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WATER REUSE POLICIES ADVANCEMENT FOR RESOURCE EFFICIENT

AQUARES A1.3 – Water reuse technology application guide

2020

Contents

1. Introduction

This document has been produced in the context of AQUARES project, to present an application guide for water reuse technologies. The AQUARES project aims to support EU regions to achieve efficient water management through water reuse, profit from the opportunities in the water market, and secure the protection of water bodies. In this context, the project pursues the integration of water reuse in national, regional and local development plans, promoting the efficient use and management of water, as well as sustainable development and eco-innovation adoption across the agricultural, industrial, urban and recreational sectors.

Water scarcity and drought events are likely to be more severe and more frequent in the future due to climate change and increasing population. Over the past thirty years, droughts have dramatically increased in number and intensity in the EU and at least 11% of the European population and 17% of its territory have been affected by water scarcity to date [1]. The potential role of treated wastewater reuse as an alternative source of water supply is now well acknowledged and embedded within international, European and national strategies. Water reuse contributes to the broader water sector which is a key component of EU eco-industrial landscape. The world water market is growing rapidly, and it is estimated to reach 1 trillion € by end of 2020.

The scope of this technology application guide is to (i) identify the best technologies to be applied in priority areas for the application of water reuse and (ii) provide suggestions to promote and support the application of the most appropriate water reuse technologies. This document is based on the evaluation of A1.2 ("Analysing the needs of AQUARES regions in water reuse") and A1.3 ("Evaluation of water reuse technologies and practices across different sectors and regions") results.

The technology application guide is structured as follows: Chapter 2 describes the benefits of water reuse along with the available waste water treatment processes and technologies. Chapter 3 presents already successful wastewater treatment applications in AQUARES territories as well as proposed treatment technologies for their sectors/areas with higher water reuse potential. Finally, chapter 4 summarizes chapter's 3 presented key information and delivers suggestions on how to promote and support the application of the most appropriate water reuse technologies in AQUARES countries.

2. Thematic background

Water reclamation is the treatment or processing of wastewater to make it reusable with definable treatment reliability and meeting water quality criteria [2]. Water reuse is the use of treated wastewater for beneficial uses, such as agricultural irrigation and industrial cooling [2,3]. Treated municipal wastewater represents a more reliable and significant source for reclaimed water as compared to wastewaters coming from agricultural return flows, storm water runoff, and industrial discharges. This section presents the problem and the related policy environment as well as the benefits of water reuse and its applications. Finally, the section focuses on all available treatment processes and technologies in wastewater treatment.

2.1. The problem and related policy environment

Annually, only 2.4% (1,100 million m^3) of treated wastewater is re-used in the EU; a volume that represents less than 0.5% of EU freshwater abstractions. While the existing water reuse rates are relatively low, their potential is rather high, being estimated to reach approximately 6.000 million m^3. According to the European Commission's assessment on the requirements of water reuse published in 2018, the adoption of water reuse solutions in Europe is still relatively limited while the potential for water reuse is particularly significant.

The water reuse issue has been identified and efforts are being intensified with the adoption of relevant initiatives concerning water reuse for irrigation, industrial uses and aquifer recharge, by both southern and northern member states. Cyprus and Malta lead while water reuse accounts for 90% and 60% respectively, while Greece's, Italy's and Spain's rates are between 5% and 12%.

European freshwater resources also face increasing tension in multiple regions because of the mismatch between the demand and the availability of water resources in both temporal and spatial scale. It is estimated that by 2030, scarcity and water tension will significantly affect half of European water basins. The issue is more prominent during summer months, affecting approximately 70 million citizens, while 30 million approximately are affected during winter months.

The reuse of treated wastewater has been highlighted within EU water policy as one possible alternative water source in water-scarce regions which may be appropriate to consider within water-scarcity planning [4]. It was also presented as a priority in the 2012 Water Blueprint [5] and it is also a supplementary measure which Member States can adopt as part of the Programme of Measures required under Article 11(4) of the WFD. Reuse of treated wastewater is further emphasised in EU policy on resource efficiency, most notably in the 2015 Communication on the Circular Economy [6] which states “in addition to water efficiency measures, the reuse of treated wastewater in safe and cost-effective conditions is a valuable but under-used means of increasing water supply and alleviating pressure on over-exploited water resources in the EU”. The Communication stated that the Commission will take a series of actions to promote the reuse of treated wastewater. These guidelines take forward one action considering the wide context of potential uses of reused water at Member State level and how this could be examined in appropriate planning. Water reuse should contribute to the UN 2030 Sustainable Development Agenda and especially its target to “substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity” and the sub-target to “By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally”.

2.2. Water reuse benefits and applications

Water reuse, as an alternative water source, can provide significant economic, social and environmental benefits, which are key motivators for implementing such reuse programmes. These benefits include [7]:

- Increased water availability
- Integrated and sustainable use of water resources
- Drinking water substitution – keep drinking water for drinking and reclaimed water for non-drinking use
- Reduced over-abstraction of surface and groundwater
- Reduced energy consumption compared to using deep groundwater resources, water importation or desalination
- Reduced nutrient loads to receiving waters
- Reduced manufacturing costs of using high quality reclaimed water
- Increased agricultural production
- Reduced application of fertilisers
- Enhanced environmental protection by restoration of streams, wetlands and ponds
- Increased employment and local economy (e.g. tourism, agriculture)

The main reclaimed water applications in the world are shown in Table 1.

Table 1. Main reclaimed water applications in the world [7, 8, 9].

Categories of use	Uses
Urban uses	Irrigation of public parks, sporting facilities, private gardens, roadsides; Street cleaning; Fire protection systems; Vehicle washing; Toilet flushing; Air conditioners; Dust control
Agricultural uses	Agricultural uses Food crops not commercially processed; Food crops commercially processed; Pasture for milking animals; Fodder; Fibre; Seed crops; Ornamental flowers; Orchards; Hydroponic culture; Aquaculture; Greenhouses; Viticulture
Industrial uses	Processing water; Cooling water; Recirculating cooling towers; Washdown water; Washing aggregate; Making concrete; Soil compaction; Dust control
Recreational uses	Golf course irrigation; Recreational impoundments with/without public access (e.g. fishing, boating, bathing); Aesthetic impoundments without public access; Snowmaking
Environmental uses	Aquifer recharge; Wetlands; Marshes; Stream augmentation; Wildlife habitat; Silviculture
Potable uses	Aquifer recharge for drinking water use; Augmentation of surface drinking water supplies; Treatment until drinking water quality

It should be noted that currently over 60 countries around the world are using centralised recycling water systems for different non-potable purposes such as toilet flushing, car washing, landscape irrigation, industries, commercial use, groundwater recharge. In some cases, this has extended to drinking water as direct and indirect potable water reuse [8, 10, 11]. In the literature, have been documented various ways of water reuse around the world. Recycling water has the highest use for agriculture (32%), landscape irrigation (20%), industrial use (19%), Groundwater recharge (2%) and the remaining 17% for urban use (17%) [12].

