# D.T3.2.3. Framework for Analysis of WW/GW and RW utilisation potential based on water Quality testing in 4 FUAs

Subtitle

Version 1
MM YYYY

## Summary

# 1. INTRODUCTION

The European Union (EU) is facing an overwhelming water shortage. One third of EU territory is already experiencing water stress, while the growing needs of populations and the impact of climate change (among other factors) will make the availability of water of sufficient quantity and quality even more of a challenge in Europe in the future. This will pose threats to agriculture, the environment, and drinking water[1].

Water is a limited resource in the EU, with one third of the EU territory experiencing water stress. The 2015 World Economic Forum Global Risk Report identified water crises – droughts, floods, and pollution – as the risk with the largest expected global impact over the coming decades. Providing water in sufficient quantity and quality to sustain human society in a changing climate is considered as one of the main challenges of the 21st century[2]. The water challenges are especially critical in cities, which host more than half of the world's population on less than 3% of the land surface. A new study estimates, through the world's first global survey of large cities' water sources, that 1 in 4 cities already is seriously water stressed[3], with different cities facing various problems.

Urban growth has a large impact on the liveability of cities and is putting huge pressure on the availability of water, food, energy and materials. Climate change will put even more pressure on cities, as it leads to increased risks of flooding, droughts and heat waves[4]. Soil sealing is also a prevalent problem, since from mid 1950s the total surface area of cities in the EU has increased by 78 %, simultaneously increasing the degradation rate of aquatic environment. With increased periodic precipitation in some parts of EU, storm water buffer capacity that has been depleted due to urbanisation now needs to be increased. Sealed surfaces direct the rainfall to the sewer networks, where it is merges with wastewater, causes problems at the WWT facilities, and prevents the rainfall from infiltrating into the soil to renew groundwater reserves.

About 30 % of the total European population was exposed to water scarcity conditions in summer 2015 compared to 20% in 2014. Water scarcity prevails in several European river basins, with different water stress levels, affecting about 15-25 % of total European territory[5] . According to EEA, approximately one fifth of the total freshwater abstracted in Europe supplies public water systems, but only 20 % of water

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[1] Outhuijse A. et.al., Alleviating Water Scarcity Across the EU: The Contribution of the European Union's Proposal for a Regulation on Water Reuse in the Agricultural Sector, European Law Blog, 27.04.2020

[2] Tarhule A (2017); The future of water: Prospects and challenges for water management in the 21st century. Competition for Water Resources, (Elsevier), pp 442-454

[3] McDonald, R.I., Weber, K., Padowski, J., Flörke, M., Schneider, C., Green, P.A., Gleeson, T., Eckman, S., Lehner, B., Balk, D., Boucher, T., Grill, G, and Montgomery, M. (2014). Water on an urban planet: Urbanization and the reach of urban water infrastructure. Global Environmental Change, 27, pp.96-105

[4] Van Hattum T. et.al., Towards Water Smart Cities, Climate adaptation is a huge opportunity to improve the quality of life in cities, report number 2787 of Wageningen Environmental Research, 2016

