Deliverable 3.1

Practice-oriented info - packages

Funding scheme:	Horizon 2020 – Coordination and Support Action (CSA)		
Project Coordinator:	BIOAZUL		
Start date of the project:	01.01.19	**Duration of the project:**	30 months
Contractual delivery date:	**30.04.2020 (deadline as stated in the DoA)**		
Actual delivery date:	**11.11.2020**		
Contributing WP:	**WP3: Knowledge exchange**		
Dissemination level:	Public		
Responsible partner:	BIOAZUL (Task leader)		
Version:	**Final**		

Contents

Executive summary

The present report is a compilation of fact sheets with practical knowledge on water reuse for agriculture. These fact-sheets are classified in 6 different info-packages, each of them oriented to satisfy the knowledge needs of the different target groups of actors identified in SUWANU EUROPE project, namely farmers, agricultural advisory groups, water reclamation operators, water engineers, authorities, consumers and general public.

Fact sheets are aimed to extract the most relevant knowledge from different topics and present a short summary of findings and insights from practical solutions, research projects and success stories. The contents should enable the reader to further search on the topics described. Further readings recommendations and references are provided in each fact sheet with that purpose.

The idea behind these info-packages is that they work as a full knowledge transfer package so that different stakeholders have access to the knowledge they may need. The classification according to target groups is only for guidance, there is no clear limit in the knowledge needs and interests among the different types of organization.

Specific attention has been paid to the recently approved EU regulation on minimum requirements for water reuse in agriculture (EU regulation 2020/741 of 25 May 2020) with two fact sheets addressing this topic.

The contents of these fact sheets will be extended in the development of on-line courses that will be available in the SUWANU EUROPE e -learning platform.

Introduction

One of the main objectives of SUWANU EUROPE project is the transfer of practical knowledge on water reuse to different target groups. Responsible water reuse requires that all actors involved are acquired with the necessary knowledge and skills to carry out their tasks and roles in a way that the use of reclaimed water does not imply a risk for human health and/or the environment. In this sense, there are many aspects ranging from water treatment technologies to governance models that need to be put in place. Thus, we have followed a multi-disciplinary approach trying to extract from practical experiences and solutions, the knowledge that could help the different actors in the water reuse value chain.

The aim of this report is to present a set of fact sheets (FS) with different topics identified by our consortium as relevant "knowledge assets" for the safe use of reclaimed water in agriculture. These fact sheets are structured in 6 different info-packages (IPs), each one oriented to provide specific knowledge according to the needs of each group identified.

Table 1: Fact-sheets contents and classification of the info-packages

Info-package - Target group	Fact-sheets contents
IP1-Farmers/irrigators	FS 1.1: Implications of using reclaimed water to obtain labels such as global gap
	FS 1.2: Effects of reclaimed water on crop quality and yield
	FS 1.3: Irrigation equipment adapted to the use of reclaimed water (e.g. drippers)
	FS 1.4: Decision support systems to monitor irrigation patterns and fertilization needs when using reclaimed water
	FS 1.5: Using reclaimed water in organic farming
IP2- Agricultural advisory services	FS 2.1: Costs benefits analysis and feasibility of using reclaimed water
	FS 2.2: Irrigation schemes when using reclaimed water: Braunschweig case study
	FS 2.3: Water and fertilizer savings when using reclaimed water
	FS 2.4: Using reclaimed water in closed hydroponic systems requires focus on sodium
	FS 2.5: Water reuse initiatives in agriculture in Europe
IP3- Water reclamation operators	FS 3.1: Reclaimed Water quality requirements
	FS 3.2: Contaminants of emerging concern (importance, fate in the environment, technologies to remove them, ecological impacts)
	FS 3.3: Antibiotic resistance and its health impacts linked to irrigation with reclaimed water
	FS 3.4: Key for success in Israel and Cyprus: main concepts in their water reuse strategy
	FS 3.5: Phosphorus recovery in water reuse
IP4- Water engineering companies	FS 4.1: Filtration membranes and new filter materials
	FS 4.2: Sensors and other innovative tools for monitoring reclaimed water quality
	FS 4.3: Light-driven technologies for producing reclaimed water
	FS 4.4: Nature based options for water reclamation processes
	FS 4.5: Other technologies for water reclamation
	FS 5.1: Environmental benefits of irrigation with reclaimed water

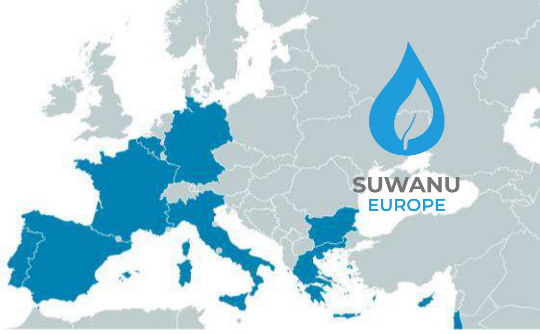
IP5- Consumers and general public	FS 5.2: Organoleptic studies of agricultural products irrigated with reclaimed water
	FS 5.3: Public perception and consumer acceptance of agricultural products irrigated with reclaimed water
	FS 5.4: AKIS & Stakeholders analysis: Improving knowledge transfer channels to foster innovation
	FS 5.5 Communicating the use of reclaimed water for agricultural irrigation: how to transfer a positive image of using reclaimed water
IP6- Authorities and policy makers	FS 6.1: New EU Regulation on reclaimed water for agricultural irrigation
	FS 6.2: Water Reuse Risk Management Plans
	FS 6.3: Water resources governance (e.g. need to incorporate reclaimed water into integrated water resources management)
	FS 6.4: Strategic planning for the use of reclaimed water in agricultural irrigation (the planning process to develop SUWANU EUROPE action plans)
	FS 6.5: Confronting barriers for agricultural irrigation with reclaimed water and promoting synergies in geographical clusters

Info-package 1: Farmers and irrigators

1 **Fact Sheet 1.1. –** Implications of using reclaimed water to obtain labels such as global gap.

The fact sheet 1.1. describes the certification and labelling scheme, and the implication of reclaimed water use on the certification and labelling for food industry, retailers and end consumers. The best practices for public acceptance of reclaimed water use are discussed as well as the guidelines for reclaimed water use in relation to the food certification standards. The development of integrated farm assurance (IFA) certification standards are discussed. Furthermore, the Global G.A.P. certification is explained, as well as the Crops for Processing (CfP) Standard and both the Feed manufacturing standard (FMS) and the compound feed manufacturing standard (CFM). All of the mentioned certifications and labels on feed and processed crops are explained in detail as well as their criteria.

Sustainable **Water treatment** and
Agricultural reuse options in Europe



Info-package 1
Farmers/Irrigators

Fact Sheet 1.1 – **Implications of using reclaimed water to obtain labels such as global gap.**

Implications of using reclaimed water to obtain labels such as global gap → Effects of reclaimed water on crop quality and yield → Irrigation equipment adapted to the use of reclaimed water (e.g. drippers) → Decision support systems to monitor irrigation patterns and fertilization needs → Using reclaimed water in organic farming

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 1 aimed at famers and irrigators, that describe the certification and labelling schema in which water reuse has to fit in.

1. Introduction:

Consumers worldwide are increasingly demanding quality foods that are produced safely and sustainably. Food Industry and Retailers around the world are rising to meet the challenge by demanding the implementation of good agricultural practices, including food safety, from their producers. In some cases, especially in the case of emerging and/or small-scale producers, meeting this demand can be difficult because Food Industry and Retailers have limited sourcing possibilities, since producers in emerging markets may not yet formally comply with food safety, natural resources management - soil and water in particular - and good agricultural production requirements, or may be unable to achieve an integrated farm assurance (IFA) certification immediately. Farmers/Producers, meanwhile, face the challenges of accessing local and regional markets without any compliance with standards or certification for their products. Reclaimed water use introduction on farming best practices has several implications on certification and on labelling for food industry, retailers and end consumers.

2. Reclaimed water use best practices for public acceptance, and their certification and labelling:

Discussions on the role of wastewater reclamation and reuse in terms of planning, implementation, information, certification and labelling started In the beginning of the nineties (Water Sci Technol (1991) 23 (10-12): 2049–2059). Major water reuse categories were identified and discussed. The emphasis was on wastewater reuse in the context of the water supply benefits to water resources management and producers/consumers information and warning giving overriding importance to inform and protect public health and to mitigate health risks.

Use of reclaimed water requires a clear definition of the quality of water required, and while water quality criteria typically focus on pathogen risk to human health, chemical contaminants may also limit suitability for some reuse applications. Both waterborne illnesses transmission along the food chain and environmental risk assessments are considered important steps in all the food certification standards.

Certifications and labels were considered one of the main references to increase trust and public consensus according to the surveys carried out by interviews. There was a high general acceptance of the reuse of water in the irrigation of food and feed crops was perceived, but much lower when destinated to the production of fresh food. Despite the fact that the EU DG Health in its guidelines had defined treated water as a low-risk water source for irrigation.

3. Certification, Labelling and the farm assurance standards (IFA):

The certification audits are a key building block for producers who need the integrated farm assurance and related certification to access demanding markets. With this tool, buyers are able to increase their sourcing possibilities by developing a network of reliable producers already linked to a common standard (IFA). The ultimate intention is to progress towards strict control of irrigation water quality on the farm level.

4. The GlobalG.A.P. experience:
GlobalG.A.P. - a private association of worldwide private membership - is the most widely accepted private sector food safety certification in the world. With more than 700 certified products and over 200,000 certified producers in more than 135 countries, Global g.a.p. has a sound foundation that is both solid enough to build trust, integrity and flexible enough to spur innovation and reputation: it works with more than 2,000 trained inspectors and auditors working for around 159 accredited certification bodies to perform independent third-party producer audits and issue international certificates. Global g.a.p. has a pioneering integrity system with independent assessments to monitor the performance of the certification bodies. It has also a secure online certification database that customers can use to check producers and validate certificates. Global g.a.p. has an extensive worldwide network of consultants to help producers with their certification process. Water quality in the food production processes from farm to fork has always been on Glabal g.a.p. focus: producers have to certify the quality of irrigation water by sampling and analysis repeated during the cropping season. Recently Global g.a.p. has launched its Spring certification product, offering standards and audit schemas for irrigation.

5. Certification and labels on feed and processed crops:
The Crops for Processing (CfP) Standard covers crops that are slated to be frozen, juiced, used to make pre-cooked meals, and used for animal feed, among other types of processing. These crops will be held to the same standard as IFA crops, with the exception of two differences: the risk-based approach to food safety - also concerning irrigation and water use and reuse - and the auditing rules. Raw farm produces destined for processing implies different risks at the farm-level and therefore the CfP Standard approaches food safety risk assessment at the farm-level differently. The CfP also differs in that it is a non-accredited standard. Producers shall perform either self-assessments or internal inspections and QMS audits or receive inspections/audits by an approved Certification Body. Self-assessments and third-party assessments will both require the completion of the Overview of Farming Operations questionnaire, implying also soil and water management practices.
The Feed manufacturing standard (FMS) and the compound feed manufacturing standard (CFM) define the control points and compliance criteria for quality assurance in the production, supply and purchase of raw materials and feed ingredients for compound feed. It covers all the production steps from the growing, purchase, handling and storage to the processing and distribution of feed. The standard covers commercial compound feed and not home-mixed feed, given that home-mixed feed does not leave the farm it is produced on. Producers who prepare home mixes must follow criteria already outlined in the Livestock or Aquaculture standard and do not require additional certification against CFM. Feed manufacturers who supply certified producers must be certified against the CFM standard.

Reference/further readings

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2 **Fact Sheet 1.2. –** Effects of reclaimed water on crop quality and yield: facts and figures.

The effects of using reclaimed water on crop quality and yield are explained, as well as the comparison between the use of reclaimed water versus the surface water. Crop behaviour and yield with the reclaimed water use has been explained for the following crops: Watermelon, pepper, tomato, cucumber and citrus. The pros and cons list of using reclaimed water in crop yields and the appropriate recommendations are made.

Info-package 1
Farmers/Irrigators

Fact Sheet 1.2 – **Effects of reclaimed water on crop quality and yield: facts and figures**

Implications of using reclaimed water to obtain labels such as global gap | **Effects of reclaimed water on crop quality and yield** | Irrigation equipment adapted to the use of reclaimed water (e.g. drippers) | Decision support systems to monitor irrigation patterns and fertilization needs | Using reclaimed water in organic farming

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 1 aimed at famers and irrigators, that describe the effects of using relcaimed water on crop quality and yield.

1. Introduction:

The use of reclaimed water (RW) improves the regions' self-sufficiency and is also a local quality resource, often more reliable than other conventional sources. For this reason, its use for agricultural purposes is expected to grow exponentially in the coming years. For instance, in semi arid regions, its use in agriculture plays a key role contributing in tackling water scarcity and droughts. Several field studies conclude that crop quality and yield using RW vary among crops. In conclusion, they have compared different irrigation techniques and water sources like reclaimed, surface, ground or desalinated water.

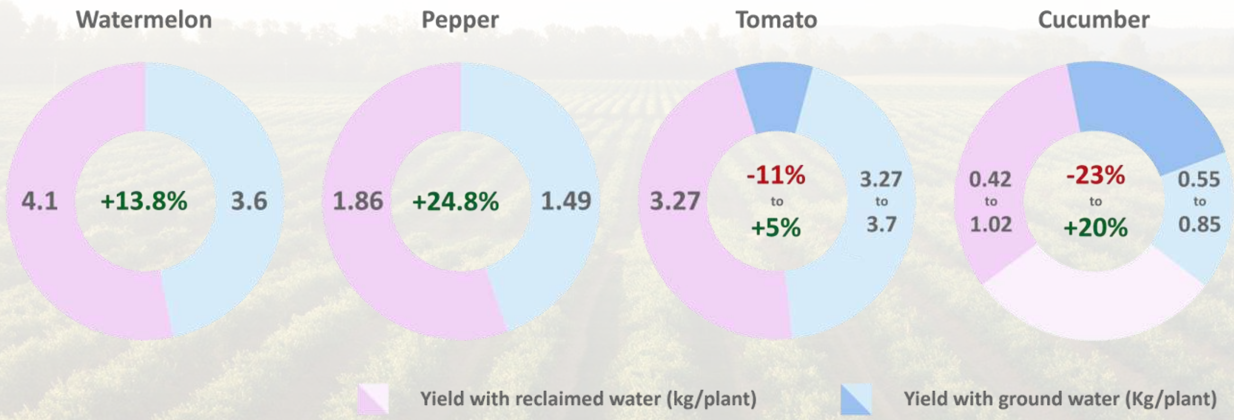

Figure 1: Variation in yield, reclaimed water vs. surface water

2. Crop Behaviour and Yield:

Watermelon: production increases by up to 13%, due to increased physiological activity. As for the content of elements such as N, K, P and Ca, the leaf content is higher in plants irrigated with regenerated water.

Pepper: foliar levels of N and P are slightly lower in plants irrigated with reclaimed water and without additional fertilisation. K levels are higher in peppers irrigated with reclaimed water. In this crop it is important to highlight the increase in yield in 24% of the plants with reclaimed water irrigation application compared to the underground, both cases including additional fertilisation.

Tomato: the nutritional state in the foliar levels shows a very similar behaviour regarding the main macro-elements (N, K, P, Ca,Mg), being the Boron higher in content than that of the RW. In relation to the yield, in some varieties there have been increases of 5% in the yield of the crop irrigated with RW with respect to the groundwater and in others a decrease of 11%.

Cucumber: depending on whether additional fertilisation is applied or not, there is a variation in yield from -23% of RW with respect to groundwater when no additional fertilisation is added to +20% in case of additional fertilisation.

Citrus: trees irrigated with RW generally have greater vigour and produce higher yields compared to surface water irrigation. In addition, less fertilisation is required without affecting the crop yield. On the other hand, the quality and quantity of the fruit is also not affected nor does it show any trend changes. Irrigation with RW has a positive influence on the nutrition of citrus fruits by bringing the concentration of macronutrients, i.e. P, Ca and K, closer to their optimum levels. However, an unbalanced supply of micronutrients in RW can cause a nutritional excess of some micronutrients, including Mn, Zn, Cu and B in citrus plants.

3. Pros and Cons of Using Reclaimed Water in Crop Yields :

PROS	CONS
Yield is greater than other water sources such as surface, underground and desalinated water	It requires a more exhaustive management of irrigation and fertilisation water, monitoring the content of fertilizing elements in order avoid exceeding the plant's needs
Significant savings in cultivation costs as the amount of fertilizer required to achieve optimum plant performance is reduced	It requires control to detect the presence of undesirable elements such as bacteria and pathogens, emerging contaminants, and heavy metals due to problems in water treatment

4. Recommendations:

- ✓ Using reclaimed water in agriculture involves a very important contribution of different elements and nutrients that plants need to produce an optimal yield.
- ✓ This type of water represents a productive improvement in crops, reducing the use of fertilizers.
- ✓ It is necessary to know the composition of the reclaimed water to be used for irrigation, so that the fertilisation requirements of the various crops are supplemented exclusively with the necessary quantities of macro- and micro-elements.
- ✓ It is recommended to control the salinity of the soil when the reclaimed water has a high salt content, as well as to perform pH corrections depending on the stage of the crops, times of the year and irrigation campaigns.

Reference/further readings

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B.F.F. Pereira, et al. Reclaimed wastewater: Effects on citrus nutrition. Agricultural Water Management 98 (2011) 1828– 1833

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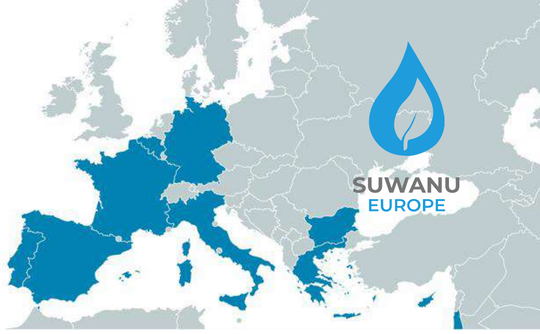
3 **Fact Sheet 1.3. –** Irrigation equipment adapted to the use of reclaimed water (e.g. drippers).

The most suitable irrigation systems for the use with reclaimed water are assessed and ranked against the key criteria related to irrigation with reclaimed water. The main areas of assessment for irrigation systems are water quality parameters, probability of minimizing environmental problems and adequacy to efficient and economical agricultural production. Drip irrigation technology is explained in detail, since it is considered the most adequate method due to the possibility of obtaining high application efficiency. Main cause of the reduction in the quality of the irrigation process over time with the use of drip irrigation is explained. Different drip types are also explained, as well as the examples of drippers. The drippers which minimize the clogging process are defined. Lastly, the equipment which is adapted to irrigation with treated wastewater is described.

Sustainable **Water treatment** and
Agricultural reuse options in Europe



Info-package 1
Farmers/Irrigators

Fact Sheet 1.3 – **Irrigation equipment adapted to the use of reclaimed water (e.g. drippers).**

Implications of using reclaimed water to obtain labels such as global gap → Effects of reclaimed water on crop quality and yield → **Irrigation equipment adapted to the use of reclaimed water (e.g. drippers)** → Decision support systems to monitor irrigation patterns and fertilization needs → Using reclaimed water in organic farming

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 1 aimed at famers and irrigators, that describe irrigation methods and equipment adapted to the use of recovered water.

1. INTRODUCTION

The increase in the demand for water resources has made necessary to increase the efficiency of its use (Brito&Andrade, 2010), with the alternative of using lower quality water in the agriculture. For this, drip irrigation is the most adequate method due to the possibility of obtaining high application efficiency (Vale *et al.,* 2013; Rowan et al., 2013). For Silva *et al*. (2012) the changes that the effluents can cause in the system are little known and clogging being the main factor to be considered. (Chinchilla, S; *et al,* 2018).

There can be no definitive answer as to which type of irrigation system is most suitable for use with reclaimed water as there are many site specific variables. However, it is possible to rank the three main irrigation systems against the key criteria related to irrigation with reclaimed water. The main areas of assessment for irrigation systems are: water quality parameters, probability of minimizing environmental problems and adequacy to efficient and economical agricultural production. (Christen. E, *et al*, 2006)

Generally drip irrigation can be used with grades of water recovered from 1 to 2 levels lower than other irrigation methods. If buried drip is used, then the risks are further reduced depending on the water source, there are several risks of clogging, precipitation and corrosion that affect the operation and longevity of an irrigation system. (Christen, E, *et al*, 2006)

2. DRIP IRRIGATION

Drip irrigation is a technology that can save water, energy and increase costs. However, for dripping to be successful, agronomic, engineering and economic measures must be taken. The precipitation of carbonates can contribute to the problem of clogging in this type of irrigation. The organic matter present in the treated wastewater, increases the growth of biofilms in the irrigation equipment, also contributing to its clogging. (ERSAR, 2010)

Drip irrigation is particularly suitable for the reuse of wastewater, as it minimizes health risks for farmers and product consumers due to contact with wastewater. The performance of drip irrigation systems using wastewater is mainly limited by the clogging of emitters, and this discourages farmers from introducing it (Capra&Scicolone, 2004).

A study by Chinchilla, S, *et al,* in 2018, reveals that the quality of effluents and their influence on clogging were identified as the main cause of the reduction in the quality of the irrigation process over time.




3. DRIP TYPES

Surface drip
Irrigation method located at low pressure, by means of drippers close to the plant.

Subsurface drip
Underground irrigation method, in which water is distributed through buried pipes, offering greater sanitary protection.

4. EXAMPLES OF DRIPPERS

G1 G2 G3

G1 - Non-self-compensating dripper, cylindrical, internal and with tortuous maze
G2 - Non-self-compensating dripper, flat, internal and with tortuous maze
G3 - Cylindrical, self-compensating dripper, internal, with tortuous labyrinth and large secondary filter.