2.3. Water reclamation technologies

Water reuse is a widely desired practice around the world, mainly applied for water resources conservation, reduction of potable water supplies consumption, and ecosystems protection. Today, there is a variety of available effective technologies for water reuse in wastewater treatment facilities. These technologies have different characteristics and are based on biological, chemical, mechanical, and natural processes. However, each technology has certain advantages and disadvantages, which should be taken into account when selecting the appropriate technological train for each water reuse application.

Treatment technologies for water reclamation and reuse probably represent the most essential segment in integrated water resources management. A variety of technologies with different nature, processes, and means used exists for the treatment. A treatment technology can be employed singly or in combination with other technologies and processes for the optimum treatment result, which is also the usual practice. Due to the numerous available technologies and processes (see Fig. 1), there is a respectively high number of possible flow diagrams for the treatment train that can be adopted, depending on the specific characteristics of each reuse application. The basic principle of wastewater treatment plants is the optimum removal of the various pollutants present in wastewater. The necessary level of wastewater treatment is defined by the effluent limit concentrations, which needs to be fulfilled before the final discharge of the effluent, and by the option of water reuse of this treated effluent [13]. Consequently, the main factors affecting the selection of a water reclamation technology, or a combination of technologies, include the water reuse application and the consequent reclaimed water quality objectives, as well as the characteristics of the source water.

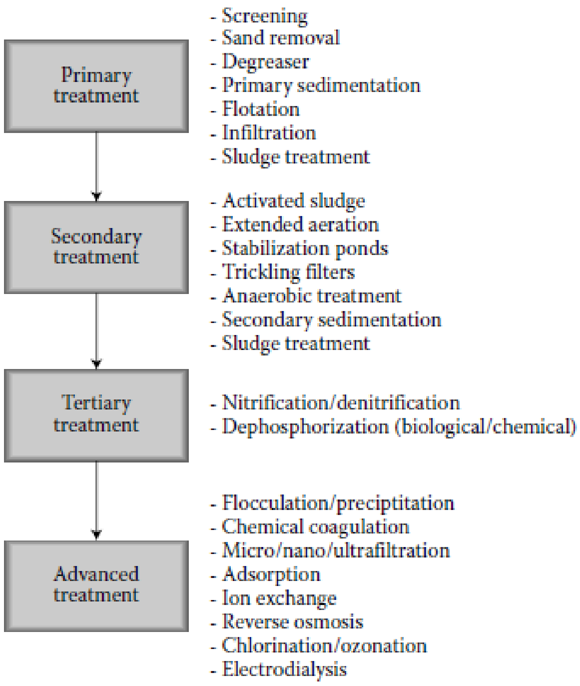

Fig. 1. Treatment processes and technologies in wastewater treatment [13].

A conventional treatment train usually includes up to two or three treatment stages: primary (preliminary), secondary, and tertiary treatment, as shown in Fig. 1. Preliminary stage includes inflow-measuring devices, and screens for the removal of large solid materials, sand, grit, and oils. The primary stage includes a first sedimentation tank for the removal of settleable solids. The primary stage is followed by the second treatment stage, where removal of suspended solids, biodegradable organic matter, and at a certain level nutrient removal takes place. The most common method is that of aerated activated sludge. A treatment train of the conventional activated sludge system includes aerated basins and sedimentation tanks in the secondary stage. Other methods for secondary treatment are trickling filters or rotating bio-contactors [14, 15], which are based on the use of fixed-media. The secondary stage usually ends with a secondary settling tank or a combination of membrane filtration and disinfection [16].

Until recently, a treatment train of two stages was common for conventional wastewater treatment. However, it was gradually realized that the effectiveness of this setup was no longer acceptable due to new challenges that came to the forefront in the wastewater treatment field: (i) adaptation of stricter regulated effluent limits for the final discharge for public health and environmental protection, (ii) decline of available water resources, (iii) rapid increase of population, (iv) industrial development, (v) realization of treated water as a potential beneficial water source with multiple reuse applications, and (vi) new groups of emerging pollutants with high health and environmental risks [17, 18]. These challenges are dictated by the concept of integrated and sustainable management of water resources, which has been introduced to international and national legislation, for example, the Water Framework Directive 2000/60/EC in Europe [19].

All these new challenges resulted in one common conclusion: the treated water from treatment facilities should be of higher quality in order to cover all these new needs and to be appropriate for various reuse applications with minimum impact on human health and the environment [13]. Conventional biological wastewater treatment cannot provide the required effluent quality, especially for discharge in ecologically sensitive areas and for the implementation of water reuse projects. Therefore, additional advanced steps should be added in the treatment train and advanced treatment technologies should be used to deliver a final effluent of higher quality. The main goal is to further treat and remove from the wastewater pollutants like organics, solids, nutrients, pathogens, and potentially toxic compounds like heavy metals or emerging pollutants (pharmaceuticals, endocrine-disrupting chemicals [EDCs], personal care products [PCPs], etc.) [20]. Thus, advanced treatment technologies could be classified according to the targeted pollutants as shown in Table 2.

Table 2. Classification of Advanced Treatment Technologies Based on the Various Target Pollutants [13].

Target Pollutant	Associated Risk	Technologies
Pathogenic microorganisms	Disease transmission	• Chlorination • Ozonation • UV radiation
Nutrients	Eutrophication in surface waters	• Nitrogen and phosphorus • Biological removal • NH_4^+ ion-exchange • Chemical precipitation • Adsorption • Constructed wetlands
Hardly biodegradable organics	Toxic for humans and the environment	• Activated carbon • Chemical oxidation with O_3, H_2O_2 or O_2 • Constructed wetlands
Heavy metals	Toxic for humans and the environment bioaccumulation	• Reverse osmosis • Nanofiltration • Chemical precipitation • Adsorption • Ion exchange • Constructed wetlands
Remained solids	Adverse effects on final effluent	• Tertiary treatment with filters (after activated sludge) • Ultrafiltration membrane • Membrane bioreactors • Constructed wetlands
Organic micro-pollutants and emerging contaminants		• Membrane filtration • Constructed wetlands

Wastewater treatment technologies can be categorised as intensive or conventional and extensive or non-conventional technologies (see Table 3). Intensive technologies refer to accelerated artificial processes that can be rapidly modified if needed and which require large quantities of energy and minimum space as well as highly specialised operation and maintenance personnel. By contrast, extensive technologies demand small amounts of energy and maximum space as they use environmental matrices and rely on natural processes for water treatment, so the processes occur at almost natural rates [21].

Table 3. Intensive and extensive wastewater treatment technologies [21].

