correct interpretation of outdoor landscape design, including the techniques to minimise water from irrigation runoff or overspray, will be showcased to trainees in order to improve their knowledge of the:

- operational characteristics of the irrigation system components, considering water-energy efficiency requirements;
- functioning of fittings and other parts of the irrigation system;
- methods and/or techniques that may be applied to secure good performance of the irrigation system, considering water-energy efficiency requirements;
- regulations and standards (local, national, international) applicable to irrigation systems.

This way, the trainees will enhance their abilities to:

- interpret the irrigation system project and dimensioning characteristics, considering water-energy efficiency requirements;
- establish the sequence of pipe installations;
- limit obstructions and improve the piping network layout, e.g. in respect to reduce pipes lengths;
- provide an estimation of the work to be carried out for the system implementation.

**Scope – Expected results**

At the end of this Unit, the candidate should be able to:

- Interpret basic drawings of outdoor and irrigation systems;
- Verify requirements for installation of outdoor and irrigation systems;
- Select the correct components and materials for an installation;
- To reduce runoff and overspray.

This Unit is constituted by 2 lessons/chapters:

LO1: Basics of outdoor and irrigation systems design

LO2: Minimisation of water waste from irrigation runoff or overspray

**Key words / basic terminology**

Irrigation system design, irrigation devices, runoff, overspray.

## 1.1 Basics of outdoor and irrigation systems design

Outdoor technical drawings typically detail the location, the paved areas, the plants that will feature the space and all the irrigation system components, including pipes, valves, junctions and irrigation devices.

When starting a project, it is essential to split the outdoor area's sections according to the irrigation devices that will be installed. Each section should have a separate valve to control the water supply so that there is an increased management capability to water the outdoor space by sections (particularly important in large spaces) and to facilitate system maintenance.

### *1.1.1 Interpretation of the basic drawings and the technical elements of the proposed outdoor and irrigation systems design*

Outdoor and irrigation systems drawings consist of diagrams that represent how the system will look like after installation. The purpose of the drawings is to provide the contractor a detailed plan to follow during installation, resulting in an adequate balance between solutions implemented and water necessities as well as infrastructural solutions that are designed and adapted to the specific location and its characteristics.

To ensure that the landscape design contributes towards water use efficiency, the project should detail all plant species according to their water needs, ensuring that all outdoor spaces have the proper irrigation system. Preferably, outdoor and irrigation systems designers should opt for native plants as these are suited to the regional environments and, thus, requiring more adequate watering. Plants with high water requirements should be avoided, e.g. turf and lawns.

One important step of designing outdoor and irrigation systems is to collect site information. Characteristics of specific outdoor areas such as sunlight or wind exposure will impact the water requirements and the type of plants that can be used in that area. Soil type is another feature that can impact plant choice and water requirements.

After analysing the outdoor space characteristics and choosing the adequate plants, the irrigation systems designer should be able to start the projection of the outdoor and irrigation systems. The first step is typically the calculation of the water meter capacity and working pressure, ensuring the availability of a water supply. After confirming the water meter capacity and working pressure, it is possible to determine the type of irrigation systems and device spacing for the outdoors. Irrigation systems may be composed of sprinklers and/or drip irrigation devices.

According to water requirements, the system designer will determine the type of devices to use, the spacing between them and the flowrates and programming necessary for the development of plants in area. Choosing the correct locations for irrigation devices is a critical aspect in the outdoor and irrigation systems design as bad locations may lead to unhealthy plants and/or to overconsumption of water. This could also lead to higher investment costs due to the use of more irrigation devices.

The contractor should be able to easily interpret the outdoor and irrigation systems drawings, so as to implement the system exactly as design. If the system was properly designed it should be clear where all pipes, junctions, cabling and irrigation systems should be located. To facilitate interpretation, drawings should always have legends, in which there should be the description of each figure in the drawing along with the technical details of that feature. Figure 1.1.1 is an example of an outdoor and irrigation system drawing.

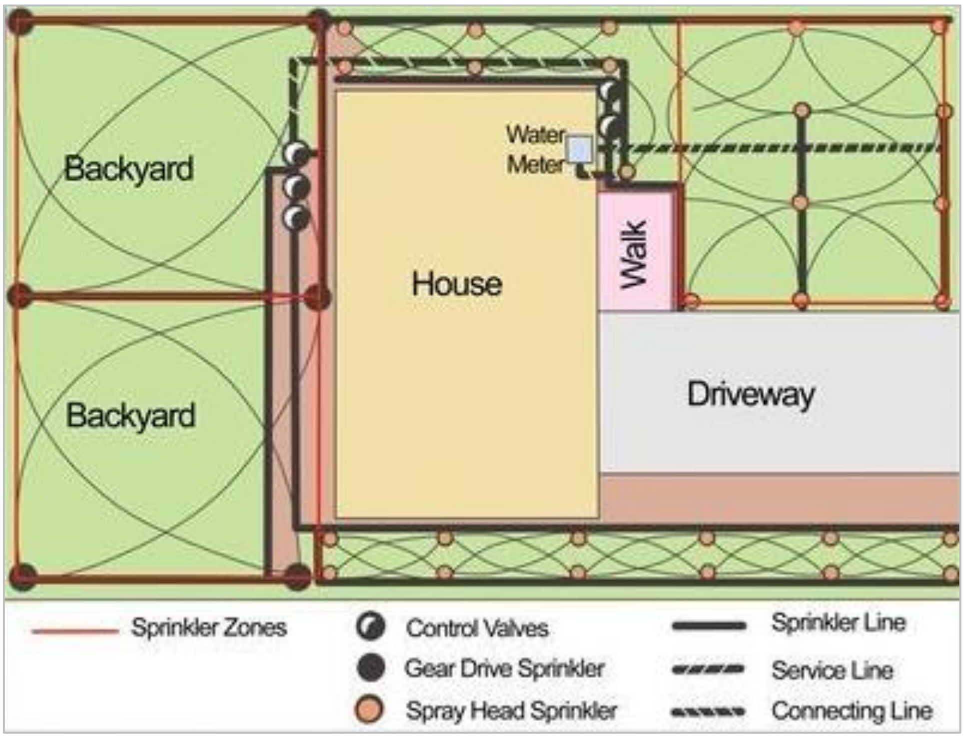



**Figure 1.1: Outdoor system drawing**

Analysing Figure 1.1.1, contractors should be able to figure out the systems that should be implemented, the spacings between irrigation devices and all other details to assemble the designed outdoor space.

### *1.1.2 Verification of the requirements of facilities under study regarding outdoor and irrigation systems*

Outdoor spaces under project need to meet certain requirements so that all components install will be compliant with good practices and normalisation standards. These requirements regard mainly the sizing of the irrigation system and the piping required. To verify these aspects, it is necessary that the project commissioning entity checks the spacing between sprinklers and drippers, the amount of irrigation devices and the size of the pipes used.

**Spacing between irrigation devices**

In dripper irrigation for dense plantation, the emitters (the irrigation system devices that provide and distribute water to the plants and soil) come already pre-installed in the dripper pipe and have a standard spacing, so it is not necessary to verify this parameter. In the case of sparse plantations, it is necessary to verify is there is at least an emitter per plantation zone.

For sprinkler irrigation, the configuration of devices depends on a number of factors, but it should be possible to analyse the configuration based on the type of devices installed and the wind speed, as it is shown in

Table **1.1**.

**Table 1.1: Distance between sprinklers as a function of configuration type and wind speed [Source: Ref. 2]**

| Sprinkler configuration | Average wind speed (km/h) | Distance between emitters |
|---|---|---|
| **Square** | 0 to 6 | 55% of diameter |
| | 6 to 13 | 50% of diameter |
| | 13 to 22 | 45% of diameter |
| **Triangle** | 0 to 6 | 60% of diameter |
| | 6 to 13 | 55% of diameter |
| | 13 to 22 | 50% of diameter |

To verify if the emitters are properly placed, it is necessary to have the technical documentation of the devices and check their range to compare the distance between them. If the distance is superior to the distance described in Table 1.1, then it should be considered the placement of more irrigation devices. If the distance is inferior, then it should be considered the removal of sprinklers or the readjustment on the distance between them.

To verify if the number of sprinklers is adequate, equation [1], which gives the minimum number of sprinklers for the green area, can be used. The real number of sprinklers can be verified in the irrigation project for comparing purposes. If the number of sprinklers is inferior to the output of equation (1), it should be considered the installation of more devices.

$$Amount\ of\ emitters = \frac{Green\ area\ [m^2] * Area\ with\ irrigation\ needs\ [\%]}{Emitter\ range\ [m^2]} \qquad [1]$$

**Pipe sizing**

As the pipes are buried in the typical irrigation system, the verification of requirements must be performed before the pipes are set underground. It should be verified that the pipes are in uniform holes without rocks and that they are at a depth of at least 10 cm to avoid deterioration.

It should be checked that the pipes size is according to the established in the project, as a function of the targeted flow rate at the end of every emitter. Also, due to pressure losses, the pipe with the lowest expected pressure level (either further away from the point of connection or at an upper ground level) should be studied to assure that this pipe has the required pressure. This is possible to calculate using equation [2]:

$$d_i = \left(\frac{4 * Q}{V * \Pi}\right)^{1/2} \qquad [2]$$

where $d_i$ is the internal diameter of the pipe (in meters), $Q$ is the flow rate of the emitter (in L/min) and $V$ is the flow velocity (in m/s), that must not exceed 1.5 m/s inside the pipes (exceed velocities may cause pipe deterioration).

The pressure differences are calculated based on the elevation differences and pressure losses (which are considered continuous along the pipe as the diameter is also constant). Between the emitter that is closest to the point of connection and the one that is furthest way, the pressure difference should not be greater than 20% above the working pressure.

The valves installed on the main line should be installed with a minimum distance of 15 cm between them in order to facilitate maintenance.

#### *1.1.3 Verification of the compatibility of the proposed equipment, materials and components with the outdoor and irrigation systems design*

To ensure that all systems designed for an outdoor space are compatible it must be taken into account the type of plants selected for the space as well as their water needs and the pressure at the point of connection. It must also be selected adequate materials for the piping.

**Selection of the irrigation system**

- Type of irrigation system

To ensure compatibility across the irrigation system, the first requirement is to have a single type of irrigation system in an irrigation zone. Irrigation zones are defined by the outdoor system designer and divide the total space according to the sun exposure, wind exposure, type of soil, plants in the area, shape of the area and location. The irrigation system designed for each area must be designed in order to fulfil the water needs of the plants present in the respective area and be adequate to the dimension and slope of the area.

Irrigation systems with high precipitation rate (rotating sprinklers) should not be used in outdoor areas with pronounced slopes or with high wind speeds due to runoff and overspray. The low precipitation rate systems are adequate to water trees, flower beds and autochthonous plants.

- Pressure

To achieve good working conditions in an irrigation system, the network pressure (static pressure) is recommended to stay between 2 and 5 bar. Higher pressures should be fixed with the installation of pressure reducing valves. To access the static pressure a manometer should be placed at the closest water tap to the point of connection. All sprinklers have information on the respective manual about the maximum pressure that they operate as intended.

**Materials**

Similar to the requirements for pipes, the materials can only be verified before being buried. The most common materials for pipes are PVC or polyethylene, which can be high or low-density. The low-density pipes are thinner and are more commonly used. One of the factors that influences the choice of a material for pipes is their sensitivity to water hammers that occur due to sudden pressure variations caused by closing valves very quickly and can result in a rupture.

### 1.2 Minimisation of water waste from irrigation runoff or overspray

A significant amount of water is wasted due to runoff and overspray from irrigation systems onto non-landscaped areas. These problems can be fixed using methods that can vary in complexity and be as complex as building terraces or as simple as adjusting the range of a sprinkler. Either way, reducing runoff and overspray can contribute to significant water savings.

### *1.2.1 Methods for the reduction of runoff*

Runoff may occur when the amount of water provided by the irrigation systems is higher than the infiltration capacity of the soil, leading to a surface drainage. Runoff can be reduced through an adequate management of the irrigation system, particularly in the case of systems with soil moisture sensors that only supply more water to the plants when most of the water in the soil has been absorbed. Runoff is also depending on the level of humidity of the soil at the time of irrigation.

To minimize runoff, the most effective irrigation is drip irrigation, as it has a very low precipitation rate and is applied very precisely in the plants roots. However, drip irrigation is not compatible with all plants. In those cases, there are sprinkler irrigation methods that can also contribute to reduce the runoff. Some of these methods are described in the following paragraphs.

- Avoiding garden areas with slopes

Slopes are more exposed to erosion, which results in higher water needs. Although runoff may occur in terrains with low slopes (only 3% gradient), it is more likely to occur in pronounced slope terrains. For these reasons, sloped gardens should be avoided whenever possible. If that is not a possibility, the outdoor system designer should consider:

  - Using plants with deep root to stabilize the soil and reduce erosion;
  - Build terraces, reducing the gradient and consequently reducing runoff.

**Figure 1.2: Garden with terraces**

[Source: HOME Stratosphere, 2020]

- Soil aeration

The process of aerating the soil consists in a cleaning method, removing dead plants and moss that stay on the surface of the soil. This process promotes water and nutrients infiltration.

- Plant a rain garden

A rain garden consists in a land depression on one area of the outdoors, that naturally collects water. These gardens usually have turf and lawns and perennial plants that have long life spans. Rain gardens are complex, with drainage systems and a water storage structures, e.g. lakes.

- Plant trees

Planting tree contributes to the reduction of runoff as their roots promote the infiltration of water in the soil. The tree canopies also reduce the erosion caused by rain.

- Rainwater harvesting

To prevent runoff associated with rain, it is possible to set up a rainwater harvesting system that will enable to have some control over the precipitation rate. There could be two different methods to capture rainwater:

  - Installation of green roofs, that will absorb part of the rainwater that falls on the buildings surrounding the outdoor area, increasing the green area of the lot and consequently reduce the overall runoff caused by rain. Green roofs also have thermal benefits for buildings and allow the use of what would otherwise be an unused space.
  - Capture and storage of rainwater in cisterns or tanks for posterior use in irrigation systems or other household uses. Cisterns are usually large storage capacity tanks that are placed underground and used to collect the rainwater. The small capacity storage tanks, often used in the Americas, are also called "rain barrels", which are placed at the end of the gutter.

**Figure 1.3: Rain barrel**

[Source: *Reference 7*]

#### *1.2.2 Methods for the reduction of overspray*

Overspray is the situation where irrigation systems are not adequately sized or located, e.g. when applying water to hardscape such as driveways, sidewalks and streets.

To prevent overspray some of the following methods can be used:

- Use of permeable driveways and sidewalks that allow water infiltration such as: pervious asphalt, pervious concrete, interlocking pavers, plastic grid pavers
- Use gutter to channel water to a garden area or a cistern instead of channelling gutter towards pavements or the sewer. If not possible, gutters should at least channel water to a permeable area.

Overspray can also happen due to improper sizing or installation of the irrigation system, directing water to pavements or streets. If so, the irrigation system should be adjusted to avoid this situation, which can include resizing (removing or replacing emitters) or readjusting the angle of the emitters.

## *Unit 2: Correct selection, installation and maintenance of outdoor water use systems, including scheduling for optimal irrigation performance*

**General description**

Water consumption vary according to many factors, so it is important that during the selection, installation and maintenance of the system components, these factors are taken into consideration, allow for the design of an optimal system in terms of water consumption.