A study about the flow of drippers with different irrigation times, applying swine wastewater and water supply, concluded that the combination of drippers G1 and G3 with the proportions of irrigation time 1h and 4h minimized the clogging process, reductions in flow values were 16 and 8%, respectively after 160 hours of operation of the irrigation units. (Batista, R, *et al*, 2014)

Also a study carried out on Drip Irrigation Assessment Using Wastewater, revealed that vortex emitters are more sensitive to clogging than labyrinth emitters. (Chinchilla, S, *et al,* 2018)

The relative sensitivity of emitters to clogging depends on many aspects. Generally large passages and high emitter flow rates are associated with less potential for clogging, to 1.3mm (0.05”) hole will reduce the effects on economic returns if the system starts to clog 50% compared to 0.8mm (0.03”) (Burt&Styles 1994). The design, installation and management of the system contribute to clogging. A good filtration system with sound maintenance should minimize the risk of clogging in most situations. (Christen. E, et al, 2006)

The National Irrigation Competence Center in Portugal (COTR), in the projects in which they participate with the same theme, does not use specific equipment. However, they consider it essential to oversize the filtration system, as well as the use of drippers with higher flow rates to prevent clogging. In the REUSE project, which they are currently developing, they intend to test specific equipment, such as different types of drippers.

3. EQUIPMENT ADAPTED TO IRRIGATION WITH TREATED WASTEWATER*

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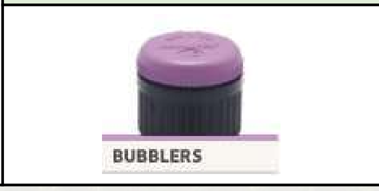
	 **BUBBLERS** 		

*HUNTER® INDUSTRIES (www.hunterindustries.com)

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4 **Fact Sheet 1.4. –** Decision support systems to monitor irrigation patterns and fertilization needs when using reclaimed water.

In the fact sheet 1.4. different decision-making tools are explained, which can help irrigators to easily and efficiently manage nutrients for their crops when irrigating with reclaimed water, and hence reduce the risks of environmental impacts due to the use of unnecessary surplus of fertilizers. FIGARO (Flexible and Precision Irrigation Platform to Improve Farm Scale Water Productivity), is a European research project which aims to increase water productivity in major water-demanding crops and develop a cost-effective precision irrigation platform. SIRRIMED project focuses on the sustainable use of water in Mediterranean irrigated agricultural systems, with the overall aim of optimizing irrigation water use. AGRINUPES, which is an EU project, has developed an effective integrated and sustainable monitoring and control system with innovative sensors, thereby minimizing the effects of water reuse and nutrient supply on the environment. DRAINUSE is a project which demonstrated the feasibility of using a full re-circulation system for soilless culture in the Euro-Mediterranean region. RichWater is a treatment system based on a compact Membrane Bioreactor (MBR) for wastewater treatment. Further information regarding all the mentioned projects is explained in detail in the fact sheet.

Sustainable **Water treatment** and
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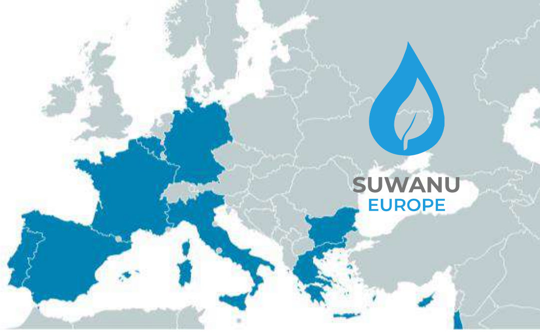

Info-package 1
Farmers/Irrigators

Fact Sheet 1.4 – **Decision support systems to monitor irrigation patterns and fertilization needs when using reclaimed water.**

Implications of using reclaimed water to obtain labels such as global gap → Effects of reclaimed water on crop quality and yield → Irrigation equipment adapted to the use of reclaimed water (e.g. drippers) → **Decision support systems to monitor irrigation patterns and fertilization needs** → Using reclaimed water in organic farming

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 1 aimed at famers and irrigators, that describe useful knowledge and efficient management tools (decision support systems) for nutrient management in the use of reclaimed water in agriculture.

1. Introduction

Reclaimed water contains valuable nutrients ideal for fertigation. However, this is usually difficult to measure by farmers who hence tend to add the same amount of fertilizers as in the conventional irrigation with freshwaters. This common practice leads to extra costs and potential contamination of soils and groundwaters by nutrient excess. Decision making tools can help irrigators to easily and efficiently manage nutrients for their crops when irrigating with reclaimed water, and hence reduce the risks of environmental impacts due to the use of unnecessary surplus of fertilizers.

2. FIGARO, Flexible and Precision Irrigation Platform to Improve Farm Scale Water Productivity

http://www.figaro-irrigation.net/

FIGARO, is a European research project, which aims to increase water productivity in major water-demanding crops and develop a cost-effective precision irrigation platform. FIGARO focuses on significantly reducing the use of fresh water on farm level through developing a cost-effective, precision irrigation management platform. The European-wide consortium developed a holistic and structured precision irrigation platform, which offers farmers flexible, crop oriented management tool with DSS (Decision Supporting System) module to optimize irrigation and fertilizers dosing.

The FIGARO decision support system combines crop growth models with data from satellites, weather stations and field-based sensors to recommend optimal water use for individual fields. Most data input is automatic, minimizing the set-up time farmers spend with the application.

Advice is calculated on a processing platform that was designed to work with a wide range of crop models and data sources. This gives users the flexibility to start with a small investment in the basic decision support technology, then add sensors and other data sources later for more precise irrigation strategies.

3. SIRRIMED

http://www.sirrimed.org

SIRRIMED project focuses on the sustainable use of water in Mediterranean irrigated agricultural systems, with the overall aim of optimizing irrigation water use. The approach proposed in SIRRIMED for reaching this goal is based on an Integrated Water Irrigation Management (IWIM) where the improved water use efficiency will be considered at farm, irrigation district and watershed scales. These strategies include innovative and more efficient irrigation techniques for improving water productivity and allow for savings in water consumption. SIRRIMED considers the development, test and validation of new deficit irrigation strategies, the sustainable and safe use of poor quality waters and the improvement of precise irrigation scheduling using plant sensors.

4. AGRINUPES

https://www.agrinupes.eu/

AGRINUPES EU project has developed an effective integrated and sustainable monitoring and control system with innovative ion selective sensors for nutrients and bio-based sensing of PPP for optimal water and nutrient supply and reuse, minimizing the effects on the environment. The main project result is the design of an improved fertigation Model Predictive Controller (MPC), which incorporates robustness and fault-tolerant features, as it can meet both the crop needs and the grower yield/costs expectations.

5.DRAINUSE

http://www.drainuse.eu/

The aim of the DRAINUSE project is to demonstrate the feasibility of using a full re-circulation systems for soilless culture in the Euro-Mediterranean region, where more than the 60% of Greenhouse production takes place. This aim will be achieved through a modular and scalable pilot system, easily adaptable to most of the agricultural scenarios in south Europe by just modifying the capacity of their components. The demonstration of a pilot system at a 1:10 scale becomes necessary for identifying potential problems, costs, energy consumption, optimization of key steps and software depuration. The system will be dimensioned as a function of the volume of drainages per day that needs to be recirculated.

6. RICHWATER

https://richwater.eu/es/

RichWater treatment system is based on a compact Membrane Bioreactor (MBR) for wastewater treatment. The design of the MBR has been adapted to the use of the effluent for irrigation of crops. The design of the RichWater treatment system allows to produce high quality effluent free of pathogens by the use of Ultrafiltration membranes while maintaining optimal content level of nutrients adapting the biological processes. The MBR is assembled to a mixing unit where the MBR effluent is mixed with clear water and a minimum amount of fertilisers according to the crop demands. With that purpose, the mixing unit integrates a software for nutrient monitoring which is able to calculate the exact amount of nutrients needed considering the existing nutrients in the reclaimed water and the crop demands. This is done through chemical analyses and nutrient balance calculations, allowing farmers and non expert staff to estimate the total of fertilisers required at each time. The mixing unit is assembled to an irrigation system (i.e. fertigation module) which distributes the nutrient rich mixture of reclaimed water and clear water to the crops.

Reference/further readings

- **Less does more with smart irrigation:** https://ec.europa.eu/programmes/horizon2020/en/news/less-does-more-smart-irrigation
- **Fertigation Management and Crops Response to Solution Recycling in Semi-Closed Greenhouses.** https://www.researchgate.net/publication/279429047_Fertigation_Management_and_Crops_Response_to_Solution_Recycling_in_Semi-Closed_Greenhouses
- **Soil Monitoring, Fertigation, and Irrigation System Using IoT for Agricultural Application:** https://link.springer.com/chapter/10.1007/978-981-10-5523-2_7
- **Use of a smart irrigation system to study the effects of irrigation management on the agronomic and physiological responses of tomato plants grown under different temperatures regimes** https://www.sciencedirect.com/science/article/abs/pii/S0378377416302608

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5 **Fact Sheet 1.5. –** Using reclaimed water in organic farming: facts and figures.

Since a large share of organic farmland in Europe belongs to countries prone to water scarcity, and water stress levels in most of European countries is high, this factsheet presents key aspects of reclaimed water use in the sustainable development of organic agriculture. Several risks and benefits of reclaimed water use in organic production are presented, as well as regulations with regards to organic farming certification and water quality requirements. The current situation of the EU water reuse sector is presented, as well as aspects for improvement. Finally, potential benefits and perspectives are explained.

Sustainable **Water treatment** and
Agricultural reuse options in Europe

Info-package 1
Farmers/Irrigators

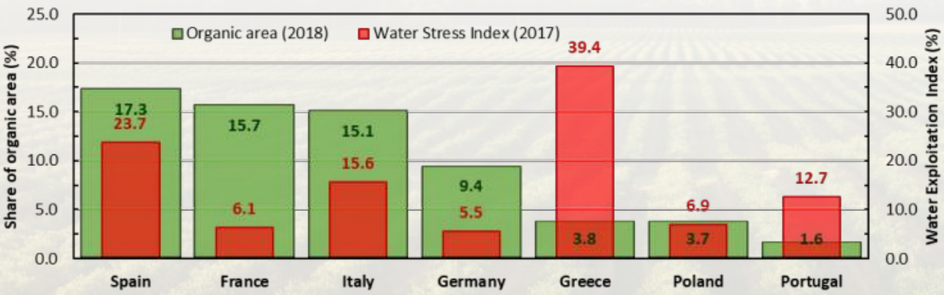
Fact Sheet 1.5 – **Using reclaimed water in organic farming: facts and figures**

Implications of using reclaimed water to obtain labels such as global gap → Effects of reclaimed water on crop quality and yield → Irrigation equipment adapted to the use of reclaimed water (e.g. drippers) → Decision support systems to monitor irrigation patterns and fertilization needs → **Using reclaimed water in organic farming**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 1 aimed at famers and irrigators, that describes the key aspects connected to the use of reclaimed water in organic farming.

1. Introduction:

Organic farming pursues a better and more sustainable agriculture by adhering to a set of principles that aim to operate as naturally as possible and minimise environmental impacts. In Europe, a large share of organic farmland belongs to countries prone to water scarcity (e.g. Spain, Italy). In 2018, the total organic area in the EU-27 was 13.43 million hectares, corresponding to about 7.5% of total agricultural area [1], and is still expected to grow. According to the 2017 Water Exploitation Index [2]. In several EU countries water resources are stressed to such a point that requires actions to ensure adequate supplies [3]. In this context, to respond to the challenges posed by a changing climate and to foster the principles of circular economy, reclaimed water represents a strategic resource for the sustainable development of organic agriculture.



WEI	Water stress level
< 10%	Low
10-20%	Potential supply constraints
> 20%	Actual water stress
> 40%	Severe water scarcity

Figure 1a: Relation between share of organic area and WEI (left); 1b WEI and water stress level (right).

2. Risks and benefits:

Organic production standards allow to use reclaimed water for crop irrigation as long as it meets water quality standards. One of the major concerns for organic farmers consists in:

- The potential presence of organic/inorganic pollutants, which, in case of accidental contamination (in particular of fruits and vegetables to be eaten raw), it may lead to a suspension or loss of the organic certification;
- Consumers reaction to the reuse of water in these productions.

However, risks can be effectively controlled through proper water treatment technologies and adequate technologies and management practices [4], and are also balanced by several benefits.

Benefits:
- Water savings
- Ameliorate soil conditions
- Fertilizer savings
- Economic benefits

Risks:
- Soil salinity increase
- Transportof pollutants
- Excess of nutrients
- Presence of pathogens

3. Regulations:

From a regulatory perspective, a widespread use of reclaimed water for agricultural irrigation purposes across member states has been limited by the lack of a common regulatory framework on environmental and health standards. Until now, each member state individually set water quality requirements, and allowed uses for reclaimed water. To fill this gap, in 2018 the European Commission adopted the *"Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse"* [5]. This initiative falls under the 2015 circular economy action plan, which includes actions to "*facilitate water reuse, including a legislative proposal on minimum requirements for reused water*", and is expected to promote the diffusion and the acceptance of reclaimed water among, farmers, stakeholders and citizens. A concrete issue is that organic farming certifications, in general set very high water quality standards. Often too high to be realistically fulfilled unless using groundwater resources. Due to that, it is necessary that certification bodies consider to include specific rules that don't jeopardize farmers willing to use such an important resource.

Class	Quality requirements				
	E. Coli (cfu/100 ml)	**BOD5** (mg/l)	**TSS** (mg/l)	**Turbidity** (NTU)	**Other**
A	≤ 10 or below detection limit	≤ 10	≤ 10	≤ 5	Legionella spp.: < 1000 cfu/l* Helminth: ≤ 1 egg/l **
B	≤ 100	≤ 25 (≤ 35)***	≤ 90 (≤ 70) ***	-	
C	≤ 1000			-	
D	≤ 10'000			-	

Table 1: Reclaimed water quality requirements for agricultural irrigation

4. Current situation and perspectives:

The EU water reuse sector is maturing both technologically and commercially, albeit at a slow rate. At present there are about 200 water reuse plants delivering 1.1 million m^3/yr of reclaimed water, but there is potential to grow up to 6 million m^3/yr [6]. At European level, 32% of recycled water is employed for agricultural irrigation, mainly in countries belonging to the Mediterranean area (Spain, Italy, France, Portugal, Greece).

Considering that at least 11% of the European population and 17% of its territory has been affected by water scarcity to date, the human pressure un natural water resources is expected to grow, and that a large share of EU organic area is in water-stressed regions It is strategic to increase the use of reclaimed water for irrigation. However, there are still aspects that need to be improved, such as regulations and a wider social acceptance have to be developed.

In addition, since lowering human impacts on natural resources is a key concept of both organic farming and the circular economy, it is desirable that organic farming sector adopt reclaimed water as a common and accepted water resource.

When properly managed, reclaimed water has proven to be a viable and useful resource to mitigate water scarcity, especially during summer periods, and also have potential benefits in improving soil health conditions and saving fertilizer by delivering to soils nutrients, micro-nutrients and organic matter [6] and should be encouraged and promoted for both organic and conventional farming.

Reference/further readings

[1] Eurostat (online data code: org_cropar); [2] Eurostat (Code: t2020_rd220); [3] Bixio et al. (2006). Wastewater reuse in Europe. Desalination. 187:89-101; [4] Chen et. al. (2013). Reclaimed water: A safe irrigation water source? Environmental Development 8:74-83; [5] COM(2018)337; [6] BIO by Deloitte (2015) Optimising water reuse in the EU – Final report prepared for the EU Commission (DG ENV), Part I.

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UNIVERSITA DEGLI STUDI DI TORINO

Info-package 2: Agricultural advisory services

1 **Fact Sheet 2.1.** – Costs benefits analysis and feasibility of using reclaimed water.

This fact sheet is aimed at agricultural advisors and describes the principle, the interest and the Cost-Benefit Analysis (CBA) method which should be integrated into the feasibility assessment process of water reuse projects. The method is described in detail as well as the difference between internal and external costs and benefits and their integration into the CBA analysis. The case study of Clermont-Ferrand in France is presented, its application and the results of an ex post CBA. Two different scenarios are presented and compared into a CBA: the water reuse scenario and the benchmark scenario. The economic Net Present Value is calculated, and the final conclusions are made.

Sustainable **Water treatment** and
Agricultural reuse options in Europe

SUWANU EUROPE

Info-package 2
Agricultural Advisory Services

Fact Sheet 2.1 – **Cost benefit analysis and feasibility of using reclaimed water**

Costs benefits analysis and feasibility of using reclaimed water → Irrigation schemes when using reclaimed water → Water and fertilizer savings when using reclaimed water → Using reclaimed water in closed hydroponic systems requires focus on sodium → Water reuse initiatives in agriculture in Europe

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 2 aimed at agricultural advisors, that describes the principle, the interest and the method of Cost-Benefit Analysis (CBA) that should be integrated into the feasibility assessment process of water reuse projects.

1. Cost-benefit analysis : a valuable method to assess water reuse feasibility

The Cost-benefit analysis (CBA) is a method used to analyze projects to determine whether they are in the public's and private sector's interest (evaluate sustainability) thanks to the assignment of monetary value to each input and output resulting from the project. The CBA starts then from the premise that an investment should only be commissioned if the benefits exceed the aggregate costs. CBAs are thus implemented (i) to compare each other technical water reuse scenarios, and alternative scenarios, (ii) to assess projects' economic profitability for a community on a specific territory, and (iii) to identify which stakeholders win/lose to draft correction actions to reach a win/win balance. This very well-known methodology is rarely carried out for water reuse projects, or only partially. Moreover [Molinos-Senante et al., 2011] highlighted that the assessment of water reuse projects usually focuses on internal costs and benefits, and that more projects are economically viable when external benefits are integrated into a CBA analysis. Thus environmental and social costs and benefits (or impacts/externalities) need to be switched to monetary values to be integrated into a CBA (Condom et al., 2012 and Molinos-Senante et al., 2010) using specific valuation methods.

2. Case study of Clermont-Ferrand (France) : application and results of an ex post CBA

The agricultural water reuse project of Clermont-Ferrand is by far the largest water reuse project implemented in France with 1400 ha equipped for irrigation since 1996. The detailed economic analysis (CBA) below is therefore an ex post assessment. The water reuse project was initiated by local farmers : they had no access to any other major water resource on the territory. Indeed, irrigation was considered indispensable: (i) to increase and secure yields in an area where climatic conditions are highly variable from one year to another; and (ii) to enable farmers to comply with production specifications from a local seed company that required irrigation on seed maize.

The main crops of the area are maize (grain and seeds), sugar beet and wheat. Seed maize has the highest gross margin for farmers. Sugar beet production is sent to a sugar factory. The wastewater treatment plant (WWTP) is adjacent to the sugar factory and to the agricultural fields (Figure 1).

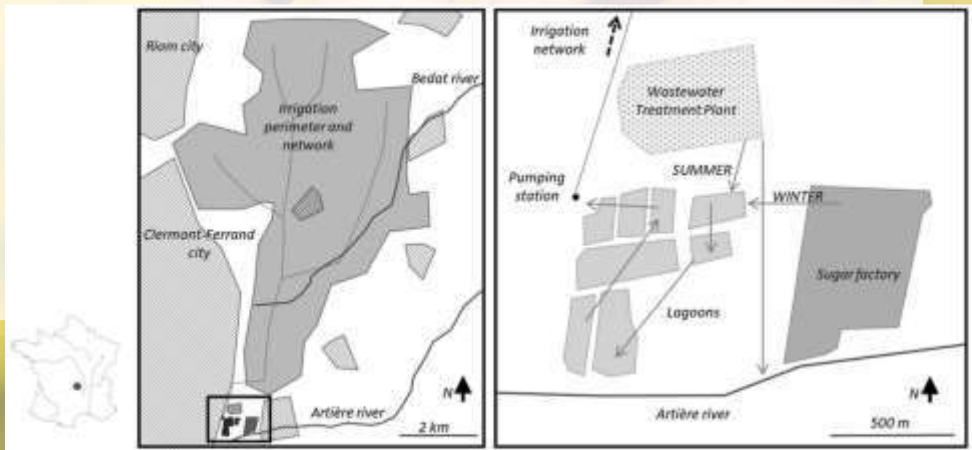

Figure 1: Water reuse scenario map, Clermont-Ferrand, Limagne Noire

Here, the implemented water reuse scenario and the benchmark scenario (no water reuse) are compared into a CBA. The main stakeholders involved are the sugar factory, the farmers (as a whole), and the funding agencies.

In the **water reuse scenario** (existing situation) pre-reclaimed water is supplied for free by the Clermont-Ferrand urban district, owner of the WWTP, to the farmers. The farmers' association is in charge of additional reclamation and responsible for irrigation water quality (compliance with irrigation water reuse regulations). A complementary reclamation is therefore required before use : 12 ha of lagoons, property of the sugar factory, are then used. In winter, the sugar factory uses the lagoons to store its effluents before spreading them onto the perimeter using the distribution system (Step 1). Then in early spring, when the lagoons are empty, they are used as tertiary treatment and storage space for reclaimed water before irrigation (Step 2).
Of the initial investments (distribution system, irrigation material, lagoon rehabilitation and sanitary studies), 59% were subsidized. The sugar factory bears part of the maintenance and operation (energy) costs proportional to the transiting volumes in Step 1.

The **benchmark scenario** (hypothetical situation) is the situation as it would have been without water reuse: farmers would have kept pumping into a small creek, the Bedat, to irrigate 200 ha (limited volume of water available) without affecting its quality. Irrigated seed maize surfaces would have significantly decreased compared to the water reuse scenario. It is considered that the rainfed crops distribution in the remaining perimeter (1200 ha) would have been similar to another rainfed perimeter located nearby.
Before water reuse implementation the effluent produced in winter by the factory used to be stored in the 12-ha lagoon system before being conveyed and treated by the Clermont-Ferrand WWTP in summer. In the benchmark scenario it is considered that the sugar factory would have kept on sending its effluent for treatment to the WWTP.

