The long history of harvesting rainwater can be traced as far back as ancient times some 3,000 years ago if not even further. Water is a basic human requirement for maintaining life; without water, no civilisation could have prospered. The Greeks and Romans first developed rainwater harvesting. They diverted rainwater off rooftops into basins excavated underground so that it could be used later on during periods of drought.

Today most fresh water exists in the form of ice, snow, groundwater and soil moisture. Only 0.3% of all fresh water is available for human consumption, and it is very unevenly distributed on the planet.

Water stress and flooding are water challenges that certain areas of the world are facing today. To solve these water challenges, we are forced to use the water resources in a more sustainable way and to find alternative ways of handling the water.

Harvesting rainwater in commercial buildings has a positive impact on the water stress and floodings mentioned above. In fact, it makes no sense to use drinking water where a lower quality of water, such as rainwater can be used. In addition, rainwater harvesting and also water reuse is becoming a vital part of green building rating schemes in various countries, and it seems that the trend towards sustainable buildings has just started.

A rainwater harvesting system in a commercial building still uses a storage tank as in the old days but the methods of harvesting, piping and distributing the water are more complex. The modern system contains methods for keeping debris out of the system at the source before it reaches the storage tank. Distribution has also been upgraded from the simple “grab a bucket and carry it away” principle to gravity fed or pressurised pump systems.

This guide describes the basics of the practical collection of rainwater run-off from the roof in commercial buildings for non-potable usage including examples of rainwater harvesting systems, how to make a water yield/demand balance, tank sizing, treatment of rainwater and pump sizing.
INTRODUCTION

Fresh water is an essential requirement for all life on Earth; however, it is a limited resource. Of all water, about 97% is salt water and only 3% is fresh water. 68.7% of the fresh water is locked up in the polar ice caps leaving less than one percentage of the earth’s water supply available for direct use.

The water cycle involves several steps from evaporation from seas, lakes and rivers, condensation and precipitation as rainfall. Rainwater, once it reaches the ground, may then infiltrate to groundwater, evaporate back to the atmosphere or create a runoff on the surface that subsequently runs into lakes and rivers. Both groundwater and surface water (rivers and lakes) can be used for the production of clean water for human consumption. After being consumed, it is called wastewater and must be treated before being discharged back into nature. A complete water cycle takes months or years to complete.

Due to the growing world population, the demand for water is projected to increase in the future, whilst the global water cycle is adversely affected by climate changes including water stress and flooding. The WHO (World Health Organisation) estimates that in the year 2025, about 1.8 billion people will be under absolute water scarcity, and 2/3 of the world’s population will be under water stress.

Rainwater usage is an important element in the water cycle for reducing the impact of the water supply challenge. Harvesting of rainwater reduces the need for the main water supply as well as ground water extraction locally. Furthermore, harvesting of rainwater has a positive impact on the flattening and delay of peak flow during heavy rainfalls which will reduce the hydraulic load on sewer and wastewater treatment plants. On a global scale, rainwater harvesting contributes to a sustainable usage of the water supply resources.

Replacing mains water consumption with rainwater is becoming an increasingly popular trend in the efforts to achieve sustainable, green buildings. Among others rainwater can replace mains water for irrigation, toilet flushing and provide water for cooling towers.

Water cycle with the implementation of rainwater harvesting. A large amount of the water consumption in commercial buildings is for non-potable usage and can therefore be replaced by rainwater.
Reasons for using rainwater in a commercial building

Financial reasons:
• Saves money by reducing the water bill

Ecological reasons:
• Reduces the extraction of ground water
• Makes efficient use of a valuable natural resource
• Reduces flooding, erosion and the contamination of surface water with sediments, fertilizers and pesticides in rainfall run-off
• Controls the excessive amounts of rainwater in urban areas

Technical reasons:
• Reduces demand on municipal water supplies
• Reduces the excessive stress on the municipal sewage system and the treatment plant

Promotional reasons:
• Enhanced image by showing investment in environmental technology
• May contribute in various sustainable building rating systems

Water consumption per head in different commercial buildings in India.

<table>
<thead>
<tr>
<th>Building types</th>
<th>Litres per head per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitals (including laundry)</td>
<td>450</td>
</tr>
<tr>
<td>a) No. of beds above 100</td>
<td>450</td>
</tr>
<tr>
<td>b) No. of beds below 100</td>
<td>340</td>
</tr>
<tr>
<td>Hotels</td>
<td>180</td>
</tr>
<tr>
<td>Hostels</td>
<td>135</td>
</tr>
<tr>
<td>Boarding schools / colleges</td>
<td>135</td>
</tr>
<tr>
<td>Restaurants</td>
<td>70</td>
</tr>
<tr>
<td>Day schools / colleges</td>
<td>45</td>
</tr>
<tr>
<td>Offices</td>
<td>45</td>
</tr>
<tr>
<td>Factories 45 (could be reduced to 30 where no</td>
<td>45</td>
</tr>
<tr>
<td>bathrooms are provided)</td>
<td></td>
</tr>
<tr>
<td>Cinema, concert halls and theatre</td>
<td>15</td>
</tr>
</tbody>
</table>

The amount of water consumed in commercial buildings varies significantly depending on various factors such as the type and size of the building, geographical location, appliances installed and human activities in the building. The table to the left shows examples of water consumption in different types of commercial buildings in India.