In the 2nd Unit of Module 5 the principles for the correct selection, installation and maintenance of outdoor water use systems, including the scheduling for optimal irrigation performance, will be presented to the participants in the training in order to:

- improve their knowledge of correctly selecting the adequate pipe material, in compliance with regulations and standards (local, national, international) applicable to irrigation system, considering water-energy efficiency requirements;
- correctly selecting the adequate equipment, soil materials and fittings that can be used for irrigation purposes, of the potential for minimization of evaporation losses.

This way, the WET trainees will enhance their abilities to:

- accurately implement the irrigation project proposed;
- correctly apply the most effective and suitable equipment and materials for correct implementation of the system, including soil materials;
- efficiently check-out the irrigation system installation;
- deliver to the client an effective irrigation system (in line with the client needs and the necessary performance and environmental requests).

**Scope – Expected results**

At the end of this Unit, the candidate should be able to:

- Identify all components in an irrigation system;
- Perform maintenance tests and commissioning;
- Optimize irrigation schedules.

This Unit is constituted by 3 lessons/chapters:
LO1: Selection and installation of outdoor systems
LO2: Testing and commissioning of outdoor water use systems
LO3: Scheduling for optimal irrigation performance

**Key words / basic terminology**

Irrigation system components, outdoor system maintenance, irrigation scheduling optimization.

## 2.1 Selection and installation of outdoor systems

Selecting the correct components for an outdoor system is key to ensure that the system is adapted to its location and variables, which in term will reduce costs for the owner in both maintenance and water consumption. It is part of the job of the system designer to design a system with the optimal components that are adapted to the plants and location, involving calculating plant water needs, choosing correct emitters, selecting ranges and precipitation rates and other engineering processes.

### *2.1.1 Correct selection of components and materials for outdoor systems*

**Irrigation devices**

For each project and outdoor section there might exist the need to implement different irrigation solutions, adapted to the plants and characteristics of that project/section. The irrigation can be performed using localized methods (low-flow devices) or methods that cover large areas. In residential outdoor areas it is better to use low-flow devices as they prevent wasting water and are adequate for smaller areas, however, the system designer should dimension the system according to the site characteristics. The most commonly used irrigation devices are:

➢ Drippers

Drippers have flows below 12 litres per hour and work at low pressure (ideally between 1 to 1.5 bar but can work in inferior pressures), making them suited to water trees and flower beds. These systems provide water drip by drip, providing water directly to the soil and enabling plants to absorb it before it evaporates, minimizing water losses. These features make drippers the most water effective watering methods (estimated 95% efficiency).

➢ Micro-spray sprinklers

Micro-spray sprinklers work in pressures between 0.5 and 2.5 bar and supply up to 300 litres per hour of water. These systems have ranges between 1 to 5 meters and are very efficient at delivering water to the soil (up to 90% efficiency).

➢ Fixed/adjustable sprinklers

Fixed/adjustable sprinklers typically work with pressures between 1.7 to 2.1 bar and have a range between 1.5 to 5.5 meters. These sprinklers are adequate to water small areas, flower beds and irregular or tilted surfaces as they have inferior precipitation rates which allows the soil to absorb the water and avoids runoff. A good practice for irrigation system designers is to not mix fixed and rotating sprinklers in the same area.

➢ Rotating sprinklers

For large areas with flat surfaces, the use of rotating sprinklers is usually recommended. These sprinklers have precipitation rates above 300 litres per hour and work in pressures between 2.5 to 5 bar. In terms of range, rotating sprinklers are typically between the 6 and 25 meters, making them ideal for watering large areas such as turf and lawns.

**Valves and pipes**

When designing an irrigation system, valves should be placed in a way that allows easy access for the operation, in the case of manual valves, and maintenance. The valves installed in an irrigation system should be check valves, preventing backflow in the pipe and the contamination of the water supply.

The pipes used for irrigation systems can be divided in the following categories:

- Main line – the pipe that connects the point of connection (e.g. placed between the water meter and the pressure regulator, if existent) to the control valves. As these are the most expensive pipes it is important to optimize the irrigation, minimizing the size of main line pipe used;
- Supply header – the pipe that connect the main line with the lateral line. Typically, is only used in irrigation systems with drippers.
- Lateral line – the pipe that connect to the supply header or directly to the valves and then to the drippers or sprinklers. To minimize pressure losses these pipes should be arranged so as to have the least possible amount of turns.

The piping configuration and the position of the valves depends on the type of irrigation, so the system designer should select the configuration adequate for each case.

For drip irrigation it is common to use PE pipes as they are more flexible, while for pipes under paved areas it is common to use PVC pipes. For other uses, the pipes must be adapted according to the strength, flexibility or other characteristics (Table ) required in the circumstance.

**Table 2.1: Irrigation pipe materials characteristics [2]**

| | Advantages | Disadvantages |
|---|---|---|
| **PVC** | ▪ Good hydraulic conductibility;<br>▪ Good resistance to fertilizers;<br>▪ Light weight. | ▪ Sensible to solar radiation and cold;<br>▪ Low flexibility;<br>▪ Sensible to water hammers. |
| **HDPE** | ▪ Good resistance to solar radiation and cold;<br>▪ High resistance to fertilizers;<br>▪ High flexibility;<br>▪ Resistance to water hammers;<br>▪ Resistance to abrasion. | ▪ Average hydraulic conductibility;<br>▪ Heavy weight. |

**Protection components**

- Pressure regulators

Pressure regulators ensure that the pressure in the whole systems remains constant, which is key for the correct functioning of the emitters (drippers and sprinklers). Irregular pressure may cause over and/or under watering leading to higher water consumption and/or soil drought. Pressure regulators should be placed as close as possible to the irrigated area and should always be placed downstream from the point of connection.

➢ <u>Filters</u>

The filters stop dirt from damaging the system components and the clogging of the emitters. Filters should be placed between the point of connection and the main line. The most common types of filters used in irrigation systems are:

- Hydrocyclone – for particles with higher density than water
- Sand – for organic matter
- Mesh – for particles inferior to 0.5 mm.

➢ <u>Air purge valves</u>

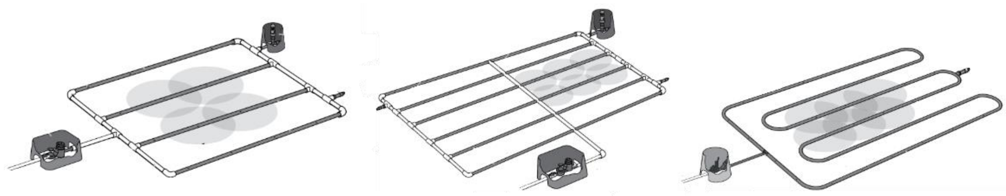
Air purge valves are components of the irrigation system that are placed in the pipes in points where there is sudden reduction of pipe diameter, or in pipes with long length or sections of convex piping. The purpose of these components is to eliminate the air inside the system, reducing the water hammer phenomenon.

**Configuration of a dripper system**

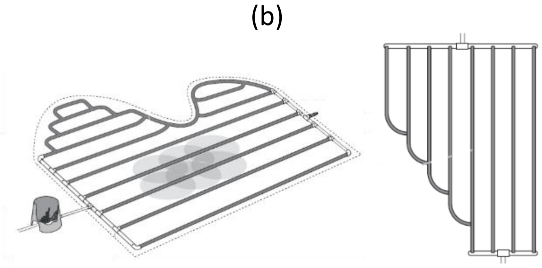
Dripper systems can be easily installed over small areas and by delivering water in a very precise and localized way it is the most efficient method of watering. Piping can be on the surface or beneath it. Buried pipes can be advantageous for small areas with irregular shapes and for sloped terrains.

The configuration types can be divided as follows:

- End feed – underground system (buried);
- Centre feed – underground system (buried) that allows better distribution of the water flow than the previous;
- Quick loop – surface system;
- Curved edge – surface system used in irregular shaped terrains;
- Branching out or joining rows – two surface systems with similar configurations.



(a) (b) (c)



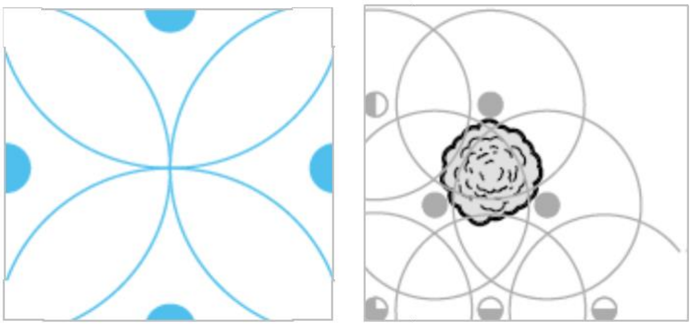
(d) (e)

**Figure 2.1: Dripline layouts: (a) End feed; (b) Centre feed; (c) Quick loop; (d) Curved edge; (e) Joining rows**

[Source: XF SERIES DRIPLINE | Design, Installation and Maintenance guide, RAIN BIRD]

### Sprinkler system configuration

Sprinklers can be arranged according to the shape of the outdoor space. Typically, they are disposed in a square or triangle, but other shapes can be used according to location.



(a) (b)

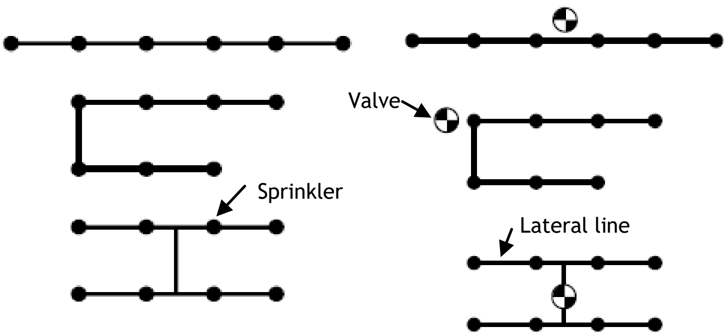
**Figure 2.2: Square (a) and triangle (b) configurations**

[Source: Residential Sprinkler System Design and Installation Guide, HUNTER; Landscape Irrigation Design Manual, RAIN BIRD]

When selecting the adequate position for sprinklers, the first step is to place sprinklers in the corners of each irrigation zone, with the appropriate angle that avoids overspray. Then, starting in one side, sprinklers must be placed bearing in mind that they must cover the whole area and the range of the sprinklers should allow to water up to the next sprinkler head (head-to-head spacing). If the side sprinklers are not enough to cover the whole are, then centre sprinklers are the option, typically ensuring a watering angle of 360º.

To design the sprinkler system, it is also necessary to define the configuration of valves and pipes. Pipes can have two types of configurations according to the valve position:

- Straight line lateral – the valve is placed at the end of the pipe;
- Split-length lateral – the valve is placed in the centre of the connection pipes, splitting the flow rate supplied by the two pipes. This configuration allows to reduce the size of the pipes and ensures a better water distribution so it should be implemented if possible.




(a) (b)

**Figure 2.3: Straight line lateral configurations (a) e Split-length lateral configurations (b)**

[Source: Landscape Irrigation Design Manual, RAIN BIRD]

### *2.1.2 Safety requirements, legislation and standards*

While some components in an irrigation system do not have to comply with international standards, the pipes (core of the irrigation system) have international norms that should comply such as:

PVC pipes

- DIN 533452 – Flexular strength = 93MPa
- ISO R 527 e DIN 53455 – Tensile strength = 49 MPa; Compressive strength = 70 MPa and Elongation at fracture = 80%
- DIN 16929 – Resistance to chemical products

HDPE pipes

- ASTMD 1603 – Amount of carbon black > 2%
- ISSO 6259 – Flexural strength = 900 $N/mm^2$; Tensile strength = 22 $N/mm^2$ and Elongation at fracture > 600%

### *2.1.3 Selection of tools, equipment, materials and fittings for installation of outdoor systems*

The installation tasks and, consequently, the tools and equipment necessary for the different emitters varies with the type of irrigation system and pipes.

Emitters' installation

Emitters (sprinklers and drippers) should be assembled through screw connections assembled in T, or elbow for the extremities. For drippers installed on the surface it is necessary to secure the irrigation pipes to the ground using clamps.

Pipe installation

To install pipes the first step is to remove the topsoil with a shovel and then open a trench manually or with an excavator in the case of compact soils. If the pipes go through paved areas it will be necessary to use water jets under the pavement and for that purpose it is possible to use a screw adapter between the pipe and the hose (pipe-to-hose threaded adapter), connecting the end of the pipe to a garden hose and connecting a stream hose nozzle on the other end.

Pipes are sold in standard sizes which means that before installing you must cut them to the correct size according to the project end using an adapted scissor. To unite the pipes, it is necessary to use T or elbow connections. In the case of surface pipes, a clamp should be to fix the union points between pipe and emitter. The typical configuration has a vertical pipe that comes out of the main line and connects to the emitter. The extremities are closed using end caps.

After closing the trench and compacting the soil manually, or with a machine, the pipes should be washed. The first wash should be made before the installation of valves and security equipment and the second wash before the installation of the emitters. The washing process should be repeated until the water comes out clear in the extremities.

## 2.2 Testing and commissioning of outdoor water use systems

Outdoor systems are exposed to the climate, high water pressures and other factors that can damage parts of the system, so it is important to test the system for flaws throughout its use, assuring its functioning and high water efficiency. Commissioning is another activity that can contribute to the same goals, usually associated with the assembly period of the life cycle of the system but with enormous potential to increase water use efficiency if correctly performed.

### *2.2.1 System diagnosis and measurements*

The maintenance of pipes in irrigation systems may not always be an easy task as most of the pipes are typically buried and it is not possible to dig them out for maintenance in a regular basis. Other methods have been used to make a diagnosis of the system.

Access points are often installed allowing partial access to sections of the pipes, which enables a visual diagnosis of these sections. In the case of small pipes for the drippers and micro-spray sprinklers, maintenance usually involves opening the pipe trench and cutting parts of the pipe that are leaking, however these pipes are either on the surface or very close to it.

In colder locations, at the end of the irrigation season the system should be completely flushed to prevent the lines from freezing as freezing water expands which can cause cracks in the pipes and consequently leaks when the irrigation is resumed.

Sprinkler maintenance typically includes yearly cleaning of the water filters, usually performed before the summer season. Also, sprinkler maintenance usually includes a regulation of the emitters' arc and range. For smaller sprinkler heads it might be necessary to clean the nozzles.

### *2.2.2 Tests for verification of system functioning*

To verify if an irrigation system is functioning properly the most immediate ways are to check if the water meter (if existent) is showing values within the expected range and to verify if plants are healthy and not dry. To have a more immediate verification it is necessary to assess each individual emitter of the system and, preferably, to a dedicated partial water meter, dedicated to irrigation (or at least outdoor uses). This way it is possible to observe daily changes and verify if there is a valid reason (such as climate conditions) behind increases and decreases in water consumption or if there is a flaw in the system.

For the purpose of maintenance, it may be interesting to verify each individual emitter, as they may have leaks due to debris that enter the device or may be misadjusted and causing problems such as runoff or overspray.

### *2.2.3 Pressure decay test*

A pressure decay test is a more advanced test and a better way to detect leaks in the pipes of an irrigation system. This test can be performed as the system is installed or at any given point as long as the pipes are drained before the test.

The pressure decay test is a type of test that involves pumping air into the pipes until a certain pressure is achieved and then monitor the pressure decay over time. Any pressure decay observed over a short time will be correlated with a leak and the velocity of that pressure decay can indicate the size of the leak.