Intensive technologies	Extensive technologies
Physical-chemical systems (coagulation-flocculation, sand filters)	Waste stabilisation ponds (maturation ponds, stabilisation reservoirs)
Membrane technologies (ultrafiltration, reverse osmosis, membrane bioreactor)	Constructed wetlands (vertical-flow, horizontal-flow)

Rotating biological contactors	Infiltration-percolation systems
Disinfection technologies (ultraviolet radiation, chlorine dioxide, ozone, peracetic acid)	

Indicative examples of intensive and extensive techniques

If water reclamation is the target, then advanced treatment technologies should be included in the treatment train. Current practice and experience implies that for more effective and safe water reuse, various technologies should be combined like membrane filtration, activated carbon, ozonation, etc., which respectively enhances the above-mentioned limitations especially in terms of costing and reliable long-term operation. Regarding intensive techniques, Membrane technology today is one of the most attractive technologies available for potable and nonpotable water reuse applications, with many advantages like lower surface area demands, more or less process automation, effective pathogen removal, and good overall performance. The hydraulic retention time in the MRB tanks is usually higher than that in conventional treatment systems, which makes the system more stable and, therefore, appropriate for relatively small facilities (<2000 m^3/d) with fluctuations of the daily inflow rate [13]. MBR systems could be used in areas with limited water sources and limited available land for water reuse applications like small communities, commercial centers, resorts, hotels, etc. Thus, MRB tanks should be preferred in areas with high water reuse potential because of Tourism. However, membrane technology still faces limitations concerning higher investment and operational costs, high energy consumption, still unavoidable use of chemicals, complex and not quite easy to handle usage, limited useful lifetime of membranes, operational problems due to fouling, and the need for specialized personnel.

As regards extensive technologies, ecological engineering developments like Constructed wetlands (CWs) technology provide a sustainable solution as an economical, effective, environmentally friendly, socio-culturally acceptable, and simple to build and operate alternative. CWs can be used for agricultural and environmental uses. However, higher area demands are the main limitation for natural systems. Thus, it is clear that each water reuse application should be assessed separately and all related individual characteristics and parameters should be evaluated before the selection of the appropriate reuse technology [13].

It should be noted that it is essential to have broad knowledge of the efficiency of the different technologies and their combinations. Regarding the efficiency and reliability of treatment technologies, further research is needed on [7]:

- The efficiency and reliability of WWTP, in order to allow reclamation technologies to be more efficient in treating secondary effluents
- Extensive technologies in countries where these technologies are most likely to be appropriate (e.g. Mediterranean countries)
- The generation of removal capacities and by-products by disinfection technologies
- Industrial-scale research with real operational conditions of WWTPs

Finally, Figure 2 presents the types and levels of wastewater treatment processes that are currently applied in most regions of the world [22].

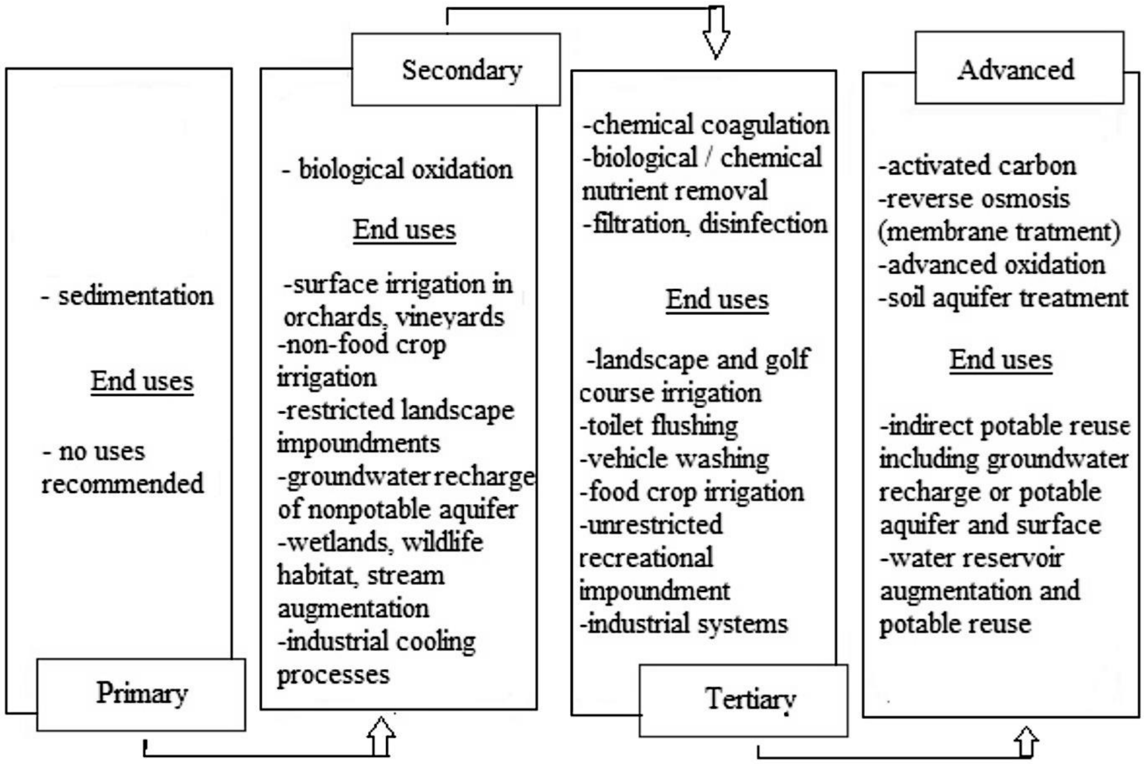

Fig. 2. Types and levels of wastewater treatment processes [22].

3. Water reuse potential and wastewater treatment technologies in AQUARES territories

Chapter 3 presents which water treatment technologies match the specificities of each AQUARES region and sector. Chapter 3 is based on the A1.2 and A1.3 deliverables of the AQUARES project, namely “Analysing the needs of AQUARES regions in water reuse” and “Evaluation of water reuse technologies and practices across different sectors and regions”.

The results of A1.2 indicate that the sectors with the highest water reuse potential in AQUARES territories are agriculture, manufacturing and power production. These sectors combine significant vulnerability to water scarcity, high water consumption and wastewater generation, intensive economic activity and substantial environmental footprint. Therefore, the use of reclaimed water could provide a viable alternative to mitigate pressures on available freshwater resources while the size of the sector can justify investments in water reuse facilities and advanced treatment methods. Lower but still significant water reuse potential has been also found in tourism, food industry and groundwater recharge. For each study area, the sectors/areas with higher water reuse potential are presented in the following Table:

Table 4. Sectors/areas with higher water reuse potential in AQUARES territories.

Region/country	Sectors/areas
Murcia Region	Agriculture and Tourism
Lombardy Region	Agriculture, Urban uses and Freshwater Recharge
Malta	Agriculture and Tourism
Municipality of Trebnje	Agriculture and Freshwater Recharge
Latvia	Food Industry, Manufacturing and Agriculture
Czech Republic	Energy Production, Manufacturing and Agriculture
Łódzkie Region	Manufacturing and Agriculture
Lower Saxony	Agriculture, Manufacturing and Energy Production

3.1. Murcia Region (ES)

Sector: Agriculture

The most suitable potential use of reclaimed water in Murcia Region is agricultural irrigation, as the primary sector is the largest water consumer in Murcia region, and mostly affected by severe water supply conditions. The percentage contribution of agriculture in the total water consumption exceeds 80%. The high-water demand cannot be completely covered by region's available freshwater resources. Instead, agriculture has a mean annual water deficit of 20% whereas a considerable share of water demand is satisfied through water imported by neighbouring regions, and reclaimed or/and desalinated water. In fact, 98 percent of water consumed in agriculture is reused, compared to 5% internationally and 15% in Spain as a whole. Additionally, agriculture is a sector particularly vulnerable to water scarcity given the low precipitation rates prevailing in the region.