The amount of consumed mains water that may potentially be replaced by rainwater in a commercial building depends on the appliances in the building and the distribution between potable and non-potable usage.

For some users, the lack of salts and minerals in rainwater – also called soft water – is an advantage as the soft rainwater does not cause lime-stone on the surface of e.g. toilets, bidets, cooling systems, cars and windows depending on the use of the rainwater. In laundry or car washer activities, when using rainwater, not only is the consumption of mains water reduced, the consumption of detergent can be decreased as well.
RAINWATER COVERAGE

The rainwater collected on the roof can replace the non-potable water used in the building. The calculation of the rainwater coverage rate is based on the rainwater yield and the water demand.

The rainwater coverage rate (%) is calculated by:

\[ \text{Coverage rate} = \frac{Y}{D} \times 100 \]

where

\( Y \) = rainwater yield
\( D \) = water demand

The two pie charts on page 9 show examples of potential replacement of mains water with harvested rainwater.

For the hotel, rainwater can substitute the water consumed for toilet flushing, irrigation, cooling towers and laundry which represent 51% of the water consumption. For the shop/supermarket 72% of the water consumption can be replaced by rainwater. The remaining water consumption requires drinking water quality or at least a higher water quality than rainwater.

EXAMPLES OF RAINWATER USAGE

Hotel, Rainwater coverage rate: 51%
Highlighted with bold: appliances that can be replaced with harvested rainwater.

Shop / supermarket, Rainwater coverage rate: 72%
Highlighted with bold: appliances that can be replaced with harvested rainwater.
ESTIMATION OF RAIN WATER YIELD

The volume of rainwater (water yield) that can be collected in an individual catchment is calculated using the following formula:

\[ Y = A \cdot i \cdot c \]

where

- \( Y \) = volume of rainwater yield (l or m³)
- \( A \) = projected roof area (m²)
- \( i \) = rainfall (mm)
- \( c \) = run-off coefficient (-)

As a guide for collection capacity, this value can be used for the calculation:

- 1 mm of rain = 1 litre (l) of water per square meter (m²) of roof footprint

Projected roof area, \( A \)

All projected roof areas that the rainwater will be collected from must be added together, regardless of the pitch, the shape, or the complexity of the roof surface. The overall footprint of the building determines the projected roof area.

\[ A = W \cdot L \]

where

- \( A \) = projected roof area (m²)
- \( W \) = width of the building (m)
- \( L \) = length of the building (m)

Rainwater harvesting is suitable for sports arenas because of their large roof area and the high water consumption for irrigation and toilet flushing and possibly make-up water for cooling towers.

**EXAMPLE: CALCULATION OF PROJECTED ROOF AREA. A (SPORTS ARENA, SYDNEY)**

A sports arena in Sydney has a roof area as shown on the photo above. Rainwater is collected from the complete area. The projected roof area is calculated as if the sports arena was circular even thought it is oval. The projected roof area is calculated by:

\[ A = \pi \cdot R^2 - \pi \cdot r^2 \]

where

- \( R \) = outer diameter
- \( r \) = inner diameter

\[ R = 160 \, m \]
\[ r = 140 \, m \]

\[ A = \pi \cdot 160^2 - \pi \cdot 140^2 \]
\[ A = \pi \cdot 160^2 - \pi \cdot 140^2 \]
\[ A = 18,850 \, m^2 \]
Rainfall, i

Rainfall is the most unpredictable variable in the calculation and hence, to determine the potential rainwater yield for a given catchment, reliable rainfall data are required, preferably for a period of at least 10 years. Also, the prediction of the water yield will be most accurate if rainfall data from the nearest weather station with comparable conditions is used.

Run-off coefficient, c

The run-off coefficient depends on the roof surface. It is described as the amount of rainwater that appears as run-off in relation to the total rainfall amount.

\[
\text{run-off (mm)} = \text{rainfall (mm)} \times c
\]

The roof material can affect both the run-off coefficient and the quality of the rainwater. With respect to the amount of rainwater to be collected, a roof surface with a high run-off coefficient is preferred. A pitched metal roof can deliver 95% of the water that falls on it (except for heavy snowfalls). A flat tar-and-gravel roof has a lower run-off coefficient; 70% can be collected. Conversely, a green roof has the lowest run-off coefficient; only about 30-50% of the water will be collected from the roof. The table to the left shows run-off coefficients for typical roof types.

The quality of the rainwater to be collected will be dealt with in the section “Rainwater Quality.”
ESTIMATION OF WATER DEMAND

This section deals with estimating the water demand (D) of the appliances to be supplied by rainwater. For a simplified approach the water demand can be assumed constant over the year. However, for a more detailed approach the fluctuations over the year should be taken into consideration e.g. make-up water for cooling systems and irrigation may vary by season.

Example:
At the sports arena in Sydney, it is the intention to use collected rainwater for the following:

- Toilet flushing
- Urinal flushing
- Irrigation
- Make-up water for cooling towers

The irrigation need for the sports arena is not included in the estimation of the water demand. The irrigation need differs from country to country and to make an estimation of the irrigation need the crop type, soil type and evaporation must be taken into consideration.

Specifications:
The table to the right shows the specification of the rainwater appliances. On average, the sports arena is used 4 days a month for games, concerts etc.