This test is a common technical test used to identify leaks in irrigation systems as it provides good accuracy and its cost is relatively low. Other possible tests to identify leak may involve the use of ultrasounds if the pipe characteristics enable its use.

#### *2.2.4 Commissioning of outdoor and irrigation systems*

Commissioning a project is the act of assessing if an engineering project is following everything that was planned in the original project design or plan. This includes checking if everything is going on the correct locations but also involves the verification of equipment that is being installed, if it corresponds to the equipment detailed by the system design in the project drawings and plan.

In an irrigation system commissioning the project implies the verification of the location of every pipe, plant and emitter being placed in that outdoor space. This includes verification whether plants and emitters are correctly matched, on contrary as it may result in overspray, and the identification of unhealthy plants in other areas of the same outdoor space.

The system designer has the objective to balance the whole system and if parts of it are needed to replace or if the equipment installed is not the same as initially project it is advisable to consult with the project designer so that he/she is able to rebalance the system, ensuring proper functioning and the maximum water efficiency.

### 2.3 Scheduling for optimal irrigation performance

Scheduling an irrigation system for optimal performance is sometimes disregarded as an important stage of the implementation of the system but it has a relevant impact in the water use and with the broader installation of irrigation controllers, this task can now be performed with sensing technology that automatically optimize schedules for irrigation according to multiple variables.

#### *2.3.1 Influential factors for water use in irrigation*

The use of water for irrigation is dependent on several factors and, one the most important factors is plants water needs. Plant water needs vary according to the type of soil, the climate of the region and plant type. For an efficient water use it is important that the plants suggested by the system designer are adequate to the outdoor space, as well as that the irrigation system and type of maintenance are adequate to the plants chosen.

**Plants**

When selecting plants, outdoor system designers should preferably select autochthones plants as these are more adapted to the climate conditions and soil of the region. System designers should also avoid plans with high water needs which is the case of turf and lawns.

The irrigation system to install should be selected according to the respective plants and should take into account the working pressure of the system and the necessary range as mentioned in the previous unit.

**Soil**

The most adequate measure to maintain a fertile soil is to use a layer of material on the surface. This protection material is called mulch and its selection should be made according to the type of plants that are located on that soil. The different types of mulch are:

- Organic mulch (hardwood chips, straw, leaves, pine needles and grass clippings) – helps to improve soil conditions, supplying nutrients as it decomposes;
- Inorganic mulch (rocks, pebbles or gravel) – helps to maintain the moisture on the soil.

The main advantages of mulch are:

- Reduction of evaporation water losses through soil surface, allowing the soil to retain water for longer periods and reducing the frequency of irrigation;
- The stabilisation of the soil temperature which contributes for a good development of roots, fungi and bacteria, contributing to a more fertile soil;
- Elimination of the weed;
- Helps to retain water on sandy soils and provides porosity to clay soils;
- Prevents soil erosion.

Despite its many advantages, it is important not to use excess amounts of mulch over the soil as it can restrict the flow of water (i.e., infiltration).

**Climate**

Climate, especially temperature, wind and rain, has a great influence on the process of evapotranspiration of plants, which affects irrigation needs. High temperatures increase plants transpiration and the evaporation of the water in the soil, increasing water needs. To reduce the effects of temperature it is important to have shaded areas in the outdoor space.

In areas with high precipitation it may not be required to use water from the public service. However, to achieve this it is necessary to manage the irrigation system according to the climate so that the system is not turned on during or after raining. It may also be advisable to have rainwater harvesting cisterns for irrigation during the months with less rain. Typically, in the Mediterranean countries it is not necessary to water plants during the winter season.

Wind contributes to the increase of water losses through evaporation, meaning that in high wind areas it is a good practise to install a wind protection barrier. Also, it is not advisable to use sprinklers during windy periods as it causes dispersion of the water, making the irrigation less effective.

Other methods for reducing water losses caused by climate conditions consist in the application of water directly to the roots of the plants which is possible using dripper irrigation systems. Outdoor space designers should consider this factor when designing the irrigation system. To attenuate the effects of climate it is essential to have a proper management of the irrigation system that could be made manually or automatically through irrigation controllers.

**Landscape design**

The adequate protection of landscape contributes for an efficient water management associated with external uses. A good landscape protection includes the definition of hydro-zones. These zones consist in grouping of areas according to the different plants present and their water needs. For each hydro-zone, the irrigation system installed should be adapted to contribute for an efficient management of water consumption.

**Maintenance**

To have the most efficient irrigation system as possible it is important to avoid higher water requirements and keep all systems in perfect condition through adequate maintenance. Regarding the irrigation system it is essential that its working pressure is in the correct interval in order to avoid pipe deterioration. The use of fertilisers should be avoided as they increase plant water needs. When fertilisers are strictly necessary, it should be preferred to use of natural organic fertilisers.

The garden should be cleaned periodically to eliminate weeds as they consume water and reduce the infiltration of water into the soil. In the case of irrigation systems, the cleaning process should involve cleaning the nozzles, the filters and the valves. For dripper systems it is advisable to install a filter in the beginning of the system to remove particles that could cause the drippers to clog.

To have an effective preventative maintenance, periodical inspections should be made to the irrigation systems in order to verify if all the components are working as they should. In colder regions the inspections should be made before the winter as it is important to drain all the water in the pipes to avoid it freezing inside the pipes and causing cracks.

### *2.3.2 Defining irrigation control scheduling*

Irrigations control can be automatic, based on the type of controller installed. These controllers can be:

- Timed – the irrigation is timed by the use and is automatically turned on according to the scheduled defined and for as long as the user programmed it to. The user should define the schedule according to the criteria mentioned in this unit, that affects plants water needs;
- Pluviometric – assess precipitation and stop the irrigation process when it rains or has rained recently;
- Moisture probe – measures the humidity in the soil and activates or deactivates the irrigation according to the moisture level programmed.

To define an irrigation schedule there are several rules that could contribute towards a significant reduction of water consumption. In the case where there is an irrigation controller, an easy practice to apply is to only start the irrigation during the night periods to reduce losses by evaporation (either before 8:00 AM or past 6:00 PM). Other good practices are to suspend irrigation when there are strong winds in order to minimise water losses due to overspray, in the cases of irrigation using sprinklers, or to suspend during rain, which can be performed automatically if there is a pluviometric sensor associated with the controller.

The user should also program the irrigation controllers in a way to avoid small periods irrigation as in those cases the water tends to only moist the top layer of the soil. The irrigation controller should also be periodically programmed in accordance with the climatic conditions (precipitation and temperature).

## *Unit 3: Detection and repair of outdoor systems leaks*

**General description**

Irrigation systems are usually under stress from several factors and leaks can be a common occurrence if there is no proper maintenance. This can result in a very high waste of water if the leak is not corrected in the shortest amount of time possible and if there are no safety valves to close the circuit in the case of a leak.

In the 3rd Unit of Module 5, techniques used for the detection and repair of outdoor systems leaks will be showcased to the WET trainees in order to improve their knowledge of the available methods for the identification of leakages in the irrigation system, and of available methods to proper repair, replacement and maintenance of the irrigation system.

This way, the WET trainees will enhance their abilities to:

- evaluate the elements of the project for irrigation demand (e.g. adequacy between project and facility proposed components);
- assess the water gains from the use of efficient irrigation systems;
- provide the clients with documented advice as a guidance for them to decide on the most appropriate (for each case) technologies and equipment;
- identify and diagnose the possible leakage occurrence throughout the fixtures and the equipment of the irrigation installation and to fix the problems;
- perform the regular maintenance of the irrigation installations.

**Scope – Expected results**

At the end of this Unit, the candidate should be able to:

- Use fault-finding methods to assess the existence of leaks in an irrigation system;
- Make the evaluation of the best methods for leak repair;
- Perform proper maintenance in irrigation systems pipes to avoid leakages.

This Unit is constituted by 2 lessons/chapters.
LO1: Leak assessment and diagnosis
LO2: Leak repair

**Key words / basic terminology**

Leak assessment, leak diagnosis, leak repair, pipe maintenance.

## 3.1 Leak assessment and diagnosis

Identifying leaks is an important step of any maintenance procedure in irrigation systems. Large leaks are usually quickly noticed if the water used in the irrigation system passes through a meter, but slow leaks may be undetected for a long time if there is no periodic assessment. The type of leak may, thus, lead to different assessment approaches.

### *3.1.1 Fault-finding methods*

In general, to verify if the irrigation network has leaks, the consumption of water meter should be registered in the beginning of an audit procedure and the amount of water used assessed by the end of the audit. If the values do not match the expected consumption, then there is probably a leak. Nevertheless, the adequate method for leak identification is also dependent on many factors, including the type of audit that is conducted or the level of precision of the meter reader.

To identify if there is a leak in the irrigation system, the auditors should consider the following rationale:

- If the meter is exclusively used for the irrigation system, the leak is probably in the irrigation system;
- If the meter captures other water consumptions besides irrigation, then the auditor must turn off the irrigation system and repeat the register of the same meter:
    - If the consumption increases again, the leak is not in the irrigation system. The leak could be in another outside water use or related to an annex building;
    - If the water consumption is constant with previous results, then the leak is in the irrigation system.

If a leak is detected in the irrigation system, the auditor should reconnect the water zone by zone in try to identify in which zone is the leak. The next step is to inspect all emitters of the identified zone to identify the exact spot of the leak. To identify the location of all emitters the auditor can use the technical drawings of the outside area.

Besides the leaks, there are other maintenance issues that lead to excessive uses of water, such as:

- Puddles of water next to the emitters
    - If the auditor can visually see puddles of water next to all the emitters in one or more areas, the plants are receiving more water than they are capable of absorbing in those areas and it is necessary to adjust the frequency or the intensity of the irrigation;
    - Otherwise the problem is in the emitters next to the puddles that should be fixed or replaced.
- Wet pavement next to an emitter is an indicator that emitter is wrongly placed or adjusted which is causing overspray. These emitters should be readjusted in order to avoid this situation;
- Under-spray is a problem caused when a sprinkler's range is not enough to get a head-to-head coverage. This can, in term, be a water use waste as it might be required to replant that area in the future, consuming more water. To correct this issue, the range of the sprinklers should be adjusted, or additional sprinklers should be added to that zone.

#### *3.1.2 Use phase analysis of outdoor system components*

Several components in an irrigation system are susceptible to problems during its use phase. In the case of the irrigation network, the most common problem are the leaks detected in the joints between emitters and pipes. Leak assessment methods should be used to identify these cases as joints are most of the time underground.

Leaks may also happen in pipes, being the most common situations due to freezing or abrasion. In colder countries it is common to have leaking pipes due to the water freezing inside and expanding causing cracks which consequently cause leaks. To prevent this issue the water should be forced out of the irrigation pipes and the valves should be closed before the cold season starts. As for the abrasion, this is natural process that happens due to the water circulation and pressure inside the pipes, meaning that older pipes are more likely to have leaks, also dependent on the type of drinking water which is supplied.

Other components of the irrigation system that could have issues are the emitters. As they are on the surface it is common for them to clog or have mechanical issues due to dirt entering the system. Other problems might be the obstruction of an emitter as the plants grow and may unintentionally cover the emitter nozzle.

In sprinkler heads, the nozzle is also susceptible to the continuous strain of the system and they may end up removed from the sprinkler head. In these cases, without the nozzle, the precipitation rate of the sprinkler is vastly increased, and overspray will occur. It is important to periodically check the nozzles of the emitter to avoid this.

### 3.2 Leak repair

After confirming the existence of a leak, it is important to perform a solid correction of the problem and prevent future leaks. In most cases, the repair of leaks will require some type of tool to facilitate the service. The tool that should be selected for each service is specific to the component of the system where the leak is present. It is important to notice that, independent of the system component where the leak is detected, it is necessary to close the water in the system to proceed to repairs.

**Nozzles**

If a leak is identified in a nozzle of a sprinkler head, a screwdriver or a special manufacturer tool may be required. This tool or screwdriver is used to release the current nozzle (if present) and then used again to tighten the new nozzle. Nozzles may end up clogging or with other issues that increase water consumption, so it is important to always check nozzles during maintenance actions.

**Emitters**

In the case of a leak related to the emitter, the options are to clean it or to replace it, if the leak continues after cleaning the emitter. To either clean or replace the emitter is necessary to unscrew the device from the joint that attached it to the pipe. In most cases the emitters are underground so it may be required a shovel to dig the device out. Unscrewing and screwing emitters is, typically, easy so the only other equipment that may be required is some thread seal tape, to ensure a watertight seal.

**Pipes**

Leaks in pipes may be the most difficult type of leaks to find and fix. After locating a leak in a pipe, it may be possible to dig the pipe trench and replace the whole section or, as in in most cases, to use a pipe cutter to cut a small section of pipe where the leak is identified. After cutting the section of pipe it is necessary to have a section of pipe with the same diameter and length of the cut section and two compression couplings. The goal is to reconnect the new section of pipe using the compression couplings on each side. To ensure a watertight seal it is important to use pipe glue in the union points. All this process must be performed in the pipe itself, so it is necessary to dig the pipe trench and clean the site of dirty so that this dirty does not enter the system or promotes a bad fix of the leak.

**Joints**

Joint leaks are very common in irrigation systems. The only method to repair these leaks is to dig in the area of the joints and replace them. In a typical system, no tool will be required to detach the old joint and attach the new one. Thread seal tape may be used in the joints to ensure a watertight seal.

**Pumps and valves**

If the irrigation system is well designed and the construction respected the original project layout, all pumps and valves should be accessible through lids on the ground. This makes it easier to fix and detect possible leaks in these components. The common solutions for leaks in these components are to clean the rubber diaphragm of any debris or to completely replace the components. To perform these repairs the common tools required are a screwdriver that enables to remove valve lids to access the rubber diaphragm or a spanner it is necessary to remove and replace the component. In the second case it may also be necessary to use new connection hardware and thread seal tape in the pump/valve unions to ensure the watertight seal.

## *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*


[1] Almeida, M. do C., Vieira, P., & Ribeiro, R. (2006). Uso eficiente da água no setor urbano. ISBN 972-99354-9-1.

[2] Cudell, G. (2020). Manual de instalação de rega. 70.