All detailed costs and benefits used in the CBA are detailed in reference [1]. Beyond OPEX and CAPEX the 2 major differences between the 2 scenarios are:

- In the benchmark scenario the sugar factory would have kept on sending its effluent for treatment to the WWTP at a high cost (€1.9 m^3), instead of spreading them on the fields, thus representing a high cost for the sugar factory.
- Total gross margins for farmers were calculated for both scenarios, considering the crop distribution.

Calculated economic Net Present Value (NPV) of the project is positive and around €10.1 Millions over 50 years (Figure 2). The project is sustainable for the community and it was worth being subsidized. The two stakeholders involved (farmers and the sugar factory) also get a positive financial NPV. Furthermore, the project's NPV would still be positive without public subsidies and the benefit shared among the two agents is largely in favour of the sugar factory.

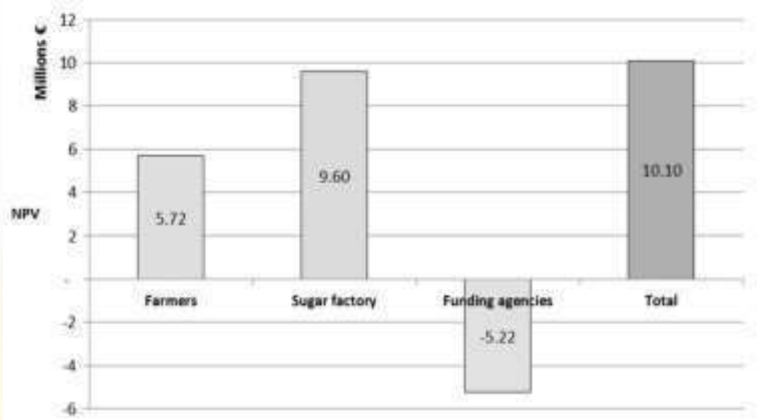

Figure 2: NPV of the different stakeholders, Clermont-Ferrand

References/further readings

[1] Declercq, Loubier, Condom and Molle, 2017, SOCIO-ECONOMIC INTEREST OF TREATED WASTEWATER REUSE IN AGRICULTURAL IRRIGATION AND INDIRECT POTABLE WATER REUSE: CLERMONT-FERRAND AND CANNES CASE STUDIES' COST–BENEFIT ANALYSIS, Irrig. and Drain. DOI: 10.1002/ird.2205
[2] Condom N, Lefebvre M, Vandome L. 2012. Treated Wastewater reuse in the Mediterranean: Lessons Learned and Tools for Project Development. Blue Plan Papers 11. Plan Bleu, Valbonne, France.
[3] Molinos-Senante M., et al. 2011. Cost-benefit analysis of water-reuse projects for environmental purposes: a case study for Spanish wastewater treatment plants. Journal of Environment Management, 92 3091-3097

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2 **Fact Sheet 2.2.** – Irrigation schemes when using reclaimed water: Braunschweig case study.

The fact sheet describes long-term experiences of a German reclaimed water irrigation practitioner regarding operation and management of the irrigation scheme. The water source, technology type and irrigation conditions are all described for the case study of the organisation 'Abwasserverband Braunschweig' (AV-BS), which is using reclaimed water for irrigation for more than 60 years. The extent of the irrigation area and the scheme size are elucidated as well as the number of farmers and hectares supplied with reclamation water. The management of the irrigation scheme, especially during the periods of water shortage is explained. Finally, the financial and economic analysis was made within the Braunschweig case study, together with the operating and maintenance costs.

Sustainable **Water treatment** and Agricultural reuse options in Europe

Info-package 2
Agricultural Advisory Services

Fact Sheet 2.2 – **Irrigation schemes when using reclaimed water: Braunschweig case study**

Costs benefits analysis and feasibility of using reclaimed water | **Irrigation schemes when using reclaimed water** | Water and fertilizer savings when using reclaimed water | Using reclaimed water in closed hydroponic systems requires focus on sodium | Water reuse initiatives in agriculture in Europe

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 2 aimed at agricultural advisors, that describes long-term experiences of a German reclaimed water irrigation practitioner regarding operation and management of the irrigation scheme.

1. Introduction

The organisation 'Abwasserverband Braunschweig' (AV-BS) is using reclaimed water in irrigation for more than 60 years. In former times wastewater was used for agricultural purposes without any reclamation. Since 1979 the wastewater coming from the city of Braunschweig passes various steps within the Braunschweig reclamation facility.

2. Water Source, technology type, irrigation conditions

The reclaimed water used for agricultural irrigation is treated in the Braunschweig reclamation facility (360.000 PE) where it passes mechanical and biological treatment steps. The reclaimed water fulfils the German irrigation water quality requirements for energy crops and processed food which have no threshold regarding microbiological parameters. After treatment, the reclaimed water is transported via gravity flow pipes to four pumping plants located in the agricultural fields of AV-BS. From the pumping stations the reclaimed water is transported via pressure pipes to the irrigations systems. The irrigations technologies consist of hose drums with a classic sprinkler at the end . Each one can cover a radius of 3 000 – 5 000 m². In total the pipe network has a length of 130 km and distributes reclaimed water to 1 350 tapping points. Due to its flat topography, the high percentage of sandy soils and the negative climate balance during vegetation period the area has optimal conditions for high intense irrigation.

Figure 1: Tapping points with irrigation machines

Figure 2: Tractor shifting irrigation sprinklers

3. Scheme size

The area supplied with reclaimed water is about 2 700 ha. In total more than 100 farmers are supplied with reclaimed water. The figure 3 represents the total extent of the irrigation area. Accordingly to the four pumping stations the total area is divided into four irrigations districts with a similar agricultural area.

4. Management irrigation scheme

Especially during summer period the amount of reclaimed water is not sufficient to cover the increasing crops water demand. Then for irrigation of its fields AV-BS uses a mix of reclaimed water (90%) from the reclamation facility and groundwater (10%) which is abstracted on-site at the four pumping stations (see table 1).

In order to guarantee that every agricultural field receives irrigation at least once a month the irrigation machines are shifted regularly by employees of AV-BS. In total AV-BS has 80 employees working on the practical irrigation performance with tractor operators, mechanics, electricians and management staff. The four pumping stations work continuously which makes a 3-shift operation necessary. Regarding the machinery AV-BS has 170 irrigation machines, consisting of a hose drum and a sprinkler, and 10 tractors in operation.

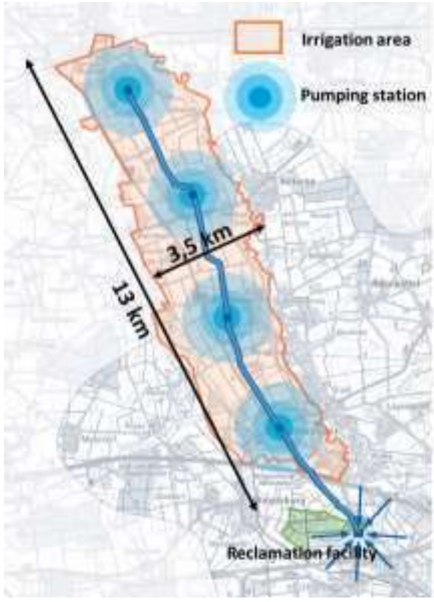

Figure 3: Extent irrigation area

Table 1: Amount of irrigation water (reclaimed + ground water)

Reclaimed water + ground water [m³]								
	2015		2016		2017		2018	
	reclaimed water	ground water.	reclaimed water	ground water.	reclaimed water	ground water.	reclaimed water	ground water.
Jan	0	0	0	0	0	0	0	0
Feb	740.379	0	764.483	0	748.645	0	478.592	0
Mar	903.994	0	839.717	0	845.499	0	936.379	0
Apr	1.026.133	0	970.501	0	811.095	0	963.742	0
May	1.148.492	81.227	1.242.344	79.200	882.328	6.400	1.218.571	281.100
Jun	1.187.915	549.000	1.156.681	80.100	1.205.379	179.200	1.348.109	561.700
Jul	1.325.812	158.100	1.165.732	229.400	1.181.262	10.300	1.265.590	426.700
Aug	1.181.153	206.000	1.119.734	231.400	1.111.463	0	1.244.118	368.300
Sep	1.087.134	0	1.084.532	73.800	1.005.711	0	1.191.498	44.500
Oct	885.870	0	1.089.021	0	965.883	0	1.186.392	0
Nov	817.235	0	918.963	0	772.060	0	935.575	0
Dec	0	0	0	0	0	0	0	0
	10.304.117	994.327	10.351.708	693.900	9.529.325	195.900	10.768.566	1.676.300
	11.298.444		11.045.608		9.725.225		12.444.866	

5. Financial and economic analysis

The irrigation area has average crop yields of 30 and 50 t/ha, respectively for grain crops and energy crops.

In 2018 the costs for operating and maintenance of the reclamation facility were about 11 million €. For operating and maintenance of the irrigation system the costs were about 6 million €. The farmers using reclaimed water pay 80 to 110 € per irrigated hectare. The operating and maintenance costs of the irrigation systems are mostly covered by wastewater fees paid by the citizens of Braunschweig as the irrigation of the reclaimed water is considered as an additional treatment step regarding micro pollutants.

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3 **Fact Sheet 2.3.** – Water and fertilizer savings when using reclaimed water: facts and figures.

This fact sheet explains in detail how water reclamation and reuse can lead to consistent water and fertilizer savings. The difference between the direct and indirect water savings is explained, as well as the underestimated fertilizer saving benefits of water reuse. The potential of nutrient recovery from raw domestic wastewater, based on literature review and examples from practice are elaborated. The potential of fertilizer savings by using reclaimed water and its benefits from using Nitrogen, Phosphorus and Potassium mainly found in reclaimed water are laid out. Lastly, the experiences, key figures from different experimentations and case studies from Lisboa (Portugal), Gruissan (France) and Sainte-Maxime (France) are given.

Sustainable **Water treatment** and
Agricultural reuse options in Europe

Info-package 2
Agricultural Advisory Services

Fact Sheet 2.3 – **Water and fertilizer savings when using reclaimed water: facts and figures**

Costs benefits analysis and feasibility of using reclaimed water | Irrigation schemes when using reclaimed water | **Water and fertilizer savings when using reclaimed water** | Using reclaimed water in closed hydroponic systems requires focus on sodium | Water reuse initiatives in agriculture in Europe

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 2 aimed at agricultural advisors, that describes water and fertilizer savings in water reuse.

1. Introduction:

Water reclamation and reuse can lead to consistent water savings. It is often the major objective targeted by projects. Water savings can be direct or indirect : 1) "direct" if we substitute a conventional water resource with reclaimed water or 2) "indirect" if we re-load a natural water resource that is then used for different uses. In case reclaimed water is used to supply "new" water uses or to increase water consumption then it is not strictly speaking leading to water savings.

Nevertheless, indirect impacts of water reuse can also be stated on agronomic systems (soils and crops) either negative as soil degradation (contamination or salinization) if water reuse is not properly managed, or positive as it may lead to increased fertility and yields. Those fertilizer savings, contrary to the water savings described before, are often more variable and difficult to foresee. This factsheet focuses mainly on the underestimated fertilizer savings benefits of water reuse. It is based on literature review.

2. Nutrients recovery potential from raw domestic wastewater

The WHO estimated in 2010 report that if all N and P from domestic wastewater were reused then it would contribute to save respectively 33% and 22% of the chemical fertilizers sold over the world (theoretical equivalence). It is also estimated that less than 1% of the volume of domestic wastewater comes from urine that represents around 80% of the nitrogen and 50% of the phosphorus treated by wastewater treatment plants. The remaining nitrogen and phosphorus mainly comes from faeces (Ecosec).

As a source of example : in Pakistan, the lease price of land with access to wastewater is 2.5 times higher than the price of land with access to surface water, which gives an idea of the value of nutrients (Ecofilae, 2011, Blue plan 11). Irrigation with urban raw wastewater applied in low and middle-income countries shall be accompanied with appropriate sanitary practices (IWMI references).

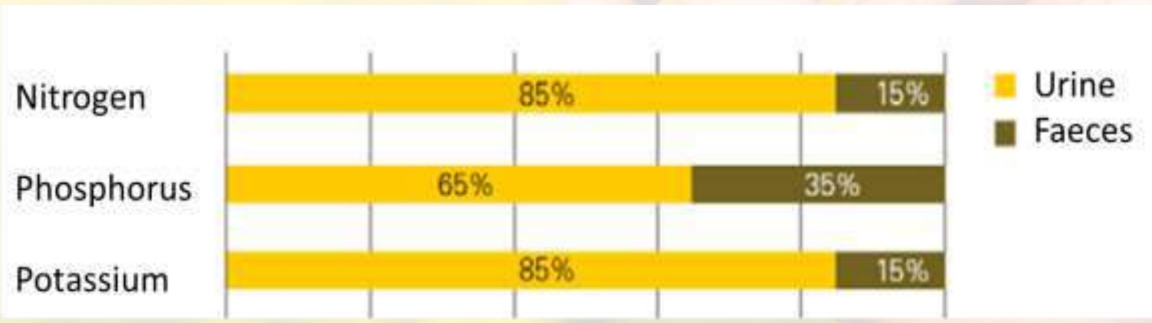

Figure 1: Nutrient share of human waste products (urine and faeces) (Source: ECOSEC, 2017 after eawag)

3. Fertilizer savings potential from reclaimed water

Fertilizer benefits from reclaimed water come mainly from **Nitrogen (N), Phosphorus (P) and Potassium (K)** but also from **organic matter** content that might be assessed with the COD (chemical oxygen demand) and COT (cut-off trench) parameters. The irrigation with reclaimed water has a degree of **similarity to fertigation**, but results compared to other studies becomes complicated as the nutrients concentrations and contents is directly linked to **wastewater origin** (town-country), as well as to **treatment techniques** used by reclamation plant. **Combined with sludge valorization** on agricultural fields water reuse could of course contribute to reach higher levels of nutrients circular economy. After conventional activated sludge systems concentrations of total N and P are generally between 15 and 35 mg/L for N and between 4 and 10 mg/L for P.

Below are detailed some key figures from different experimentations and case studies.

3.1 Experimentation in Lisboa (Portugal)

The Institute of Agronomy (ISA – Portugal) carried out a test to assess the "short term potential of reclaimed water and sewage sludge for ornamental lawn fertilization and irrigation. [...] Irrigation with reclaimed water compared to public water irrigation showed a positive effect on lawn installation through higher growth of grass and higher dry matter yield. This effect increased even more, when sewage sludge produced in the wastewater treatment plant (WWTP) was applied to soil, which proves once more its benefits as an organic fertilizer. At the end of the experiment, an increase of some soil parameters (pH, electrical conductivity, organic matter, Ca^{2+}, Na^{+}, K^{+}, Mg^{2+} and $NH4^{+}$) was observed, indicating that reclaimed water irrigation can cause a soil sodization."

3.2 Experimentation in Gruissan (France)

In Gruissan the INRA carried out tests to assess the benefits of reclaimed water on fertilizer savings for vineyards irrigation. The results highlight that fertilizer contribution of reclaimed water would be important. In this study 19–39 Unit N, 0.5–1.1 Unit P and 14–28 Unit K/Ha were supplied with reclaimed water while the total annual fertilization needs are 20-70 Unit N, 3-10 Unit P and 25-70 Unit K/Ha.

3.2 Case study of Sainte-Maxime (France)

The Golf of Sainte-Maxime (France) switched from potable water to reclaimed water in 2006, thus leading to consequential water savings for the city relying mainly on water resources supplied by other regions. Beyond direct financial benefits related to water price the Golf also constated afterthought indirect benefits in terms of fertilizers : fertilizers purchases were divided by 3 but, during the first years, the greenkeeper had some difficulties to adapt his fertilization plan and he had to hire additional seasonal employments to face the increased need for mowing and even to purchase growth retarders (France, IRSTEA-Ecofilae, ONEMA 2014).

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4 **Fact Sheet 2.4.** – Using reclaimed water in closed hydroponic systems requires focus on sodium.

The fact sheet describes the different models of hydroponic systems and the essential need of sodium management in hydroponic system using reclaimed water. The difference between the open, semi-closed and closed hydroponic systems is explained, together with the importance of sodium in hydroponic systems. Since sodium accumulation has been identified as the primary obstacle to recirculation, and the main source of sodium entering the water and nutrient cycle originates from the water source, examples of effective ways of sodium management from different studies are made. The classification of water quality is explained, and the sodium threshold values are made. Finally, the examples of technologies for selective sodium removal are given.

Sustainable **Water treatment** and
Agricultural reuse options in Europe

Info-package 2
Agricultural Advisory Services

Fact Sheet 2.4 – **Using reclaimed water in closed hydroponic systems requires focus on sodium**

Costs benefits analysis and feasibility of using reclaimed water → Irrigation schemes when using reclaimed water → Water and fertilizer savings when using reclaimed water → Using reclaimed water in closed hydroponic systems requires focus on sodium → Water reuse initiatives in agriculture in Europe

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 2 aimed at agricultural advisors and describes the essential need of sodium management in hydroponic system using reclaimed water.

1. Introduction

In the North-Western part of Europe, a considerable part of greenhouse production is performed in so-called "closed hydroponic systems", referring to the recirculation of water and nutrients throughout the growing cycle. Although these closed systems require few water inputs per kg production, recent dry summers urged some farmers to search for additional water sources in order to meet the crops' water needs. In this context, the use of reclaimed water is being discussed as a potential alternative water source for closed hydroponic systems. Understanding the presence, effect and eventual removal needs of a variety of compounds in treated wastewater is necessary prior to reuse this water source for agricultural irrigation. For closed hydroponic systems, specific attention needs to be given to the sodium ($Na+$) concentration. This factsheet focusses on the importance of sodium management when using reclaimed water in closed hydroponic systems.

2. Open, semi-closed, and closed hydroponic systems

In horticultural crop production, hydroponics refers to a method to grow crops without soil. Instead, crops are grown with or without growing media (e.g. stone wool, peat, perlite, coconut fiber, pumice, etc.). Nutrient solutions supply water and minerals to the crops. In contrast to soil, the buffering capability of the growing medium is rather limited. Therefore, an excess of nutrient solution is applied assuring that all plants receive sufficient water and minerals, and that the salt accumulation in the growing medium is prevented. This excess of nutrient solution is referred to as drain water. When all drain water is recycled, the hydroponic system is defined a "closed" system, in case only part of the drain water is recycled, the system is referred to as "semi-closed." If no recirculation is applied, the system is "open".

Figure 1. Blossom end rot in tomatoes, one of the effects of sodium misbalance of the nutrient solution.

3. The importance of sodium in hydroponic systems

For almost all terrestrial plants, sodium is not essential for either growth and development or reproduction. Therefore, the uptake of sodium by the crop is only limited, resulting in the accumulation of this component in the recirculated drain water. High concentrations might cause negative effects on plant production and quality as shown in Figure 1.

Recent studies identified sodium accumulation being the primary bottleneck keeping farmers from 100% recirculation [1,2]. In hydroponic systems, the main source of sodium entering the water and nutrient cycle originates from the primary water source. Fertilizers, plant protection products, disinfection products, etc. contribute to a much lesser extent. In case the water source does not meet the criteria of at least class 3 (Table 1), it is not suitable for use in greenhouse hydroponic horticulture. In Flanders, sodium concentrations in reclaimed water amount 2,0 to 6,4 mMol/l (based on a limited number of samples).

Table 1 Classification of water quality. A water source of class 1 can be used for most applications. A water source of class 2 is not suitable for cultures with limited root volume or when only limited amounts of water can be applied. A water source of class 3 is not suitable for salt sensitive crops [3].

Quality class	EC (mS/cm)	Na (mMol/l)	Na (ppm)
Class 1	<0.5	0.0-0.5	0-11
Class 2	0.5-1.0	1.5-3.0	34-69
Class 3	1.0-1.5	3.0-4.5	69-103

Table 2 Sodium threshold values of 1980s versus more recent research outcomes [5,6].

Crop	Old threshold value (1980s) (mMol/l)	Threshold value based on recent research (mMol/l)
Tomato	8-10	18-20
Sweet pepper	6	8-10
Rose	6	-
Gerbera	10	-

Table 2 provides an overview of some crops' sodium tolerance. These varies strongly depending on the type of crop. Most threshold values are based on research initiatives of the 1980's and included considerable safety margins. More recent Dutch research showed that with an adequate sodium management, crops like tomato and sweet pepper could be grown with nutrient solutions containing sodium levels of respectively 18-20 mMol/l and 8-10 mMol/l. Simulations based on the "Water streams model" of Wageningen University [4] showed that in case a threshold value of 8 mMol/l Na would be maintained in tomatoes using reclaimed water as an additional water source during periods of water shortage, around 1.000 m^3 per hectare should be discarded. In case the threshold value is increased to 18 mMol/l using the same water source, the discarded volume would decrease to only 500 m^3 per hectare. A higher threshold would enable longer recirculation of the water. In case tap water would have been used (with low presence of sodium), no discharge would have taken place. The concentrations of sodium in both the primary water source entering the hydroponic system as the accumulation in the drain water require careful attention, especially using reclaimed water.

4. Selective sodium removal

In the past years, a series of technologies were developed supporting selective sodium removal. The technologies are based on a series of working principles, e.g. nanofiltration sometimes combined with reversed osmosis to treat the permeate, electro dialysis, modified ion exchange, …. In most cases, the removal processes showed being semi-selective as it showed being difficult separating, for example, sodium and nitrate as they have very similar characteristics.

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5 **Fact Sheet 2.5.** – Water reuse initiatives in agriculture in Europe: facts and figures.

Understanding to which extent, where and how this practice has found implementation in Europe is important, hence this fact sheet describes the water reuse initiatives in Europe. The SuWaNu Europe project resulted in the largest collection of water reuse initiatives specifically intended for agricultural irrigation. Besides their identification and geographical distribution, information was retrieved on initiatives' size, clearly identifying several hotspots in Europe. The origins of the reclaimed water for the agricultural sector as well as the agricultural end-users are described. Different methods of water reclamation treatment and the the advanced water reclamation trains for agricultural irrigation (performed after the secondary treatment) is explained. Finally, further information on the initiative, with a link to the online initiative database and the Deliverable 1.2 is given.