<table>
<thead>
<tr>
<th>Specifications:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toilets:</strong></td>
</tr>
</tbody>
</table>
| No. of toilets | 400  
| Flush volume | 7 litres  
| No. of flushes per day: 15 flushes x 2 hours use | 30  
| **Urinals:** |  
| No. of urinals | 400  
| Flush volume | 1 litre  
| No. of flushes per day: 30 flushes x 2 hours use | 60  
| **Cooling towers:** |  
| Cooling capacity during April to September | 175 MW = 500 tons  
| 10 running hours per day during April to September | 300 hours/month  
| Cooling capacity during October to March | 3.5 MW = 1,000 tons  
| 10 running hours per day during October to March | 300 hours/month  

* Cycles of concentration vary dramatically from site to site due to differences in water intake quality and the water treatment plan.

** Calculation: Monthly Water Demand (Sports Arena, Sydney)**

**Toilet and urinal flushing:**

No. of toilets/urinals • flush volume • no. of flushes per day • days of usage/month

- 400 toilets • 7 l per flush • 30 flushes per day • 4 days/1,000 l = 336 m³
- 400 urinals • 1 l per flush • 60 flushes per day • 4 days/1,000 l = 96 m³

**Make-up water for cooling towers (evaporation and blow down**):

Evaporation: 6.8 l/h of evaporation per ton of cooling • running hours per month/1,000 l

6.8 l/h • 1,000 tons • 300 hours/1,000 l/6 months = 2,040 m³

Blow down: Volume of water for evaporation/no. cycles -1

2,040 m³/month /3 cycles -1 = 1,020 m³

Monthly volume of make-up water = 2,040 m³ + 1,020 m³ = 3,060 m³

** Blow down is water wasted from the cooling tower due to the content of impurities.**

**Calculation of water demand per month:**

The total water demand per month for toilet flushing, urinals and make-up water for cooling towers is as follows:

- **Period: October – March:**
  
  336 m³ + 96 m³ + 3,060 m³ = 3,492 m³/month

- **Period: April – September:**
  
  336 m³ + 96 m³ + 3,060 m³ • 0.5** = 1,962 m³/month

** The cooling capacity from April to September is 50% of the cooling capacity from October to March and therefore the water demand for make-up water for the cooling towers is also 50%.**
STORAGE TANK

The storage tank is used to store the rainwater so that it is ready for use when needed.

Tanks for storing rainwater are available in a range of suitable materials, including galvanised steel, fibreglass, polyethylene and concrete.

The main requirements for the tank are that it:
- is structurally sound
- is watertight and light-proof
- incorporates access openings for monitoring and maintenance
- features openings that are appropriately screened, to prevent insects and small animals from entering the storage tank

Location of tank
The location of the storage tank depends on the available space inside or outside the building. It is important that the tank is placed so that the water temperature is kept as low as possible to limit bacterial and algae growth.

Underground tank
- Can be installed under trafficated areas (with concrete support)
- Takes up no space in the building
- Has high excavation costs
- Keeps the water cold and protects the stored water from freezing in the winter if placed below the frost depth
- Must be secured to prevent the tank from lifting when emptied

Above ground tank
- Has low excavation costs
- Takes up space on the building site
- Is easy to access for maintenance
- Is exposed to harsh weather
- Risk of frozen water, if used in cold climates
- May eliminate the need for a pump to extract water
- Needs to be anchored to the ground when there is no water in the tank
- Is subject to direct sunlight and therefore has warmer water

Indoor tank
- Has no excavation costs
- Takes up space inside the building
- If placed at the top of the building, the building must be reinforced
- Has a risk of too high water temperature
- In case of leakage from the tank, the building must be protected against flooding e.g. by means of gullies
- Low or no risk of frozen water during cold seasons

Sectional tank
For larger capacities of water, multiple tanks may be connected to meet storage requirements. Sectional tanks are constructed from modular panels that are bolted together on site. They are particularly useful as they enable confined spaces (such as a basement area or void) to be utilised for rainwater storage.
Sizing the storage tank

As the tank is by far the most expensive part of the rainwater harvesting system, it is worthwhile spending time on calculating the optimal tank size. The rainwater yield and the water demand are used to estimate the needed capacity of the tank.

The size of the storage tank depends on several factors, and there are several ways to size the tank. The following factors influence the choice and size of the tank:

- Acceptable storage time in the storage tank
- Size of the projected area
- Estimated rainwater yield (on a daily basis if possible)
- Expected number of days without rain
- Required water demand
- Space available inside and outside the building
- Financial resources
- Number and frequency of overflow
- Load capacity of the floor slap

There are various methods for calculating the size of the storage tank. The calculation is theoretical and should be taken as a guideline only.

The size of the storage tank can be based on:

- Yield/demand balance: The balance between the monthly rainwater yield and the monthly water demand for the rainwater appliances.
- Number of drought days according to a standard, e.g. DIN 1989.

Recommendations and guidelines:

- Data for daily rainfall and daily water demand are preferable for sizing the storage tank. They will result in a more detailed view of the water level in the tank and therefore a more precise sizing of the storage tank can be achieved. Furthermore, the frequency and number of overflows for a given tank size can be read.
- If the tank is too small, there is a risk that the top-up of mains water will be too high.
- If the tank is too big, the number of overflows per year will be too low to keep the water quality up.
Calculation of tank size based on monthly yield / demand balance

One way of calculating a tank size estimated to provide water throughout an average year is to use monthly yield and water demand data and to assume that at the start of the wetter months, the tank is empty. The following formula should then be used for each month:

\[ V_t = V_{t-1} + (Y - D) \]

where

- \( V_t \) = theoretical volume of water remaining in the tank at the end of the month
- \( V_{t-1} \) = volume of water left in the tank from the previous month
- \( Y \) = monthly water yield
- \( D \) = monthly water demand

Starting with an empty tank, \( V_{t-1} = 0 \).