Wastewater reuse practices

Most of the waste water treatment plants (WTTP) operating in the region provides advanced tertiary wastewater treatment (rotating drum screens), biological nutrient removal, and disinfection (chlorination) that make the water reclaimed suitable for irrigation use. In addition, the location of most WWTPs is relatively close to agricultural areas facilitating the distribution of reclaimed water for irrigation purposes.

The fragmented application of efficient water management techniques in agriculture irrigation has led to significant wastewater discharges in wetlands, thereby reducing the quality of water, accumulating organic waste, and causing eutrophication. It should be noted that Tertiary waste water treatment is preferable for agriculture uses (see Fig. 2) as the treated water can be easily used for food crop irrigation [22]. The WWTP of Molina de Segura treats 5.7 Hm^3/year from the urban area of the town, various residential areas and five industrial estates. The objectives of the reuse of reclaimed water are to ensure good quality water to the agricultural sector with continuity while extending the life of the resource in a circular economy perspective. The sewage treatment plant has a discharge authorization to the Segura River, but previously the water is stored in lagoons, where five water concessionaires carry out the catchment. The quality of the reclaimed water has allowed the transformation of these lagoons into an artificial wetland of international interest.

The WWTP uses a combination of physical-chemical systems (bar screening, grit and oil removal), primary sedimentation, disinfection technologies (UV), activated sludge and sand filtration to treat approximately 15.600 m^3/d (dry weather average ≈ 650 m^3/h; wet weather maximum ≈ 2.500 m^3/h). Reclaimed water is stored in 5 lagoons, with a total capacity of 360,000 m^3. The last lagoon acts as a point of capture on the part of the 5 concessionaires of the waters, keeping the rest always full to maintain the ecological activity of the wetland.

<u>Sector: Tourism</u>

In addition to the traditional water demand for crops, there is currently also an increasing demand for water for the booming tourist developments. Tourism represents a key driver of regional economy, accounting for 12.5% of the annual output. While tourism accounts for only a small share of total water consumption (less than 2%), its strong seasonality puts additional pressure on Murcia's depleted resource base. Remarkably, it is estimated that a Spanish city dweller uses half of litres per day compared to a tourist. The above indicates that the industry faces a significant water deficit (especially during summer peak seasons) and is therefore subject to water scarcity issues.

<u>Wastewater reuse practices</u>

Though most of WTTPs in the region apply advanced and tertiary treatment methods, which is the minimum treatment level foreseen by the national law (Reuse of Reclaimed Water: Quality Criteria) for using reclaimed water in tourism, only one plant (Molina de Segura) has been commissioned to supply tourism facilities with reclaimed water. Thus, in cases of individual hotels, campsites and huts, biological treatment would be preferable without limitations. There are different options depending on the individual circumstances, but in principle the described techniques for pre-treatment (i.e. Sedimentation plants, Dewatering press, Dry toilets, Filter sack plants) and biological treatment (i.e. Biofilm processes, activated sludge systems) are applicable to all cases of the aforementioned categories [23]. Furthermore, it should be mentioned here the high applicability of Membrane bioreactors (MBR) in such cases. The hydraulic retention time in the MRB tanks is usually higher than that in conventional treatment systems, which makes the system more stable and, therefore, appropriate for relatively small facilities (<2000 m^3/d) with fluctuations of the daily inflow rate [13]. Finally, according to Fig. 2, Tertiary waste water treatment is an option for Tourism needs as the treated water can be used for golf course irrigation and toilet flushing [22].

3.2. Lombardy Region (IT)

<u>Sector: Agriculture</u>

The economy of Lombardy is characterised by a wide variety of industries ranging from traditional sectors, such as agriculture and livestock to heavy and light industries (e.g. mechanical, electronics, metallurgy, textiles) whereas there is a growing demand for water resources. Agriculture, a sector, which contributes over 40 billion euros every year to the regional economy, consumes over 31 billion m^3 of water annually to cover the irrigation needs of 700,000 ha of surface area with crops. The largest share of this volume comes from surface water resources (89%) while the rest from underground sources (e.g. springs), rainwater and treated wastewater. The agriculture is therefore strongly reliant on natural resources while only a small share of precipitations (18% of the total rainwater is collected and used in productive uses) and reclaimed water is utilised for irrigation purposes. On the contrary, the low price of freshwater supply for irrigation alongside with the limited number of WWTPs connected with agricultural facilities are the most prominent inhibitors to water reuse. Further to this, water inefficient agricultural processes and the subsequent discharge of wastewater with nitrates have caused significant degradation of water resources in south and central Lombardy, according to the Lombardy Regional Agency for Agricultural and Forest Services. Further to the aforementioned potential uses, treated effluents can be also used for groundwater aquifers discharge (filtration – no abstraction for potable reuse) and the supply of industrial water uses (once-through, non-contact cooling water), as long as their quality characteristics meet the effluent quality standards of the applicable legislation on water reuse. This can be achieved through secondary wastewater treatment [22].

Wastewater reuse practices

Regarding the Agriculture reuse potential, the successful wastewater treatment strategy presented in Murcia region is suggested. Most vegetable washing waters are extensively recycled with the solids removed by settlement and filtration. The recovered soil can be returned to the land. Animal slurries require special handling and are usually treated by containment in lagoons before disposal by spray or trickle application to grassland. Constructed wetlands can sometimes be used to facilitate treatment of animal wastes, as are anaerobic lagoons [13]. Finally, a technology called APT (advanced primary treatment) that basically consists of a coagulation–flocculation process coupled with high-rate sedimentation has been successfully applied for agricultural wastewater reuse [24].

Sector: Urban/domestic uses

The consumption of urban drinking water in Lombardy is estimated at 600 million m3, corresponding to an average per capita daily consumption of 177.5 liters. According to common surveys, about the 50% of domestic uses do not require drinking water (i.e. washing machine, w.c, etc.). Although Lombardy is rich in water, in some areas (e.g. Apennines) the supply of drinking water was intermittent in some summer periods, due to dry periods. Then, the reuse of water at building or urban scale could reduce the impact on drinking water availability, fighting the effect of climate change.

Wastewater reuse practices

In 2016, a building placed in the centre of Milan was restructured: the technologies in place allow the collection, treatment and reuse of grey (from bathroom sinks and showers) and meteoric waters. The uses of reclaimed water include toilet flushing, domestic laundry washing, car washing, irrigation, external pavement cleaning. The drinking water savings is up to 50%.