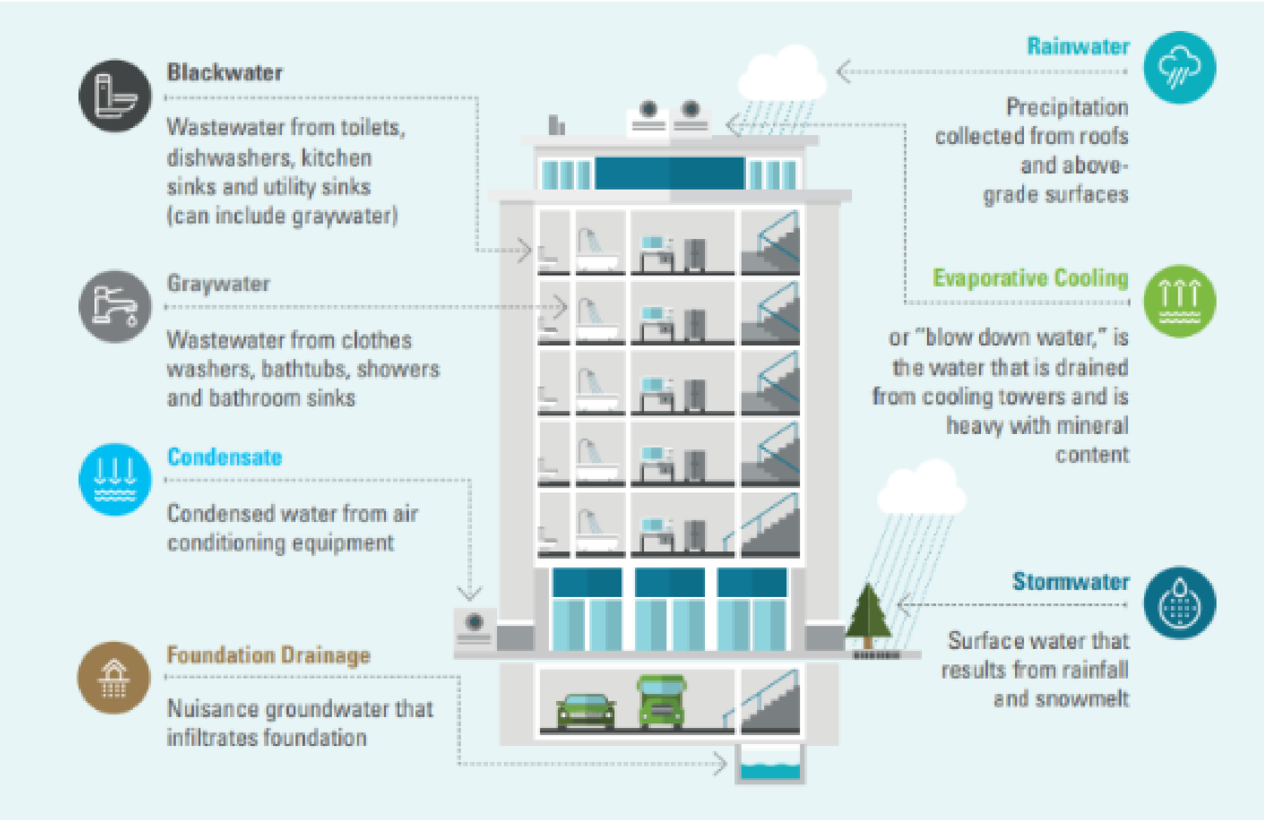
[5] Use of freshwater resources, European Environmental Agency, 10.10.2018

used by the sectors receiving a public water supply is actually consumed. The hot spots are metropoles, high population density areas and popular tourist destinations.

Direct reuse of water after treatment represents only about 1 billion cubic metres of treated urban wastewater annually, which corresponds to approximately 2.4 % of the treated urban wastewater effluent or to less than 0.5 % of annual EU freshwater withdrawals. The multitude of interconnected water problems faced by cities demands a structural and systemic approach to address and resolve as many issues as possible and put cities at the European forefront as regenerative water centres.

A sustainable practice must meet economic feasibility, social responsibility and environmental protection and this may not be the same for every case or location. Urban areas have become the center of attention from every point of view, and with all the reasons since this is where resource consumption has been intensified and not only that, but also residues and emissions are concentrated in this areas. Urban water must be supplied for all sorts of uses: domestic, industrial or agricultural and at the same time, environment, society and economy must be maintained or enhanced to maintain or achieve sustainability.

The aim of this deliverable is to provide a framework for rainwater and wastewater quality testing in order to determine the applicability and usability of harvested rainwater and waste water as alternative water resources at an affordable cost, which is specifically related to the two of the United Nation's Sustainable Development Goals: SGD 3 - Good health and well-being and SDG 6 - Clean water and sanitation.


Blackwater
Wastewater from toilets, dishwashers, kitchen sinks and utility sinks (can include graywater)
Graywater
Wastewater from clothes washers, bathtubs, showers and bathroom sinks
Condensate
Condensed water from air conditioning equipment
Foundation Drainage
Nuisance groundwater that infiltrates foundation
Rainwater
Precipitation collected from roofs and above-grade surfaces
Evaporative Cooling
or "blow down water," is the water that is drained from cooling towers and is heavy with mineral content
Stormwater
Surface water that results from rainfall and snowmelt

# 2. RAINWATER HARVESTING

Rainwater harvesting system (RWHS), where runoff from roofs and impervious areas is collected and utilized, is a prominent solution to deal with water scarcity by conserving available water resources and the energy needed to deliver water to the water supply system. The impact of climate change on water resources can also be reduced by rainwater harvesting. RWH is becoming an important part of the sustainable water management around the world. Therefore, applying RWHS would be very beneficial to provide non-potable uses such as irrigation and household use.