- If after any month \( V_t \) is positive, the water will be stored in the tank and be available for the water demand ahead.
- If after any month \( V_t \) exceeds the volume of the tank, water will be lost to overflow.
- If \( V_t \) is ever a negative figure, demand exceeds the available rainwater. If the system is connected to critical appliances like toilets, mains back-up is recommended. For more information on mains back-up see page 30.
- If the calculated yearly run-off exceeds the yearly water demand, \( V_t \) will only be negative if periodical overflows reduce the amount of water collected so that it is less than the demand.

The tank size is not necessarily based on collecting the total roof run-off. If the water demand is less than the amount of collected water, some overflow may occur while the demand is still met. If the water demand is to be met throughout the month, the tank should be large enough so that \( V_t \) is never negative.

The greater the values of \( V_t \) over the whole year, the greater the certainty of meeting the water demand when rainfalls are below average or when dry periods are longer than normal.

The greater the security, the higher the cost of the tank.

The pros and cons of sizing the tank on the basis of monthly rainwater yield/demand balance are listed below.

Pros:
- Yield fluctuations and variation in water demand during the year is taken into consideration, meaning higher security and therefore reduced need for mains water back up.
- Will result in more precise sizing of the storage tank.

Cons:
- Possibly higher tank cost.
- Poor availability of monthly precipitation data.
The size of the storage tank is determined for the sports arena in Sydney by means of a monthly yield/demand balance.

Example, January:

- Rainfall, Sydney (column A): Data from page 12
- Rainwater yield, Y (column B): See page 13
- Water demand, D (column D): See page 15
- Total volume stored in the tank at the end of the month (column F):
  \[ V_t = V_{t-1} + (Y - D) \]
  \[ V_t = -7.370 \text{ m}^3 + (1.764 \text{ m}^3 - 3.492 \text{ m}^3) \]
  \[ V_t = -9.098 \text{ m}^3 \]

- Deficit/surplus (column G):
  \[ Y - D = 1.764 \text{ m}^3 - 3.492 \text{ m}^3 \]
  Deficit = -1.728 m³

- Mains top up volume (column H):
The volume of mains top up must cover the deficit calculated in column H: -1.728 m³. When the value calculated in column H is positive the surplus of rainwater is stored in the tank.

Size of storage tank
The monthly level in the storage tank can be read in column F. The minimum storage required is the maximum value in column F. In this example the value is 594 m³.

Rainwater coverage rate:
\[ \frac{Y}{D} \times 100 = \frac{20.747}{32.724} \times 100 = 63\% \]
Calculation of tank size according to DIN1989

The size of the tank is based on the smallest value of the rainwater yield or the water demand per year. The tank is sized to accommodate 6% of the water demand, corresponding to 21 days of drought. The rainwater will be able to cover the water demand for a dry period of 3 weeks.

If the water demand is larger than the rainwater yield, the tank size is calculated as follows:

$$ Y < D \quad T = Y \times 0.06 \text{ m}^3 $$

If the rainwater yield is larger than the water demand, the tank size is calculated as follows:

$$ D < Y \quad T = D \times 0.06 \text{ m}^3 \quad \text{where}$$

- \( D \) = water demand
- \( Y \) = rainwater yield
- \( T \) = tank size

The pros and cons of sizing the tank according to DIN 1989 are listed below:

**Pros:**
- Easy calculation and sizing of the storage tank
- Availability of yearly rainfall data

**Cons:**
- The fluctuations in water yield and dry periods over the year is not taken into consideration. As a consequence the storage tank could be either too small or too large.

**EXAMPLE: TANK SIZE (SPORTS ARENA, SYDNEY)**

- **Tank sizing according to DIN1989:**
  - Rainwater yield: 20.747 m³/year
  - Water demand: 32.724 m³/year

As \( Y < D \) (20.747 m³ < 32.724 m³), the tank size is calculated as follows:

$$ T = 0.06 \times 20.747 \text{ m}^3 = 1.245 \text{ m}^3 $$

DRAINAGE SYSTEM

Depending on the roof design a drainage system with gutters for a pitched roof or drains on a flat roof is chosen.

For a flat roof, either a conventional drainage system based on gravitation or a syphonic drain system can be used.

Characteristics of a syphonic drainage system:
- Syphonic systems require fewer outlets and downpipes than a gravity system.
- Collection mains can be routed horizontally throughout the building; no need for pipes to be fitted on a gradient.
- Multiple rainwater outlets can be connected to a single connector.
- Up to 80% fewer downpipes are required, resulting in cost savings on materials and reducing associated groundwork. It also gives architects more freedom with regard to design.
- Pipe diameters are smaller due to full volume discharge.
- Complete control over the downpipe discharge location gives increased design and programme flexibility.
- Rainwater can be easily routed to a storage tank and distributed to various appliances.
RAINWATER DELIVERY SYSTEM

The rainwater can be delivered to the appliances by means of various pumping solutions. In this section, the most common solutions are described.