[3] Hunter (2018). Residential Sprinkler System Design and Installation Guide: https://www.hunterindustries.com/sites/default/files/design_guide_Residential_System_LIT-226-PT.pdf

[4] Rain Bird (2000). Landscape Irrigation Design Manual: https://www.rainbird.com/sites/default/files/media/documents/2018-02/IrrigationDesignManual.pdf

[5] Rain Bird (2000). Low-Volume Landscape Irrigation Design Manual: https://www.rainbird.com/sites/default/files/media/documents/2018-02/LowVolumeGuide.pdf

[6] Rain Bird (2014). XF Series Dripline Design, Installation and Maintenance Guide: https://www.rainbird.com/sites/default/files/media/documents/2018-02/XF-Series-Design-Installation-Maintenance-Guide.pdf

[7] WaterSense: https://www.epa.gov/watersense/outdoors (accessed on June 26, 2020)

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 5*

| | | |
|---|---|---|
| 1. | **Proper design of the irrigation system includes…** | |
| | a) Dividing the garden into irrigation zones with similar water needs | x |
| | b) The use of the most efficient irrigation system in the entire irrigated area | |
| | c) The triangular sprinklers configuration | |
| | d) The use of tubes with the same diameter over the entire length of the network | |
| 2. | **Which of the following methods contribute to the minimisation of water waste from irrigation runoff?** | |
| | a) Design gardens with slopes | |
| | b) Use of permeable driveways and sidewalks | |
| | c) Rainwater harvesting | x |
| | d) All of the above | |
| 3. | **Which of the following measures contribute to the minimisation of overspray?** | |
| | a) Direct the gutters to paved areas | |
| | b) Use of permeable driveways and sidewalks | x |
| | c) Plant a rain garden | |
| | d) Promote soil aeration | |
| 4. | **Which of the irrigation systems is the most efficient?** | |
| | a) Spray irrigation with rotating sprinklers | |
| | b) Drip irrigation | x |
| | c) Micro sprinkling | |
| | d) Spray irrigation with fixed/adjustable sprinklers | |
| 5. | **Select the correct statement regarding the selection and installation of tubes for irrigation systems.** | |
| | a) The lateral line tubes are the most expensive so their length should be minimised | |
| | b) PVC tubes are more flexible than Polyethylene (PE) tubes | |
| | c) PVC tubes are the most suitable for installations under paved areas | x |
| | d) Straight line lateral configurations allow a better water distribution than split-length lateral configurations | |
| 6. | **Which of these measures contributes to less water consumption?** | |
| | a) Planting of native plants | |
| | b) Use of mulch | |
| | c) Proper irrigation system programming | |
| | d) All of the above | x |
| 7. | **Which of the following tasks is <u>not</u> performed in the irrigation system maintenance process?** | |
| | a) Verification of compliance of the installed irrigation system with the projected | x |
| | b) Elimination of weed plants | |
| | c) Cleaning of filters, valves and irrigation nozzles | |
| | d) Adjustment of the irrigation system programming | |
| 8. | **Which of the following irrigation control systems is suitable for saving water?** | |
| | a) Programming the activation of the system for the early afternoon | |

| | | |
|---|---|---|
| | b) Pluviometric system for suspending irrigation during periods of rain | x |
| | c) Moisture probe, for watering suspension when there is sufficient humidity in the air | |
| | d) All of the above | |
| 9. | **Which of the following evidences may indicate leaks in the irrigation system?** | |
| | a) Wet pavement next to emitters | |
| | b) Atypical water consumption | |
| | c) Dried plants | |
| | d) All of the above | x |
| 10. | **Which of these is not a way to correct the insufficient water coverage of the irrigation system?** | |
| | a) Adjust the range and angle of the emitters | |
| | b) Add emitters | |
| | c) Replace the irrigation system with a more efficient one | x |
| | d) Adjust the service pressure | |

# MODULE 6: COMMUNICATION WITH THE CUSTOMERS / CONSUMERS

## *SUMMARY*

Communication with customers/ consumers is essential to guarantee that water and energy supply and usage are adequately maintained and used efficiently, with minimal water and energy inefficiency. Good counselling on the adequate infrastructure, together with the correct selection of fixtures and appliance, can help them limit their water and energy demand, with positive saving effects on household water and energy bills. The use of standards of water efficiency and energy efficiency in buildings, together with new solutions and technologies, may be important drivers to the promotion of water efficiency.

Herein, and aligned with a possible route of the expert technician and auditor patch into the building/household (from outside to the inside), water systems may be divided into the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production.

The 1st Unit of the *Module 6 – Communication with the customers/consumers* deals with providing clear information and guidance to customers on the selection of effective materials, equipment, appliances and fixtures. This includes fundamental regulations and certifications, a preliminary study for data gathering and definition of the overall audit approach, the necessary tools (i.e., measuring equipment, material) to onsite measuring and the necessary documentation to prepare the field visit information report.

The 2nd Unit of the Module 6 – *Communication with the customers/consumers* deals with the principles of providing guidance to consumers on the impact of consumer behaviour on water-energy savings. Advising on the implementation of water saving measures, including identification of best practices, efficient appliances and measures to increase building performance and the elaboration of a proposal to the customer/consumer.

## *Unit 1: Providing clear information and guidance to customers on the selection of effective equipment, appliances and fixtures*

**General description**

In the 1st Unit of Module 6 the WET trainees will be taught how to provide clear information and guidance to customers on the selection of effective equipment, appliances and fixtures in order to improve their knowledge of:

- regulations and standards (local, national, international) applicable to all types of hydraulic systems, considering water-energy efficiency requirements, for guidance and supporting the customer/client, to correctly propose adequate materials, equipment, appliances and fixtures;
- the operational characteristics of the thermo-hydraulic system components, considering water-energy efficiency requirements, for guidance and supporting the customer/client;
- procedures to make a diagnosis over the facility and assessment of consumer behaviour, to make recommendations to the customer/client considering water-energy efficiency requirements (in line with the customer/client needs and the necessary performance and environmental requests);
- cost-benefit of the different alternatives that can be proposed.

**Scope – Expected results**

After the end of attending this learning unit, the WET trainees will be able to:

- Discuss with the customer and make recommendations, considering water-energy efficiency requirements (in line with the client needs and the necessary performance and environmental requests);
- Evaluate the matching between the facility characteristics and client demands, considering water-energy efficiency requirements;
- Propose improvement options over the initial project and provide different alternatives, based on cost-benefit analyses;
- inform about the advantages of water-energy efficient networks, including material, equipment, appliances and fixtures, with the implementation of water-energy saving measures
- Provide information on water-energy retrofit options, including the cost-benefit analysis.

**Key words / basic terminology**

Proposal development, project management, energy saving techniques, water saving techniques, explanation techniques, efficient use.

## 1.1 Cost-effective integrated water-energy saving interventions for buildings upgrades

### *1.1.1 Legislation and regulations applicable to hydraulic installations and systems*

The regulations and legislation in force applicable to hydraulic systems, installations and water equipment that need to be considered in new construction, rehabilitation or integral reform of buildings can be mainly of

- International and European scope;
- National level;
- Regional and local (provincial and municipal) scope.

**International / European scope**

• **European Council Directive 91/271/EEC of 21 May 1991** concerning urban wastewater treatment, which already establishes the need for treatment, collection from agglomerations, installation of appropriate treatment systems for such water, and defines criteria for the identification of sensitive discharge areas (lakes, streams, rivers, etc.) and less sensitive areas. Likewise, the deadlines for compliance with such measures are set, in defence of the environment and according to the size of the population and discharge area (according to different criteria in terms of level of requirement), which ranged from the 31st December 2000 for agglomerations of more than 15,000 inhabitants and 31st December 2005 for nuclei of 2000 to 15,000 inhabitants.

The purpose of the Directive is to protect the environment from the negative effects of the discharges of the mentioned wastewater. Namely it foresees that:

- wastewater shall be reused where appropriate, and
- Member States shall minimize any adverse effects on the environment in the reuse of wastewater.

• **Water Framework Directive 2000/60/EC (WFD) of the European Parliament and of the Council of 23 October 2000**, establishing a framework for European community action in the field of water policy. According to the Water Framework Directive (WFD), Member States should ensure that the direct or indirect reuse of treated wastewater does not lead to changes in the chemistry of surface water bodies which would compromise the achievement of the ecological and chemical status objectives, including avoiding deterioration in the water status specified in the Directive on priority substances 2008/105/EC, including special protection for water bodies used for the abstraction of drinking water.

Moreover, it is stated that Member States may reuse treated wastewater in the recharge of aquifers as a measure to contribute to the WFD objectives for groundwater as long as:

- Such recharge is subject to prior authorization.
- The quality of the reused water does not compromise the quality objectives for groundwater specified in the WFD and the Groundwater Directive 2006/118/EC /GWD).
- The associated controls should be reviewed periodically as necessary to reflect the progress of potential contaminants and their impacts.

**National Level**

• **Water Law (LA), 29/1985, of 2 August is the basic regulation of water reuse**, where the basic requirements for water reuse were already beginning to be established according to the treatment processes, quality and intended uses.

The existing regulations clearly determine the quality of the treated water according to its destination:

- Discharge to sanitation, in the case of urban centres;
- Discharge into the nearest watercourse or ditch, in the case of isolated single-family homes or in rural areas (for these there would also be the possibility of a filter well or septic tank on the same plot);
- Reuse.

### *1.1.2 Relevant energy certifications and reference documents*

**Energy certification systems for homes and buildings**

The systems towards the evaluation of the sustainability in buildings are methods that evaluate the environmental impact that the construction of a building generates in the environment. A third party evaluates the energy performance of the building with respect to its surroundings according to its standards. These methods include protocols that classify buildings (in some cases they also refer to urban development) according to their degree of sustainability or compliance with certain indicators or strategies determined by the system itself, and which subsequently certify the building or the urban development performance. Although assessing the sustainability in buildings, the methods differ and the types of components assessed are different amongst the initiatives.

The most widely spread certification systems in Europe are:

- BREEAM (United Kingdom)

- LEED (United States of America - USA)

- VERDE (Spain)

- PASSIVHAUS (Germany)

**Reference documents**

• **Guidelines for the integration of water reuse into water planning and management in the context of the Water Framework Directive**: the document developed explores the policy and planning context for the reuse of treated wastewater in a collaborative programme of the European Commission and all its member states as well as non-governmental organizations. It reflects an informal consensus positioning the best practices agreed between all participants in the drafting and does not necessarily reflect the formal and official position of each EU member state.

It is important to stress that there is no single solution and that existing regulations and standards should be carefully revised, as well as the onsite particularities. In fact, there is no "one size fits all" solution to water scarcity across the EU or amongst different regions and realities within the countries.

The guidelines point out that water can be reused for a variety of purposes (agriculture, landscape, urban, environmental, industrial, etc.) and the document describes the range of possible economic and environmental benefits. It also provides guidelines on the interpretation of EU legislation in its application to water reuse and emphasizes the need to ensure compliance with relevant EU environmental legislation.

• **National reports and best practices on water planning and management.**

• *Example 1 - The OPPA (water policy observatory) report of 2018: " Challenges of water planning and management in Spain"*: the report is the result of the research project "State of the question of water planning, management and policies", which has been financed by the Spanish Ministry for Ecological Transition in the 2018 call for the awarding of grants to third sector entities or non-governmental organizations that carry out activities of general interest considered to be of social interest in the area of scientific and technical research of an environmental nature.

• *Example 2 - The best practices compilation of Águas de Portugal (AdP)*: AdP is Portugal's state-owned holding group providing water services to both companies and municipalities in the field of water supply and wastewater sanitation. Their website lists a series of good practices in different areas, among which combatting climate change, operational management and efficiency, and valuing the landscape and biodiversity. Moreover AdP produces an annual report on the state of the art of water management in Portugal (policies, developments, main interventions on the environment…).

• **Water – Energy Nexus in Europe (Science for Policy report by the Joint Research Centre)**: the interdependencies between water and energy are well known and have become a subject of increasing attention for the scientific and political communities. Water is used throughout the energy industry, and the water system needs energy to collect, pump, treat and desalinate water. Increased water and energy needs, or changes in water availability due to climate change could have significant effects on the energy system.

The operation of the water sector can offer solutions to increase the flexibility of the European electricity system. This can be achieved by powering water treatment and desalination plants with renewable energy and by using water supply and distribution networks to store energy. All the above considerations indicate that the use and management of water and energy resources must be addressed simultaneously. The "water-energy nexus" approach is possible to maximize opportunities to increase energy efficiency in the water sector, to exploit the potential of the water system as a source of flexibility for the energy system, to extract more energy from water, and to reduce the water footprint of energy industries.

This report summarizes the main results achieved so far within the Water Energy Food and Ecosystem Nexus (WEFE Nexus) project which is a flagship project within the Energy Nexus in Europe research. It addresses, in an integrated manner, the interdependencies and interactions between water, energy, agriculture, water supply and treatment, as well as the environment. These interactions have so far been largely underestimated. The WEFE-Nexus can be described as a way to overcome the view of stakeholders' resources as individual assets by developing an understanding of the broader system. It is the realization that acting from the perspective of individual sectors cannot help to address future societal challenges.

• **Regulation Related to Recycled Water of 1st October 2018 (revised) Titles 17 and 22 California Code of Regulations Sate Board, Division of Drinking Water (DDW), Recycled Water Regulations**: this regulation has a great impact on the protection and prevention of pollution by implementing cross-connections with a specific control program: ordinances and standards of use, surveys to identify users of water reuse networks with risks, list of types of non-return flow valves according to the risk associated with the installation: valves with double control (DC), pressure reduction devices (PR) and air gap separation (AG).

Title 22, Code of Regulations, includes a chapter (Nr 3) that defines the requirements and criteria in water recycling. Article 3 defines the type of uses: for irrigation of crops, parks, school yards, residential gardens, golf courses or other irrigation (with limits and automated control of the turbidity of the incoming and outgoing water), for filling reservoirs, for air conditioning and refrigeration systems, and for the following:

- Toilets and urinals flushing;
- Bait drain traps;
- Industrial process water that may come into contact with workers;
- Structural firefighting;
- Decorative fountains;
- Commercial laundries;
- Filler consolidation around drinking water pipes;
- Manufacture of artificial snow for commercial outdoor use;
- Commercial car washes, including hand washes if the recycled water is not heated, where the general public is excluded from the washing process.

Recycled water used for the following uses should be at least disinfected with secondary recycled water

- Industrial boiler feed
- Non-structural fire fighting
- Filler consolidation around non-potable pipes
- Soil Compaction
- Concrete mix
- Road and street dust control
- Cleaning of roads, sidewalks and outdoor work areas
- Industrial process water that will not come into contact with workers.

### 1.2 Benchmarking and identification of the saving potential

In order to assess the costumer (consumer) profile and perform monitoring activities, water-energy audits may be undertaken. The basic principles of the process include *benchmarking* and *identification of the saving potential* through onsite measurements and observations. This combines a *preliminary study*, an *audit/diagnosis* of the household/building and *sampling and monitorization*.

To make an estimation and assessment of the building water balance, including the energy use under the water-energy nexus, some basic elements need to be provided by the customer/consumer to the technician expert or auditor.

**Preliminary study**

The preliminary study (before the first field visit) should include a survey to the owner/user and a request to have access to the available documentation regarding the building, infrastructure, system, appliance, fixtures or any elements on the technical, financing or administrative aspects, useful for building characterisation. With respect to the possible available documentation, the following may be considered as necessary:

- Basic elements in building/household at the design, construction or built stages: water and wastewater networks (written elements, measurements and drawings), outside area with irrigation network (written elements, drawings), architecture or final drawings (if concluded), pool characteristics (type of treatment, covering, equipment and water saving strategies);
- The manual of the building/household, the maintenance plan and the logbook of the main building/household interventions (renovation or replacement of pipe, fixture or appliance), provided by the constructor or the owner;
- Technical specifications or catalogues of the fixtures (brand, model, functionality, flow), appliances (brand, model, functionality, water and energy usage) and domestic hot water production systems (model and energy source), e.g., provided by the respective suppliers at the time of buy or rehabilitation;
- Acquisition bills or any other documents of administrative relevance that may refer to the installed equipment, fixtures, materials, etc.;
- Service (water and energy) bills, preferably from the last 2-5 years and after the latest infrastructure intervention (replacement of pipe, fixture or equipment);
- Technical and scientific references (e.g., labelling) from national or independent authorities with non-commercial claim for performance evaluation of the installed components.

Based on the provided information and documentation, which may vary with the owner/user or the regulatory mandatory procedures, different information can be provided. The collected data and resulting information should be used to produce a preliminary characterisation report, where the type of building/household in-hand (e.g., apartment, house) and construction stage at the time of the audit/visit (e.g., project, new building, and old building) need to be identified.