Rainwater harvesting is not a new concept, it was applied as early as 4500 B.C. by the inhabitants of southern Mesopotamia (present day Iraq) and by other inhabitants of different regions in the Middle East. The Romans later developed the primitive rainwater harvesting systems into more sophisticated systems in order to irrigate their lands. Moreover, rainwater harvesting systems were also employed in ancient Persia, where large underground cisterns were deployed to store the surface runoff; remains of these cisterns are still visible. There are ample objectives of rainwater harvesting systems that include directing storm water runoff to natural depressions or reservoirs. Moreover, this water can be used for irrigation, supplying household water, supplying drinking water and injecting this water into the ground to replenish groundwater supply. Furthermore, in-situ rainwater harvesting systems may reduce the carbon footprint of water collection and the distribution cycle, as well as reducing the cost of water transportation.

Collecting and using rainwater may decrease the use of municipal and groundwater. Since the rainwater collected from roofs is relatively cleaner than the rainwater collected from other impermeable surfaces such as roads, roofs are the largest impervious surface in residential areas to be used as catchment areas and allow the harvest of water that would otherwise enter into the storm-water drainage system. This may reduce storm-water runoff and the necessity for downstream storm-water management and treatment. Rainwater is clean as it falls, but the surface that this water is collected from contains the contaminants, therefore necessary treatment and filtration is needed before storing this water. Harvested rainwater is used mainly for irrigation and toilet flushing.

Rainwater harvesting, though is an ancient technique to collect run-off rainwater for domestic water supply, agriculture and environmental management, it is not widely applied. Rainwater harvesting systems could potentially play a key role in helping cities meet their water demand, as an alternative to conventional water treatment technologies such as desalination and other costly technologies. The query is motivated by the increasing necessity to find preventive and corrective measures that help cope with water supply problems, especially considering climate change effects and water supply problems in arid areas.

## 2.1. Intended Use of Non-Potable Rainwater

Non-potable water is water that does not meet the standards for human consumption but is suitable for other purposes, depending on the water quality of a given non-potable water source and its intended end-use. Most people do not realize that most of the water used in buildings does not need to be potable. For instance, many would say flushing our toilets with drinking water is a “waste.” In fact, 95% of water used in commercial buildings and 50% of water used in multi-family residential buildings is for non-drinking water needs.

The non-potable water associated with buildings—rainwater, stormwater, and wastewater—has traditionally been considered either too expensive or too dirty to reuse, but that is not necessarily the case. This water, which is typically collected and carried away from the buildings, can be treated onsite to a level of quality that makes it safe to use again immediately for specific, dedicated purposes. Onsite treatment is cost-effective and safe and has proven effective in meeting water quality standards while reducing the need for potable water and the energy consumed in its delivery.

Water reuse treats and recycles water faster than nature, on a scale that our centralized infrastructure is not currently designed for, in a cost-effective way, and closer to the building or site where that water can be used again. Water reuse matches appropriately treated water with appropriate uses. We call this “fit-for-purpose” water use. Fit-for-purpose water allows us to save high quality drinking water for just that: drinking. Instead of flushing drinking water down the toilet, we can treat water to a quality not on par with drinking water standards, but still sufficient to protect public health and meet the non-potable demands of a project: toilet/urinal flushing, landscape irrigation, cooling towers, etc. This approach saves precious drinking water by reducing the amount of potable water required in a building, while also decreasing the amount of wastewater discharged to the municipal system.

## 2.2. Catchment and Storage of Rainwater

The quantity of rainwater that can be collected from a surface such as a roof is dependent on its size and texture. Moreover, the material of the catchment surface will affect the rainwater quality through the contaminants that might be present on the surface. The gutters and downspouts will lead the rainwater from the catchment surfaces to the storage system. The purpose of the filtration system is to prevent the flow of debris from the surfaces to the pipes of the storage system. This can be done by installing screens that can accumulate the debris and may be cleaned manually. The size and material of the debris will dictate the size of the screens. Moreover, leaf guards can be installed to prevent the entry of leaves to the pipes. An important part of the filtration system is the first "flush" removal. The first flush of rainwater will contain material that has collected on the catchment surface since the last rainfall event, which may include dust, pollen, leaves, insects, bird faeces, and other residues. It is recommended to divert from 0.2 mm to 2 mm of the runoff as first flush depending on the quality of water[6].

The storage system is usually the largest investment aspect of the rainwater harvesting system. Therefore, it requires careful analysis to provide the optimal storage capacity and structural durability at the lowest possible cost. Storage reservoirs are in two categories: surface and sub-surface storage tanks. The water reservoir may be constructed from many different materials that include fiberglass, polypropylene, concrete or metal. Cisterns should be made to inhibit algal growth and they should be screened to prevent mosquito breeding. Furthermore, they should be cleaned regularly to ensure the cleanliness of the stored water. In the systems intended for non-potable uses such as irrigation and toilet flushing, screens and first flush diverters are sufficient for treatment thereby reducing the cost of the system. On the other hand, potable use of the collected rainwater will require treatment and disinfection to remove contaminants and toxins in order to meet drinking water standards.