Sustainable **Water treatment** and
Agricultural reuse options in Europe

Info-package 2
Agricultural Advisory Services

Fact Sheet 2.5 – **Water reuse initiatives in agriculture in Europe: facts and figures**

- Costs benefits analysis and feasibility of using reclaimed water
- Irrigation schemes when using reclaimed water
- Water and fertilizer savings when using reclaimed water
- Using reclaimed water in closed hydroponic systems requires focus on sodium
- **Water reuse initiatives in agriculture in Europe**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 2 aimed at agricultural advisors, that describes the water reuse initiatives in Europe.

1. Introduction

In the light of the European Union's agreed proposal on minimum requirements for the reuse of water in the agricultural sector (COM/2018/337), it is relevant to understand to which extent, where and how this practice has found implementation in Europe. Previous work has been done in mapping water reuse schemes in Europe. The AQUAREC project (Bixio & Wintgens, 2006) and Water Reuse Europe (Water Reuse Europe, 2018) identified several European water reuse initiatives in agricultural, industrial or urban applications. The SuWaNu Europe project resulted in the largest collection of water reuse initiatives specifically intended for agricultural irrigation. Besides their identification and geographical distributions, information was retrieved on initiatives' size, implementation stage, water sources, farming systems, irrigation methods, water reclamation treatments, distribution systems, costs, user agreements… This resulted in overview maps, an online public database and an analysis report of existing practices and research projects reusing water for agriculture in Europe.

2. Water reuse initiatives in agriculture in Europe

A total of 79 initiatives using reclaimed water for agricultural irrigation in Europe were mapped. The collection needs to be considered as a non-exhaustive listing and evaluation of initiatives using reclaimed water in the agricultural sector. Initiatives were selected for their 'demonstrative character' referring to for example the possibility to visit the initiatives. The list contains representative and innovative cases that capture the wide variety of reuse possibilities across the countries in the SuWaNu Europe consortium.

3. Size of water reuse initiatives

The collected reuse initiatives differ in size. Figure 1 shows the annually reclaimed water volume used for irrigation across the initiatives, clearly identifying several hotspots in Europe. The largest ones are situated on the Spanish coast between the cities of Almería and Valencia which counts 7 locations reusing water to irrigate more than 2,000 hectares. In the area to the East of Hannover in Germany, a concentration of three middle- to large-scale initiatives have found implementation. Furthermore, two reclamation plant reclaim Milan's urban wastewater to provide irrigation water to 28,000 hectares of agricultural land. The islands of Crete and Cyprus harbour a high concentration of middle-scale initiatives specifically intended for agriculture reuse. The Netherlands and Flanders (Belgium), the Department of Occitan (Franc), the Western part of Andalucía (Spain), Alentejo (Portugal) and Puglia (Italy) are regions with a moderate concentration of small-scale initiatives – often yet in the pilot or research phase.

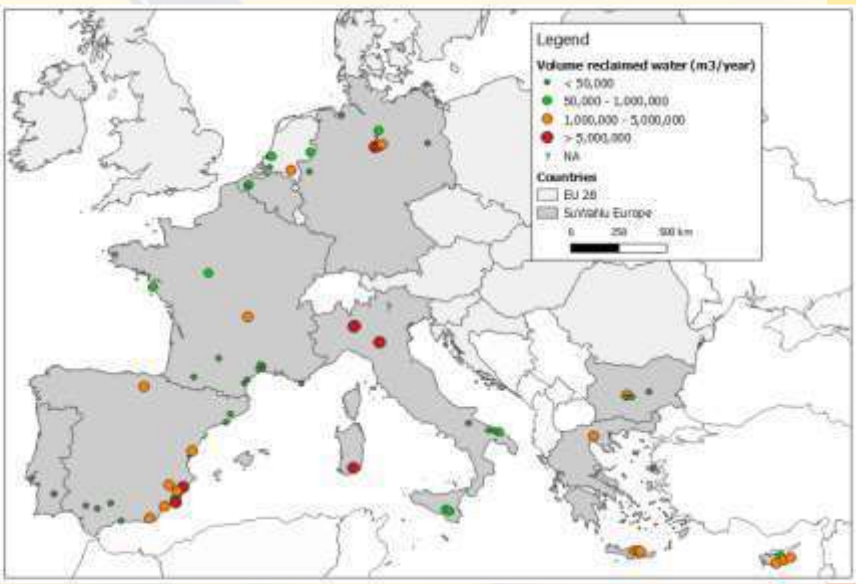

Figure 1 Annual volume reclaimed water (m3) per initiative

4. Reclaimed water sources

The water reclaimed for the agricultural sector has different origins. This strongly determines the initial water quality and by consequence the treatment requirements or irrigation purposes. The review differentiates the initiatives using wastewater from municipal origin (59) from the ones specifically reusing the effluents of the food processing industry (10). A minority of the initiatives includes wastewater from another origin.

5. Agricultural end-uses

The risk exposure of reclaimed water to health and environment depends on the agricultural use, the crop cultivated and the applied irrigation method. Regarding these previously mentioned criteria, the JRC assigned minimum reclaimed water quality norms and monitoring frequencies (Alcalde-Sanz et al., 2017). Northern European countries predominantly use reclaimed water to irrigate arable crops. Whereas, Southern European countries apply reclaimed water more often to permanent crops. The irrigation method defines to which extent the edible parts of the crops are in contact with the reclaimed water. More than 65% of the collected reuse initiatives make use of drip irrigation to supply the reclaimed water to the crops. This category contains both drip irrigation supplied below ground (sub-surface irrigation) as drip lines placed at the soil surface. Also for greenhouse crops the supply of reclaimed water is often through drip irrigation. The database counted 14 initiatives applying the reclaimed water with sprinkler irrigation.

6. Water reclamation treatment

In general, secondary treatment refers to the mandatory wastewater treatment allowing to discharge treated wastewater into freshwater. This water must comply with the Urban Waste Water Directive 91/271/EEC. A treatment beyond secondary treatment is necessary to allow the use of treated water for irrigation purposes. Figure2 shows the use of advanced treatment trains across the recorded initiatives. After the secondary treatment many Mediterranean countries perform coagulation-flocculation, sand filtration and disinfection. This technique is carried out in 18 initiatives, including most of the largest and fully-operational reuse schemes.

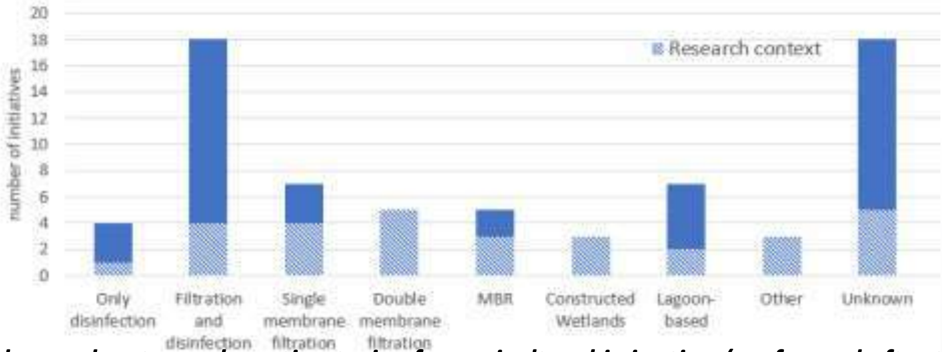

Figure 2 Advanced water reclamation trains for agricultural irrigation (performed after the secondary treatment)

Further information

- The **online initiative database** (https://suwanu-europe.eu/database/) contains the collected and summarized reclaimed water projects. When entering the "Initiatives" landing page, visitors have access to a broad range of search options, allowing them to perform geographical, thematic or keyword searches. Users willing to find out more, can click on the initiatives and will be guided to a more detailed information page.
- **Deliverable 1.2 Review of existing knowledge, material and links** (accessible on the project's website) gives a detailed description of the database including many maps and figures.

References

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10 **Fact Sheet 6.5. –** Confronting barriers for agricultural irrigation with reclaimed water and promoting synergies in geographical clusters.

The barriers which prevent the widespread implementation of water reuse in Europe and at a global scale are discussed in this fact sheet. The key barriers and challenges are identified and were grouped into the following categories: complexity, cost, risk and production. Furthermore, the barriers were grouped in two main categories: technical and non-technical barriers, both of which were detailed in the fact sheet. Moreover, issue of overcoming the mentioned barriers is explained, with the synergistic approach discussed in detail.

Sustainable **Water treatment** and Agricultural reuse options in Europe

Info-package 6
Authorities and Policy Makers

Fact Sheet 6.5 – **Confronting barriers for agricultural irrigation with reclaimed water and promoting synergies in geographical clusters.**

New EU Regulation on reclaimed water for agricultural irrigation → Water Reuse Risk Management Plans → Water resources governance → Strategic planning for the use of reclaimed water in agricultural irrigation → **Confronting barriers and promoting synergies in geographical clusters**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 6 aimed at authorities and policy makers, that describe suitable and effective ways to confront and overcome the barriers for agricultural irrigation based on key policy priorities. It also proposes synergies for adaptation in different geographical clusters.

1. Introduction:

Water reclamation and reuse is considered a priority according to the dependency on the amount of the water needs in each geographical region. Several technologies developed are being well-established and applied for water reuse in many countries. Still, there are numerous barriers that prevent the widespread implementation of water reuse in European and at a global scale. Those barriers can be overcome through the adaptation of innovative **socio-economical, technological and ecological strategic plans**. The agricultural sector, that shows the highest water demand of all sectors, needs to expand the applications of water reuse in agriculture. Issues and barriers such as storage, distribution, risk management and financing must be addressed and confronted.

2. Key barriers to reclaimed water in agriculture in the EU:

Despite the reuse of treated wastewater being an accepted practice in many EU Member States experiencing water scarcity issues, including Spain, Italy, Cyprus, France, Greece, Malta and Portugal, **only a small proportion of treated wastewater is currently reused in the EU**. The reuse potential that could be achieved in the case of stronger regulatory and financial incentives at the EU level are of the order of **6,000 million m³/year by 2025**. **Italy, Germany, France, Spain, Portugal and Greece** are the six Member States in the EU with the highest reuse potential. Spain is the one with the highest water reuse rate, expressed as a percentage of their total annual water abstraction, estimated in 4% of their total annual water abstraction by 2025. In order to increase the amounts of reclaimed water for agricultural irrigation we have to overcome some barriers.

The key barriers and challenges identified can be grouped into the following categories:

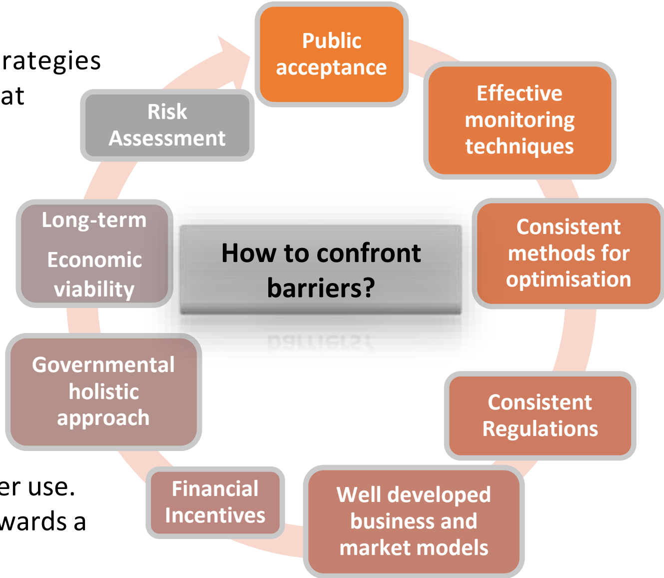
	COMPLEXITY	Water reuse is more complicated than conventional resources
	COST	Water reuse is more expensive than conventional resources
	RISK	Water reuse is perceived as being more risky than beneficial
	PRODUCTION	Possible trade barriers for food products grown using reused water

3. Technical and non technical barriers:

There are two main categories in which barriers can be grouped: Technical, including all aspects on water reclamation and irrigation in research and applied methods, technologies and infrastructures and non-techical such as Institutional, financial, organizational barriers and poor public perception and education. In many cases combined obstacles lead to reluctance in water reuse.

4. How to overcome the barriers:

These barriers have to be overcome if wastewater reuse strategies are to be adopted on a larger and more effective scale than at present. The ultimate goal will be to develop a high eco-innovation potential in terms of technologies and services related to water recycling In agriculture and other sectors. We need to provide significant potential for creation of synergies and opportunities for increasing water resources efficiency.



5. Synergies and opportunities:

Synergies should be identified and strongly encouraged in a multi-level approach. The participation of all sectors is critical to overcome the barriers and move forward to reclaimed water use. There are many opportunities given to follow the roadmap towards a synergistic approach:

Synergy approach

- Engage agricultural communities
- Public outreach programs to build awareness
- involve agricultural community in planning strategies
- Public outreach campaigns
- Stakeholders' involvement
- Promote synergies between stakeholders, key players, funding organizations
- Enhance partnership in regional (ERDF) and European funding projects
- Engage in EIP-AGRI operational and focus groups
- Build multi-actor communities for knowledge exchange
- Translate knowledge into practice
- Build bridges between research and practice

Reference/further readings

Enabling synergies between European Structural and Investment Funds, Horizon 2020 and other research, innovation and competitiveness-related Union programmes Guidance for policy-makers and implementing bodies, 2014, European Commission

EU-level instruments on water reuse. Final report to support the Commission's ImpactAssessment, 2016, European Commission

Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge, JRC, 2017, European Commission

https://ec.europa.eu/environment/water/reuse.htm

https://ec.europa.eu/eip/agriculture/en

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Conclusions

The info-packages presented in this report are intended to bridge the knowledge gap for each target group. However, the info-packages should not be used only by the target groups they are assigned. For instance, there is not a clear line which separates the knowledge needs of water operators and engineers and the same can be applied to other target groups. Although we tried to extract the most relevant knowledge for farmers, engineers, authorities, consumers, etc., the idea behind these info-packages is that they are considered as a full knowledge transfer package where each practitioner can access to the specific knowledge needed. Therefore, the classification into info-packages is a guidance where the different target groups may find more easily those practical experiences and solutions that may fit their needs. Moreover, it is also encouraged that all target groups have access to all info-packages fostering an inter-disciplinary transfer of knowledge.

Fact sheets are not an extensive compilation of the knowledge for each topic. On the contrary, they present a summary of relevant experiences, technologies and practical solutions. The short extension of the fact sheets is intended to facilitate their use as training material in conferences and workshops. The contents should enable the user to further search on the topics described. Further readings recommendations and references are provided in each fact sheet with that purpose.

Moreover, the contents of these fact sheets will be extended in the development of on-line courses that will be available in the SUWANU EUROPE e-learning platform. These courses will be a complementary capacity building tool to transfer the existing knowledge in water reuse.

New EU regulation on minimum requirements for water reuse in agriculture (approved in May 2020) has been addressed with two specific fact-sheets (i.e. FS 6.1 and FS 6.2 respectively) with the objective of bringing the latest regulatory changes and provide the most recent and updated knowledge to the potential users of this material.

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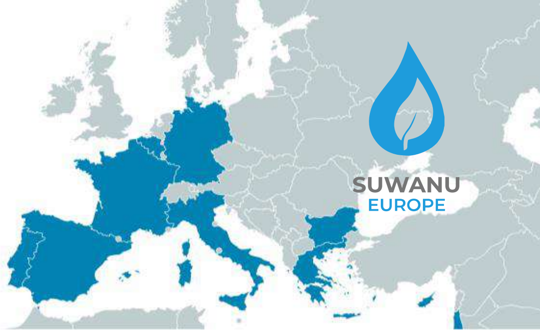
Info-package 3: Water reclamation operators

1 **Fact Sheet 3.1.** – Reclaimed Water quality requirements: facts and figures.

This fact sheet describes the basic quality requirements for a safe and profitable water reuse in agriculture. Water quality is defined, and the principal components of the water quality impacts risk analysis. The different biological hazards and the minimum requirements for the biological hazard are also explained. Besides the biological hazards other kinds of hazards are also defined with the main physical and chemical parameters which need to be checked while defining the water quality for any specific water reuse schema. The health risk quantification studies (QMRA) done on the potential effects on human health of eating vegetables irrigated with reclaimed water are discussed. The results of the EU-funded SAFIR project are presented along with its worst-case scenario analysis. The conclusions with respect to the necessity of more stringent measures show that there is no need for such measures.



Sustainable **Water treatment** and
Agricultural reuse options in Europe

Info-package 3
Water Reclamation Operators

Fact Sheet 3.1 – **Reclaimed Water quality requirements: facts and figures**

Reclaimed Water quality requirements | Contaminants of emerging concern | Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water | Key for success in Israel (and Cyprus?) | Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describe the basic quality requirements for a safe and profitable water reuse in agriculture.

1. Introduction:

Water quality is a highly relative concept that greatly influences the suitability for a particular use or the impacts on soils, irrigation equipment and crops productivity. The quality has to ensure effective protection of human health, environment and agriculture, beside fulfilling the requirements of the user. The latter become particularly true when it comes to water reuse water quality standards, that must be set on a fit for purposes criteria. The assessment of the minimal water quality requirements for reuse shall be based on case specific risk analysis. The principal components of the water quality impacts risk analysis are : i) irrigation / fertigation technology used and impact on the equipment functionality; ii) soil characteristics and impact on soil fertility; iii) impact on the crop and on the produces; iv) impact food hygiene; v) protection of the operator's health. A safe water reuse can be granted by a multiple barrier approach.

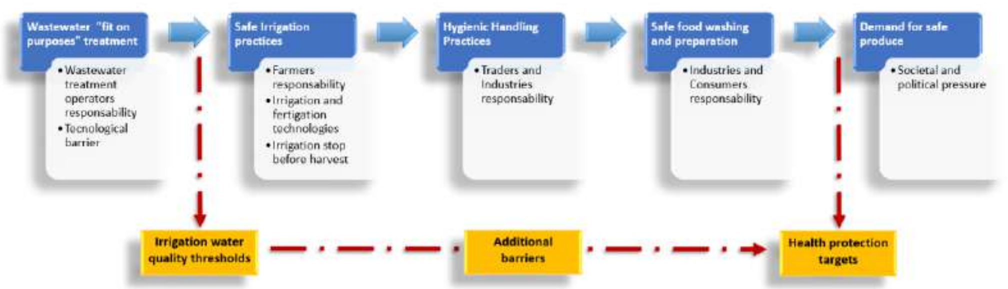


Figure 1: Water quality multi-barrier approach

2. Biological Hazard :

Reclaimed water quality class	Iundicative Technology Target	E.coli	BOD_5	TSS	Turbidity	Other
		MPN./100 ml	mg/l O_2	mg/l	NTU	
A	Secondary treatment + filtration and disinfection	≤ 10	≤ 10	≤ 10	≤ 5	*Legionella spp* <1000 cfu/l where there is risk of aerosolization *Intestinal nematodes (helminth eggs)* ≤ 1 egg/l for irrigation of pastures or forage
B	Secondary treatment + disinfection	≤ 100	≤ 25	≤ 35 WWTP>10000 PE ≤ 60 2000>WWTP<10000 PE	-	*Legionella spp* <1000 cfu/l where there is risk of aerosolization *Intestinal nematodes (helminth eggs)* ≤ 1 egg/l for irrigation of pastures or forage
C	Secondary treatment + disinfection	≤ 1000	≤ 25	≤ 35 WWTP>10000 PE ≤ 60 2000>WWTP<10000 PE	-	*Legionella spp* <1000 cfu/l where there is risk of aerosolization *Intestinal nematodes (helminth eggs)* ≤ 1 egg/l for irrigation of pastures or forage
D	Secondary treatment + disinfection	≤ 10000	≤ 25	≤ 35 WWTP>10000 PE ≤ 60 2000>WWTP<10000 PE	-	*Legionella spp* <1000 cfu/l where there is risk of aerosolization *Intestinal nematodes (helminth eggs)* ≤ 1 egg/l for irrigation of pastures or forage

Figure 2: Bio-hazards Minimum requirements

Excreta-related pathogens (viruses, bacteria, protozoan, helminths and multicellular parasites) pose serious risks to human and animal health. Pathogens can survive for long periods of time in soil or on crop surfaces. Infection can follows several exposure pathways, but in particular: ingestion or inhalation of water/droplets; ingestion of food produces; ingestion of meat from animals grazing on pastures or fed with forage crops irrigated with reclaimed water. Legally binding quality standards for water reuse have been developed by several Member States, besides non-binding standards developed by international organisations. The recently published "Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse" is setting minimum standards for a safe water reuse in agriculture (figure 2).

3. Other Hazards:

Although when it goes for water quality the main focus is on biological hazards, there are also other aspects that must be considered. Irrigation involves many aspects and has great impacts not only on food higiene. The agriculture success and ecosystem health are highly dependable on the quality of water applied. Given the complexity of the matter and the growing attention from the legislator, from various production sectors and from civil society, any attempt to define the water quality standards must take into due consideration the potential short/long term impacts on irrigation and irrigation systems, on plants, on agricultural land and soil biota, on the agricultural products quality, on the rural landscape. Figure 3 reports the main physical and chemical parameters to be checked defining the water quality for any specific water reuse schema. The reported threshold can vary in function of the crop, the soil characteristics (salinity, acidity/alkalinity or structure), the irrigation method. To protect the irrigation equipment from clogging or deterioration also the water corrosivity, incrustability, salt precipitation, biofilm and algae proliferation need to be considered.