**Building/household profile diagnosis**

- **Consumption profile**

Household water systems may be comprised of the following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production and distribution. With basis on these typical consumptions taking place in residential buildings, the overall audit approach will consider five main areas:

1. Water sources and infrastructure – alternative sources of water and the water network distribution infrastructure;
2. Outdoor uses – exterior area property of the building/household owner/user, including garden, pool, paved areas, roof;
3. Water fixtures – taps, toilets, shower heads and other types of fixtures present;
4. Water appliances – washing machines and dishwashers;
5. Domestic hot water production – energy production equipment and domestic hot water network.

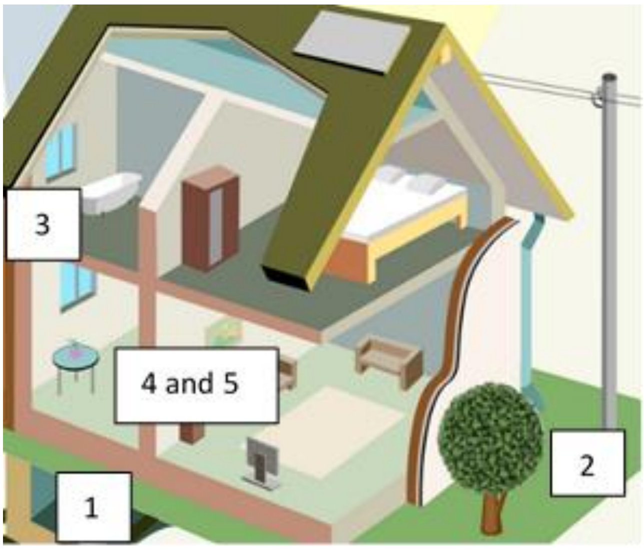



**Figure 3.1: Five main areas in buildings: (1) water sources and infrastructure, (2) outdoor uses, (3) water fixtures, (4) water appliances, (5) domestic hot water production.**

Consumption profile may be assessed through a survey, where the owner/consumer provides information regarding the overall use of the building/household (e.g., in use, no use) and occupation (e.g., main/temporary, number of people). The survey should also include questions regarding consumer habits/behaviour, to further assess water fixture and appliance water and energy usages, as well as calculate the potential savings derived by the implementation of water saving measures.

At the residential building sector, the most representative uses are usually associated with showering and bathing, with ca. 39%, leaving equipment/appliances (dishwasher and washing machines) with ca. 20%. Changes in the consumption distribution profile may be due to variations in outdoor areas, which are also affected by the geographical location of the building, climate and season of the year. Water losses (not shown in the figure) are usually around 4-5% and may be attributed to leakage in the distribution network, fixtures and appliances.

A diagnosis of the building infrastructure should consider the definition of the sampling approach, including the identification of the necessary instrumentation and implementation to the diagnosis of each water point. This information is important to estimate consumer demand profile or to the evaluation of the impacts of the implemented water efficiency measures.

- **Sampling and monitoring**

Definition of the sampling approach (Figure 1.2, with an example provided in Figure 1.3) includes definition of: the sampling method (discrete or continuous), the measuring type (qualitative or quantitative), the data acquisition period, the monitoring timeframe and equipment installation (invasive or not-invasive). The number of fixtures/equipment to analyse should include total number of taps (kitchen, sink and bide), the total number of toilets and any other water points, as part of the building/household.

The technology for each of the fixtures/equipment observed needs to allow guidance over the possible technologies promoting water saving behaviour (e.g., dual flushing systems). The age of the fixtures/equipment may allow to suggest maintenance measures or the pertinence of improved rehabilitation. The definition of the sampling approach should be done by the time of the preliminary study.

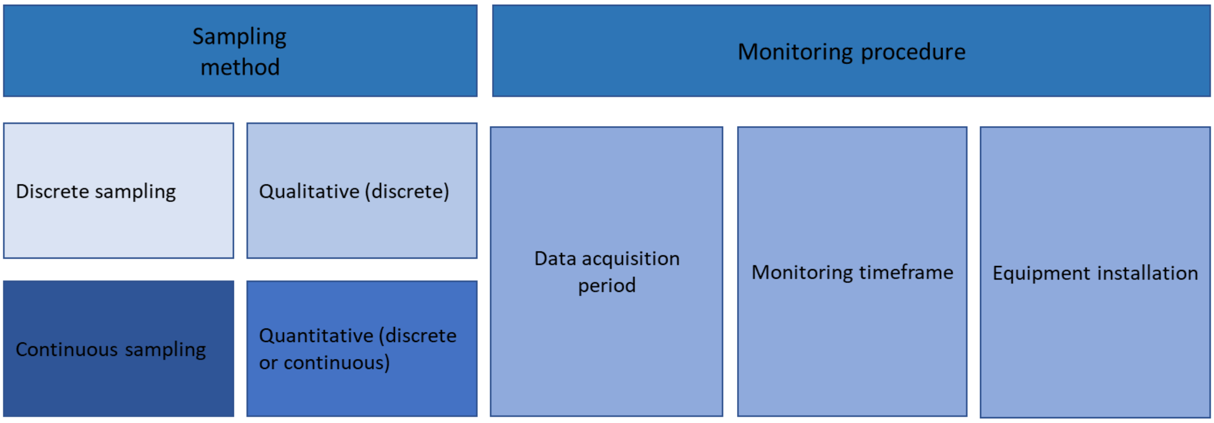



**Figure 1.2: Sampling approach: sampling method and monitoring procedure**

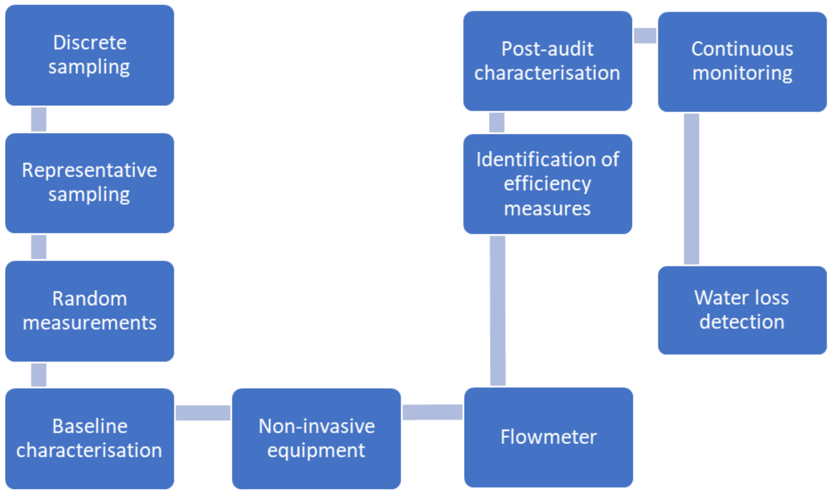



**Figure 1.3: Example of a sampling approach**

In a building/household, the set of measuring equipment that may be included to assess water efficiency performance evaluation may be as follows:

- Flowmeter – adequate to measure the flow in a fixture or pipe (Figure 1.4). Measuring equipment specifications should consider a representative flow length, allowing the possibility of measuring low and high flows in common fixture households. Resolution should be adequate to measure flow in litres per second.
- Calibrated volume – adequate to measure the capacity of a toilet flush. It may be used as a flowmeter together with a time watch. Resolution should be adequate to measure litres.
- Ruler or dimension reader – measuring equipment of dimensions to calculate areas for gardening, pavements, etc. Resolution should be adequate to measure cm.
- Thermometer – adequate to measure water temperature. Measuring equipment specifications should consider the need of doing rapid reads and it should not be easily breakable. Resolution should be adequate to measure cold and hot water temperatures of ca. 0-100 ºC.
- Pressure reader – adequate to measure flow pressure in a fixture or pipe. Resolution should be adequate to measure pressure of ca. 1-10 bar.
- Timer – adequate to measure time and assess flow rate together with volume measurements. Resolution should be adequate to measure seconds.
- Thermography – adequate to perform thermal imaging inspection for the detection of temperature differences in distribution pipes (Figure 1.5), useful to detect water losses or pipe scaling. Equipment should be adequate to measure the temperature gradient in the water pipes.

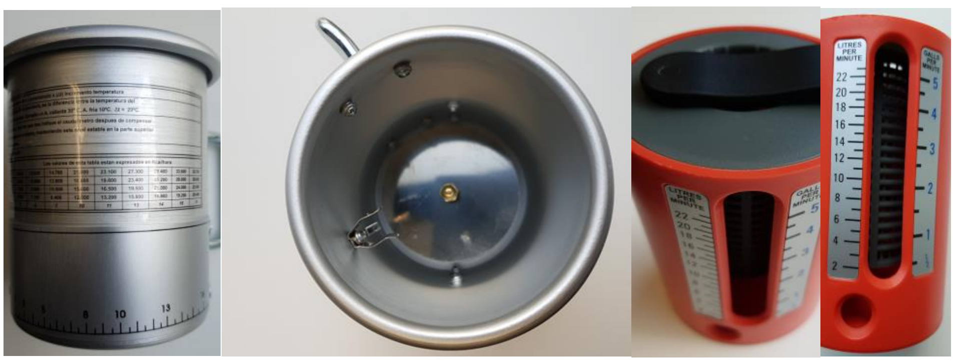


**Figure 1.4: Flowmeter equipment to measure the flow at fixtures**

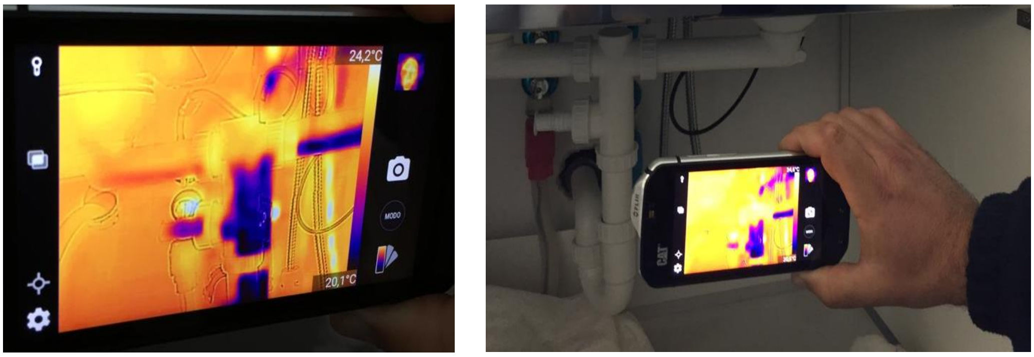



**Figure 1.5: Thermographic equipment to measure temperature differences**

During the audit, it is important to fill-in an audit sheet and take photographs systematically, as an attempt to make an audit record. The audit should include the number of fixtures and appliances present, existence of flow or volume restrictors, the existence of leakages, as well as behaviour observations.

The diagnosis of the water and energy consumption levels in fixtures and appliances consider all water points. On-field, for installation of the equipment and perform the measurements, specific tools may be required. With respect to the equipment, the calibrated volume, the ruler, the thermometer and the timer may be used for discrete sampling, while the flowmeter and the pressure reader may be used for sampling and continuous monitoring.

Amongst these two, the choice for sampling or continuous monitoring may rely on the required accuracy of the measurements or, for instance, when it is necessary to undergo a comprehensive analysis on the existence of water losses or in finding the consumer behaviour pattern. The appropriateness of using invasive or non-invasive equipment should be carefully evaluated, given differences in accuracy together with the objective of conducting the measurements.

**Figure 1.6: Ultrasonic (in-line) water flow equipment (non-invasive)**

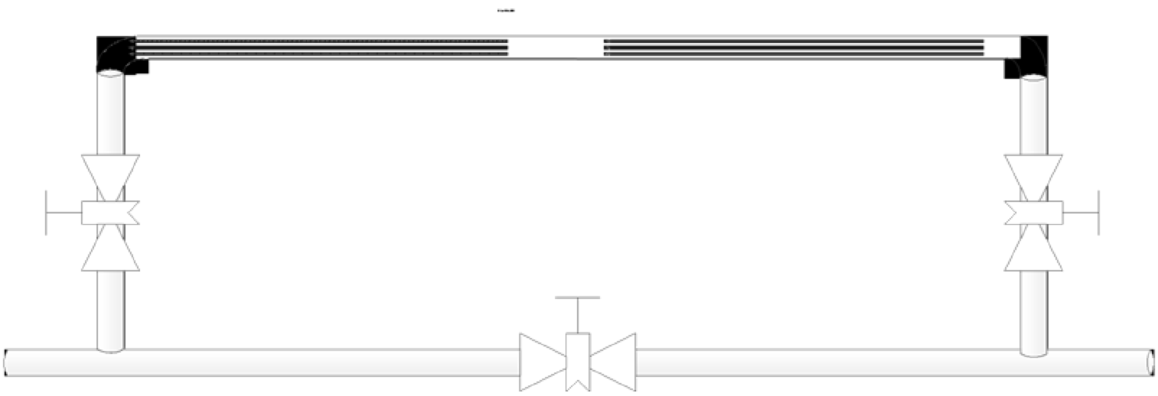


**Figure 1.7: Mechanical water flow equipment (invasive)**

## 1.3 Principles of explanation and consulting techniques

Identification of the water and energy efficiency measures allows the auditor to give advice and guidance to the customer/consumer, aiming at the improvement of the overall building/household performance and resilience. The expert technician and auditor should be able to present the advantages/ disadvantages per efficiency measure, based on the customer/consumer behaviour and expectations, including financial outcome, technical performance and water saving dimensions. Comparisons over the different possible measures and the corresponding advantages/disadvantages should be included in the documented proposal with the identification of the efficiency measures, as well as guidance to the customer/consumer on the quick-win measures in terms of financial turnover.

- **Financial outcomes, technical performance and water saving dimensions**

The identification of the payback time per measure or the calculation of the net present value is important to determine the viability of the investment, only considering the financial outcome. The calculations over the investments should include the total investment, such as material, labour, transport costs, as well as the expected maintenance requirements. To analyse the overall viability of the measure, the technician expert and auditor should also consider the total time of the project, assumed to be the expected lifespan of the measure. This may be considered as the average time of the measure (e.g. network, pipe, equipment), from implementation until the guarantee of its technical performance or obsolescence.

The **payback period** (PB) refers to the time needed to repay the initial investment (1$^{st}$ equation below), while the **net present value** (NPV) is calculated in terms of currency (2$^{nd}$ equation below). The net present value may be relevant to consider in long-term investments. Unlike in the payback period calculation, which is blind to variations in the money value, the net present value may suffer positive effects due to tariff increases or negative effects due to the opposite.

$$PB = \frac{Investments}{Calculated\ savings\ per\ year}\ [years]$$

$$NPV = \frac{Calculated\ savings\ per\ year}{(1+i)^t} - Initial\ investment\ [€]$$

Where:

*i*: required return or discount rate
*t*: number of time periods.

The financial gains that can be obtained through the implementation of the water-energy efficiency measures need to be accompanied by the improvements over technical performance. Technical performance should be assessed by the efficiency gains of the measure (e.g. expressed in percentage), the technology upgrade and user's comfort level. Technical performance should be observed under the water-energy nexus, meaning that upgrades in water efficiency should not lead to inefficiencies in energy efficiency, and the other way around.