- A submersible pump providing rainwater from the storage tank to the rainwater appliances.
- A dry-installed self-priming pump lifting the rainwater from the storage tank and pumping it to the rainwater appliances.
- A feed pump providing rainwater to a dry-installed booster system, which provides the pressure for delivering the water to the rainwater appliances.

The latter option is the most commonly used in commercial buildings as it provides the highest safety and a reliable water supply.

As the water demand in a commercial building varies both during the day and seasonally, it is recommended to use pumps with variable speed, either by having an integrated frequency converter or by using an external variable frequency drive. This will have a positive effect on the energy consumption of the system.

System with submersible pump

 Suitable for irrigation and smaller commercial buildings. A second submersible pump can be installed in the tank for stand-by.

System with self-priming pumps

Rainwater harvesting system with self-priming centrifugal pumps:

Suitable when
- access to the pump is required
- there is a short distance between the storage tank and the location of the pumps.

Pros:
- The pump is visible meaning easy access in case of service.

Cons:
- The distance between the storage tank and the pump is limited by the suction lift.
- Requires space inside the building.
- Leaks on the suction pipe result in unreliable pump performance.
- The pump is accessible, meaning a risk of vandalism to the pump.
About self-priming pumps

The dry-installed self-priming pump is able to lift water from the storage tank and boost the water to the rainwater appliances. Be aware that the maximum suction lift is 7-8 metres. The distance between the storage tank and the pump is limited by the suction lift.

The suction lift includes:
- the height difference between the lowest water level in the tank and the inlet of the pump.
- the friction loss in the pump, pipe and the valves.

The longer the suction pipe, the shorter the suction lift.

It is important that the suction pipe rises continuously toward the pump. When sizing the pump, it is important to include the suction lift as a negative number.

To prevent the suction line from running empty during priming and operation, a foot valve must be mounted at the end of the suction line. It is recommended that a strainer is mounted at the suction pipe to prevent particles, leaves etc. from entering the pipe system.

If a hose is used for the suction pipe, it must be of a non-collapsible type.

Before start-up, the pump must be filled with the specified amount of water to enable it to self-prime.

If more self-priming pumps are mounted in the system, it is recommended that each pump is provided with a suction pipe with a foot valve.

System with dry-installed pump, feed pump and buffer tank

Suitable where a reliable water supply is needed and where there is a long distance between the storage tank and the pumping system.

**Pros:**
- Reliable pump operation and thereby reliable water supply.

**Cons:**
- Pumps and buffer tank take up space inside the building.
Mains water backup

During prolonged dry periods or frost periods, the rainwater resource can run empty. In order to ensure the continued use of the appliances connected to the rainwater harvesting system, e.g. toilets and washing machines, a system with mains water backup is required.

The idea of such a system is that as long as there is rainwater available in the rainwater storage tank, the system uses this and in periods when the rainwater storage tank is empty, the system will automatically switch over and supply the building with mains water.

When a rainwater system is connected to the water mains, it is important to follow local protection regulations for the prevention of pollution of the mains water. Regulations in different parts of the world use different solutions.

Requirements for prevention, examples:
- In Europe, an air gap between mains water and rainwater is required (EN1717)
- In Pacific Asia, a double check valve is required
- In the USA, an air gap and/or a RPBA (reduced pressure backflow assembly) valve is required

Always contact the local office for more information about regulations.

Buffer tank (in-between tank)

A buffer tank can be used in systems with mains backup. The buffer tank is normally placed inside the building and is much smaller than the storage tank. The amount of mains water is limited to the smaller volume of the buffer tank which is therefore a more cost-effective solution than filling up the storage tank with mains water.

The buffer tank is a controlled unit which in principle functions like a toilet cistern. The mains water can either be added directly to the buffer tank or to the inlet pipe to the tank. In addition to the back-up of mains water, the buffer tank also provides the possibility of switching 100% to the use of mains water when the storage tank is being cleaned. It only requires that a shut-off valve is mounted on the suction pipe to the storage tank.

According to EN1717, an air gap is required for preventing cross contamination between the rainwater and the mains water.

**Diagram:**

- 1. Connection for mains supply
- 2. Solenoid valve
- 3. Funnel
- 4. Pipe to storage tank
- 5. Control wire

\[ H = \text{air gap at } 2 \times d, \text{ and at least } 20\text{mm according to EN 1717} \]
RAINWATER QUALITY

Though rainwater initially is very clean, it can be polluted from dirt on the roof area and the drainage system that the rain contacts. The degree of pollution varies significantly by location and season. The pollution is primarily caused by the following:

- Faeces from birds, rodents and other animals, containing microorganisms and organic material.
- Sand dust and organic particles deposited by the wind.
- Airborne fall-out from industrial or agricultural chemical pollutants.
- Corrosion and leaching from construction materials of the roof and drainage system.

For non-potable use of rainwater, the major health risk is the incidental intake of small volumes of water via droplets or mist (aerosols) during the intended use, and from direct or indirect skin contact. By far the largest health risk in this context is pathogens and the content of organic material causing the microorganisms to grow in the storage and distribution system.

Hygiene

The hygienic standard of water is often described by reference to coliform bacteria that are not themselves pathogens (disease causing bacteria) but indicate that pathogens can be present.