.	Ec_w	SAR	Sodium	Chloride	Boron	pH	Arsenic	Cadmium	Chromium	Copper	Manganese	Nickel	Lead	Selenium	Zinc
	dS/m		me/l	me/l	mg/l	$logH^+$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
OPTIMAL	0.70	0.70	-	-	0.70	6.50	0.05	-	-	0.10	-	-	-	-	-
CRITICAL	3.00	0.20	3.00	3.00	3.00	8.00	5.00	0.01	0.10	0.20	0.20	0.20	5.00	0.02	2.00

Figure 3: Physical and chemical water quality

4. More strict means more safe?:

Although of high relevance, there are very few health risk quantification studies (QMRA) and epidemiological studies on the reuse of properly treated reclaimed water. Scientific literature, does not report cases of human diseases caused by reclaimed water in the EU. The EU-funded SAFIR project assessed the potential effects on human health of eating vegetables irrigated with reclaimed water (SAFIR, 2009). QMRA analysis results show that the microbiological health risks as a result of eating tomatoes or potatoes irrigated with recycled water produced by the SAFIR project were minimal. A bacterial strain DNA analysis proved that the E. coli bacteria found in soil and on produce doesn't stem from the irrigation water, they originated in the environment by, e.g., wild animals faecal contamination. The food safety in water reuse schemas is confirmed by the experience of Cyprus or Israel, countries with a long experience of reusing water for irrigation and groundwater recharge, and where almost all the treated effluents are now being reused. However, farmers should be aware that accidental ingestion of soil irrigated with recycled water could pose a health risk. The SAFIR project carried out a worst case analysis including peak E. coli concentrations found in soil, but never in the water, in the health risk calculations. In the worst case some irrigation practices exceeded the WHO maximum permissible risk level of 1 case of mild diarrhoea in 1,000 farmers occupationally exposed to this soil quality per year, and in one of the study areas the QMRA modelling found that roughly 7.5 farmers per 1,000 farmers per year could expect a mild case of diarrhoea. This scenarios are more likely when water reuse is combined with sludge distribution. Hence, the application of the WHO thresholds (2006) resulted in safe food production: there is no need to more stringent measures.

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Wastewater treatment and use in agriculture - FAO irrigation and drainage paper 47

Guidelines for the safe use of wastewater, excreta and greywater - Volume 4. Excreta and greywater use in agriculture

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SUWANU EUROPE

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2 **Fact Sheet 3.2.** – Contaminants of emerging concern (importance, fate in the environment, technologies to remove them, ecological impacts).

The fact sheet describes the importance of contaminants of emerging concern (CECs) in reclaimed water as well as their fate in the environment, ecological consequences and treatment options for their removal from effluent wastewater. The generally examined categories in reclaimed water are explained as well as the platform for a systematic consolidation of data and standardization of methods for assessing emerging hazards associated with wastewater reuse. The process of how the CEC reach the environment is examined with its different sources along with the transformation products (TPs) found in the produced effluent. The ecological impacts of the CECs presence in reclaimed water its consequences and concerns are discussed. Various studies and evidences made with regards to CECs presence such as pharmaceutical residues and its impacts on human health and effects on plants are presented. Lastly the fact sheet presents the treatment options for the removal of CEC from reclaimed water such as Membrane Bio Reactor (MBR) technology and Advanced Oxidation Processes.

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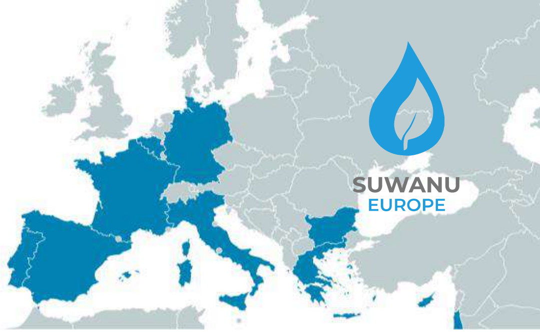

Info-package 3
Water Reclamation Operators

Fact Sheet 3.2 – **Contaminants of emerging concern (importance, fate in the environment, technologies to remove them, ecological impacts)**

Reclaimed water quality requirements → **Contaminants of emerging concern** → Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water → Key for success in Israel (and Cyprus?) → Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describes the importance of contaminants of emerging concern (CECs) in reclaimed water as well as their fate in the environment, ecological consequences and treatment options for their removal from effluent wastewater.

1. Contaminants of emerging concern in reclaimed water–why are they important?

The presence of contaminants of emerging concern (CECs) in raw wastewaters and reclaimed water, is an important issue to address when assessing hazards to human health and ecosystems during the practices of reclaimed water disposal and reuse. According to the NORMAN network (NORMAN network, 2017), a CEC is "a substance currently not included in routine environmental monitoring programs and may be candidate for future legislation due to its adverse effects and/or persistency". Currently, there is not a standardized categorization of CECs, and generally examined categories in reclaimed water include chemical compounds, such as pharmaceuticals (including antibiotics), personal care products, micro/nanoplastics, Per- and Polyfluoroalkyl Substances (PFAS), pesticides and certain microbial contaminants such as antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs). Among CECs, pharmaceuticals belong to a group of increasing interest due to their pharmacological activity, their rising consumption deriving from their use in human and veterinary medicine and their ubiquitous environmental presence (Kümmerer, 2008).

The COST Action ES1403: 'New and Emerging challenges and opportunities in wastewater REUSe' (NEREUS) has provided the platform for a systematic consolidation of data and standardization of methods for assessing emerging hazards associated with wastewater reuse, in particular the most concerning ones from both the public health and environmental perspectives and how these can be overcome (http://www.nereus-cost.eu/).

2. How CECs reach the environment

Wastewater treatment plants (WWTPs) often reduce the emission of CECs, primarily by phase separation during which some of the CECs are removed into the sludge. This process, however, does not fully eliminate the presence of CECs in effluents produced by the WWTPs. Many pharmaceuticals remain in the produced effluent, some undergo partial metabolism that produces transformation products (TPs) (Radjenović et al., 2009). These TPs can be just as persistent and toxic as their parent compounds, and as such their presence in effluent only contribute to the risk associated with effluent reuse (Escher and Fenner, 2011). When reused, effluent may be seen as a source of CECs, introducing them to receiving water bodies due to the incomplete removal of CECs in common wastewater treatment technologies.

Another main source of CECs to the environment is through the disposal of treated effluents and sludge from plants that produce chemicals considered as CECs such as pharmaceuticals, flame retardants and personal care products. Due to the fact that a wide spectrum of chemical and microbial contaminants with different physicochemical properties and toxicological characteristics must be managed, requiring suitable responses by the applied wastewater treatment process, the abovementioned premises give an idea of the complexity of the issues arising from the presence of CECs in raw wastewater and reclaimed water.

3. Ecological impacts of the presence of CEC in reclaimed water

The presence of CECs in reclaimed water may have a variety of ecological impacts, including among others, endocrine disruption in higher order organisms (e.g., fish, amphibians) and the development of antimicrobial/antibiotic resistance in lower order organisms, such as bacteria. The accumulation of CECs in organisms through direct/indirect contact with these residual compounds, may exacerbate abnormal hormonal control leading to impairments of the reproductive system, decreased fertility, increased cancerous cell prevalence, effects which may be preserved through future generations of impacted organism (Belhaj et al., 2015). Antibiotic compounds have been recognised as an important category of CECs, due to their adverse effects on aquatic ecosystems (Kümmerer, 2009). The greatest concern of the release of antibiotic residues in reclaimed water, is associated with the potential development and spread of antibiotic resistance among bacteria in receiving aquatic environments, which potentially leads to a reduction of the therapeutic potential of antibiotic compounds against human and animal bacterial pathogens.

New evidence suggests that CECs such as pharmaceutical residues might be accumulated in agricultural produce grown using reclaimed water (Malchi et al., 2014). The same research also shows that to consume pharmaceuticals in levels approaching those used for therapeutic purposes, one must consume unrealistic amounts of vegetables on a daily basis. On the other hand, biochemical and molecular evidence by Christou et al. (2016) highlighted that various pharmaceuticals in reclaimed water may act as an emerging abiotic stress factor of alfalfa plants, as alfalfa plants were shown to employ detoxification mechanisms once exposed to high pharmaceutical concentrations (Christou et al., 2016). Another study by Christou et al. (2017), has shown that concentrations of pharmaceutical residues in soil and tomato fruits vary, depending on the duration of irrigation and the origin of the wastewater applied, as well as the physicochemical properties of pharmaceuticals, with acidic pharmaceutical uptake and bioconcentration increasing with long-term irrigation with reclaimed water.

4. Treatment options for the removal of CEC from reclaimed water

The refractory nature of pharmaceutical residues found in WWTP effluents and reclaimed water has driven the development of technological solutions whose aim is to overcome the inability of their adequate removal by conventional WWTP processes. Membrane BioReactor (MBR) technology and Advanced Oxidation Processes (AOPs) have exhibited enhanced removal capacity of pharmaceutical microcontaminants from WWTP wastewater matrices and are proved to be powerful treatment processes for the removal of organic persistent and biologically-recalcitrant pharmaceutical compounds (Karaolia et al., 2017). These processes include homogeneous solar-driven photocatalytic processes such as UV/H_2O_2 and photo-Fenton oxidation and the heterogeneous photocatalysis process (Rizzo et al., 2019). Additional methods for CECs removal from effluent involve filtration using biologically active media, and effluent desalination combining ultrafiltration and reverse osmosis. Various combinations of the abovementioned processes can be seen in facilities applying such advanced treatment to effluents. Technology selection at each WWTP is determined based on a combination of scientific and local considerations, including regulatory requirements, cost, water quality goals among others. The removal of CECs and their TPs is the focus of many groups in academia, industry, and policymakers, and is an important driver for an active field of science full of new, interesting and ground-breaking innovations.

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3 **Fact Sheet 3.3.** – Antibiotic resistance and its health impacts linked to irrigation with reclaimed water.

The antibiotic resistance is explained and the contribution of widespread use and misuse of antibiotic compounds to proliferation of antibiotic resistance determinants, specifically related to the release of reclaimed water. The studies done on the concentrations of antibiotic residues in reclaimed water are discussed and the schematic representation of the spread of antibiotic resistance in the environment via reclaimed water is shown. A holistic and multisectoral approach called the One Health Action Plan, aimed at addressing the antimicrobial resistance on multiple fronts is explained. The conclusions on the outcome, the fate and spread of antibiotic-resistant bacteria and their associated genes are made.

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Fact Sheet 3.3 –Antibiotic resistance and its health impacts linked to irrigation with reclaimed water

Reclaimed water quality requirements → Contaminants of emerging concern → **Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water** → Key for success in Israel (and Cyprus?) → Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators and provides information regarding antibiotic resistance determinants in reclaimed water and the potential health impacts linked to irrigation with this type of water.

1. Introduction:

Antibiotic resistance is an antimicrobial resistance (AMR) phenomenon, occurring when an antibiotic compound has lost its ability to effectively control or kill bacterial growth; in other words, the bacteria are resistant and continue to grow and multiply in the presence of therapeutic levels of an antibiotic (U.S. FDA, 2016).

The widespread use and misuse of antibiotic compounds and their uncontrolled emission in the environment was shown to contribute to the proliferation of antibiotic resistance determinants, antibiotic-resistant bacteria (ARB) and their associated genes (antibiotic resistance genes, ARGs) (collectively hereby denoted as ARB&ARGs).

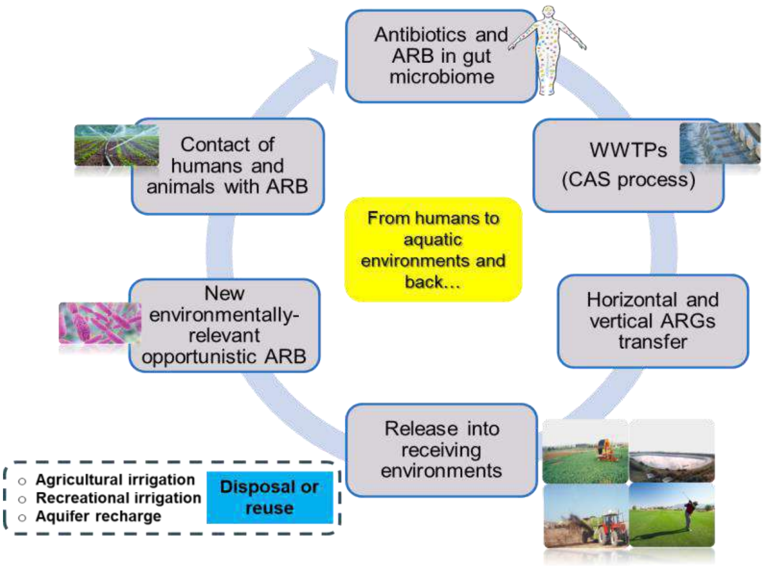
A great concern of the release of reclaimed water nowadays, is associated with the potential development and spread of antibiotic resistance among bacteria in receiving aquatic and terrestrial environments, which potentially leads to a reduction of the therapeutic potential of antibiotic compounds, against human and animal bacterial pathogens.

2. The framework of antibiotic resistance in reclaimed water environments:

Various studies have shown that the concentrations of antibiotic residues in reclaimed water were shown to exceed the bacterial Minimum Inhibitory Concentrations (MICs) for sensitive pathogenic bacteria, thus promoting the prevalence of ARB among total bacterial populations (Bengtsson-Palme and Larsson, 2016), and making antibiotics an important class of contaminants of emerging concern (CECs) for further and closer examination. However, the anthropogenic contribution of antibiotic residues even at very low concentrations (ng to μg L-1) which may be well below the clinically-relevant MICs, has been shown to contribute to the drive of the selection of ARB, thus altering the natural background diversity and size of the environmental ARGs pool, thus contributing to the dissemination and development of antibiotic resistance (Bengtsson-Palme and Larsson, 2016).

As a result, ARB&ARGs in reclaimed water are now gaining scientific attention, and as a result are recently starting to be increasingly included in lists of hazardous agents to be examined, when investigating environmental hazards and risks posed by the practices of reclaimed water disposal and reuse. It was reported that ‘resistance anywhere is resistance everywhere’ by Prescott (2014), and that antibiotic resistance is a ‘highly multifaceted topic at the interface of human, animal and plant health, food hygiene and environmental science’ by Butaye et al. (2014).

In addition to the above, the unearthing of ‘new’ genes to reclaimed water encoding for antibiotic resistance mechanisms, points to the indication that established full-scale WWTPs operating with the CAS process, are significant hubs of ARB development and dissemination. As the CAS process operates with a high, nutrient-rich and a microbially-dense biomass, CAS treatment tanks present ideal environments for the persistence of ARGs in CAS, reclaimed water as well as in biosolids used as soil manure, which once gained and re-purposed by pathogenic bacteria, may have adverse effects on therapeutic courses (Schematic 1).



Schematic 1. Schematic representation of the spread of antibiotic resistance in the environment via reclaimed water (Schematic by Karaolia, 2018)

3. The One Health Approach:

A holistic and multisectoral approach, **-the One Health Action Plan-** is one that aims at addressing AMR on multiple fronts. This approach is a broad, system-based approach aiming at providing solutions to complex problems such as AMR, and considers underlying structural factors affecting this issue, such as socio-political, material, biological and economic factors. In more detail, AMR is addressed in this approach, through the closing of knowledge gaps on the release and spread of antimicrobial-resistant organisms in the environment, and the development of new technologies which have the potential to enable efficient and rapid antimicrobial compound degradation in WWTPs.
Due to the aforementioned complexity of the issue of AMR, the 71st session of the UN General Assembly identified antimicrobial resistance as a dominant global health concern, placing it high on the agenda of national policy makers, international organisations and financial institutions in developed and developing countries, alike. National action plans to tackle this issue in line with the One Health Action Plan have been pledged by states, with interventions targeted at urban wastewater treatment, agriculture, livestock and human health (WHO, 2017).

4. Conclusions:

Still, the understanding of the underlying forces driving the mechanisms of action of such antibiotic resistance determinants, of their exact identity and of their specific genomic context in the environment, remains uncertain. As an outcome, the fate and spread of ARB&ARGs due to the contribution of human and/or clinically-relevant activities and not due to the presence/structure of the background communities is still unclear and may pose a major public health issue and an emerging challenge to combat, globally. Therefore, the lack of inclusion of ARB&ARGs in existing regulations regarding reclaimed water discharge and reuse worldwide, poses a potential risk of ARB&ARGs contamination of ground- and surface-water, wildlife and food chains.

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4 **Fact Sheet 3.4.** – Key for success in Israel and Cyprus: Main concepts in their water reuse strategy.

Since one of the main goals of the project is to learn from existing knowledge, good practices and regional experience, this fact sheet presents the experience and expertise of Israel and Cyprus in water reuse for agriculture. The fact sheet summarized the main concepts that are common to both Israel and Cyprus which were identified as the background for the successful reuse in both countries. The concepts which are described are: centralized management, regional water scarcity, education and water use culture, regulations, pricing, infrastructure and trust.

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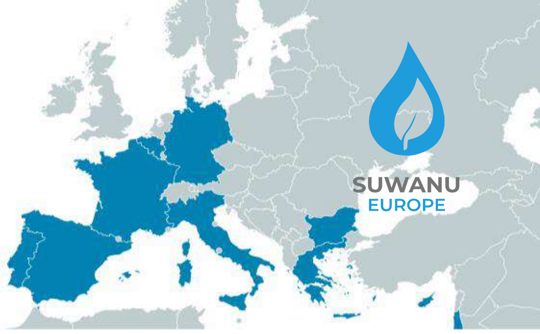

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Fact Sheet 3.4 – **Key for success in Israel and Cyprus: Main concepts in their water reuse strategy**

Reclaimed water quality requirements | Contaminants of emerging concern | Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water | **Key for success in Israel and Cyprus** | Phosphorus recovery in water reuse

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describe the keys for successful application of reclaimed water in agriculture.

Introduction

SuWaNu Europe thematic network was created to bridge gaps between the water and agriculture sectors by accelerating the uptake of research results in the field of water reuse in agriculture and increase the reuse of treated wastewater. One of the main goals of the project is to learn from existing knowledge, good practices and regional experience. Israel and Cyprus were selected to present their experience and expertise in water reuse for agriculture.

A series of fact sheets was created as part of the SuWaNu Europe thematic network to identify best practices that can lead to increased reuse and assess the reasons, mechanisms and circumstances that lead to the successful reuse in both countries. These 'lessons learned' fact sheets cover the same topics for both Israel and Cyprus, thus presenting two different approaches to be served as an inspiration for identifying the best solutions suitable for a given locality. The fact sheet presented here summarizes the main concepts that are common to Israel and Cyprus and were identified as the background for the successful reuse in both countries. It is provided as an overview of the basic conditions needed for the successful implementation of reclaimed water for agriculture reuse.

Centralized Management

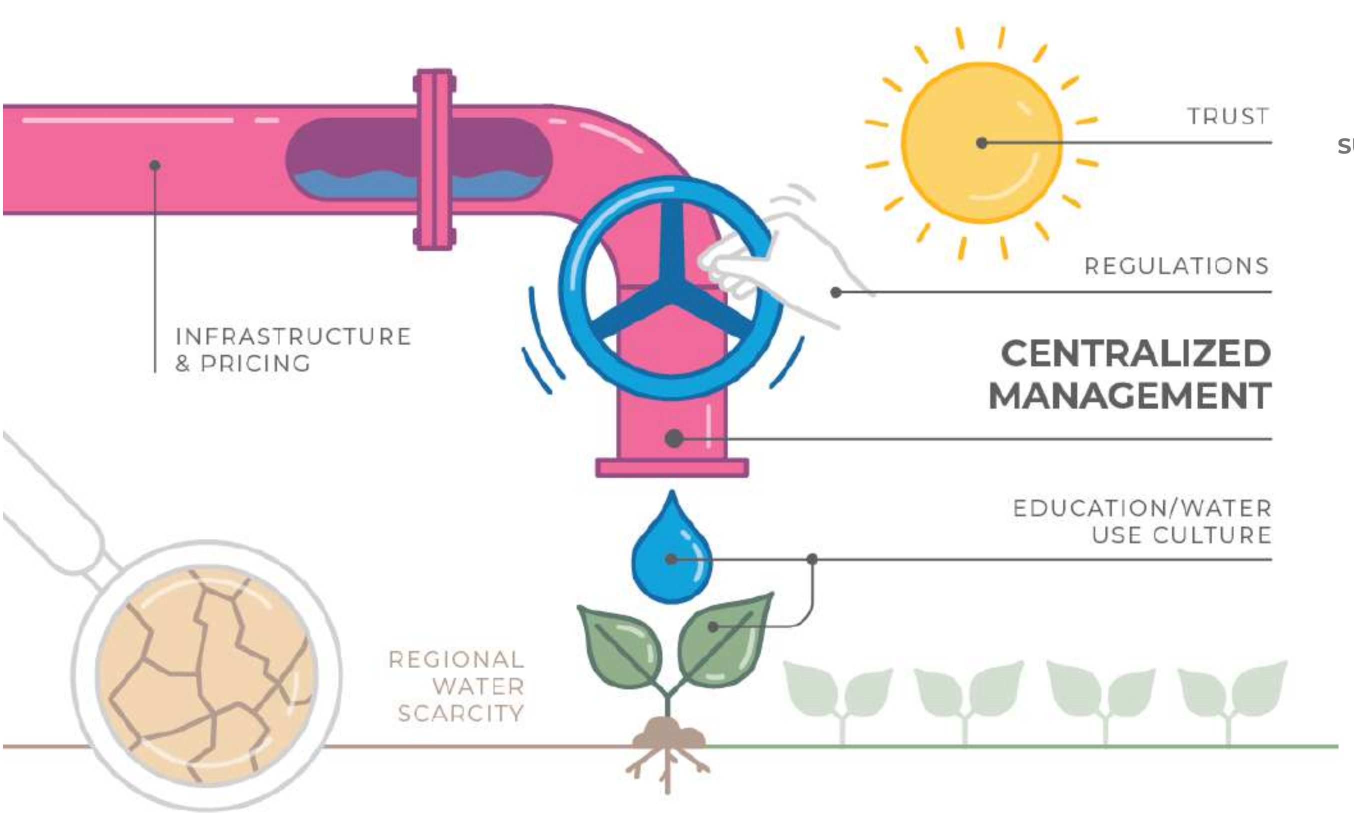
The water sector is centrally managed at the state level. This allows an integrated view and control of all resources and of their accessibility to the consumers at various time frames, at a national scale. When utilized appropriately, this approach can create synergy between different sectors and key stakeholders, allowing the effluent produced by one sector to be efficiently used as a resource by another thus turning a nuisance into a valuable resource.