With respect to the calculated savings, these may vary with consumer behaviour. Perception of consumer habits may, therefore, help to make good estimations on the expected savings. Likewise, these need to be adequate to the potential real savings, or the calculated paybacks and net present value may be over or underestimated. Calculations over the water and energy saving estimations should be also presented to the customer/consumer. These estimations should not be neglected, given the overall importance of water as a natural resource and of energy efficiency in house bills. In fact, whenever possible, the expected prevented $CO_2$ emissions should be included in measure comparison.

- **Documented proposal with technical specifications**

The audit process and the identification of water-energy efficiency measures should conduct to a proposal with technical specifications to improve the overall system water-energy performance. As part of the audit report, and as guarantee of the expected outcomes and savings of the implemented efficiency measures, the expert technician and auditor should elaborate the technical specifications required to the implementation of the water-energy efficiency measures.

The main elements that should be included in the technical specifications document are the following:

✓ **Design, technical and financial aspects**
  - Installation design
  - Technical specifications of the fixtures, equipment, materials
  - Technical specifications of the construction materials
  - Budget and payment conditions
  - Financial outcomes, technical performance and water saving dimensions.

✓ **Selection, grant and evaluation requirements**
  - Selection criteria for fixtures, equipment, materials
  - Grant criteria for fixtures, equipment, materials
  - Evaluation criteria for fixtures, equipment, materials.

✓ **Work execution, term and resources**
  - Reception of the work
  - Work execution term
  - Resources.

## *Unit 2: Providing guidance to consumers on the impact of consumer behaviour on water-energy savings*

**General description**

In the 2nd Unit of Module 6 the principles for providing guidance to consumers on the impact of consumer behaviour on water-energy savings will be taught to the WET trainees in order to improve their knowledge of the consumer behaviour relating to the purchasing of water-energy efficient and/or environmentally preferable goods, and of the consumer behaviour relating to the use of water and energy consuming appliances and equipment.

**Scope – Expected results**

After attending this learning unit, the WET trainees will be able to enhance their abilities to:

- understand and discuss the consumers' real water-energy needs;
- guide the consumers choices in what regards to water-energy consuming equipment / appliances / fixtures towards more efficient and/or preferable solutions from the environmental point of view (even if the cost is higher compared to the conventional ones);
- provide tips and guidelines for an efficient, economical and safe use of the thermo-hydraulic installations.

**Key words / basic terminology**

Consumer decision-making, behavioural economics, water consumption habits, environmentally preferable goods, individual thermo-hydraulic equipment, efficient installation use, safe use.

## 2.1 Understanding consumer behaviour relating to the purchase of water-energy efficient and environmentally preferable goods

### *2.1.1 Understanding consumer decision making*

**Principles of the consuming decision process**

From a consumer perspective, when it comes to the act of purchasing, decision-making involves taking into account a wide range of variables, starting with the price and quality of the product but including many other items like, the cultural context, personal identity or values. Decision making models are often used by marketers and blend both economic theory and psychology to assess human behaviour relating to the act of purchasing (as presented in figure 2.1).

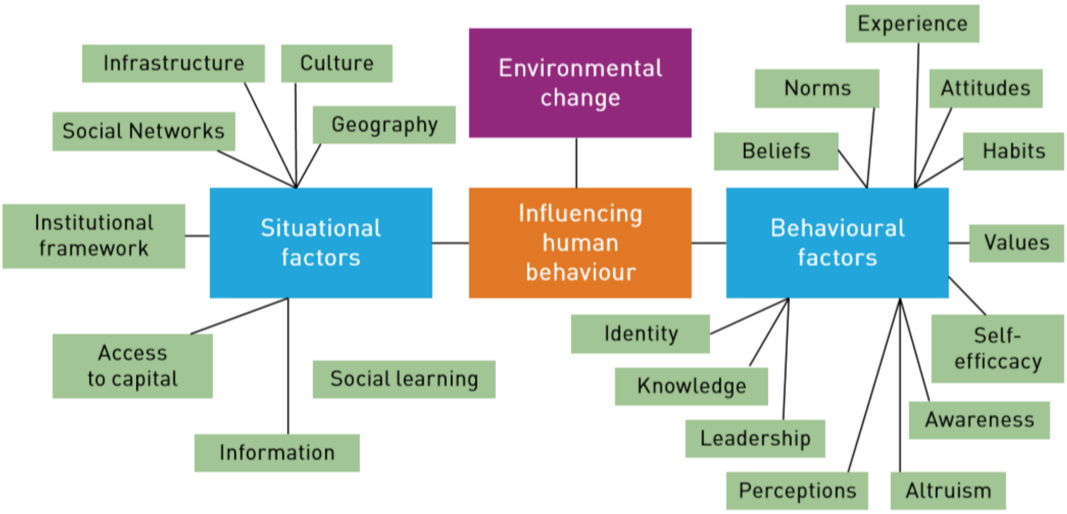



**Figure 2.1: Situational and behavioural factors influencing human behaviour**

[Source: Defra, Sustainable Lifestyles Framework, 2011]

The Consumer Decision Model was originally developed by Engel, Kollat and Blackwell in 1968 and has since been revised, but still provides a widely recognized outline of the six different stages of the purchasing process:

| |
|---|
| 1) Needs recognition → 2) Information Gathering → 3) Evaluation of the Alternatives → 4) Purchasing Act → 5) Consumption act → 6) Post purchase evaluation |

According to this model, the consumer first **recognizes the need** to purchase a product or service, once the need has been confirmed, the next step is **gathering information** in order to **assess the purchasing alternatives**. Once the **purchasing act** has taken place, the consumer **consumes** the product or uses the services and closes the consuming decision process by conducting a **post-purchase evaluation.**

**Consuming decision-making strategies**

When taking a purchasing decision between multiple products or services we often rely on "shortcuts" like social cues combined with a heuristic approach. In other words, we take into account "social trends" and devise "hands on" strategies depending on the particular context of the task at hand.

Literature on consumer decision making has defined 7 different strategies which fall into three main categories:

1) Compensatory strategies: imply according a positive value to certain desired aspect of one product/service to make up for an undesired aspect
2) Non-compensatory strategies focus on one desired or undesired aspect of a given product/service as necessary for the purchase
3) Partially compensatory strategies consist on giving certain amount of importance to different aspects of one service/product.

Case Study: Electric vehicle (EV) purchase in Sweden

The results of this study highlight the influence of 5 main factors which involve both **situational factors** and **behavioural factors**: Social norm, Personal norm, Ecological Attitudes, Opinion Leading (individuals who are communicators of innovative ideas and practices in broad social networks), Opinion Seeking (individuals who look for reference from interpersonal sources).

The main conclusions of the study are:

- EV adopters have more education, higher income, cohabitate, and live in larger cities than the other groups.
- EV adopters exhibit higher levels of personal norms (PN), social norms (SN), and opinion leadership (OL).
- The levels of opinion seeking (OS), are significantly lower among EV adopters than among "Non-adopters".

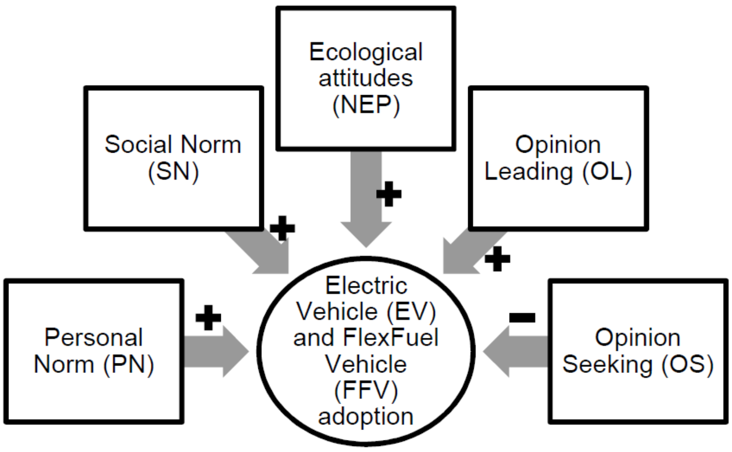



**Figure 2.2: Factors influencing electric vehicle adoption**

[Source: Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden, Journal of Cleaner Production 154 (2017)]

This study suggests that the consumer decision of adopting more efficient and innovative water appliances and diminishing water consumption is often the result of an increased level of personal norms and social norms and opinion leading attitudes. This set of factors will have an effect on water energy audits as they will influence the consumption profile of the costumer and make the technical performance and water saving dimensions more relevant for the costumer than the financial outcomes.

### *2.1.2 Understanding ethical and environmentally preferable consumerism*

**Sustainable Development and Consumerism definition and scope**

The concept of **sustainable development** is now broadly adopted in our societies. It was first brought to the attention of international public opinion at the Earth Summit in Rio de Janeiro in 1992. At this Earth Summit, the UN defined sustainable development as "promoting patterns of consumption and production that reduce pressure on the environment" while at the same time "meeting the basic needs of humanity".

There is now a consensus in the scientific world about the effect of human activity on climate change and its devastating effects on the planet. The **current socio-economic model** of production and consumption is not only closely linked to **climate change** but also **clashes with the planet's biophysical limits**.

The consequences of the current development model are already measurable in terms of loss of biodiversity, alteration of natural ecosystems, restrictions on access to energy and an increase in extreme weather events, as well as the socio-political implications: conflicts linked to the scarcity of resources, the growing number of climate refugees and the increasing number of natural disasters. In this context, **consumption** has become **a priority for action against climate change**.

Sustainable consumption applied to the consumption of natural resources and energy can be defined as:

> Adjusting as accurately as possible resources to the existing needs promoting practices that contribute to care and preserve the environments in which we operate.

Sustainable consumerism is driven both by economical drivers and responsible or ethical consumption. A definition of this concept proposed by The Ethical Consumer Research Association is:

> Personal consumption where choice has been informed by a particular ethical issue –be it human rights, social justice, the environment or animal welfare.

In other words, **ethical consumption** is in sharp contrast to traditional or so-called mass consumption, and is based on the contemplation of the following criteria: **Ethics**, that considers values as the basis for buying and consuming; **Ecology**, this is a consumption that is careful with the environment and natural resources, and **Solidarity**, which takes into account the working conditions of the people involved in making the product or providing the service.

**Main drivers of "green" consumerism**

Although it is difficult to separate "green consumerism" from the broader notion of "ethical consumerism", to put it on a nutshell: green consumerism mainly focuses on practices derived from ecological concerns and principles.

From a psycho-social perspective

According to recent studies on the field of green consumption the psycho-social basis for this behaviour is the combination of a sense of Green Self-efficacy which reinforces the consumer’s Perceived Consumer Effectiveness. These two concepts describe the situation in which an individual is convinced of the impacts of his/her consuming actions on the environment because:

1) The consumer believes in the efficacy of his/her own consuming acts.
2) The consumer has pre-existing knowledge and “green” values.

The outcome of these two pre-conditions is a “green purchasing decision”.

From a sociological perspective

The following social conditions and values are some of the main drivers of green consumerism which have been identified:

1) *Social influence and Ecological attitudes*: Personal and social norms are well proven to influence both “discourse”, intentions and actual behaviour. The socialization of the idea that we should take into account the environmental impact generated by everything we consume, is the starting point to promote practices that in one way or another will curb the immense environmental challenges of the Earth. In other words, the social norm that “the well-being of the planet is our own well-being” is a strong driver of green consumption.
2) *Public authorities and Corporations responsibility*: Policy making, legal and financial regulation and corporate responsibility highly influence green consumption. This is due to the fact that corporations and governments have the power to promote policies and regulate the interaction of all the agents involved in a production system. It is thus, often their role to ensure that each phase of the economical chain respects and is responsible for the environmental impact. Assessing processes that may promote or go against the efficient use of natural resources and energy production, may as well cause a reduction of the levels of any type of pollution.
3) *Education and awareness*: Finally, green consumerism relies heavily on the awareness and education of the world's population concerning the importance of the preservation of natural resources and the importance of counteracting climate change. An educated population will have both the environmental consciousness to motivate change in consumption patterns and the technological tools to propose new environmentally friendly processes and consuming models.

## 2.2 Understanding consumer behaviour relating to the use of water and energy consuming appliances and equipment

### *2.2.1 Water-energy consuming patterns and trends in European regions*

**Fresh water availability**

As established in the previous section, social influence plays an important part in guiding individual behaviour, and especially behaviour which can be viewed as pro-social and/or pro-environmental.

When it comes to water consumption patterns and the purchase of environmentally friendly thermo-hydraulic equipment's, the same rules apply but another major factor comes into play: like **the climate zones** and geography**.**

**Water stress**, when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use, is a common problem in southern Europe. Overall water availability is revealed in figure 2.3 (water exploitation by river basin use in Europe), which highlights the fluctuation in the Water Exploitation Index, i.e. an index which compares water use against available renewable water resources (Water Exploitation Index of above 20% implies that the water unit is under stress), in European countries depending on the season and the region concerned. Southern countries are further affected by water scarcity in the summer.

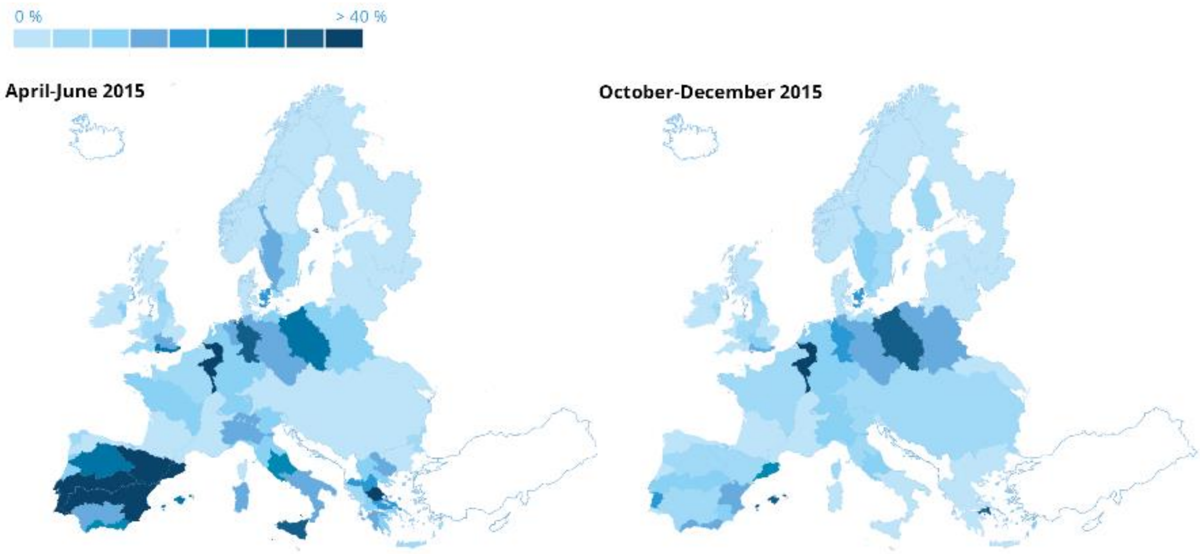



**Figure 2.3: Water exploitation by river basin use in Europe**

[Source: European Environment Agency, 30 August 2018]

__**Water and energy consumption in European households**__

According to the European Environment Agency, freshwater use of households represents, on average, **144 litres** per person per day. This corresponds to around **three times the established water needs** according to the WHO (World Health Organization): "*Access to 50-100 litres per person per day ensures a low impact on health*".