- **Total coliform**: The total count of all coliforms. Coliforms are common in the environment and are usually found in all non-sterilised surface waters. Total coliforms are a weak indicator of fecal contamination.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Adverse effect on quality</th>
<th>Indicating parameter</th>
<th>Typical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria and viruses</td>
<td>Adverse effect on health</td>
<td>Fecal Coliform</td>
<td>100 counts/100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Coliform</td>
<td>1,000 counts/100 ml</td>
</tr>
<tr>
<td>Organic substances</td>
<td>Color and taste</td>
<td>TOC (total organic carbon)</td>
<td>0 – 140 mg/l</td>
</tr>
<tr>
<td></td>
<td>Nutrients for growth of bacteria</td>
<td>COD (chemical oxygen demand)</td>
<td>0 – 70 mg oxygen/l</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Color (absorption of UV light at 436 nm)</td>
<td>0 – 0,045</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>Adverse effect on health</td>
<td>Cobber (Cu)</td>
<td>0 – 6 mg/l</td>
</tr>
<tr>
<td></td>
<td>Color and taste</td>
<td>Lead (Pb)</td>
<td>0,5 mg/l</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc (Zn)</td>
<td>0 – 6 mg/l</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>Can harbor bacteria and viruses. Can release organic substances, serving as nutrients for bacterial growth</td>
<td>TSS (total suspended solids)</td>
<td>1,000 mg/l</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Turbidity</td>
<td>0,3 – 10 NTU</td>
</tr>
<tr>
<td>Acids and bases</td>
<td>Some industrial pollutant can act as acids or bases in their reaction with the water. This can increase the corrosiveness of the rainwater</td>
<td>pH</td>
<td>4,5 – 6,5</td>
</tr>
</tbody>
</table>

Typical quality of roof run-off and indicating parameters. (Values can deviate significantly in specific cases, depending of the catchment area.)

- **Fecal coliforms**: A sub-group of total coliforms that consists of the coliforms that lives in the intestinal tract and in faeces. Fecal coliforms are a strong indicator of fecal contamination.

- **E.Coli**: A sub-group of fecal coliforms. Some strains of this group can cause diseases; the most notorious strain is E.Coli O157:H7. E.Coli is a very strong indicator of the presence of pathogens.

The closer you get to the center of the circle shown to the left, the stronger the indication that fecal contamination has taken place, and that pathogens can be present, and consequently the lower the number that can be tolerated.

Other quality parameters that are important for the hygienic standard of the rainwater are:

- **TOC (Total Organic Carbon)**: This is a measure of the amount of organic substances found in the water sample. The TOC is important for hygiene because the organic substances serves as “food” for bacteria and can cause the bacteria to grow to large numbers, for instance in the storage tank.

- **Turbidity**: This is the cloudiness or haziness of a fluid caused by individual small particles (suspended solids). Low NTU values (Nephelometric Turbidity Unit) indicate high water clarity while high NTU values indicate a high content of suspended solids (TSS) that can carry with them microorganisms and organic matter.

- **COD**: Organics which can be oxidised by chemical oxidation.
Compliance with legislation and standard

There are no common or universal standards regarding rainwater usage. The hygienic standard that must be observed depends very much on the intended use and local standards and regulations.

Examples of hygienic standard requirements are shown in the table to the right.

Good maintenance practice

In order to achieve acceptable hygienic conditions of the rainwater harvesting system the following maintenance must be considered:

- Roof: Avoid overhanging vegetation, as it can provide a nesting place for birds and access routes for other animals, and increase the amount of leaves and litter accumulating on the roof. Keep the roof well clean from moss, lichen, leaves and litter.

- Gutter: Avoid ponding where litter and still water can stay for a long time; keep a steady fall towards the drain to ensure that the gutter can be fully drained. Keep the gutter well clean of litter and leaves.

- Drain: Use a sieve mesh, e.g. size 2-4 mm that prevents larger particles and litter from entering the rainwater storage and distribution system.

- Storage tank: The tank should be light proof to avoid algae growth. The tank must be vented, and the venting pipe should be properly protected from insects, rodents and inflow of surface water other than water from the roof.

### Table: Microbial Quality Guidelines

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.Coli &lt;1/100 ml</td>
<td>Fecal coliforms &lt;10,000/100 ml</td>
<td>Fecal coliforms GM &lt;1,000/100 ml</td>
<td>Intestinal enterococci 95% &lt;200/100 ml ****</td>
<td>E.Coli 95% &lt;1,000/100 ml Enterococci 95% &lt;400/100 ml</td>
</tr>
<tr>
<td>Intestinal enterococci &lt;100/100 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Fewtrell and Kay 2007
* Category A - irrigation of crops likely to be eaten uncooked.
** Marine sites to be classified as good.
*** Freshwaters GM = geometric mean. All measures per 100 ml.
**** Intestinal enterococci: Indicator of the presence of pathogenes.

Summary of microbial quality guidelines that could be applicable to the non-potable use of rainwater.

The relevant design and dimensioning of the storage tank is described in the section “Sizing the storage tank” pages 18-24. It is important that the tank is dimensioned so that it overflows regularly, as this will discharge the top layer of floating pollutants that could otherwise build up over time and which, if excessively thick, will promote bacteria growth and reduce the oxygen content of the water in the tank.

- Recirculation of the water: In case water is stored in the storage tank for longer periods, it is recommended to recirculate the water in order to maintain the oxygen content in the tank.