Regional Water Scarcity

The lack of adequate water supply to meet all demands creates a prolonged need and an understanding that using alternative water sources is a must, because the natural fresh and groundwater resources are limited and do not suffice to supply the demand.

Education/ Water Use Culture

Lasting educational programs that become embedded into the country culture and education system at a national scale can be used to increase awareness for the need to conserve water and for its sustainable use. Establishing this state of mind increases the willingness to accept the concept of water reuse.



Regulations
A coherent framework of local regulations needs to be in place to enable the safe reuse of effluent with different quality for various purposes.

Pricing
Competitive pricing mechanisms can be applied to direct water consumers into using a desired water source. For example, water pricing for a certain water source can vary depending on the designated use. Similarly, within a specific sector different water sources can have different rates, making certain water sources more economically viable than others. This pricing mechanism can have a major role in managing the water sector as a self-financing, independent market.

Infrastructure
The presence of a large-scale infrastructure system is needed to efficiently connect large effluent producers (metropolitan areas) with scattered agricultural consumers.

Trust
The trust established between key players and stakeholders is the core of a thriving water sector that can support all consumers, while meeting all local water demands. Regarding water reuse, this mainly refers to the trust between those managing the water sector and the agricultural sector, which enables long-term planning on the government side and operational flexibility by the farmers side. This trust is the basis for changing strategies and implementing new large-scale management and reuse policies.

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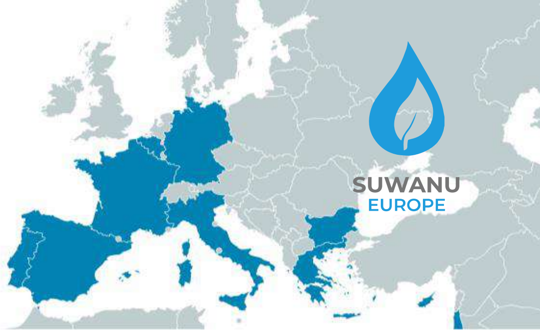
5 **Fact Sheet 3.5.** – Phosphorus recovery in water reuse.

The fact sheet describes innovative methods of phosphorus recovery, in its liquid and solid forms, from wastewater for its later use in agriculture. Different technologies for phosphorus recovery are explained, such as RichWater, High Rate Algal Pounds and Struvite production. The RichWater technology combines an efficient water treatment at a low cost by using a Membrane Bioreactor (MBR), with a mixing station for the optimal water and nutrients combination, and a control system and monitoring with different water, plant and soil sensors. The RichWater's point of view allows for a source of pathogen free water as well as water and fertilizer saving in agriculture. The High Rate Algae Ponds (HRAP) system uses algal ponds for wastewater treatment, which if algae are harvested, requires less than one-tenth of the area to recover phosphorus compared to terrestrial crops/pastures. Using the algal based phosphorus recovery could significantly expand offshore and be used as a good supplementary livestock feed due to their high protein content. Struvite production uses the large wastewater production coming from intensive livestock farming which has a high concentration of phosphorus. Struvite production, as a valuable slow-release mineral fertilizer, combines the removal of phosphorus from livestock wastewater with its recovery and reuse as fertilizer.

Sustainable **Water treatment** and Agricultural reuse options in Europe



Info-package 3
Water Reclamation Operators

Fact Sheet 3.5 – **Phosphorus recovery in water reuse.**

Reclaimed water quality requirements → Contaminants of emerging concern → Potential Antibiotic resistance and health impacts linked to irrigation with reclaimed water → Key for success in Israel and Cyprus → **Phosphorus recovery in water reuse**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 3 aimed at water reclamation operators, that describe innovative methods to recover phosphorus, in its liquid and solid forms, from wastewater for its later use in agriculture.

INTRODUCTION

1. RichWater

The RichWater technology combines an efficient water treatment at low-cost using a Membrane Bioreactor (MBR), with a mixing station for the optimal water and nutrients combination, and a control system and monitoring with different water, plant and soil sensors. This combination allows offering a source of pathogen free water and *in situ* response to the watering demand and fertilization of each type of plant and soil. The Treat & Reuse MBR is designed to have a perm- selective membrane, which serves as a barrier that allows selective extraction of compounds from a wastewater stream. This characteristic allows the system, to have in the effluent, or liquid phase, the highest possible concentration of Phosphorous and Nitrogen (Nitrate $NO3-$).

2. High Rate Algal Pounds (HRAP)

An alternative for taking the wastewater to the plants is to instead take the plants to the wastewater. Algal ponds and macrophyte wetlands are already in widespread use for wastewater treatment and if harvested, require less than one-tenth of the area to recover phosphorus compared to terrestrial crops/pastures. The algal biomass grown to recover phosphorus from wastewater can be utilized in several ways such as for a fertilizer or as a food source in its own right. Plant biomass also has the potential to be used in other added value products such as human food supplements, cosmetics and extraction of high value cellular components all of which applications represent a saving of mined phosphorus resources. However, these more specialized products generally require specific strains of algae to be grown rather than the mixed cultures typically found in wastewater treatment systems.

3. Struvite production

Phosphorus is a key factor causing water eutrophication, on the other hand, it is also a non-recyclable, nonrenewable, and quite valuable resource. On the other side, the intensive livestock farming is a pillar industry in agricultural economy and an important way to increase rural incomes However, it usually produces large amount of livestock wastewater containing high concentration of phosphorus. If this wastewater was not treated reasonably, it would not only lead to the pollution of water eutrophication, but also waste nonrenewable resources and would become one of the major contributors to phosphorus loss.

1. RichWater

1.1.Technology:

The MBR used in RichWater is a system of low energetic consume designed for the treatment module of residual waters in a way that the nutrients (Phosphorous and Nitrogen mainly) stay even after the treatment, while the pathogens are purged (with a disinfection system). The mixing station gets an adequate combination of water and water coming from the MBR, which is transferred to the fertigation module (drip irrigation). The adequate level of mixture is determined via soil nutrient sensors. The main module is specifically designed for water treatment, which is composed by a MBR for low-cost water treatment and a disinfection system, which provide a pathogen free effluent. This technology has been developed after 5 years of research and it is specifically focused on trying to find an innovative water treatment plant destined to agricultural watering. RichWater's point of view allows for water and fertilizer saving in agriculture. The water treatment plant operators, using this system, will have the possibility to offer a new product to their potential clients: watering water rich in nutrients and free from pathogens. The farmers will have an ensured and constant water source, which in arid regions is highly beneficial. The implementation of the system in the agricultural production process supposes a more sustainable use of water resources, a saving in costs of fertilizers and water and the possibility for the fruit/vegetables producers to adjust the fertigation level depending on their concrete necessities using a mixture of water and treated water:

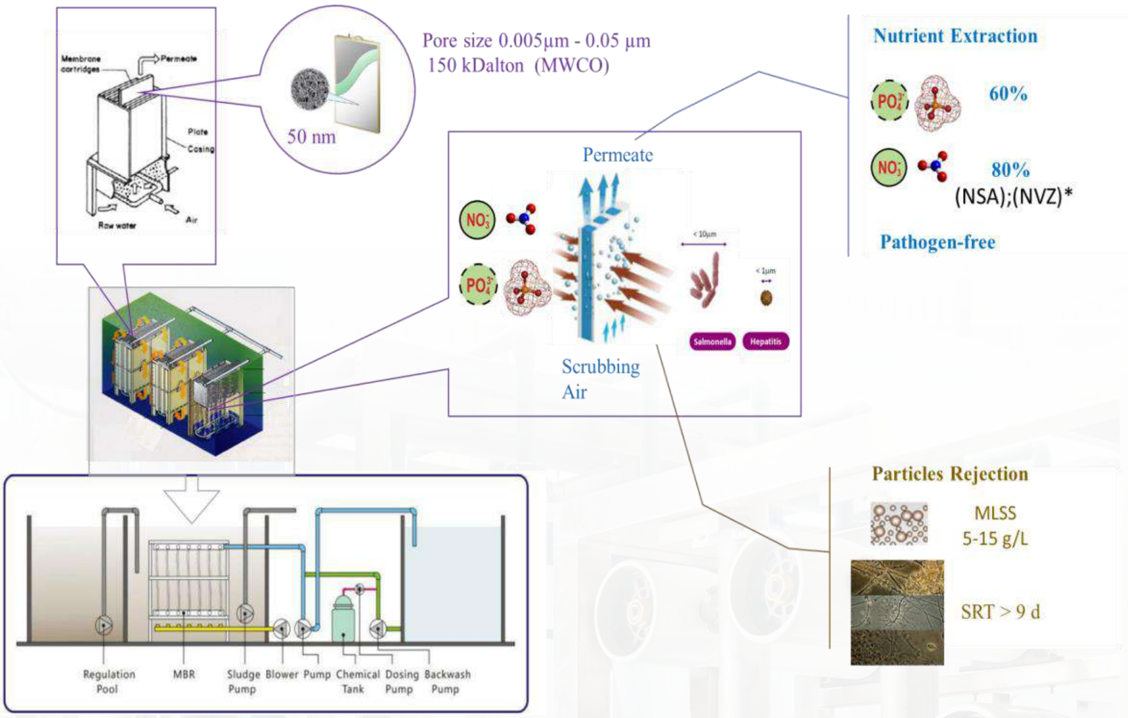


Figure 1: MBR system's functioning diagram

****Denitrification required Nitrate Vulnerable Zone (NVZ) European Legislation limit of 50mg/L Nitrate (N).***

1.2 Application in phosphorous recovery

Phosphorus is present in both organic and inorganic forms in municipal wastewaters. The typical generation of phosphorus in wastewater is 2.7-4.5 g/capita/day. The majority of phosphorus in municipal wastewaters is present as phosphate (PO_4^{3-}) which is soluble. The Treat Reuse MBR is designed to have a perm-selective membrane, which serves as a barrier that allows selective extraction of compounds from a wastewater stream (Pore size around 0.005µm and 0.05µm and 150 kDalton. molecular weight cut off (MWCO)). This characteristic allows the system, to have in the effluent, or liquid phase, the highest possible concentration of Phosphorous and Nitrogen (Nitrate NO_3^-) due to extraction; experimental and practical results around 50-60% of phosphate in liquid phase after T&R MBR shows that the phosphate size (PO_4^{3-}) is smaller than the molecular weight cut off (MWCO) of membrane.

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2. High Rate Algae Ponds (HRAP)

2.1. Technology:

HRAP system generally consist of three main parts: a primary settler, a shallow raceway or pond where microalgae grow and wastewater treatment is carried out, and a harvesting unit to recover the biomass and separate it from the water. Therefore, there will be two outlet lines, one for the clarified, treated water and the second for the biomass. The pond itself consists of an external and central wall, two raceways and reversals, and a paddlewheel which makes the water flow in order to homogenize the mixed liquor, so that it all receives the same solar irradiation, and to avoid the microalgae culture settling as well. The HRAP system is divided in two independent ponds of 335 m^2 each, HRAP-1 and HRAP-2, working in parallel. They have 4 m of channels with 20 cm width walls. Both ponds have two baffles at the reversals and a tear constructed in both ends of the central wall, in order to improve the hydraulic behavior. Water depth is set to 30 cm, so that the total volume is 200 m^3. The system operates under a hydraulic retention time (HRT) of 4 days, which could be optimized and modified depending on the results. Following this HRAP, each pond will be fed with 25 m^3 /day by means of two centrifugal pumps.

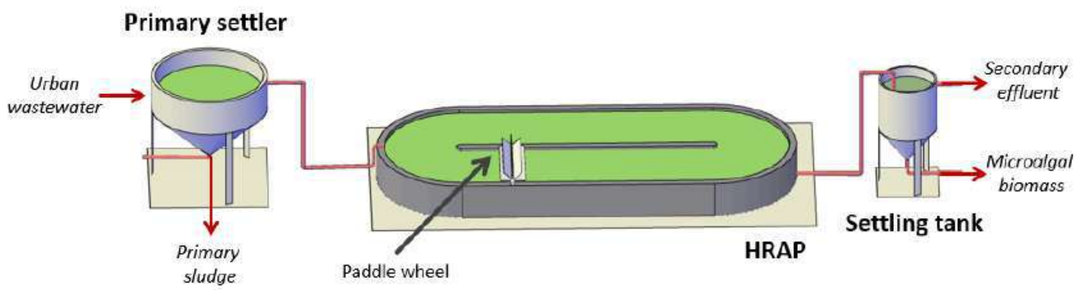

***Figure 2: Picture of*an HRAP montage**

2.2. Application in phosphorous recovery

As we look out to a phosphate scarce future, algal based phosphorus recovery could significantly expand offshore. Around the world there are massive discharges of wastewater directly to seas and oceans. Thus installation of booms to form offshore floating pond systems around the naturally buoyant discharges from wastewater outfalls has been proposed. Optimizing for algal growth and harvesting from offshore systems may even present superior economics to 'on shore' algal cultivation due to the absence of the highly significant land cost component. It has been shown that algal biomass can retain stored phosphorus for some days. Furthermore, with regard to its fertilizer potential, seedling growth using dried algal biomass has been compared to commercial fertilizer and it has shown a growth at comparable levels. However, overall these issues from harvest to application are currently quite poorly covered by the literature for algae. Algae have been identified as making a good supplementary livestock feed, such as for chickens, due to their high protein content.

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3. Struvite production

3.1. Technology

Using the water from the first phase, it enters the CO2 stripping unit, where the airflow will eliminate the CO_2 from the water. This water is then transported to the struvite reactor, where it will be mixed with NaOH and $MgCl_2$, by mixing the phosphorous containing water with the NaOH and the Magnesium, the precipitation of struvite is forced. This struvite is transported to the settler with the water, where it will be separated, allowing the clear water to continue the treatment and collecting the struvite inside the settler.

Figure 3: Sruvite production montage

3.2. Application in phosphorous recovery

The intensive livestock farming produces massive livestock wastewater with high concentration of phosphorus. Discharge of these compounds to surface water not only causes water eutrophication but also wastes phosphorus resources for plant growth. Therefore, it's necessary combining the removal of phosphorus from livestock wastewater with its recovery and reuse as fertilizer. As a valuable slow-release mineral fertilizer, struvite production has become a focus in phosphorus recovery. It is reckoned that 100 m3 wastewater could form 1 kg of struvite. If all the wastewater in the world is treated by struvite production, 63,000 tons of P2O5 could be recovered, equaling to 16% of the phosphate rock production of the world. And 171 g struvite can be recovered from livestock wastewater per square meter at most and the purity as high as 95% without washing. Therefore, recovery of struvite returning to the farmland is a developmental trend of struvite recovery technology.

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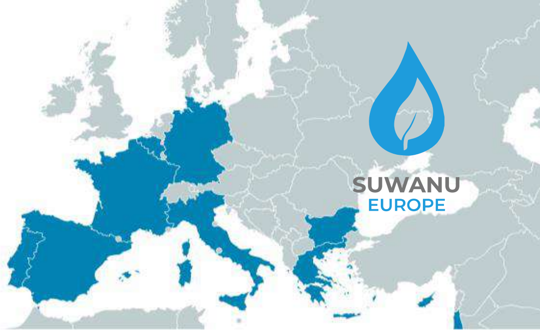
Info-package 4: Water engineering companies

1 Fact Sheet 4.1 – Filtration membranes and new filter materials.

In factsheet 4.1. a new Membrane Bio reactor RichWater MBR technology is presented, the RichWater technology is explained, as well as the difference between the RichWater Membrane Bioreactor and the Standard Membrane Bioreactor. The implementation of the new system for water reclamation in agriculture is elaborated as well as all potential benefits. Implementing the system in the agricultural production process results in an eco-friendlier use of water resources, cost savings for freshwater and fertilizer and the possibility for commercial food producer to adjust the fertigation unit for individual needs using a mixture of fresh and treated water. The efficiencies of pathogen removal and other parameters such as E coli, BOD 5, COD and Turbidity is extremely effective.

Sustainable **Water treatment** and
Agricultural reuse options in Europe



Info-package 4
Water Engineering Companies

Fact Sheet 4.1 – **Filtration membranes and new filter materials.**

Filtration membranes and new filter materials → Sensors and other innovative tools for monitoring reclaimed water quality → Light-driven technologies for producing reclaimed water → Nature based options for water reclamation processes → Other technologies for water reclamation

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 4 aimed at water engineering companies, that describe how the Membrane Bio reactor RichWater MBR technology under certain design and operation, provides a pathogen-free and nutrient-rich effluent (fertilizer savings and thus lower costs), where on average, 60% and 80% of the phosphorous and nitrogen (if possible, denitrification process can be avoided) are satisfactory extracted from the wastewater inflow, respectively (Nutrients remain in liquid phase). It correspond to a low-energy intensive treatment, which innovates the Standard MBR system.

INTRODUCTION

RichWater Technology.
The RichWater technology combines an efficient water treatment at low-cost using a Membrane Bioreactor (MBR), with a mixing station for the optimal water and nutrients combination, and a control system and monitoring with different water, plant and soil sensors. This combination allows offering a source of pathogen free water and in situ response to the watering demand and fertilization of each type of plant and soil. The Treat & Reuse MBR is designed to have a permselective membrane, which serves as a barrier that allows selective extraction of compounds from a wastewater stream. This characteristic allows the system, to have in the effluent, or liquid phase, the highest possible concentration of Phosphorous (PO_4^{3-}) and Nitrogen (Nitrate NO_3^-).

Figure 1: RichWater -HORIZON 2020 Project

1. RichWater MBR vs Standard MBR

Standard MBR has tended to generate treated water of higher purity with respect to dissolved constituents such as organic matter and ammonia, both of which are significantly removed by the activated biomass within the reactor. In contrast, and as upgrade of the Standard MBR process, we will present the innovation of RichWater MBR Which can be defined as a membrane process (low energy intensive treatment), which combines extraction (i e Nitrogen and Phosphorus) and rejection (i.e. Particles and Pathogens) in a semi permeable and selective immersed membrane with a pore size between 40 to 50 nm and 150 kDalton (MWCO) for the treatment of wastewater and effluent reuse in direct agriculture irrigation.

Under certain design and operation, the system provides a pathogen free and nutrient rich effluent (fertilizer savings and thus lower costs), where on average, 60 and 80 of the phosphorous and nitrogen (if possible, denitrification process can be avoided) are satisfactory extracted from the wastewater inflow, respectively (Nutrients remain in liquid phase).

Moreover, in the RichWater MBR system, parameters such as E coli, BOD 5 COD, Turbidity, and SS were effectively removed by the treatment, with average efficiencies higher than 99%, 95%, 94%, 90%, 98% and 98% respectively (strict EU legal framework can be achieved for discharge and water reclamation in agriculture).

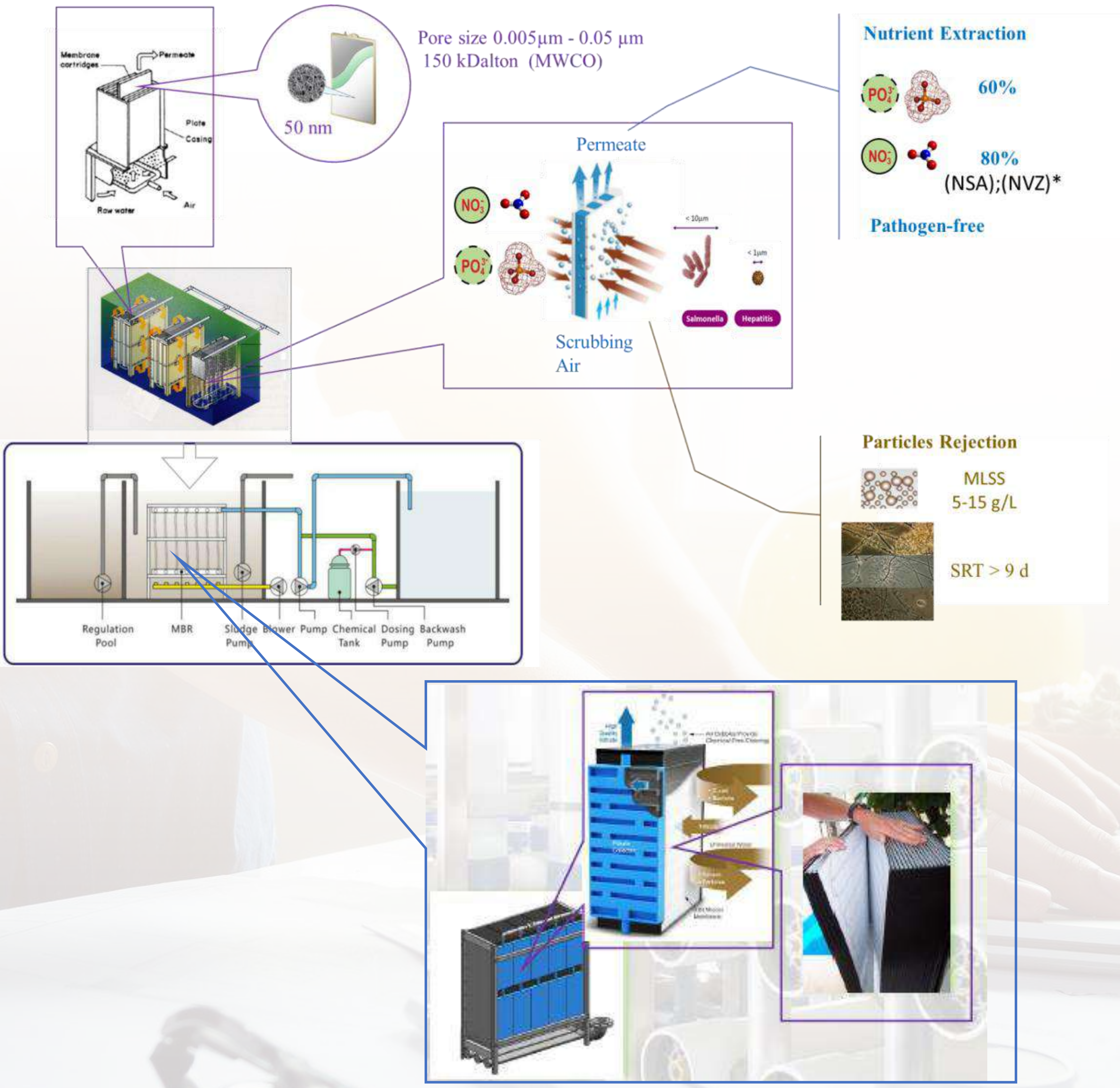


Figure 2: MBR system's functioning diagram
Denitrification required Nitrate Vulnerable Zone (NVZ) European Legislation limit of 50mg/L Nitrate (N).