The following data sheds light on the average household habits concerning water consumption:

A bath: 150-300 litres
Shower: 50-100 litres
Flushing a toilet: 10 litres
Washing dishes by hand: 23 litres
Dishwasher: 20-40 litres.
Washing machine: 40-80 litres
Defrosting food under the tap: 25-25 litres
Washing the car with a hose: 200-500 litres.

Moreover, water consumption and energy consumption are closely related. In Europe, on average,

**water heating represents 14%** of the European household's energy use, the second largest energy use after space heating (64%). In Spain, for instance, the Domestic Hot Water (DHW) main energy source is gas, and it amounts for 1598 ktoe, followed far behind by petrol (579.8 ktoe), electricity and renewables. Over the course of the past 7 years renewable energies as a source of DHW have increased and gas has decreased although remained stable during the past 3 years.

It's clear that water sustainability—the greatest guarantee for its availability—requires responsible consumption and proper management. As highlighted by the report "Sustainable lifestyles baseline report", European lifestyles are unsustainable as they result in over consumption and excessive pressure on natural resources.

This is due to many factors:

- Policy measures focus on environmental impacts of consumption and production processes and technology solutions, rather than on **influencing** how and why people select and **use certain products**.
- The policy measures are insufficient in the face of **rising incomes, material living standards and the consequent impacts of consumption** as well as the widening gap between rich and poor.
- Widely held perception of **wellbeing** as intimately **linked to a high level of material consumption i**n the dominant consumer culture of the twentieth century.

### *2.2.2 Principles of circular economy and consumption reduction habits*

<u>**Circular economy principles**</u>

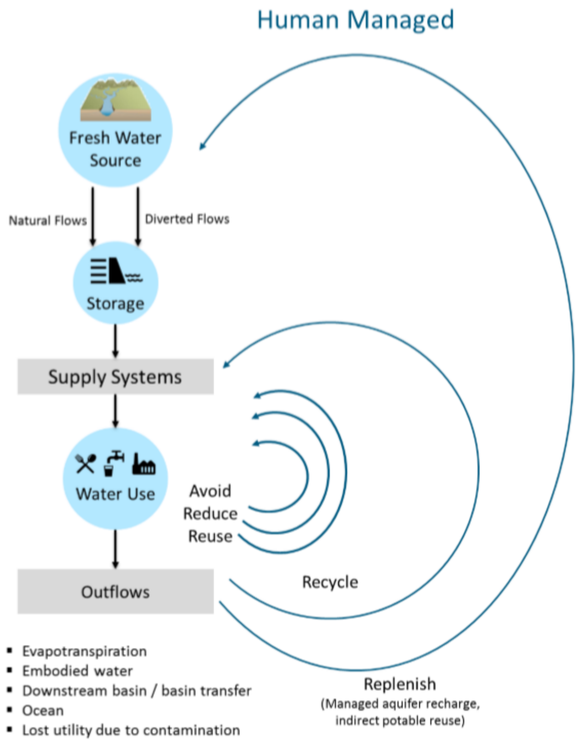



**Figure 2.4: 'Butterfly' diagram adapted to represent the Human Managed Circular Water Economy**

[Source: *Water and Circular Economy*, Ellen Mc Arthur Foundation. October 2018]

In attaining a sustainable approach to water consumption a circular economy scheme must be applied. According to the Ellen MacArthur Foundation, a circular economy is characterized by challenging linear growing patterns proposing a circular approach affecting all production phases: limiting the **extraction** of raw materials (in this case water), **designing** efficient (water) systems, adjusting the (water) **distribution,** encouraging resource (water) **use reduction**, implementing **recollection** (of water) and restarting the cycle with the **reuse** of waste remains (in this case grey and wastewater).

Summarizing, circular economy applied to water systems is based on three main principles: **Design out waste and pollution**, **keep resources in use by reusing and recycling** and **regenerate natural systems**.

**Consumption habits**

The following infographic summarizes European's domestic water uses and how significant amounts of water could be saved by adopting easy water saving practices when using water systems and appliances. Indeed, overall **water savings could represent up to 100 litres per day**, per person.

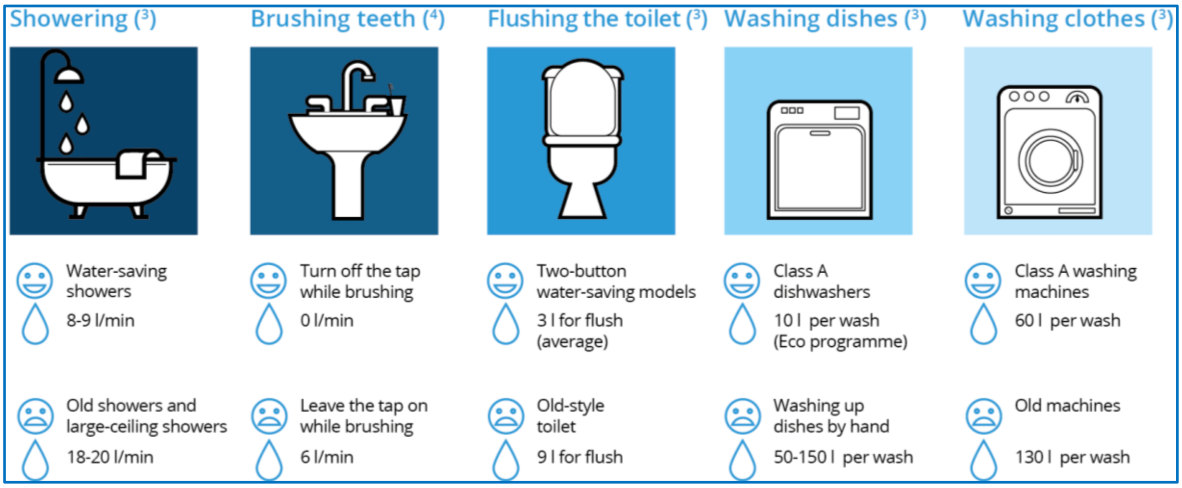



**Figure 2.5: Water use at home**

[Source: Infographic Prod-ID: INF-87-en, European Environment Agency, last modified 10 Dec 2019]

**Tips for reducing water consumption habits**

On a **societal level**, according to a study conducted by DEFRA (U.K.), more responsible domestic water use could be enhanced by implementing the following general actions:

- ✓ Implementing and optimizing water metering systems in scarce areas.
- ✓ Encouraging users to buy more water efficient appliances/products.
- ✓ Encouraging labelling of water efficient appliances/products, alongside energy efficiency ratings.
- ✓ Encouraging collaborative consumption (sharing, swapping, trading, etc.).
- ✓ Disseminating the environmentally friendly behaviours by authorities.

Some of the domestic consuming practices recommended to avoid the spilling of water resources are:

In the bathroom

- ✓ It's always better to take a shower than a bath. A 5-minute shower requires 100 litres with a normal head and 50 litres with a saving head equipped with a flow reducer against 250 litres with a bath.

- ✓ Turn off the tap while soaping, shaving, brushing your teeth. Don’t let the water run and use it only when you really need it. For example, turn off the tap while you're soaping, use a glass when you're brushing your teeth, and if you're shaving it's enough to have water in the sink, etc.
- ✓ Don't use the toilet as a wastebasket 9 - 10 litres (the capacity of the toilet cistern) of water is wasted every time the toilet is used to flush a cigarette butt or paper instead of the wastebasket.

Using the washing machine and dishwasher

- ✓ Use the washing machine when it is full and use the half load button, if available, only when in a hurry. This program does save water and energy, but consumption increases by 30% compared to a full machine.
- ✓ Adjust the detergent dosage according to the water hardness. Soft water needs less detergent than hard water. The detergent dosage according to water hardness is included in the recommendations for use on detergent packaging. To find out if your city's water is "soft, hard or very hard" you can go directly to your city's water service or to the company that manages this service (the contact number should be included on your water bill). You can also wash your hands with soap; if you lather too much, the water is soft; if it is too hard to lather, it is hard.
- ✓ Avoid pre-washing whenever possible.

Exterior water use

- ✓ For street and yard cleaning, the use of a broom and dustpan saves up to 200 litres compared to cleaning with a hose.
- ✓ It is convenient to water the garden in the hours of less heat; this way less water will be lost by evaporation.
- ✓ Irrigation must be approached with flexibility, adapting it to the weather. It is advisable to check the degree of humidity of the soil before water.

## 2.3 Knowing the proper use practices that lead to efficient, economical and safe use of the installations

### *2.3.1 Use recommendations for sanitary installations*

**Selection of efficient plumbing elements**

There are water-saving devices that can be easily adapted to existing elements. Their prices are low and allow a significant saving in water consumption. In addition, their installation does not offer great difficulties.

**Aerators/perlators for taps and showers**: These devices replace the traditional "tap atomizers" and incorporate air into the water jet, thus reducing water consumption without reducing comfort. The reduction in water consumption from taps can be as much as 40%.

**Double flush mechanisms for toilets**: The simple replacement of the traditional flush mechanism by another with a double button allows savings of up to 60% of the water consumed. The user can choose the volume of the flush depending on the use made.

**Water-saving shower heads**: Efficient shower systems (either fixed or telephone type), reduce the outflow to about 10 litres/minute, while the consumption of a traditional shower is about 20 litres/minute. These devices have mechanisms that prevent the user from noticing the decrease in flow.

The efficiency of these devices is linked to the knowledge and use of these measures by users.

__Other mechanisms__

**Pressure reducers in the main network:** The flow rate from the sanitary equipment depends directly on the pressure in the network. The following table shows the variations in the flow rates of the same sanitary apparatus depending on different pressures.

| | 6 bar | 3 bar | 1 bar |
|---|---|---|---|
| Flow rate | 25 l/min | 17 l/min | 12 l/min |

If there is a high pressure, it should be lowered to the recommended values. Consumption will be reduced without affecting the thermic comfort.

**Flow reducers in taps**: These are devices that can be incorporated into the pipes of the washbasins, as well as those of the showers in the changing rooms, in order to prevent water consumption from exceeding a set consumption (normally 8/10 litres per minute). If the installation has a low pressure, the quality of service may be impaired.

**Interruptible flushing systems in low flush toilets**: This system allows the flush to be interrupted voluntarily when the button or handle is pressed a second time, or by lowering the plunger.

**Counterbalance for cistern**: This is a mechanism that is attached to the flushing mechanism of the cistern and works by the effect of gravity. The flow of water is interrupted as soon as the handle is no longer operated. It can be adapted to both high and low cisterns.

**Pedal-operated taps**: These are the most efficient taps for industrial kitchens (in bars, restaurants and cafes), as well as the most hygienic.

In the case of a new plumbing installation, there is a wide range of options to ensure water and energy savings (thermostatic taps, single-lever mixers with two-phase opening, electronic taps, etc.). It is recommended that, before choosing the products, the consumer gets information about the different options available on the market through specialized installers or specific websites.

The following table sets out the (indicative) requirements for plumbing fixtures to be considered water efficient.

| Type of installation | Minimum required | Best available technology |
|---|---|---|
| Taps | Flow rate between 6 and 8 l/min | Cold start system with staggered opening |

| | | |
|---|---|---|
| Public taps | Timer with flow rate less than 8 l/min. | Electronic tap with a timer and flow rate regulated at 6 l/min |
| Showers | Timer and Spray economizer. Maximum flow rate 10 l/min | Timer with possibility of voluntary stop and economizer sprinkler system with a maximum flow rate of 10 l/min |
| Flush toilets | With single discharge switch. | Cistern with double discharge. Maximum volume of discharges 3 or 6 litres. |
| Urinals | Timer with maximum discharge of 1 | Optical-electronic cell individual for each urinal (maximum discharge with pre-wash 1 litre) |

### *2.3.2 Use recommendations for cooling and heating systems*

**Choose the air-conditioning unit with air cooling**

If an air conditioner is to be installed in a house, a product that cools the room using air to condense and not water should be chosen. In any case, the one that consumes the least energy and requires that it does not use gases that attack the ozone layer such as chlorofluorocarbons (CFCs), which are already prohibited, or hydro chlorofluorocarbons (HCFCs), must be selected.

Tips to improve the efficiency of the air conditioning system:

- Use double glazing or special glass if possible, which will allow good insulation from the outside environment, both in heating and air conditioning.
- A temperature difference of more than 10º/12°C should be avoided between the outside temperature and the temperature inside the air-conditioning system.
- Do not demand too much cold from the air conditioner when starting it up. It will not cool down any faster, it will only waste more energy.
- Clean or replace the filters periodically, otherwise the fan works more, consumes more energy and can be a source of contamination by distributing accumulated dust and dirt. Regularly clean the drainage tray, to also avoid a source of contamination.
- Check the water heating system and isolate the distribution pipes

Tips to reduce water consumption of the air conditioning system (also allowing for energy savings):

- Insulate the distribution pipes and hot water storage elements.
- Check and repair all leaks as soon as possible. Install a condensation recirculation system.
- Replace refrigerated appliances without water recirculation with refrigerated appliances with recirculation. The first type of appliances involve high water consumption and must be avoided if efficient consumption is to be achieved. Devices of this type are usually air conditioners. For reducing this consumption, it is possible to connect the appliance to a cooling tower. Evaluate the possibility of replacing it with an air-cooled appliance.

- Reuse the air conditioning water for, for example, watering green areas.

### *2.3.3 Use recommendations for saving water in household appliances*

In addition to the water uses made directly by the user/client, there are other points of water consumption on which it is easy to act and obtain positive results. This is the case of the kitchen, on which intense use is usually made for a number of hours a day. Therefore, any minimal improvement in the efficient use of water will translate into a significant reduction in consumption.

**Dishwashers:** In most cases, the option of doing a manual wash versus using a dishwasher can be an unnecessary expense (about 25 litres if the tap is turned off while scrubbing). Therefore, it is recommended that specific washing equipment be installed for the type of activity of each establishment (house, bar, cafeteria, hotel/restaurant, hospital, etc.).

When choosing a dishwasher, pay attention to the volume of water required per cleaning cycle and the number of meals to be served. According to the European Eco-label, which sets out and certifies the ecological criteria for these appliances (water consumption, energy efficiency, prevention of excessive detergent consumption, recycling, noise emissions and efficiency of washing and drying), an efficient dishwasher with 10 place settings should not consume more than 15 litres of water per cycle.

**Washing machines:** According to the European Eco-label, which sets out and certifies the ecological criteria for these appliances (water consumption, energy efficiency, spin efficiency, noise, prevention of excessive detergent consumption and recycling), an efficient washing machine should not consume more than 12 litres of water per kilogram of laundry in the normal cotton cycle at 60ºC, i.e. 96 litres per cycle for a 7-8 kg capacity washing machine.

The instructions of use for the washing machine should further provide advice on the correct environmental use and, in particular, on the optimal use of energy, water and detergent when the machine is put into operation (extract from the Commission Decision of 17.12.1999 establishing the ecological criteria for the award of the Community eco-label to washing machines).

The systems included in a washing machine to achieve efficient water use can be either mechanical (filters, valves, etc.) or based on electronic systems that optimize washing. Efficient washing machines usually have the following systems:

<u>Mechanical systems</u>

- Non-return valves that prevent water and detergent from being lost down the drain.
- Systems to cut off the water supply in case of leak detection.
- Filters to retain objects introduced in the garments, which avoid the obstruction of the drainage.