- Construction materials: The roof, drainage system and rainwater system should be constructed of materials that do not release dangerous substances to the rainwater.
Treatment of rainwater
The treatment of rainwater depends on the need. If the good maintenance practices described on page 34-35 are followed, rainwater can often be used with only relatively simple filtration, like a coarse screen or a first flush diverter. For example, in the case of single family residences in Germany and Belgium, rainwater is usable without further treatment for laundry machines and toilet flushing, and where there is no legislation regulating the quality requirement. In case the quality does not fulfil the requirements, additional treatment may be necessary; see a brief description on the following pages.
<table>
<thead>
<tr>
<th>Rainwater treatment</th>
<th>Technologies</th>
<th>Effect</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-tank</td>
<td>Coarse screen</td>
<td>Reducing sand, dust, microorganisms and organic substances</td>
<td>Cheap, easy installation and maintenance, frequently satisfactory</td>
<td>Only coarse particles, leaves and twigs are removed, maintenance is required</td>
</tr>
<tr>
<td></td>
<td>Mesh or screen filter</td>
<td>Reducing sand, dust, microorganisms and organic substances</td>
<td>Cheap, the effect depends on the mesh size; the finer the better</td>
<td>Tend to plug; the finer the mesh the worse. High maintenance requirement</td>
</tr>
<tr>
<td></td>
<td>First flush diverter</td>
<td>Removal of organic particles, to reduce colour, smell and re-growth of microorganisms in the storage tank</td>
<td>Cheap, easy installation, low maintenance requirement. Frequently satisfactory</td>
<td>Approx. 10% of the water is lost in filtering</td>
</tr>
<tr>
<td></td>
<td>Down spout filter collector</td>
<td></td>
<td>Cheap, easy installation, low maintenance requirement. Frequently satisfactory</td>
<td>Approx. 10% of the water is lost in filtering</td>
</tr>
<tr>
<td></td>
<td>Vortex rain filter</td>
<td></td>
<td>Cheap, low maintenance requirement</td>
<td>Approx. 10% of the water is lost in filtering. Has to be installed underground</td>
</tr>
<tr>
<td></td>
<td>Hydro-cyclone</td>
<td>Less maintenance, low risk for clogging</td>
<td>More complex than the above, minimum flow requirement for proper function, not as effective for removing organic particles. Needs high velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand filter</td>
<td>More effective than the above for removing organic particles and microorganisms</td>
<td>More expensive and more complicated to operate, needs a regular back-flush. The back-flush can be automated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activated carbon filter</td>
<td>Removal of dissolved organic substances</td>
<td>The primary advantage of a carbon filter is that not only organic particles but also dissolved organic matter is absorbed by the carbon, so the filtered water will contain so little organic material (TOC) that no micro-organisms can grow</td>
<td>Relatively high cost, needs to be backwashed regularly, over time will become exhausted and require replacement</td>
</tr>
</tbody>
</table>

Description of rainwater treatment.
### Rainwater treatment Technologies Effect Advantages Disadvantages

<table>
<thead>
<tr>
<th>In-tank</th>
<th>Technologies</th>
<th>Effect</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorination</td>
<td>Disinfection</td>
<td>Chlorine has a good residual effect, meaning that it can stay active for a long time in the water, providing long-term protection against microorganisms</td>
<td>Can give chlorinated by-products which may present a health hazard Has a distinct odour that is unpleasant to many people Some forms of chlorine are to be handled as dangerous chemicals</td>
<td></td>
</tr>
<tr>
<td>Ozonation</td>
<td>Disinfection</td>
<td>Has a residual effect, and shorter time is needed to kill the bacteria than with chlorine</td>
<td>The gas is poisonous, and proper ventilation is required</td>
<td></td>
</tr>
<tr>
<td>UV filtration</td>
<td>Disinfection</td>
<td>Easy installation with no chemicals involved, only electric power is used</td>
<td>No residual effect. Needs a very fine (5 micron) pre filter. The lamp needs to be replaced annually.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-tank</th>
<th>Technologies</th>
<th>Effect</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV filtration</td>
<td>Disinfection</td>
<td>Easy installation with no chemicals involved, only electric power is used</td>
<td>No residual effect. Needs a very fine (5 micron) pre filter. The lamp needs to be replaced annually.</td>
<td></td>
</tr>
<tr>
<td>Fine filter</td>
<td>Removal of fine particles, improvement of turbidity</td>
<td>Cheap and effective for removal of fine particles</td>
<td>Needs regular maintenance, provides reduced bacteria but is not reliable as a disinfectant</td>
<td></td>
</tr>
<tr>
<td>Activated carbon filtration</td>
<td>Removal of colour and odour. Removal of disinfection by-products from in-tank disinfection</td>
<td>Provides protection from pesticides and many organic chemical pollutants, as well as removal of colour and odour</td>
<td>Relatively high cost Needs to be backwashed regularly, and over time will become exhausted and require replacement</td>
<td></td>
</tr>
</tbody>
</table>

Description of rainwater treatment.
PIPES AND TAPS

Rainwater is non-potable and to reduce the risk of cross-connection and contamination of the mains water supply it is essential that all rainwater pipework is both readily distinguishable from the pipework used for mains water and instantly recognizable wherever it is located, for example in the basement of a building or beneath the street.

Internal rainwater appliances should be identified, for example via a label like the one shown to the right.

External taps supplying rainwater should be identified with a safety sign labelled ‘RAINWATER’ or ‘NON-DRINKING WATER’. It is recommended that signs comply with local standards. Where sensitive groups are involved who may not obey signs (for example at childcare centres), additional controls should be considered such as using taps with removable handles or locating taps 1.5 metres or more above the ground.