[6] Harb Rayaan, Assessing the potential of rainwater harvesting system at the Middle East Technical University – Northern Cyprus campus, Sustainable environment and energy systems, Middle East Technical University – Northern Cyprus campus, 2015

## 2.3. Ensuring Rainwater Quality

Pre-treatment of stormwater is usually significantly different from rainwater pre-treatment, due to the potential presence of sediment, clay, zoonotic organisms and parasites, and hydrocarbons from landscape, roads, or parking lots. Screening systems are typically required to handle trash, after which comes further treatment depending on the collection surface. In areas affected by snowfall, there is the added issue of salts used on roads and sidewalks.

Potential alternate water source from rainwater requires a first step to remove non-biological material in the water, coarse biological material, or fatty biological material which may be difficult to remove in the subsequent treatment steps. This step might include fine and/or course screens, settling tanks, and grease traps. As there is inherent flow variability in most alternate water sources, the primary treatment step often also includes some form of flow equalization to buffer diurnal, seasonal, or random variability. Flow equalization assures the effectiveness of the secondary biological treatment, as well as a more consistent supply for reuse applications.

If rainwater is harvested through green roofs, the influent water may be brown in colour, due to tannins leached from organic material or due to residual suspended solids. If this is the case, microfiltration or media filtration may be needed, coupled with chlorine. Tertiary treatment required for rainwater/stormwater use is dependent on the reuse application and local regulations.

Appropriate sizing of the storage tank is critical. Sizing calculations should be based on typical meteorological year rainfall data, roof catchment area, appropriate runoff factor, and non-potable demand. In general, tank sizing should be large enough to provide a reliable water source throughout the year. For a collection area greater than 200 square meters, filtering and first flush diversion are typically achieved with a vortex filter (*first flush diversion refers to sending an initial flow of rain- or stormwater away from the catchment system as a means allowing only cleaner water to enter the system*). These filters utilize the centrifugal motion of water in the filter to scour the collection screen. This significantly increases the duration between manual cleaning events and is very effective for removing particles above 400 microns.

For example, in the Pilot Rainwater Harvesting Study Ireland[7], physico-chemical rainwater quality showed 100% compliance with the EU Bathing Water Regulations. Compliance with the EU Drinking Water Regulations was achieved for all parameters except pH and Lead. The micro biological rainwater quality showed 100% compliance with the EU Bathing Wayer Regulations. Compliance with Drinking Water Regulations was achieved for 10 of the 19 sampling dates. The significantly improved water quality results from “real” rainwater tanks suggest that, at a minimum, rainwater tanks can supply water of acceptable quality for toilet flushing and outdoor use and via hot water systems for hot water use.

[7] McCarton, L., O'Hogain, S., Reid, A., McIntyre, N., Pender, J.: Pilot Rainwater Harvesting Study Ireland. 14th International Rainwater Catchment Systems Conference. Malayasia, 2009

# 3. MINIMUM REGULATORY STANDARDS FOR REUSE OF WASTE WATER[8]

The water resources of the Union are increasingly coming under pressure, leading to water scarcity and a deterioration in water quality. In particular, climate change, unpredictable weather patterns and drought are contributing significantly to the strain on the availability of freshwater, arising from urban development and agriculture.

The Union's ability to respond to the increasing pressures on water resources could be improved by wider reuse of treated waste water, limiting extraction from surface water bodies and groundwater bodies, reducing the impact of discharge of treated waste water into water bodies, and promoting water savings through multiple uses for urban waste water, while ensuring a high level of environmental protection. The communication of the Commission of 14 November 2012'A Blueprint to Safeguard Europe's Water Resources' points to the need to create an instrument to regulate standards at Union level for water reuse, in order to remove the obstacles to a widespread use of such an alternative water supply option, namely one that can help to reduce water scarcity and lessen the vulnerability of supply systems.

In its communication of 2 December 2015'Closing the loop – An EU action plan for the Circular Economy', the Commission committed to taking a series of actions to promote the reuse of treated waste water, including the development of a legislative proposal on minimum requirements for water reuse. The Commission should update its action plan and keep water resources as a priority area in which to intervene.

As a global phenomenon, climate change does not spare Europe and the possibility of extensive water shortages in many parts of the continent is a constant threat, especially over the summer season when other aggravating factors such as tourism provide additional pressures on water resources. In Europe, agriculture is the second largest abstractor of water (26%), but in specific regions such as Italy and southern Spain, agriculture is the main water consumer with 200 and 350 Mm3 per year respectively. Yet, only 2% of the wastewater treated in Europe is reused, well below its potential which is projected to be 6000 Mm3 per year by 2025[9].