2. Water Reclamation for Agriculture.

The RichWater system is based on a new groundbreaking system combining low-cost and energy efficient MBR treatment, a module for mixing the optimal fertigation water connected to the up-to-date irrigation technology and an advanced monitoring /control module including soil sensors to guarantee demand-driven and pathogen-free fertigation. Implementing the system in the agricultural production process results in a more eco-friendly use of water resources, cost savings for freshwater and fertilizer and the possibility for commercial food producer to adjust the fertigation unit for individual needs using a mixture of fresh and treated water. A low energy MBR has been designed for the wastewater treatment module in a way that the contained nutrients (mainly nitrogen and phosphorus) remain after the treatment whilst pathogens are removed. The mixing station mixes the appropriate proportion of freshwater and the treated wastewater coming from the MBR, which is then fed into the fertigation module (drip irrigation). The appropriate mixing level is determined by monitoring the level of nutrient content in the soil via sensors; this information is sent by remote control to the monitoring unit, which converts the signals to be read by the control unit. The control unit automatically adjusts the mixture inside the mixing module via valves according to the crop’s demand.

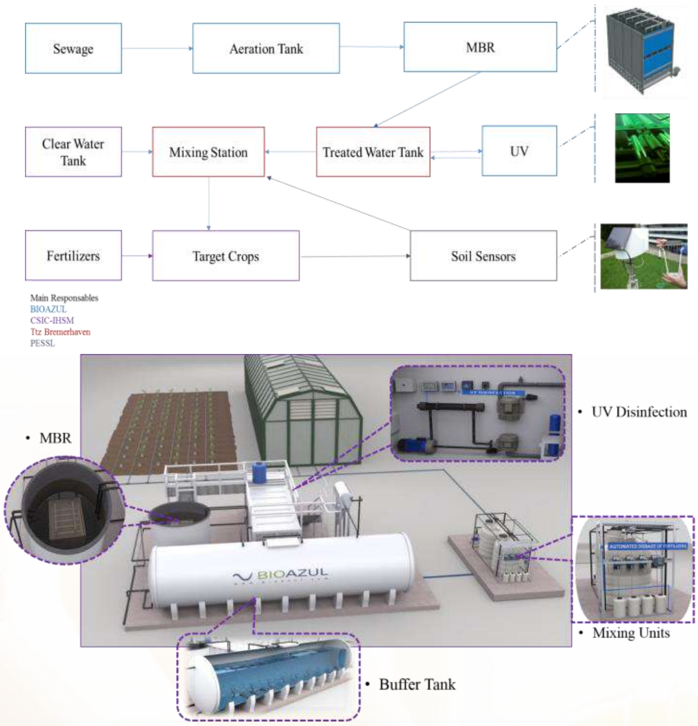


Figure 3 RichWater Modules for water reclamation in agriculture.

3. Further Reading

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SUWANU EUROPE

ttz Bremerhaven

2 **Fact Sheet 4.2 –** Sensors and other innovative tools for monitoring reclaimed water quality: facts and figures.

In the factsheet 4.2. different innovations to detect pathogens or the dissolved organic carbon are described. As for the pathogen measurement, the technology and application in water reclamation of flow cytometry is explained. The technology of flow cytometry is based on characterizing viable (active or inactive) cells. Regarding the dissolved organic carbon, the technology and the application of UV LED fluorescence sensor is explained. Furthermore, upcoming innovation is also discussed which improves pathogen detection. It requires no water treatment, no reagents, functionalization or sample pre-treatment, which makes it cheaper and really easy to handle while applying in water reclamation.

Sustainable **Water treatment** and Agricultural reuse options in Europe

Info-package 4
Water Engineering Companies

Fact Sheet 4.2 – **Sensors and other innovative tools for monitoring reclaimed water quality: facts and figures**

Filtration membranes and new filter materials → **Sensors and other innovative tools for monitoring reclaimed water quality** → Light-driven technologies for producing reclaimed water → Nature based options for water reclamation processes → Other technologies for water reclamation

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 4 aimed at water engineering companies, that describe different innovations to detect pathogens or the dissolved organic carbon. For the pathogen measurement, it will be discussed the flow cytometry, and for the dissolved organic carbon, it will be discussed an UV LED fluorescence sensor.

INTRODUCTION

1. Flow Cytometry

The majority of waterborne bacteria are non-cultivable and do not form colonies on available standard microbiological culture media. As a consequence, these bacteria are not picked up by cultivation-based detection methods. Among the cultivation-independent methods, flow cytometry is prominent due to its speed and reproducibility of results with different types of water. The determination of the bacterial concentrations can be performed within 15 minutes and is possible in an online format. Apart from pure quantification the technology allows the differentiation between intact (living bacteria) and membrane-compromised bacteria (dead/damaged).

2. UV Led Sensor

Continuous online monitoring of dissolver organic matter (DOM) is urgent for the future smart cost-effective control during water treatment. On the other hand, frequent monitoring for dissolved organic carbon (DOC) and toxic disinfection byproducts (DBP) is relatively expensive and time-consuming. As a result, many agencies are highlighting the need for surrogate monitoring of DOC and estimation of DBPs formation potential. Hence it is necessary to develop a kind of cheap, small, less energy consume but sensitive sensor, which can provide real-time feedback signals for automatic optimization of operation parameters and estimation of DBPs formation during water treatment. Spectral measurements including UV absorbance and fluorescence signals that are associated with bulk DOM, offer particularly promising solutions for frequent online monitoring.

3. Upcoming innovation

Despite all efforts to develop real-time monitoring systems, there is still a lack of robust, continuous, accurate and verifiable real time devices that demonstrate potential for large-scale implementation. Their widespread application has been limited due to an inability to reliably obtain accurate, cost-effective water quality data. On the other hand, the majority of online monitoring systems developed are direct adaptations of traditional, laboratory-based analytical methods not originally designed for field applications. Additionally, they are required to operate in extreme and variable environments whilst still obtaining accurate and reproducible results. Consequently, these methods require frequent calibration and maintenance and often consume large quantities of chemical reagents. In addition, the analysers often suffer from cross responses due to matrix variations between the standards and samples analysed, as the measurement conditions are not controlled. There are also significant economic and logistics costs associated with maintenance of remote equipment due to the difficulty to detect problems such as sensor fouling.

1. FLOW CYTOMETRY

1.1. Technology

The membrane integrity of a cell is a well-accepted criterion for characterizing viable (active or inactive) cells and distinguishing them from damaged and membrane-compromised cells. This information is of major importance in studies of the function of microbial assemblages in natural environments, in order to assign bulk activities measured by various methods to the very active cells that are effectively responsible for the observations. The principle of this approach is to use simultaneously a permeant (SYBR Green; Molecular Probes) and an impermeant (propidium iodide) probe and to take advantage of the energy transfer which occurs between them when both probes are staining nucleic acids. A full quenching of the permeant probe fluorescence by the impermeant probe will point to cells with a compromised membrane, a partial quenching will indicate cells with a slightly damaged membrane, and a lack of quenching will characterize intact membrane cells identified as viable.

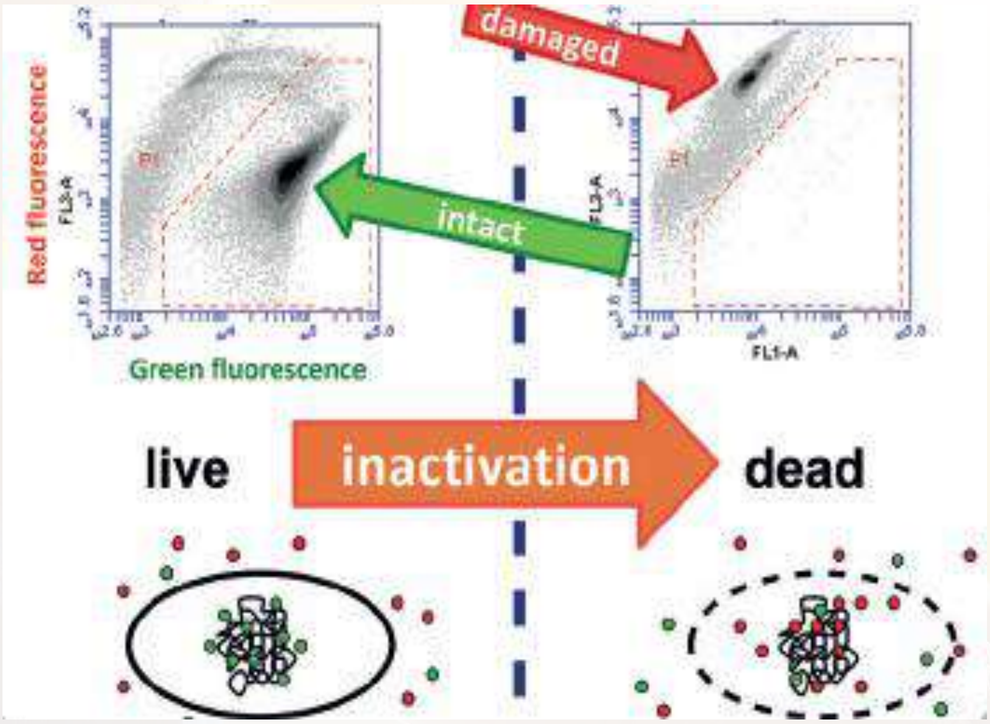

Figure 1: Exemplary flow cytometry density diagram of a bacterial suspension with living/ intact membrane cells (in red-dotted area), resp. with dead damaged membrane cells (outside of the dotted area) after colouration with two dyes

1.2. Application in Water Reclamation

As for other water types, flow cytometry offers fast and reliable determination of bacterial cell numbers in the field of monitoring water reclamation processes. Based on the fact that the detection isn't based on the cultivation of the bacteria, the entire bacterial population in the water is measured independent of their growth requirements. While traditional hygienic indicator bacteria such as coliforms, intestinal enterococci or *Clostridium perfringens* are typically not detectable after membrane filtration and total colony counts are only available after 2–3 days, flow cytometry offers a sound data base for the microbiological assessment of the efficiency of different water treatment steps. The method is compatible with the 'Hazard analysis and critical control points' (HACCP) concept as the rapid detection of changes in the microbiology provides a good basis for process control decisions.

2. LED UV FLUORESCENCE SENSOR

2.1. Technology

The LED sensor, which measures the UV280 absorbance, protein-like and humic-like fluorescence simultaneously, is feasible to monitor chromophores and fluorophores with good sensitivity and accuracy. The liquid chromatography with organic carbon detector combined with 2D synchronous correlation analysis further demonstrated how the DOM components of large molecular weight were transformed into small moieties as a function of the decrease of humic-like fluorescence. High performance size exclusion chromatography with multi-UV absorbance and multi-emission fluorescence scans are applied to spectrally characterize samples.

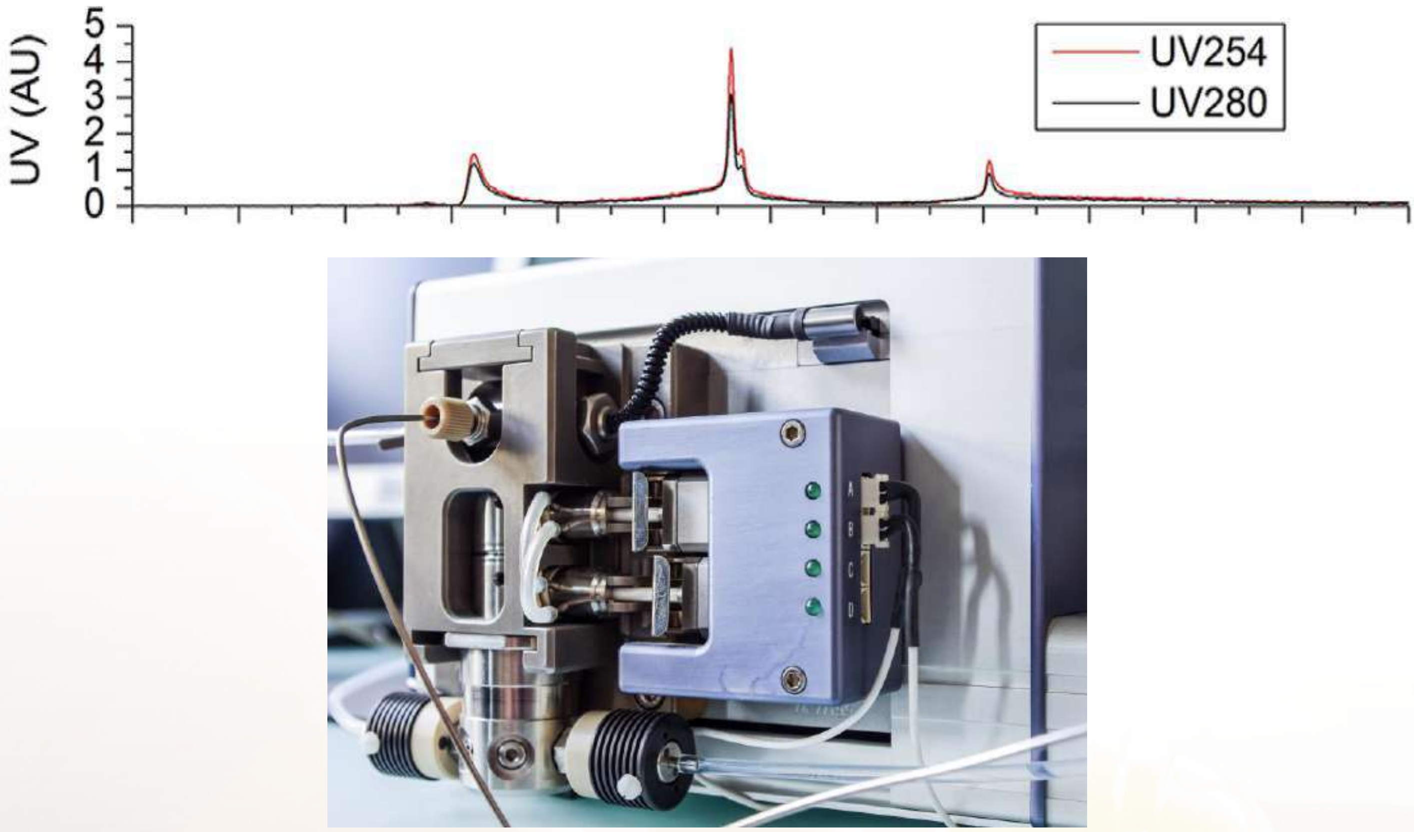

Figure 2: Picture of a spectrophotometer with a diagram showing the peaks measured at UV254 and UV280

2.2. Application in Water Reclamation

Chlorination is the most widely used disinfection practice during water treatment, because it is effective against most pathogens and provides residual disinfecting capacity. However, toxic disinfection byproducts (DBPs) unavoidably form due to reactions between chlorine and natural organic matter (NOM), which has caused serious public health concerns. Many studies suggest that DBPs are cytotoxic and genotoxic, and chronic exposure to DBPs is associated with bladder and colon cancer in humans. Being able to detect this products with LED UV fluorescence sensor, could reduce the concentration of these products at the of the treatment.

3. UPCOMING INNOVATION

3.1. Technology

For the particular case of pathogen detection in water there is a promising perspective for photonic sensors that improve biological detection taking advantage of the natural fluorescence property of some bacteria, such as *Escherichia coli*. The pathogen sensor proposed by AIMEN aims to detect natural bacteria fluorescence in real water sample in in situ measurements. A thorough study with real water samples will make the difference with the existing state of the art in this field. This sensor will not give an accurate *E. coli* quantification, but will perform a monitoring that can stablish an estimation of pathogen presence. This has to be understood as an early alarm system, that would imply the need of further lab analysis to confirm the presence and CFU of pathogens in the water. It is also not very specific, but it requires no water treatment, no reagents, functionalization or sample pre treatment, which makes it cheaper and really easy to handle.

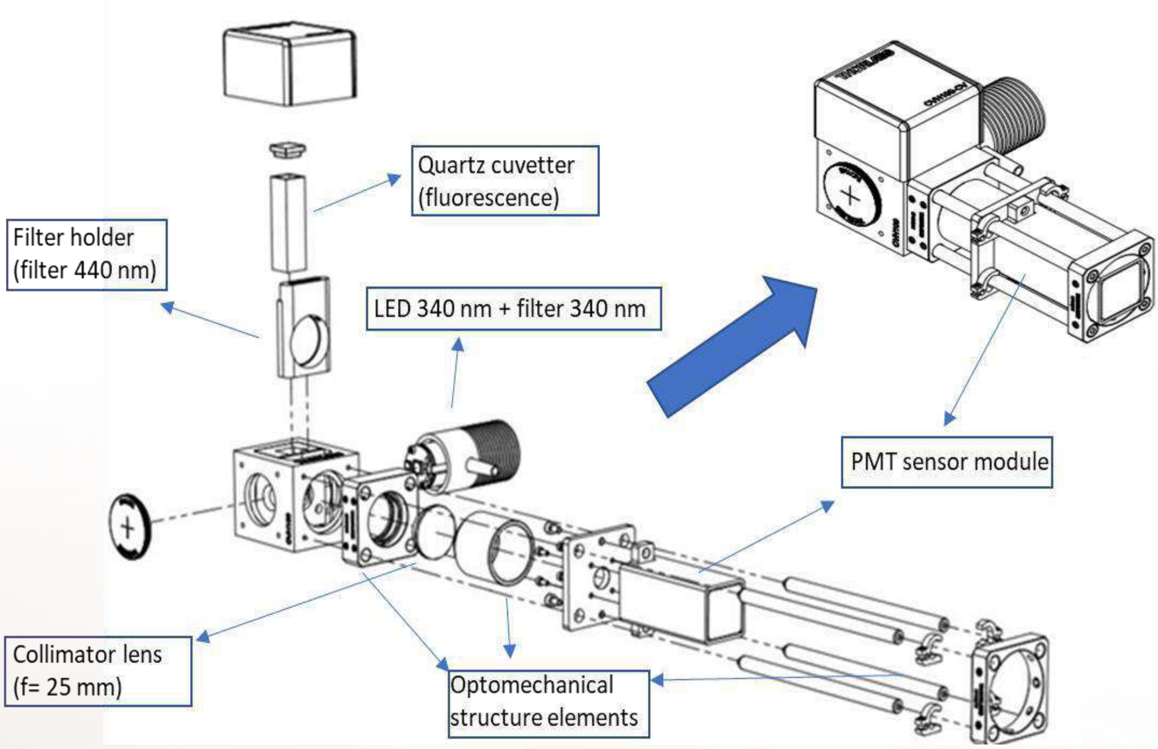

Figure 3: PMT sensor setup suggested by AIMEN for fluorescence measurements of *E. Coli*

3.2. Application in Water Reclamation

There have been some sensors developed to directly measure natural fluorescence of these bacteria in real conditions without sample treatment and using water circulation systems to reproduce an in-line water monitoring solution. However, there is no report of any of these sensors being used in real sites or monitoring water real samples from water treatment plants. But with the pathogen sensor proposed by AIMEN, this sensor would be an in-line real time monitoring arrangement, continuously measuring fluorescence emission in a bypass in the water treatment plant. If the sensor works properly, it will be a breakthrough in monitoring real water samples outside lab conditions without sample treatment, reagent addition or expensive devices.

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3 **Fact Sheet 4.3 –** Light-driven technologies for producing reclaimed water.

The factsheet 4.3. describes the UV disinfection systems, which are one of the most common and most effective technologies for water and wastewater disinfection. The process of how the UV disinfection works is described, as well as effectiveness of the UV disinfection system which depends on multiple characteristics. Technical specifications of the UV disinfection system and the main components of the system are introduced. The optimum wavelength to effectively inactive microorganisms is explained. Furthermore, the differences between the sources of UV radiation- low pressure (LP) or medium pressure (MP) mercury arc lamps are made clear. UV lamp maintenance is described as well as the advantages of Ultra Violet Light Emitting Diodes (UV-LEDs), the use of which could be exploited for improvement of treatment efficiency.

Sustainable **Water treatment** and
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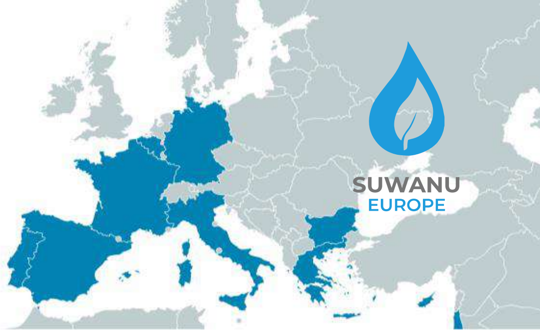

Info-package 4
Water Engineering Companies

Fact Sheet 4.3 – Light-driven technologies for producing reclaimed water

Filtration membranes and new filter materials → Sensors and other innovative tools for monitoring reclaimed water quality → **Light-driven technologies for producing reclaimed water** → Nature based options for water reclamation processes → Other technologies for water reclamation

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 4 aimed at water engineering companies, that describe different reclamation technologies able to provide a treated effluent that complies with the standards for irrigation in agriculture.