The marking and labeling of pipes and rainwater appliances may differ geographically. For correct labeling and marking of pipes and taps the local council or other relevant regulatory authority must be contacted for information about specific requirements that need to be met.

PUMP SIZING

The sizing of the pump system for the rainwater harvesting system is based on the required flow to the rainwater appliances and the required pressure (head).

The required head is determined by the following:
- The static head – the difference between the lowest water level in the storage tank and to the pump suction port
- The pressure loss in the linear pipe, valves and fittings

The minimum required flow that the pump should be able to provide is determined by the load profile of the appliances connected to the rainwater harvesting system.
The booster system: WebCAPS' 1st choice is HYDRO MULTI-E 2 CRIE 20-3.

The selected booster system consists of two CRIE pumps both fitted with motors with integrated variable frequency drive. One pump acts as master pump and the other one is slave. The wetted parts are made in stainless steel EN/DIN 1.4301.

The system is fit for the pump job. The duty point \( Q = 38.2 \, \text{m}^3/\text{h}, \, H = 30 \, \text{m} \) is equivalent to 93% of the maximum performance of the booster system.

In WebCAPS the dimensioning flow rate for the toilets and urinals is determined according to DIN 1988:

Flow per unit:
- Flush valve for urinals: 400
- Tap toilet tank DIN 19542: 400

The dimensioning flow is: 38.2 m³/h.

This means that the booster system must be able to provide a flow rate of at least 38.2 m³/h.

The pumps discharge head:
- Geodetic height: 15 m
- Friction loss in pipes and fittings: 5 m
- Discharge pressure (consumer): 1 bar

The rainwater storage tank is excavated outside the building.

Selected installation type:
- Boost up from break tank

The rainwater harvesting system includes a booster system and mains back-up with double check valve.
GLOSSARY

**Activated carbon:**
A water treatment medium found in block, granulated or powered form which is produced by heating carbonaceous substances, bituminous coal or cellulose based substances such as wood or coconut shell. Activated carbon is commonly used for dechlorination and for reducing trace and soluble materials such as organic chemicals from water.

**Air gap:**
According to EN1717, an air gap is required for preventing cross contamination between the rainwater and the mains water.

**Blow-down water:**
The portion of the circulating water flow that is removed from cooling towers (usually discharged to a drain) in order to maintain the amount of Total Dissolved Solids (TDS) and other impurities at an acceptably low level.

**Buffer tank:**
Tank used in rainwater installations with mains back up complying with EN1717. The smaller buffer tank is filled with mains water instead of the big storage tank.

**Coliform bacteria:**
Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system.

**Disinfection:**
The act of disinfecting, using specialized cleansing techniques that destroy or prevent growth of micro organisms capable of causing infection.

**Drought days:**
The number of days without precipitation.

**Evaporation:**
Process of liquid water becoming a vapor.

**Filtration:**
Physical removal of liquid-borne contaminants by means of separation from the output flow.

**First flush diverter:**
A device or method for removal of sediment and debris from the roof by diverting initial rainfall from entry into the storage tank.

**Floating inlet:**
Floating inlets draw water from just below the surface where the highest quality, cleanest water lies.

**Groundwater:**
Water that occupies the pores and crevices of rock and soil beneath the Earth’s surface.

**Gutter:**
Channel along a roof’s edge to catch and direct storm water.

**Make-up water:**
The water that must be added to the circulating water system in order to compensate for water losses such as evaporation, drift loss, blow-out, blow-down, etc.

**Mains water back up:**
In case there is no rainwater in the storage tank mains water is provided.

**Microorganism:**
Living organism (such as a bacteria, fungi, viruses) too small to be seen with naked eye but visible under a microscope.

**Pathogen:**
Organism that is capable of causing disease in humans and animals.

**Precipitation:**
Water that has precipitated from the atmosphere (e.g., rain, snow, mist, dew).

**Projected area:**
The footprint of the roof area from where the rainwater is collected.

**Rainwater:**
Water from natural precipitation that is not contaminated by use.

**Rainwater yield:**
Useful water volume (water inflow) determined over a certain period of time for use as non-potable water.

**RPBA:**
The Reduced Pressure Backflow Assembly is designed to prevent backflow caused by backpressure or backsiphonage.

**Runoff coefficient:**
Estimated proportion of rainfall that becomes water runoff.

**Syphonic drainage:**
Syphonic drainage system is designed to run completely full of water, whereas the conventional (gravity) drainage system is designed to run only 1/2 full (1/2 empty).

**Smoothing inlet:**
By using a smoothing inlet, sediment and biofilm on the bottom of the storage tank will not be stirred.

**Storage tank:**
A reservoir used to hold collected rainwater before distribution.

**Surface water:**
Water that collects on the ground or in a stream, river, lake, wetland, or ocean.

**Precipitation:**
Water falling from the atmosphere as rain, snow, sleet, hail, or other form.

**Projected area:**
The overall footprint of the collection surfaces determines the projected roof area.

**Water demand:**
The water consumption required for the rainwater appliances connected to the rainwater harvesting system.

**Water reuse:**
Using water that would otherwise be discharged to wastewater or stormwater systems, for domestic, commercial, agricultural or industrial purposes.
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For more information on Grundfos Commercial Building Services and our services, please visit www.thinkingbuildings.com

Here, you can read all about our products or use our online tools, including the timesaving Quick Pump Selection tool.