Reuse of properly treated waste water, for example from urban waste water treatment plants, is considered to have a lower environmental impact than other alternative water supply methods, such as water transfers or desalination. However, such water reuse, which could reduce water wastage and save water, is practised only to a limited extent in the Union. This appears to be partly due to the significant

[8] the REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse

[9] Water Reuse Europe Review 2018 – ISBN: 978-1-5272-2364-6

cost of waste water reuse systems and the lack of common Union environmental and health standards for water reuse, and, as regards, in particular, agricultural products, due to the potential health and environmental risks and potential obstacles to the free movement of such products which have been irrigated with reclaimed water. Water reuse could contribute to the recovery of the nutrients contained in treated urban waste water, and the use of reclaimed water for irrigation purposes in agriculture or forestry could be a way of restoring nutrients, such as nitrogen, phosphorus and potassium, to natural biogeochemical cycles.

## 3.1. REGULATION (EU) 2020/741

The adoption at first reading of "Minimum requirements for water reuse" on the 7th April 2020 reflected the pressing need for the harmonisation of water reuse practises across Europe. It also demonstrated a collective vision and focused effort involving stakeholders and the public through various consultations, evidence gathering and advice from members of the scientific community, and the development of numerous impact assessments. The Commission has been careful to ensure that the wider implications of the legislation for national and regional economies and agricultural systems are well understood. According to Simona Bonafè (S&D, IT) lead MEP and vice chair of the Group of the Progressive Alliance of Socialists and Democrats in the European Parliament, this legislative tool is a milestone towards the transition to a circular economy for water resources. In this way, step by step, the EU is bringing concrete results for the environment.

Since the objectives of this Regulation, namely the protection of the environment and of human and animal health, cannot be sufficiently achieved by the Member States, but can rather, by reason of the scale and effects of the action, be better achieved at Union level, the Union may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty on European Union. In accordance with the principle of proportionality as set out in that Article, this Regulation does not go beyond what is necessary in order to achieve those objectives.

There is great potential for the recycling and reuse of treated waste water. With a view to promoting and encouraging water reuse, the indication of specific uses within this Regulation should not preclude Member States from allowing the use of reclaimed water for other purposes, including industrial, amenity-related and environmental purposes, as considered necessary in the light of national circumstances and needs, provided a high level of protection of the environment and of human and animal health is ensured.

It is necessary to ensure that the use of reclaimed water is safe, thereby encouraging water reuse at Union level and enhancing public confidence in it. Production and supply of reclaimed water should therefore only be permitted on the basis of a permit, granted by competent authorities of Member States. In order to ensure a harmonised approach at Union level, traceability of reclaimed water and transparency, the substantive rules for such permits should be laid down at Union level. However, the details of the procedures for granting permits, such as the designation of the competent authorities and deadlines, should be determined by Member States. Member States should be able to apply existing procedures for granting permits, which should be adapted to take account of the requirements introduced by this Regulation. When designating the parties responsible for the drawing up of the water reuse risk management plan and the competent authority for the granting of the permit for production and supply of reclaimed water, Member States should ensure that there is no conflict of interests.

In order to effectively protect the environment and human and animal health, reclamation facility operators should be primarily responsible for the quality of reclaimed water at the point of compliance. For the purposes of compliance with the minimum requirements laid down under the REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse and with any additional conditions set by the competent authority, reclamation facility operators should monitor the quality of reclaimed water. It is therefore appropriate to establish the minimum requirements for monitoring, consisting of the frequencies of the routine monitoring and the timing and performance targets for validation monitoring. The reuse of treated urban waste water for agricultural irrigation is a market-driven action, based on the demands and needs of the agricultural sector, in particular in certain Member States that face water resource shortages. The reclamation facility operators and the end-users should cooperate to ensure that reclaimed water produced in accordance with the minimum quality requirements established by this Regulation meets the needs of the end-users regarding crop categories. In cases where the quality classes of the water produced by the reclamation facility operators are not compatible with the crop category and irrigation method already in place in the area served, for example in a collective supply system, water quality requirements could be met by using, at a subsequent stage, several water treatment options alone or in combination with non-treatment options for the reclaimed water, in line with the multi-barrier approach.