Sector: Freshwater Recharge

Wastewater reuse practices

As regards the Freshwater Recharge, Tertiary and Advanced treatment processes can be chosen [22]. Since 2014 Fiordelisi s.r.l. reuses part of the wastewater produced during the processing and packaging operations for irrigating its own fields and thus reducing the groundwater demand. For this purpose, a full-scale tertiary treatment was commissioned and added to the conventional primary and secondary treatments already in place. The desired outcome is the production of water for irrigation of the company's own fields in order to reduce groundwater exploitation and ensure constant availability of the resource. In addition, the possibility of reduction of fertilizers usage due to the presence of residual nutrients (K, N) in the treated water was evaluated. Before implementing the reuse of reclaimed water, the company used to extract groundwater for both cultivating the crops and for processing the food; however, the water availability was scarce. Due to growing production, the water requirements significantly increased up to reaching, during the warm season, the maximum flow rate available for irrigation.

3.3. Malta

Sectors: Agriculture and Tourism

In Malta, industrial activity is limited compared to agriculture and tourism. Agriculture is the largest water consumer with over 18 million m^3 of water each year to be used for the irrigation of crops. Agriculture is also a sector particularly vulnerable to water scarcity considering the low precipitation rates prevailing on the island. Agriculture is still a key driver for regional growth, contributing over 110 million euros to regional economy every year. As mentioned previously, Tertiary and Advanced wastewater treatment are suitable for agricultural needs [22]. The WWTPs, which serve the island, are connected with 3 special reclamation units (polishing plants) that employ a 4-stage process that includes biological nutrient removal and disinfection, ultrafiltration, reverse osmosis and advanced oxidation, to produce high quality water in compliance with the standards and requirements defined by the national law for agricultural use of reclaimed water. Treated sewage from the wastewater treatment plants was previously discharged to the sea. This is now being passed through tertiary treatment polishing plants that ensure high security of the finished product. In addition, the proximity of polishing plants to cultivated areas facilitates the distribution of potentially reusable wastewater for irrigation. In Malta, the annual volume of potentially reusable treated wastewater can reach up to 26 million m^3 per year; 18 million m^3 of wastewater effluents from domestic uses and 8 million m^3 from industrial activities. As a result, irrigation water needs can be completely covered through the reclamation of wastewater effluents while the surplus could be used for aquifer recharge to control overexploitation and saltwater intrusion that adversely affect the quality of groundwater used for domestic and industrial purposes. Further to the water demand for crops, there is also a constantly growing need for water within the tourism industry especially during the summer peak period. Tourism is traditionally a water intensive industry. The average volume of water consumed per tourist during summer amounts up to 312 litres per day when the average water consumption in the country (all year round) is 110-115 litres per capita. Notwithstanding this, at the time being, the national law on water reuse does not permit the use of reclaimed water for tourism and recreational activities. Malta, therefore, will need to introduce new water quality standards, harmonised with EU practices, to support the wider utilisation of reclaimed water in industries facing severe water supply conditions, in an attempt to alleviate pressures on groundwater resources and secure reliability and security of water supply in the country.

Wastewater reuse practices

Tertiary and Advanced treatment systems are common in the country. The treatment process involves the polishing of treated wastewaters produced from a conventional (biological) urban wastewater treatment plant, through the successive application of Ultrafiltraton, Reverse Osmosis and Advanced Oxidation treatment phases. In as much the treatment system can be considered to include four treatment barriers to ensure the quality and safety of the produced water.

Reclaimed water is pumped from the polishing plants to dedicated distribution reservoirs, from where it is distributed through a dedicated network by gravity to automated supply points. Users can access the reclaimed water from these supply points through the use of an electronic key-card. Consumption is monitored remotely at a centralised control unit operated by the Water Utility.

The motivation behind the application of this combination of technologies is the development of an alternative water resource which is safe to use both for the public and the environment. Water reuse will enable the diversification of the national water resource base, enabling the national water demand for the agricultural and industrial sectors to be met whilst ensuring the sustainable use of natural water resources. The project gives due consideration to risk assessments to ensure the safety of the water produced to human health. In addition, by reducing the dependence on groundwater resources, reclaimed water will contribute to the future sustainability of groundwater dependent terrestrial ecosystems which are considered as important natural areas of high recreational value important for human health. As regards the impact of the applications on the environment, reclaimed water is being used in lieu of natural water resources (groundwater) hence enabling this resource to recover and progressively achieve good quantitative status objectives required under the EU Water Framework Directive.

3.4. Trebnje (SI)

<u>Sectors: Agriculture and Freshwater Recharge</u>

Treated wastewater can be a reliable alternative water resource for Trebnje. It can have a key role in integrated water resources management, addressing both water demand and supply. At the same time, reclaimed water can aid to foster environmental protection and maintain a good ecological status of rivers/lakes and coastal waterbodies whilst alleviating pressures on underground water resources; the only source of potable water in the region. The increased pollution of water bodies and/or inadequate funds for the exploitation of available resources, render integrated water resources management and water reuse a necessity. Practically, the central WWTP applies tertiary level of treatment and hence operates in compliance with the standards set by the national legislation on urban wastewater treatment. The national regulation allows the use of properly treated wastewater to agricultural, urban, and industrial reuse as well as aquifer recharge; direct and indirect reuse to supplement potable water supply is not considered at the moment. Overall, the most appropriate potential reclaimed water use (apart from environmental enhancement) in Trebnje is crop irrigation. In Trebnje over 153,498 m^3 of water were used for the irrigation of crops in 2018. As the mean annual volume of potentially reusable treated wastewater is about 1,270,000 m^3, the demand for irrigation can be potentially covered completely. Further to this, the surplus could be used to recharge groundwater aquifers in an attempt to control overexploitation and pollution, or alternatively to get discharged into mainland and coastal water bodies in order to enhance the quality of water.

<u>Wastewater reuse practices</u>

Wastewater reuse practices in Slovenia are limited to few pilot (research) projects and initiatives/investments of some companies. The industry realised that water reuse can generate substantial savings: closing the loops in industry and use of secondary resources in construction sector, based on EU action plan for the Circular Economy. Sustainable water management in areas with dispersed settlements, as in the case of Slovenia, represents specific problems. In these areas, the construction of large municipal wastewater treatment plants, long branched sewage systems and pumping stations is financially unattainable. Thus, the use of small wastewater treatment plants with improved efficiency of cleaning emerges as a sustainable alternative and shows the great potential.

A pilot project that included the development and construction of a prototype waste water treatment system allowed the reuse of treated water for secondary purposes in households and for common public needs achieving up to 30% reduction of drinking water consumption. The system is especially appropriate for regions with dispersed settlement, as in the case of the Municipality of Šentrupert, where the prototype system was located. The first phase of the multistage treatment of urban waste water is performed in a small waste water treatment plant, through a commonly used treatment technology for urban waste waters in the parts of Slovenia with dispersed settlements. Primary treatment in a small waste water treatment plant consists of physical separation and sedimentation of solid waste particles from waste water. Secondary treatment represents aerobic and anaerobic microbiological treatment. Aerobic treatment takes place in aerated basin of small waste water treatment plant, where ammonia is removed by nitrification process by transformation into nitrates. In compartments of the small waste water treatment plant where anaerobic conditions are established, nitrates are transformed into nitrogen gas by facultative anaerobe bacteria. Organic pollutants, phosphates, excess nutrients, and potentially toxic elements are accumulated in the organic matter of growing bacteria, which form flocks that gradually settle as the active sludge in the settling basins – clarifiers. Part of active sludge is later inoculated back into the aerobic treatment to enhance the microbiological treatment process. Partly purified water, which is suitable for release into surface waters, is at the outflow from the small waste water treatment plant collected and pumped in an advanced multistage batch water treatment system for additional purification to reach quality suitable for reuse.