<u>Electronic systems</u>

- Electronic pre-soak systems instead of pre-wash (shower effect).
- Turbidity sensors, which measure the degree of soiling of the water each some time (in some cases, less than 10 seconds) and determine the temperature, amount of water and washing time to achieve an optimal result with the least consumption of resources.
- Systems for detecting the weight of the clothes introduced, which allow the consumption to be adjusted to the amount of clothes to be washed.

- Specific programs for each type of laundry, dirt, etc., to be selected by the user.

#### *2.3.4 Use recommendations for saving water in green areas*

Today there are options that allow to combine the maintenance of beautiful and pleasant gardens with a responsible use of water. These gardens use xeriscaping techniques, a form of gardening that aims to make efficient use of water in the gardens, adapting to the climatic conditions of the environment without building arid or cactus-plagued gardens.

The basic concepts to achieve a garden with minimum watering needs are the following:

1. The design of the garden
2. Soil analysis
3. The selection of species
4. Lawn areas and green carpets
5. The efficient irrigation
6. Maintenance.

**Design of the garden**: Good pre-design will help us provide guidance along of all phases of the creation of the garden and ensure that the different water saving techniques are well. Any design must begin with a careful recognition of the local climate and environmental characteristics of the terrain: it must be identified which areas are wetter and drier, which are sunnier or shadier, which are more exposed to wind and which are more sheltered.

This recognition of the terrain is very useful when designing the garden, because it allows:

- To adapt to its characteristics: for example, the sunniest areas (those exposed to the midday and afternoon sun) will be the most suitable for plants that appreciate light and resist dryness better.
- Make corrections: e.g. by arranging plant barriers to act as wind-breaks or by placing trees to provide shade in the sunniest points.

**Soil analysis**: An essential element of any garden is its soil. We must stress that one of the most effective measures is to choose the plant species that best adapt to the soil conditions (pH, texture, type of drainage, etc.) instead of rectifying one or another.

The characteristics of the soil will condition the plant species that are viable and will also influence water consumption. In fact, the speed at which the water is absorbed by the soil, as well as the capacity that it has to retain, depends largely on its texture, i.e. the proportion of sands (particles that are between 0.05 and 2 mm in diameter), silts (between 0.002 and 0.05 mm) and clays (particles smaller than 0.002 mm) that it contains.

In clay soils (which are those containing more than 55% of clays) water penetrates with difficulty and tends to spread on the surface, producing waterlogging and runoff. On the other hand, in sandy soils (with more than 85% sand) water penetrates very easily and is lost in the subsoil, as the capacity to retain humidity is very low. Therefore, although for different reasons, neither very sandy nor very clayey soils are suitable for the garden. Soils known as loam (with less than 25% clay and similar proportions of sand and silt) or clayey loam are much more suitable.

If the soil of the land to be landscaped does not have a minimum quality, it will be necessary to make amendments or corrections, such as:

- Sometimes the land has been filled in with rubble from nearby buildings. In this case a layer of soil must be added, removing, if necessary, part of the previously deposited materials.
- If the soil is poor in organic matter it is highly recommended to add it, especially in the areas dedicated to flowers or bushes. This improves the capacity of the soil to absorb and store water that will be available to the plants.
- If the soil is excessively clayey, it is advisable to install a drainage system and frequently add organic matter.

**Selection of species:** Selection of the species planted in the garden will condition not only the amount of water consumed, but also the maintenance that must be performed. In addition, plants may be especially demanding in terms of nutrients, etc.

Taking into account this great variability, plant selection can be oriented towards autochthonous species, which have the advantage of being totally adapted to the climatic conditions of the zone in which we live. The amount of irrigation required will decrease considerably, since its growth cycle is regulated according to the meteorological characteristics of each time of the year. A number of native species can be found in most of the nurseries in the region, so it is recommended to consult with the sellers of the area, to specify the most suitable plants.

**Lawn areas and green carpets:** Lawns are the biggest consumers of water in modern gardens and require frequent and intensive maintenance. Usually, more than two thirds of the total water consumed in lawns is dedicated to their maintenance. Therefore, limiting its extension in the garden is a safe way to reduce water consumption in a stable way. In the case of swimming pools, the lawn represents one of the greatest attractions for carrying out the activities surrounding it, such as lying in the sun, etc.

Different actions must be considered to minimize water use related to this:

- Design the lawn areas in a simple way, as they are easier to water (circle, square, rectangle).
- Value variety: choose very resistant grasses with much lower water requirements instead of other more ornamental grasses with higher needs. For example, there are drought-resistant species on the market such as Cynodon dactylon (Bermuda), Pennisetum clandestinum (Kikuyu), Zoysia japónica (Zoysia), Stenotaphrum secundatum (Gramón, Hierba de San Agustín), Paspalum notatum (Hierba de Bahía) among others.
- Keep in mind that grasses that require less consumption tend to have wider leaves, being very suitable for warm climates. Select the type of grass according to the type of soil, climate, rainfall, temperature, humidity, predominance of sun and shade, resistance to intense trampling, uses, etc. For example in cool climates the most resistant to water shortage are Festuca arundinacea and Festuca ovina, being appropriate as they predominate in the planting mixture.
- Avoid planting grass in all areas away from the places of use and enjoyment, as well as in areas with pronounced slopes, where it is better to opt for upholstery plants.
- Evaluate the possibility of using artificial grass in some specific areas such as terraces, pool edges, sports facilities such as football, paddle and hockey courts, play areas, etc., as their water consumption is much lower.

**Green upholstery**: Fortunately, it is possible to achieve attractive green carpets in the garden without having to resort to grass. For this purpose, we have a series of "ground cover" or upholstery plants, which are very interesting because:

- they are able to go deeper with their roots, fixing better to the soil and making better use of water;
- they require very little care as they don't need periodic mowing;
- they provide beautiful visual effects thanks to their flowers or fruits.

When choosing the species, it is important to bear in mind that not all carpet plants can be walked on. Groundcover plants can be used between slabs, on paths, in cracks in walls, under trees or in green carpets to walk on or look at.

**Use of floor coverings**: One of the most effective techniques for reducing water loss through evaporation, which also achieves a pleasant aesthetic effect, consists of covering garden surfaces with materials such as stones, gravel, bark, etc. These coatings, also called mulch, prevent water loss because:

- they prevent excessive heating of the soil;
- they protect against the wind;
- they prevent the formation of crusts on the surface of the soil;
- they hinder erosion and surface run-off.

In addition, the coatings prevent the appearance of weeds, protect against frost and facilitate the concealment of irrigation systems.

**Efficient irrigation**: There are items to consider as regards 'efficient' irrigation, for example to define different irrigation zones. Indeed, one of the basic principles for efficient watering is to differentiate in the garden between high, moderate and low watering zones, distributing the species and designing the watering systems so that water can be supplied independently to each zone. Only in this way, each group of species can receive the amount of water needed.

The most commonly used irrigation systems in gardening are:

- Sprinkling;
- Drip and Micro-spray;
- Manual.

The main characteristics of the irrigation alternatives are shown in the Table below.

**Table 2.1: Main characteristics of the most commonly used irrigation systems in gardening**

| | Spraying and diffusion | Localized irrigation: drip, micro-sprinkler, micro-diffusion | Manual watering |
|---|---|---|---|
| Main features | Watering in the form of rain | Localized wetting by surface and buried ducts | Flooding of the entire surface |
| Slope of the land | Not recommended for slopes (as they may cause runoff and | Adaptable to all terrains and slope | Levelling with 0-1% slope |

| | | | |
|---|---|---|---|
| | overspray) | | |
| Permeability | Any | Any | Not recommended for highly permeable soils |
| Nature of the soil | Very suitable for very light soils | Any | Soils with good permeability |
| Flow rate fluctuation | Rigorous adjustment | Very tight fit | Very weak adjustment |
| Adaptability to cultivation | Adaptable to most crops | Only valid for certain crops | Can be used for all crops |
| Wind action | Affect application efficiency | The effect to drip irrigation is null and for the others it barely affects | Affect |
| Erosion risk | Weak | Null | Weak |
| Cost of irrigation works | High or very high | High | Depends on the terrain |
| Water losses | Reduced | Very small | Depends on the ability of the irrigator; they can be elevated |
| Crops | Variables | All garden species | Variables |

For savings and effective watering, location-based irrigation systems (drip and micro-spray) are especially recommended. These systems are more efficient if they are coupled with a programmer, which allows to give the plants the exact amounts desired, on the days and times set.

**Maintenance:** Proper maintenance is essential to maintain the beauty and attractiveness of our garden, as well as its efficiency in water use. In a summarized way the necessary practices of maintenance of a garden resulting from xeriscaping are the following:

- Irrigation: Besides being attentive to the weather conditions, to avoid unnecessary watering, it is necessary to pay attention to the irrigation system, periodically checking the absence of leaks and its good functioning.
- Pruning: Trees, in principle, do not need to be pruned; the plant, balanced with its natural bearing, is healthier and uses water more efficiently.
- Replacement of those plants that have not taken root or have dried out.
- Weeding: To avoid the appearance of weeds, it is advisable to dig the areas of the cork trees and the flower beds. However, the use of coverings will save us a great deal of this heavy activity.
- Mowing: Short grasses consume more water than those that are kept tall. In addition, high and infrequent mowing helps the grass to harden, and in the long run it is more resistant to pests, diseases and drought.
- Covers or "mulch": Every year it is necessary to replace made up beds with fine organic coatings and check that the other padding adequately covers the floors, replacing what has been lost.

# *REFERENCES AND FURTHER READINGS (MEDIA & RESOURCES)*

## *RESOURCES AND FURTHER READINGS*


1. UNESCO roadmap for implementing the Global Action Programme on Education for Sustainable Development 2014: https://unesdoc.unesco.org/ark:/48223/pf0000230514
2. Use of freshwater resources in Europe indicator Assessment Prod-ID: IND-11-en Also known as: CSI 018 , WAT 001 Created 04 Nov 2019 Published 23 Dec 2019 : https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-3/assessment-4
3. "2015 How many litres of water does a person need per day?": https://blog.ferrovial.com/en/2015/03/how-many-litres-of-water-does-a-person-need-per-day/
4. What is a circular economy? A framework for an economy that is restorative and regenerative by design, Ellen Mac Arthur Foundation: https://www.ellenmacarthurfoundation.org/circular-economy/concept
5. Habits, Routines and Sustainable Lifestyles Summary Report: A research report completed for the Department for Environment, Food and Rural Affairs by AD Research & Analysis November 2011.


## *REFERENCES FOR MODULE 6*


1. Guía Práctica Sobre Ahorro De Agua: https://www.camarazaragoza.com/medioambiente/docs/publicaciones/publicacion98.pdf
2. Prasad, Ram & Jha, Manoj. (2014). Consumer buying decisions models: A descriptive study. International Journal of Innovation and applied studies. 6. 2028-9324.
3. J Payne, JR Bettman, EJ Johnson (1991). Consumer decision making - Handbook of consumer behaviour, p. 50-84
4. Sharma, Nitika & Dayal, Rekha. (2017). Drivers of Green Purchase Intentions: Green Self-Efficacy and Perceived Consumer Effectiveness. Global Journal of Enterprise Information System. 8. 27. 10.18311/gjeis/2016/15740.
5. Jansson, Johan; Nordlundad, Annika & Westinae, Kerstin (2017) Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden Journal of Cleaner Production 154 (2017) 176e187
6. 2019. Ministry for the Ecological Transition and the Demographic Challenge of Spain: https://www.miteco.gob.es/es/
7. Backhaus, J, Breukers, S, Mont, O, Paukovic, M and Mourik, R (2012) Sustainable lifestyles: today's facts & tomorrow's trends. D1.1 Sustainable lifestyles baseline report. 43030648, UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP), Amsterdam.
8. Beat the Microbead (2018) Beat the Microbead. http://www.beatthemicrobead.org/ (Accessed 0603-2018).

## *SELF-ASSESSMENT QUESTIONS FOR MODULE 6*

| | | |
|---|---|---|
| 1. | **Which are the phases and logical progression of the consuming decision model?** | |
| | a. 1) Needs recognition → 2) Information gathering → 3) Evaluation of the alternatives → 4) Purchasing act → 5) Consumption act → 6) Post purchase evaluation | x |
| | b. 1) Information gathering → 2) Needs recognition → 3) Evaluation of the alternatives → 4) Purchasing act → 5) Consumption act → 6) Post purchase evaluation | |
| | c. 1) Evaluation of the alternatives → 2) Needs recognition → 3) Information gathering → 4) Purchasing act → 5) Consumption act → 6) Post purchase evaluation | |
| 2. | **Water auditing to a building or household may apply to:** | |
| | a. Buildings and households in use. | |
| | b. Buildings and households in the design phase, in use or non-habited. | x |
| | c. Collective use buildings. In the residential sector it does not make sense. | |
| 3. | **What are the 3 main principles of circular economy?** | |
| | a. Implement efficient resource extraction, adapt resource consumption to existing resources and reuse output resources. | |
| | b. Maintain resource extraction, implement recycling of resources and adapt consumption to existing resources. | |
| | c. Design out waste and pollution, keep resources in use by reusing and recycling them and regenerate natural systems. | x |
| 4. | **To measure flow in a fixture, the technician may (*please choose all the correct ones*):** | |
| | a. Install a flowmeter | x |
| | b. Calculate flow with the indication of volume and time | x |
| | c. Calculate flow with the formulation: $Q=U \cdot S$ | x |
| | d. Verify the fixture nominal flow | x |
| 5. | **On average, what is the amount of water that could be saved by adopting easy water saving practices (concerning systems and appliances)?** | |
| | a. 50 litres per day per person | |
| | b. 100 litres per day, per person | x |
| | c. 200 litres per day, per person | |
| 6. | **What are the best available technologies for water efficient plumbing fixtures?** | |
| | a. Taps with cold start system and staggered opening | |
| | b. Showers with a timer and with the possibility of a voluntary stop and economizer sprinkler system with a maximum flow rate of 10 l/min | |
| | c. Flush toilets with cistern with double discharge with a maximum volume of discharges of 3 or 6 litres | |
| | d. Public electronic tap with flow rate regulated at 6 l/min | |
| | e. All of the above | x |
| 7. | **Before performing an audit, the expert technician and auditor should:** | |
| | a. Collect data regarding the building or household, in order to do good characterisation of the site and save time when performing the visit | x |
| | b. Do nothing, it is only by the time of the visit that it is possible to make the site recognition and undergo the audit | |

| | | |
|---|---|---|
| 8. | **A complete water audit should include:** | |
| | a. The following fundamental component groups: water sources and infrastructure, outdoor uses, water fixtures, water appliances and domestic hot water production. | x |
| | b. All water uses, irrespectively of the existing component groups. | |
| | c. All fixtures, appliances and domestic hot water should only be evaluated in an energy audit. | |
| 9. | **Which of the following tips will improve the efficiency of the air conditioning system?** | |
| | a. Use double glazing or special glass if possible, which will allow good insulation from the outside environment, both in heating and air conditioning. | x |
| | b. A temperature difference of up to 15°C is ok between the outside temperature and the temperature inside the air-conditioning system. | |
| | c. Refrigerated appliances without water recirculation are the most efficient option. | |
| 10. | **In the comparison between different measuring equipment, ultra-sound flowmeters:** | |
| | a. Are more flexible than the mechanical flowmeters, because of being more reliable. | |
| | b. Are more flexible than the mechanical flowmeters, because of being non-invasive. | |
| | c. Are always less advantageous than the mechanical flowmeters. | |
| | d. Maybe more/less advantageous, depending on the local circumstances. | x |

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