The provisions of this Regulation are intended to be complementary to the requirements of other Union legislation, in particular with regard to possible health and environmental risks. In order to ensure a holistic approach to addressing possible risks to the environment and to human and animal health, the reclamation facility operators and competent authorities should take into account the requirements laid down in other relevant Union legislation, in particular Council Directives 86/278/EEC (8) and 91/676/EEC (9), Directives 91/271/EEC, 98/83/EC and 2000/60/EC, Regulations (EC) No 178/2002 (10), (EC) No 852/2004 (11), (EC) No 183/2005 (12), (EC) No 396/2005 (13) and (EC) No 1069/2009 (14) of the European Parliament and of the Council, Directives 2006/7/EC (15), 2006/118/EC (16), 2008/105/EC (17) and 2011/92/EU (18) of the European Parliament and of the Council, and Commission Regulations (EC) No 2073/2005 (19), (EC) No 1881/2006 (20) and (EU) No 142/2011 (21).

The minimum requirements for the safe reuse of treated urban waste water reflect available scientific knowledge and internationally recognised water reuse standards and practices and guarantee that such water can be safely used, thereby ensuring a high level of protection of the environment and of human and animal health. In light of the results of the evaluation of this Regulation or whenever new scientific developments and technical progress so require, the Commission should be able to examine the need to review the minimum requirements set out in Section 2 of Annex I and, where appropriate, should submit a legislative proposal to amend this Regulation.

With a view to developing and promoting the reuse of properly treated waste water as much as possible and in order to bring about a significant improvement in the reliability of properly treated waste water and in viable use methods, the Union should support research and development in this area through the Horizon Europe programme.

## 3.2. Recycled Waste Water Testing Parameters

### 3.2.1. Sensory properties of recycled waste water

Effluent recycled waste water has several physical properties (sensory) that have to be considered at the time of effluent sample collection, mainly:

- Colour
- Colour intensity
- Turbidity
- Sediments
- Foaming
- Odour
- Odour intensity

### 3.2.2. Chemical parameters

I. **Undissolved substances. ISO 11923:1997** describes a method for the determination of suspended solids in raw waters and waste waters by filtration though glass-fibre filters. The lower limit of the determination is approximately 2 mg/l. Floating oil and other immiscible organic liquids interfere.

II. **Determination of biochemical oxygen demand. EN 1899-1: 1998**. This European Standard specifies a determination of the biochemical oxygen demand of waters by dilution and seeding with suppression of nitrification. This standard is applicable to all waters having biochemical oxygen demands greater than or equal to the limit of determination 3 mg/l of oxygen and not exceeding 6000 mg/l of oxygen.

III. **Turbidity. ISO 7027-1:2016** specifies two quantitative methods using optical turbidimeters or nephelometers for the determination of turbidity of water: a) nephelometry, procedure for measurement of diffuse radiation, applicable to water of low turbidity (for example drinking water); b) turbidimetry, procedure for measurement of the attenuation of a radiant flux, more applicable to highly turbid waters (for example waste waters or other cloudy waters). Turbidities measured according to the first method are presented as nephelometric turbidity units (NTU). The results typically range between <0,05 NTU and 400 NTU. Depending on the instrument design, it can also be applicable to waters of higher turbidity. There is numerical equivalence of the units NTU and formazin nephelometric unit (FNU). Turbidity measured by the second method is expressed in formazin attenuation units (FAU), results typically range between 40 FAU and 4 000 FAU.

### 3.2.3. Microbiological parameters

I. **Detection and enumeration of bacteriophages — Part 2: Enumeration of somatic coliphages. ISO 10705-2:2000.** This part of ISO 10705 specifies a method for the detection and enumeration of somatic coliphages by incubating the sample with an appropriate host strain. The method is applicable to all kinds of water, sediments and sludge extracts, where necessary after dilution. The method is also applicable to shellfish extracts. In the case of low phage numbers, a preconcentration step may be necessary for which a separate International Standard will be developed.

II. **Enumeration of Legionella. ISO 11731:2017** specifies culture methods for the isolation of Legionella and estimation of their numbers in water samples. These methods are applicable to all kinds of water samples including potable, industrial, waste and natural waters. These methods can be used for water related matrices, e.g. biofilms, sediments, etc. Not all Legionella species are culturable; therefore, the methods described in this standard do not recover all species of Legionella.

III. **Enumeration of Clostridium perfringens. ISO 14189:2013** specifies a method for the enumeration of vegetative cells and spores of Clostridium perfringens by the membrane filtration method in samples of water intended for human consumption. However, the method can be applied to all types of water samples provided they do not contain particulate or colloidal matter that interferes with filtration.