The first stage entails nanoremediation, which is based on the use of an innovative treatment process with the utilization of nanoscale Zero-Valent Iron (nZVI). This nanomaterial, due to high redox activity and through Fenton type chemical reactions, is capable of disinfection, degradation of several organic pollutants, and removal of potentially toxic elements – heavy metals from waste water. The nanoremediation stage is followed by additional stages of water treatment, namely: i) treatment with oxidizing agents, ii) sand and activated carbon filtration, and iii) ion exchange. The combination of nanoremediation with conventional treatment processes ensures that all pollutants are efficiently removed from water and that use of purified water does not represent any threat for the end-users.

3.5. Łódzkie Region (PL)

Sectors: Manufacturing and Agriculture

In Łódzkie, though water shortage conditions have been exacerbated over recent years, reclamation of treated wastewater is not a widespread practice. The foreseen integration of the EU regulation on minimum requirements for water reuse into the national water governance context promotes the implementation of wastewater reuse in Łódzkie Region and provides an opportunity to explore the potential for using reclaimed water in different uses/activities. Water resources availability is mainly reliant upon surface and underground freshwater, which is not only becoming depleted but also is subject to contamination due to uncontrolled discharges and poor wastewater management. Therefore, non-conventional solutions such as the reuse of treated wastewater can be a viable alternative for the region. Overall, the sectors associated with the higher water reuse potential in Łódzkie Region are industry and agriculture. Industry is the second larger water consumer in the region, accounting for 6.5% of total water abstractions. Industry is second most important (after services) pillar of the regional economy. The majority of the province's industrial and manufacturing plants are concentrated within the Łódź Industrial District; thus, creating a source of high volumes of wastewater effluents that can be treated and reused in industrial and commercial activities. Major industries in Łódzkie include textiles and clothing, pharmaceuticals, rubber, food and beverage processing, machine making, ceramics, and logging. In terms of pollution, wastewater discharges from industrial and commercial sources contain nutrients and chemical pollutants that without tertiary level of treatment will inevitably affect the quality of receiving water bodies, posing serious dangers for human health and biodiversity.

Wastewater reuse practices

As Łódzkie region presents a high water reuse potential for manufacturing and agriculture, Tertiary treatment processes are proposed (e.g. chemical coagulation, biological/chemical nutrient removal, filtration, disinfection) [13, 22]. An example showing the combination of different treatment technologies derived from A1.3 deliverable, is presented below.

Textile production processes (textile refinement) require an excessive amount of water - an average of 100L/kg. The Biliński Textile Factory (derived from A1.3 deliverable) decided to introduce technologies enabling the recovery of treated wastewater thus bearing economic and environmental benefits. The application is on-site, entailing physical-chemical systems, membrane technologies, disinfection technologies, waste stabilisation ponds and electrocoagulation (P removal) and the process is monitored on a daily basis. The wastewater treatment and recycling system assumes its division into three streams with respect to biodegradability:

- The first stream (approximately 50% of the sewage generated by the plant) is low-loaded sewage with mineral pollution and is subject to biological treatment.
- The second stream consists of wastewater whose components could adversely affect the operation of the activated sludge, thus it is pre-treated with coagulation-flocculation and is consequently directed to the municipal sewerage system.
- The third stream consists of highly salinated waste water from the dyeing processes which is treated by means of electrocoagulation, creating a brine used again in the same process.

The technology is transferable to other textile industries and can be adapted to the needs of other industries. Environmental results include improving the quality of wastewater discharged, reducing the amount of wastewater discharged, reducing the consumption of water resources, and minimizing the intake of groundwater as well as the minimisation of environmental emissions on a regional scale (i.e. improvement of the quality of the WWTP operation and reduction of low-molecular salt emissions in the River basin) and the minimisation of the impact of groundwater intake.

3.6. Lower Saxony (DE)

In Lower Saxony, the sector that exhibits high water reuse potential are agriculture, manufacturing and energy. They combine significant vulnerability to water scarcity, high water consumption and wastewater generation, intensive economic activity and extended environmental impact. What is more, the size of potentially supplied activities can justify water reuse investment.

Sector: Agriculture

Agriculture is one of the most water intensive economic sectors in Lower Saxony. Until recently, farmers relied on rain alone to water their crops. But as summers have been made hotter and drier, farmers are forced to tap into underground freshwater resources to address their growing needs for water. Notably, in some regions, especially in the North-East of Lower Saxony, water scarcity has emerged as a crucial issue for agriculture. In 2018, farmers experienced a 22 percent loss in agriculture production as a result of the prolonged drought during summer. Overall, the potential reuse of effluents from irrigation, which amount to around 10 million m^3 every year, could significantly reduce the annual water deficit caused by low precipitation, alleviating at the same time pressures on freshwater resources. In addition, agriculture is one of the mainstays of Lower Saxony's economy. The primary sector, strongly weighted towards livestock and crop cultivation (wheat, rye, oats, potatoes, dairy, beef cattle), generates over 5 billion euros annually, representing 1.8% of the regional GDP.

Agriculture is also a major regional employer, with more than 80,000 people working in relevant fields. Agriculture, however, is responsible for excessive water pollution, resulting from intensive and unsustainable crop and livestock activities. Notably, the wastewater resulting from agricultural activities (seepage, erosion, run-off, drainage, afforestation) has been found to contain dangerous chemicals and nutrients that have contaminated 1214 flowing water bodies in the territory.

Wastewater reuse practices

The region has already experience in water reuse and an increasing interest has been recorded for further projects. Currently, there are 2 wastewater treatment plants that apply tertiary treatment, and supply crops with reclaimed water for irrigation.

Sectors: Manufacturing and Energy Production

Apart from communal wastewater reuse only few known applications of industrial reuse are known. Since 1987, purified production wastewater from the sugar industry has been made available in Northeastern Lower Saxony (Uelzen). In two reservoirs of the Uelzen Water Association, 1 Mm^3 of water, which is produced every year in the winter months in the Uelzen plant of Nordzucker AG and was anaerobically cleaned, is stored and used by the agricultural industry for irrigation during the growing season [24]. Furthermore, there are examples of decentralized reuse schemes. For instance, there is a new residential area in Hamburg (Jenfelder Au) where source separation of domestic wastewater into blackwater and greywater as well as local utilization of energy is implemented. The greywater and the blackwater streams are directed to a decentralized treatment facility and subsequently discharged along with storm water to a water cascade and pond system [25].

Wastewater reuse practices

Lower Saxony presents a high water reuse potential for energy production, manufacturing and agriculture thus, Secondary and Tertiary treatment processes are proposed (e.g. biological oxidation, chemical coagulation, biological/chemical nutrient removal, filtration, disinfection) [13, 22]. An example showing the combination of different treatment technologies derived from A1.3 deliverable, is presented below.