IV. **Enumeration of Escherichia coli and coliform bacteria. ISO 9308-1:2014/Amd 1:2016** specifies a method for the enumeration of E. coli and coliform bacteria. The method is based on membrane filtration, subsequent culture on a chromogenic agar medium and calculation of the number of target organisms in the sample. Due to the low selectivity of the differential agar medium, background growth can interfere with the reliable enumeration of coliform bacteria and E. coli, for example in surface waters or shallow well waters. This method is not suitable for these types of water. This part of ISO 9308 is especially suitable for waters with low bacterial numbers that will cause less than 80 total colonies on chromogenic coliform agar. These may be drinking water, disinfected pool water or finished water from treatment plants.

# 4. RECOMMENDED GREYWATER REUSE STANDARDS TO BE CONSIDERED[10]

The concept of quality-related, material flow separation and its corresponding treatment for the purpose of reuse is being increasingly applied in industrial processes. This approach is relatively new in the urban water management. New Alternative Sanitation Systems (NASS) on basis of the Standard DWAA 272 considers separate collection of household material flows directly at the generation site or point of origin. For each incidental material flow, there exists the possibility of its separate drainage, treatment and subsequent utilisation/recycling. The implementation of NASS follows through the establishment of two material systems (*blackwater: yellow and brown water, and greywater*) or three material systems (separate collection of brown water, yellow water as well as greywater).

Independent of the NASS concept, greywater, quantitatively the most relevant partial flow of household wastewater, arises always separately from black, brown and yellow water in both material systems. Therefore, site-adapted reuse or treatment concepts for greywater has an important role to play in all cases.

Taking into consideration the selected NASS concept and site conditions, the separately collected greywater can be treated and reused as service water in areas, where drinking water quality is not mandatory (irrigation, toilet flushing, etc.), or it is treated according to the legal requirements and safely discharged into the environment.

Due to the greywater quality, which exhibits very low nutrient content (nitrogen and phosphorus) compared to household wastewater, the processing and treatment technologies for

| Microbiological Parameter | | | Washing machine (n/100ml) | Author | Bathtub/Shower, Hand washbasin (n/100ml) | Author | Kitchen/ Dishwasher (n/100ml) | Author | Unseparated greywater (n/100ml) | Author |
|---|---|---|---|---|---|---|---|---|---|---|
| Bacteria | Indication parameter | Faecal coliforms | $10^1 – 10^4$ | A B C K | $10^1 – 10^6$ | A B C K | – | | $10^2 – 10^6$ | M O |
| | | Total coliforms | $10^1 – 10^8$ | A B C | $10^1 – 10^9$ | A B C E K N | – | | $10^5 – 10^8$ | M P O |
| | | E. coli | $10^1 – 10^6$ | G | $10^1 – 10^7$ | G K N | $10^5 – 10^8$ | G | $10^1 – 10^2$ | M O |
| | | Faecal streptococci | $10^1 – 10^7$ | A B C G K | $10^1 – 10^4$ | A C G K | $10^3 – 10^8$ | G | $10^2$ | M O |
| | | Total colony counts | – | | $10^2 – 10^8$ | B E | – | | – | |
| | Other | Pseudomonas aeruginosa | – | | n. n.– $10^3$ | E K | – | | $10^2 – 10^5$ | M |
| | | Salmonella sp. | n.d. | A | n.d. | A K | – | | – | |
| Protozoa | | Cryptosporidium | n.d. | A | n.d. | A | – | | n.d. | M |
| | | Giardia | n.d. | A | n.d. | A | – | | – | |

Notes:

n. d. not determined

A) Christova-Boal et al. (1996)
B) Rose et al. (1991)
C) Siegrist et al. (1976)
D) Santala et al. (1998)
E) Burrows et al. (1991)
F) Shin et al. (1998)
G) Hargelius et al. (1995)
H) Butler et al. (1995)
I) Birks et al. (2004)
J) Ramon et al. (2004)
K) Eriksson et al. (2002)
L) Palmquist&Hanaeus (2005)
M) Casanova et al. (2001)
N) Jefferson (2001)
O) Oldenburg & Otterpohl (2005)
P) Elmitwalli et al. (2003)

Figure SEQ Figure * ARABIC 2: Microbiological greywater load depending on the origin source.

[10] German DWA Set of Rules, Guideline DW greywater and greywater partial flows, German Association for Water, Wastewater and Waste (DWA), October 2017

greywater differ from the classical ones for wastewater treatment. If reuse of the treated greywater is planned, it is necessary that it undergoes biological stabilisation and disinfection.

The NASS has designed special guidelines for different applications of greywate reuse determining specific requirements on the treatment quality and thus will have a significant influence on the needed system technology. The quality level of greywater can be characterised according to the type of use as:

- C1: mechanical, biological treatment and stabilization of greywater of the Type A - low grade greywater, i.e. greywater excluding drains from kitchen and washing machines. Characterisation: storage and aeration for reuse as toilet flush water in private sector.
- C2: mechanical, biological treatment and hygienisation of greywater of the Type A and Type B - high grade greywater, i.e. greywater from kitchen drains and/or washing machines. Characterisation: storage and treatment for reuse in private and public sectors.

Technologies corresponding to the uses are listed in the figure below 4. This compilation is not exhaustive with regard to technology and allocation of particular uses to the single technologies.
Resident-specific, design information from a conventional wastewater treatment system cannot be simply transferred due to the specific composition of the greywater. Treatment of greywater depends on the subsequent use or discharge. It should be appropriately equipped and dimensioned according to the type of use.

| Criteria | | Quality requirements for treated greywater | |
|---|---|---|---|
| Use category | | C1 | C2 |
| Treatment method | | Treatment/Stabilisation | Treatment and hygienisation |
| Greywater | | Type A | Type A<br>Type B |
| Biochemical/chemical-physical parameters | Turbidity | – | < 2 NTU |
| | $BOD_5$ | – | < 5 mg/l |
| | $O_2$ Saturation | > 50 % | > 50 % |
| | pH | 6.5 – 9.5 | 6.5 – 9.5 |
| Hygienic parameters | Total coliforms | No requirement | < 10,000/100 ml |
| | E. coli | | < 1,000/100 ml |
| | P. aeroginosa | | < 100/100 ml |
| | sampling | – | Reservoir/Consumer |
| Recommended use | Toilet flushing (private) | + | + |
| | Irrigation (private)<br>lawn, ornamental plants | – | + |
| | Irrigation crop plants<br>(for consumption) | – | + |
| | Laundry (private)* | – | + |
| | Toilet flushing (public) | – | + |
| | Exemplary processes and other treatment stages | FB, SF, FLB, Stabilisation | FB, SF, FLB, MBR<br>+ UV, UF, RO |
| | UV-Anlage | MBR Membrane bioreactor | FLB Fluidised bed reactor |
| | UF Ultrafiltration | FB Fixed bed reactor | SF Soil filter system |

# 5. CONCLUSIONS – FRAMEWORK FOR 4 FUAs

## 5.1. Rainwater Utilisation Potential

In order to properly define the utilisation potential in each pilot, several aspects of rainwater collection (harvesting) should be considered. There are six components of any rainwater harvesting system[11] that should be considered in order to determine the necessary (if any) pre-treatment:

a. Catchment area
b. Gutters and downspouts
c. Filtration system
d. Storage system
e. Delivery system
f. Treatment system

After determination of said base harvesting properties, the intended use of the rainwater should be specified in order to further elaborate, which pre-treatment options should be implemented, if necessary due to physical requirement or to comply with local, national or European regulation:

- In cases, where stormwater will be collected, particular focus should be paid to presence of sediments, clay, zoonotic organisms and parasites, and hydrocarbons from landscape, roads, or parking lots and mitigating pre-treatment options to relieve the sotrmwater of said particles.
- In cases of rainwater collection through greenery (*e.g. green roofs, permeable green surfaces*) the rainwater will be brown in colour, due to tannins leached from organic material or due to residual suspended solids. In this case, microfiltration or media filtration may be needed, coupled with chlorine.

[11] Hamid, T.A., and Nordin, B., (2011). Green campus initiative: Introducing RWH system in Kolej Perindu 3 UiTM Malaysia, 3rd International Symposium and Exhibition in Sustainable Energy Environment (ISESEE), Melaka

## 5.2. Waste Water Utilisation Potential

Initially, the following main aspects should be considered and explored in order to assess the potential of recycled waste water reuse potential:

I. The quality of recycled water effluent intended for reuse. The quality parameters of WWTP effluents have to be monitored for sensory (physical) and chemical properties, thus this data should be available to the WWTP operators and national agency responsible for monitoring of effluent quality. However, additional testing should be done, as described in 3.2.3., in order to comply with Regulation (EU) 2020/741.

II. Intended use of recycled waste water. Quality standards could vary based on the intended use of recycled waste water. The stringiest quality standards are foreseen for agricultural reuse, whereas standards for industrial reuse or for other urban uses, such as watering of green surfaces and road cleaning, may be laxer. In depth analysis of all relevant, most national standards, should be done after determining the effluent quality and intended use to determine the "fit-for-purpose" appropriateness and utilisation potential.

III. On-site close-loop system. A slightly different approach should be taken in cases, where a close-loop waste water treatment and reuse system is envisaged (*e.g. within one industrial production line*). Herein, the intended use is predefined, whereas influx quality parameters for the same industrial process will vary and should be defined by the industrial operators.