The Steinhof sewage treatment plant (STP) was built in 1979. The treatment plant includes primary sedimentation as well as activated sludge treatment for the removal of bulk organic carbon. The nutrients nitrogen and phosphorus are partially removed biologically. The STP has a capacity of 350,000PT and treats an average volume of 21,000,000 m³ wastewater each year. Two thirds of the treated wastewater, an average amount of 15,000,000m³ per year, are used for the irrigation of the 3000ha of the sewage association Braunschweig (AVBS) agricultural area. The remaining third enters irrigation fields as a final treatment step, before it is discharged into the Aue-Oker-Canal [26].

The wastewater recycling scheme is supported by the local policy in Braunschweig, by the involved districts as well as the water authority. The main objective of the reuse scheme was wastewater disposal and, at the same time, meeting the high-water demand and nutrient requirements of the irrigation land. In addition, the reuse scheme should be cheaper for the citizens than conventional wastewater treatment system.

Based on a Life Cycle Assessment analysis [27] of the environmental impacts of the wastewater reuse scheme at Braunschweig, the application has both positive and negative impact on the environment as:

- local nutrient loads and resulting eutrophication potential of the receiving surface water are reduced by more than 50% compared to direct discharge of secondary effluent,
- water footprint of agricultural irrigation is reduced by substituting the use of groundwater resources,
- water reuse leads to additional energy demand and associated emissions of the system (29 % increase in net energy demand).

The main challenges encountered include the increasing demands on water quality and the revised fertilizer and sewage sludge legislation that restricts agricultural utilization of sewage sludge as well as the heavy metals in the sewage sludge which is added to the sprinkled water. The latter is addressed through the construction of the indirect discharger monitoring, thereby sustainably lowering, the heavy metal concentrations in the wastewater and thus also in the sewage sludge.

3.7. Greece

<u>Sectors: Tourism and Agriculture</u>

Greece, and predominantly several south-eastern and island areas, receives severe pressure on water resources, further intensified by the seasonal high-water demand of the tourism and agriculture sector. Thus, the integration of treated wastewater into water resources management is significant for meeting future water demands.

The Joint Ministerial Decision on water reuse quality levels and treatment processes (JMD 191002/2013), foresees water reuse for:

- Urban uses (including landscape irrigation, recreational uses, car washing, and firefighting).

- Irrigation of crops and commercial nurseries (with or without restrictions).

- Industrial uses (including cooling, boiler feeding, and processing).

- Aquifer recharge not used for potable uses.

<u>Wastewater reuse practices</u>

All the aforementioned reuses demand mainly Secondary and Tertiary treatment processes to be applied [8, 24]. An innovative concept derived from A1.3 deliverable for water reuse within the urban environment is presented below.

Pilot sewer-mining application (Athens, Greece): Sewer-mining is a less known decentralized wastewater reuse technology option which can be deployed at an intermediate scale. It entails extracting wastewater from local sewers, treating it at the suitable quality level and using the output for local non-potable uses while returning treatment residuals to the sewer system. As a result, the need for both expensive conveyance systems from end of pipe treatment installations and dual reticulation infrastructure is eliminated [28].

The pilot application examined sewer mining, as an innovative concept for distributed reuse within the urban environment, making use of advanced Information and Communication Technology solutions for monitoring and management. The application involved a double-membrane treatment scheme (i.e. compact membrane bioreactor and reverse osmosis MBR-RO) and the treatment unit had a capacity of 10 m^3/d. As regards the ICT monitoring and management system, 21 physical and chemical characteristics are measured through the use of 10 sensors which are connected to a sensor controller turning the signals received from the sensors into digital data. The integration of an ICT system into the application allows for (i) automated maintenance and (ii) remote operation thus reducing operational costs [28].

4. Recommendations

4.1. Recommendations on selecting the optimal water treatment technology

A variety of different technologies is now available to achieve an optimum effluent quality suitable for reuse applications. However, when selecting the appropriate technology for water reuse, certain parameters should be taken into account including the operational scale, the desired end use of the treated water, the economic feasibility, the environmental impact, the social perspective, and local/regional customs and practices [13, 22]. Sustainability is a crucial factor in water reuse, meaning that water resources conservation dictates the use of technologies that are economically viable, technically and institutionally appropriate, socially acceptable, and can effectively protect the environment and the natural water resources.

Table 5 summarizes the main outcomes of Chapter 3. It includes different AQUARES regions along with proposed levels of wastewater treatment processes for the sectors/areas with higher water reuse potential.

Table 5. Proposed wastewater treatment processes for the specific needs of each AQUARES region/country.

Region/country	Needs	Proposed treatment processes	Indicative technologies
Murcia Region	Agriculture Tourism	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, Disinfection
Lombardy Region	Energy Production	Secondary, Tertiary	Biological oxidation, Chemical coagulation, Biological/chemical nutrient removal, Filtration, Disinfection
	Agriculture	Tertiary	Chemical coagulation, Biological/chemical nutrient removal, Filtration, disinfection
	Freshwater Recharge	Tertiary, Advanced	Chemical coagulation, Biological/chemical nutrient removal, Filtration, Disinfection, Activated carbon, advanced oxidation, reverse osmosis (membrane treatment)
Malta	Agriculture Tourism	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, Disinfection
	Agriculture	Tertiary	Chemical coagulation, Biological/chemical nutrient removal, Filtration, disinfection

Municipality of Trebnje	Freshwater Recharge	Tertiary, Advanced	Chemical coagulation, Biological/chemical nutrient removal, Filtration, Disinfection, Activated carbon, advanced oxidation, reverse osmosis (membrane treatment)
Latvia	Food Industry	Advanced	Activated carbon, advanced oxidation, reverse osmosis (membrane treatment)
	Manufacturing	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
	Agriculture	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
Czech Republic	Energy Production	Secondary, Tertiary	Biological oxidation, Chemical coagulation, Biological/chemical nutrient removal, Filtration, Disinfection
	Manufacturing	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
	Agriculture	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
Łódzkie Region	Manufacturing Agriculture	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
Lower Saxony	Agriculture	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
	Manufacturing	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection
	Energy Production	Secondary, Tertiary	Biological oxidation, Chemical coagulation, Biological/chemical nutrient removal, Filtration, Disinfection
Greece	Agriculture Tourism	Tertiary	Chemical coagulation Biological/chemical nutrient removal Filtration, disinfection

4.2. Recommended actions to promote and support the application of the most appropriate water reuse technologies

The provision of safe and reliable water reuse systems relies heavily on technologies that are demonstrated to be responsive and resilient to the dynamics of diverse sources of water for potential reuse and needs of various use applications. This section presents proposed actions to promote and support the application of the most appropriate water reuse technologies. More specifically, AQUARES countries could [29]:

- Integrate, coordinate, and enhance technology demonstration and validation programs to provide reliable performance information to support water reuse (For entities to evaluate the adoption of water reuse, reliable and actionable technology performance and cost data could be generated and shared)
- Provide case examples and identify candidates for water reuse system implementation
- Identify monitoring best practices for various sources of water and reuse application (Develop guidance or best practices relating to sampling and monitoring techniques based on the source water type and use application of reclaimed water)
- Coordinate and integrate water reuse programs and policies
- Compile EU transnational policies and approaches to implement water reuse programs (Compile existing state-level statutes, regulations, policies, programs, frameworks, and/or approaches that are currently in place for water reuse)
- Enhance transnational collaboration on water reuse (e.g. the EU countries could create ongoing forums for states to share and discuss experiences and attributes of their water reuse programs)
- Compile and Develop Water Reuse Program Outreach and Communication Material (Compile examples of outreach and communication strategies and techniques that have been implemented for successful reuse projects, and develop new materials based on the needs articulated by stakeholders. The materials could address programmatic themes with the overarching goal to educate key audiences, such as the public, decision makers, and key message carriers (e.g., public health professionals). A potential aspect of the framework could be an outreach and communications kit (with contents such as talking points; press materials; public safety announcements; and other utility, state, and tribal enforcement and compliance assistance materials) crafted and tailored for different audiences)
- Develop a community of practice around water reuse (A community of practice can serve as a "network of practitioners with a shared passion who learn how to do something or how to do something better through repeated interactions." A water reuse community of practice would create a peer network of water reuse stakeholders and professionals both face-to-face and

virtually. The repeated convenings could bring together examples of lessons learned, implementation challenges, regulatory strategies, recognition and partnership programs, communication approaches, and outcomes to catalyze water reuse projects)

- Pursue a national branding campaign for water reuse (Initiate a collaborative campaign to assess the public's understanding and acceptance of water reuse. This campaign could be available nationally, while recognizing regional variation in reuse based on local understanding of needs)

5. References

[1] European Commission (2018). Water reuse. Why reuse treated wastewater? https://ec.europa.eu/environment/water/reuse.htm

[2] Asano, T., Burton, F., Leverenz, H., Tsuchihashi, R., Tchobanoglous, G. (2007). Water Reuse: Issues, Technologies, and Applications. Publisher: McGraw-Hill Professional.

[3] Yazan, I., Fawzi, B., Vincenzo, N., Shadi H. (2019). Numerical modeling of an integrated OMBR-NF hybrid system for simultaneous wastewater reclamation and brine management. Euro-Mediterranean Journal for Environmental Integration. 4 (1): 23.

[4] Communication from the Commission to the European Parliament and the Council (2007). Addressing the challenge of water scarcity and droughts in the European Union COM (2007) 414.

[5] Commission Communication (2012). Blueprint to Safeguard Europe's Water Resources COM (2012)673.

[6] Commission Communication (2015). Closing the loop - An EU action plan for the Circular Economy. COM (2015)614.

[7] European Commission (2014). Water Reuse in Europe. Relevant guidelines, needs for and barriers to innovation.

[8] Asano, T., Burton, F.L., Leverenz, H.L., Tsuchihashi, R., Tchobanoglous, G. (2007). Water Reuse: Issues, Technologies, and Applications. McGraw-Hill, New York.

[9] Chen, Z., NGO, H.H., Guo, W.A. (2017). A Critical Review on end use of Recycled water. Masters' thesis, Australia.

[10] Angelakis, A.N., Gikas, P. (2014). Water reuse: Overview of current practices and trends in the world with an emphasis on EU states. Water Utility Journal 8, 67–78.

[11] Gikas, P., Tchobanoglous, G. (2008). The role of Satellite and Decentralised Systems in Water Resources Management. J. Environ. Manag. 90 (1), pp144–p152.

[12] European Union (EU) (2016). EU-Level Instruments on Water Reuse, Final Report to support the Commission's Impact Assessment. Luxemburg, Europe.

[13] Stefanakis, A. (2015). Modern water reuse technologies. Handbook of urban water reuse, Edition: 1st, Publisher: CRC Press, Taylor and Francis Group.

[14] Daigger, G.T. and Boltz, J.P. (2011). Trickling filter and trickling filter—suspended growth process design and operation: A state-of-the-art review. Water Environment Research, 83(5), 388–404.

[15] Tekerlekopoulou, A.G., Pavlou, S., and Vayenas, D.V. (2013). Removal of ammonium, iron and manganese from potable water in biofiltration units: A review. Journal of Chemical Technology and Biotechnology, 88(5), 751–773.

[16] Tchobanoglous, G., Burton, F.L., and Stensel, H.D. 2002. Wastewater Engineering: Treatment and Reuse, 4th Edition. Metcalf & Eddy, McGraw-Hill, New York.

[17] Sonune, A. and Ghate, R. (2004). Developments in wastewater treatment methods. Desalination, 167, 55–63.

[18] Zhou, H. and Smith, D.W. (2002). Advanced technologies in water and wastewater treatment. Journal of Environmental Engineering and Science, 1, 247–264.

[19] EC. (2000). Establishing a framework for community action in the field of water policy. Directive 2000/60/EC of the European Parliament and of the Council, Official Journal of the European Communities, L 327/1, 23 October.

[20] Asano, T., Burton, F.L., Leverenz, H.L., Tsuchihashi, R., and Tchobanoglous, G. (2007). Water Reuse: Issues, Technologies, and Applications. Metcalf & Eddy Inc., AECOM, McGraw-Hill, New York.

[21] Alcalde-Sanz, L., Gawlik. (2014). Water Reuse in Europe Relevant guidelines, needs for and barriers to innovation - A synoptic overview. European Commission, Joint Research Centre Institute for Environment and Sustainability.

[22] Ungureanu, N., Vladut, V., Dincă, M., Zăbavă, B. (2018). Reuse Of Wastewater For Irrigation, A Sustainable Practice In Arid And Semi-Arid Regions. Conference: 7th International Conference on Thermal Equipment, Renewable Energy and Rural Development (TE-RE-RD) at: Drobeta Turnu Severin, Romania.

[23] Styles D., Schönberger H., Galvez Martos J. L. (2017). Best Environmental Management Practice in the Tourism Sector, EUR 26022 EN, doi:10.2788/33972.

[24] Ostermann, U. (2017). Beregnung in Nordostniedersachen - Anpassungsstrategien an den Klimawandel. Wasser, Energie und Umwelt, 482-490.

[25] DWA (2019). German Association for Water, Wastewater and Waste, Non-Potable Water Reuse - Development, Technologies and International Framework for Agricultural, Urban and Industrial Uses.

[26] Seis, W. (2012). Risk assessment auf Braunschweig wastewater reuse scheme. KWB, Berlin.

[27] Kraus, F., Seis, W., Remy, C., Rustler, M., Jubany i Guell, I., Espi, J.J. and Clarens, F. (2016). Deliverable D3.2: Show case of the environmental benefits and risk assessment of reuse schemes. Public report in the DEMOWARE project (www.demoware.eu), KWB, Berlin.

[28] Makropoulos, C., Rozos, E., Tsoukalas, I., Plevri, A., Karakatsanis, G., Karagiannidis, L., Lytras, E. (2018). Sewer-mining: A water reuse option supporting circular economy, public service provision and entrepreneurship. Journal of Environmental Management, 216, 285–298.

[29] US EPA (2019). National Water Reuse Action Plan – Draft September 2019.