1. Introduction

Ultraviolet (UV) light is a form of electromagnetic radiation invisible to the human eye. UV electromagnetic spectrum is between X-rays and visible light. Within the range of wavelengths between 200 and 300 nanometers, UV light has germicidal properties, meaning it is capable of inactivating microorganisms, such as bacteria, viruses and protozoa.

UV disinfection systems are one of the most common and most effective technologies for water and wastewater disinfection. A significant body of scientific research has proven UV light's ability to inactivate an extensive list of pathogenic bacteria, viruses and protozoa. Moreover, water can be disinfected and treated with UV light without the addition of supplemental chemicals. And the special advantage: pathogens cannot build to resistance to UV light.

UV disinfection is based on a physical process that instantly neutralizes microorganisms as they pass by ultraviolet lamps submerged in the effluent (liquid). UV light inactivates cells by damaging their nucleic acid (DNA and RNA), thus preventing the replication of microorganisms. When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce. The process adds no chemicals to the water and therefore, has no impact on the chemical composition or the dissolved oxygen content of the water.

However, the damage of nucleic acid does not prevent the cell from experiencing metabolism and other cell functions. Some of the damages of the UV light may be repaired by enzyme mechanisms within the cell; therefore, microorganisms can repair themselves and become infectious again after the UV light treatment. Consequently, the UV treatment has to provide enough dosage of UV light to ensure that nucleic acid is damaged beyond the stage where it can be repaired.

The effectiveness of a UV disinfection system depends on the characteristics of the wastewater, the intensity of the UV radiation, the amount of time the microorganisms are exposed to the radiation and the reactor configuration. Disinfection success is also directly related to the concentration of colloidal and particulate constituents in the wastewater. Colloids and other molecules may absorb part of the UV light reducing the exposure of microorganisms to germicidal UV light. Therefore, water quality entering the UV system plays a significant role in the disinfection performance.

The adoption of ultraviolet light for wastewater disinfection has grown significantly over the past few decades. Thousands of municipalities have converted from chemical-based disinfection, such as chlorine gas, to UV due to the significant safety advantages for their communities, plant employees and local water bodies.

2. Technical specifications

The main components of a UV disinfection system are a reactor, mercury arc lamps and a control box. The optimum wavelength to effectively inactive microorganisms is within the range of 250 to 270 nm (UV-C). The intensity of the radiation emitted by the lamp dissipates with the distance to the lamp.

The source of UV radiation is either a low pressure (LP) or medium pressure (MP) mercury arc lamp with low or high intensities. LP lamps work with approximately 0.01 mbar (1 Pa) and MP lamps with higher than 1 bar (100 kPa). MP UV lamps are generally used for large facilities. They have approximately 15 to 20 times the germicidal UV intensity of low pressure lamps. The MP UV lamp disinfects faster and has greater penetration capability due to its high intensity. However, these lamps operate at higher temperatures with higher energy consumption than LP UV lamps.

3. UV lamps maintenance

Since UV radiation must reach the bacteria to inactivate them, the housing for the light source must be kept clean. Commercial products are available for rinsing the unit to remove any film on the light source. An overnight cleaning with a solution of 0.15 percent sodium hydrosulfite or citric acid effectively removes such films. Some units have wipers to aid the cleaning process.

4. Ultra Violet Light Emitting Diodes (UV-LEDs)

Light-emitting diodes (LEDs) differ from conventional lamps because they are built with semiconductor materials such as silicon or sapphire. Latest improvements in semiconductor technology have made ultraviolet UV-LEDs a viable alternative to conventional UV systems. UV-LEDs have longer life, are less fragile, and are free of toxic components such as mercury. One of their advantages is the ability to generate UV radiation at specific wavelengths which could be exploited to improve treatment efficiency by designing treatment systems for specific applications. Moreover, high-power-density UV LEDs and advanced controls allow for a much smaller footprint compared to traditional UV systems. However, UV LEDs present higher initial cost compared to mercury vapour lamps and relatively costly materials, including nanoceramics and aluminium nitride which must be used on the circuit board to provide the necessary thermal conductivity

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4 **Fact Sheet 4.4 –**Nature based options for water reclamation processes.

Nature-based solutions (NBS) are defined as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience”. The benefits of using Nature-based solutions and the effectiveness of such solutions are presented. The examples of NBS for water reclamation are given and include constructed wetlands, reed beds, green roofs and sustainable urban drainage systems (SUDS). All the exampled mentioned are described, as well as their usage for different water treatments. The factsheet describes the effectiveness for removal of total suspended solids, biological oxygen demand and chemical oxygen demand, also with regards to the removal of nutrients for each of the mentioned examples.

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Fact Sheet 4.4 – **Nature based options for water reclamation processes**

Filtration membranes and new filter materials | Sensors and other innovative tools for monitoring reclaimed water quality | Light-driven technologies for producing reclaimed water | **Nature based options for water reclamation processes** | Other technologies for water reclamation

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 4 aimed at water engineering companies, that describe different reclamation technologies able to provide a treated effluent that complies with the standards for irrigation in agriculture.

1. Introduction:

As stated by the European Commission, nature-based solutions (NBS) are defined as *"solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience"*[1]. While mitigating climate change effects or increasing biodiversity are some of their most common benefits, there exist certain NBS contributing to water management and security. In this sense, NBS are recognized for holding a great potential as water treatment and reuse systems[2]. The effectiveness of such solutions will depend on the technology selected, the quantity and quality of water to be treated, and the local conditions (e.g. climate, precipitation patterns, etc.). Examples of NBS for water reclamation include constructed wetlands, reed beds, green roofs or sustainable urban drainage systems (SUDS).

2. Constructed wetlands:

Constructed wetlands (CW) are probably the most common NBS for water treatment and reuse. They consist of a large gravel and sand-filled basin that is planted with wetland vegetation. As water flows through the basin, the filter material filters out particles and microorganisms degrade the organics. This solution can be used for rainwater treatment, combined sewer overflow treatment, greywater treatment, and polishing of outflow from existing wastewater treatment plants (i.e. advanced treatment after secondary or tertiary treatment). CW can remove up to 88% of TSS (total suspended solids), 92% of BOD (biological oxygen demand) and 83% COD (chemical oxygen demand) even after more than 20 years of operation. With regards to nutrients, it is estimated that 46-90% of TP (total phosphorus) and 16-84% of TN (total nitrogen) could be removed, depending on the system selected2. It is also reported that CW can remove organic and inorganic pollutants such as pesticides, heavy metals and CEC (contaminants of emerging concern). The effectiveness of CW to remove various pharmaceuticals has also been demonstrated in Ukraine, as well as by other studies at pilot scale[3]. The removal pathways are the uptake by plants, microbial degradation, adsorption and subsequent sedimentation, and also photodegradation. Some of the most common CW systems are: free-water surface CW, horizontal subsurface flow CW and vertical flow CW[4].

Provided the CW is well designed and maintained, the resulting treated water can be suitable for reuse applications. The Spanish Centre for New Water Technologies (CENTA) has wide experience in R+D and innovation applied to CW as solutions for water reclamation[5].

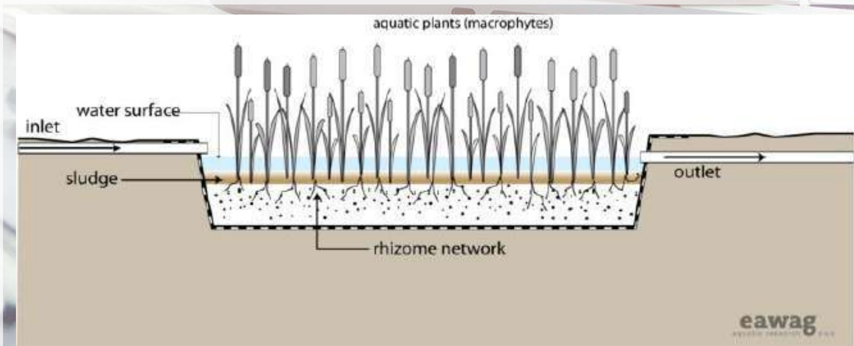

Figure 1: Free-water surface constructed wetland

Figure 2: Reed bed

3. Reed beds:

These aquatic plant-based systems allow bacteria, fungi and algae to digest organic matter present in wastewater. The effluent percolates through the layers of sand and gravel in an enclosed bed which operates aerobically to break down pollutants, including turning toxic ammonia into nitrates.

A horizontal flow bed would follow a vertical one and operate anaerobically – turning nitrates to nitrogen gas. Additional treatment stages, such as willow bed, could provide additional treatment and improve the quality at the final outlet[6]. Studies show that the removal efficiency of contaminants like TSS, TDS, BOD, COD, etc. varies with the type of aquatic plants used[7]. Reed beds are therefore considered as an effective and reliable secondary and tertiary treatment method where land area is not a major constraint, offering an interesting opportunity for water reuse.

4. Green roofs:

Green roofs can yield positive results in terms of water availability and quality[3]. This system enables rainfall infiltration and helps slow stormwater runoff reducing the rate at which water reaches the drainage system. Up to 75% of the stormwater they receive can be retained on average[8]. When combined with tanks for collection of rainwater harvested, the reuse of water for irrigation or toilet flushing is possible. Green roofs are also being explored as greywater treatment solutions to minimise the treatment footprint and usage of land[9]. These natural treatment technologies require reduced capital and operational costs, but further research should consider the feasibility for greywater treatment and recycling[10].

Figure 3: Green roof

5. Sustainable Urban Drainage Systems (SUDS):

Figure 4: SUDS

SUDS are drainage systems holding rainwater back while treating pollution and releasing the effluent slowly, without overwhelming the watercourse or sewer systems[11]. SUDS can effectively remove TSS, NH_4^+-N and COD when combined with grassed swales, but the removal rate is related with the hydraulic retention time and adsorption capability of plant roots. An innovative and smart framework[12] was developed to combine permeable pavements, allowing water to infiltrate into the ground, with “smart” cisterns for rainwater harvesting, whereas an intelligent flood monitoring system using stream/river monitoring cameras provides real-time images of water revel. This innovative approach allows municipalities to reuse water in agricultural and landscape irrigation.

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5 **Fact Sheet 4.5 –** Other technologies for water reclamation.

Advanced treatment technologies are reviewed, which can be applied to reach superior reclaimed water quality suitable for unrestricted irrigation and the removal of additional pollutants which are not typically removed during conventional wastewater treatment.

Managed Aquifer Recharge (MAR) is the intentional recharge of different types of water to convenient aquifers for subsequent recovery or to achieve environmental benefits. One of the methods is the Soil Aquifer Treatment (SAT) which uses natural water resources for effluent reclamation. The process within the Soil Aquifer Treatment are explained, together with their removal of pathogens, organic matter, and other undesirable compounds.

Advanced Oxidation Processes and their removal of Trace Organic Chemicals, which are not fully transformed or removed by traditional reclamation methods are introduced and explained. The necessity of using this kind of treatments is explained along with the several different Advanced Oxidation Process technologies.

Lastly, the process and the use of Biologically Active Filtration is explained, together with the combination of the usage along with other treatment solutions.

Sustainable **Water treatment** and Agricultural reuse options in Europe

Info-package 4
Water Engineering Companies
Fact Sheet 4.5 – Other technologies for water reclamation

Filtration membranes and new filter materials → Sensors and other innovative tools for monitoring reclaimed water quality → Light-driven technologies for producing reclaimed water → Nature based options for water reclamation processes → **Other technologies for water reclamation**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 4 aimed at water engineering companies, that describe different reclamation technologies able to provide a treated effluent that complies with the standards for irrigation in agriculture.

1. Introduction

Water reclamation for irrigation can be practiced for a variety of agricultural needs, each requiring different water quality. Diverse types of technologies can be combined to reach the desired water quality, the highest quality goal being seen as an equivalent to the use of potable water. To allow reclamation for irrigation purposes several water quality goals must be reached simultaneously, including salinity, turbidity, pH, nutrient load and pathogen removal. Nowadays there is an increasing demand for the removal of additional pollutants which are not typically removed during conventional wastewater treatment such as pharmaceuticals, personal care products, pesticides, herbicides and hormones. This section will review advanced treatment technologies which can be applied to reach superior reclaimed water quality suitable for unrestricted irrigation and better.

2. MAR and SAT

Figure 2 - Soil Aquifer Treatment

Managed Aquifer Recharge (MAR) is the intentional recharge of different types of water to convenient aquifers for subsequent recovery or to achieve environmental benefits. One of the methods is the Soil Aquifer Treatment (SAT) which uses natural water resources for effluent reclamation. Aquifers are subterranean soil layers that can contain and convey water. In SAT, effluent is spread over dedicated basins where they can infiltrate to the underlying aquifer. During the infiltration, often practiced in areas with thick sand/sandstone soil layers, treated wastewater pass through the upper layers of the soil where changing oxidation conditions provide a wide range of physical-chemical and biological processes. This process significantly improves the quality of the effluent by removing pathogens, organic matter, and other undesirable compounds. producing reclaimed water of very high quality that meet the requirements for unrestricted irrigation and in some cases, also most of the requirements set for drinking water. The region of the aquifer receiving the infiltrated effluents then becomes a seasonal and multi-year storage basin for large quantities of reclaimed effluent ready for reuse, unaffected by short term changes to effluent quality or system malfunctions. The long-term storage and infiltration process also provide a superior natural means for pathogen removal, assuring the safety of the reclaimed effluent (Sharma and Kennedy 2017; Sprenger et al., 2017).

3. Advanced Oxidation Processes

Trace Organic Chemicals (TOrCs), such as pharmaceuticals and personal care products, are not fully transformed or removed by traditional reclamation methods. Increasing demand for their removal from irrigation water and before discharging effluents to natural streams calls for the use of advanced treatment methods that use oxidation to break down TOrCs (for more information on TOrCs see FS 3.1).

Advanced Oxidation Processes (AOP) typically apply the use of highly reactive molecules or radicals which are unstable, with a half life in water of only a few seconds to a few minutes and must therefore be generated on site. These unstable molecules/radicals can readily react with certain functional groups on organic molecules and facilitate their mineralization to CO_2 and H_2O. Many other organic chemicals that are not fully mineralized by AOP can still be partially degraded structures that are often more biologically available, making them more susceptible to biodegradation.

There are several AOP technologies, including ozonation, UV/H_2O_2, photocatalysis, Fenton reactions and others that are still being developed (Alharbi and Price, 2017).

Figure 3 - ozonator at the Shafdan WWTP R&D center

4. Biologically Active Filtration

This process provides and engineered solution which mimics many of the aspects provided by SAT: effluent slowly percolates through filtration media in a process that allows both mechanical filtration and biodegradation of organic matter by bacteria launched on the filtration media. Typical filtration media are either anthracite or Biologically Active Carbon (BAC), both of which provide a large surface area for bacteria growth. One of the common uses for biologically activated filtration is after AOP (typically ozone), to allow biodegradation (complete mineralization) of molecules that were transformed during ozonation. The combination of ozonation and BAC filtration is now mandated in Switzerland before discharging effluent to streams for downstream reuse for both potable and irrigation purposes. Biologically active filtration can also be used as a pre-treatment to ozonation and other advanced treatments, when additional filtration/nitrification/ biological degradation of organic matter is needed before entering the advanced treatment stage (Hellauer et al., 2017; Lakretz et al., 2017).

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Info-package 5: Consumers and general public

1 Fact Sheet 5.1 – Environmental benefits of irrigation with reclaimed water: facts and figures.

The factsheet goes in detail about the water use and water demand globally, accompanied with relevant facts and figures. Water use in agriculture, specifically its waste is discussed in detail as well as the methods and techniques which can be used to reduce the water consumption in agriculture. Furthermore, the impacts on the use of reclaimed water in agriculture are discussed, especially various environmental, health and energy benefits. More specifically, the benefits linked to the use of reclaimed water in agriculture and verified on farms are presented, as well as the risks related to the reclaimed water use.

Sustainable **Water treatment** and
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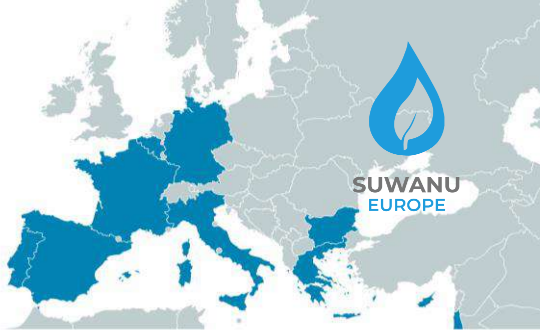


Info-package 5
Consumers and General Public

Fact Sheet 5.1 – **Environmental benefits of irrigation with reclaimed water: facts and figures**

Environmental benefits of irrigation with reclaimed water | Organoleptic studies of agricultural products irrigated with reclaimed water | Public perception and consumer acceptance | AKIS & Stakeholders analysis | Communicating the use of reclaimed water

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 5 aimed at consumers and general public, to describe the environmental benefits of irrigation with reclaimed water.

1. Introduction:

There are environmental and climate challenges of increasing importance worldwide, that are interconnected with our main systems of production and consumption, and that have put us in a trajectory of unsustainable use of our natural resources. Global population growth (expected to reach 10 billion by 2050) will continue to put pressure on resources, with water demand increasing 55% by 2050. Climate change is also contributing for the ever-bigger challenge of having water in sufficient quantity and quality for all.

2. Water for agricultural irrigation:

Global freshwater withdrawals is estimated at 3,928 km^3 per year (AQUASTAT, 2017), and it is predicted that this demand will increase significantly over the coming decades. Of this consumption, on average, agriculture alone uses about 70%, whereas sectors such as industry uses 22% and domestic and trade only 8%.

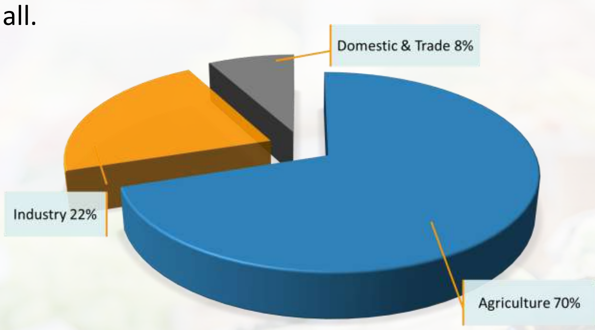
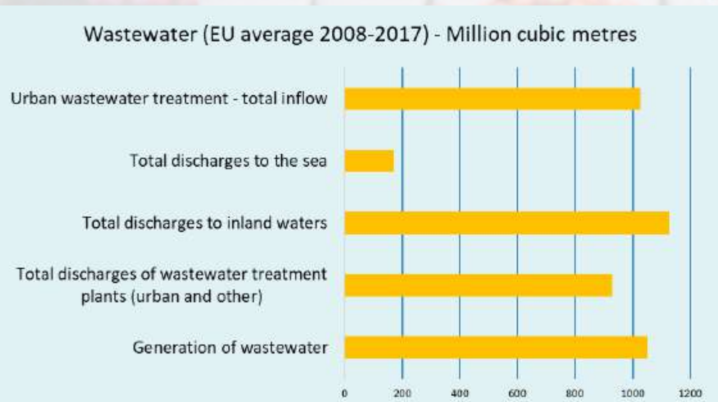


Figure 1: Average Water Consumption



According to FAO, almost half of the water used for agricultural purposes is wasted. If agricultural activities reduced water consumption by 10%, this volume would be enough to supply twice the world's population. One way to reduce water consumption in agriculture is the adoption of more localized irrigation techniques (drip irrigation or micro sprinkler) that save water. But not all agricultural activities allow the use of these techniques. On the other hand more than 40,000 million m^3 of wastewater is treated in EU every year and only 964 million m^3 are reused, so there is a potential for further uptake this valuable resource.

3. Impacts on the use of reclaimed water in agriculture:

Reclaimed water is gaining an increasing role as a reliable alternative source of water, pushing from 'treatment and disposal' to 'reuse, recycle and resource recovery'. There are also other by-products that can be used such as nutrients, leading to decreasing in costs for the agricultural sector.

The impacts of using reclaimed water can go beyond those at farm level and environmental health, having implications on food and energy security as well as climate change mitigation.

This will lead to a reduction in freshwater abstractions for agriculture, making this resource available for other uses, such as direct human consumption. The use of reclaimed water will also prevent the discharge of wastewater to water bodies.

The treatment of wastewater to an acceptable standard for the use that is intended (i.e. 'fit-for-purpose' treatment), will prevent unnecessary costs of overtreating the water (Figure 3).

Figure 2: Example of a sign used in a farm

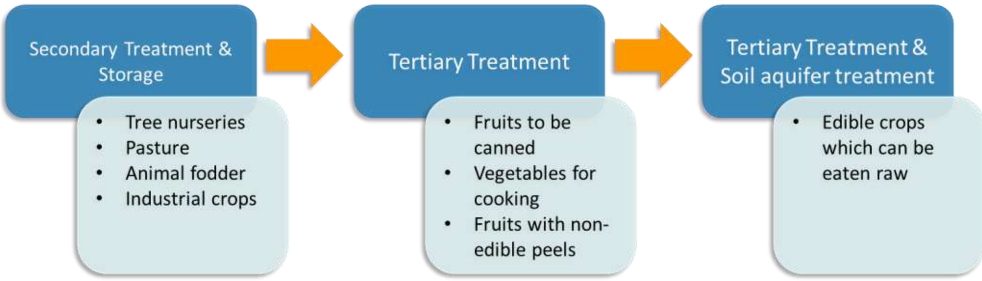


Figure 3: 'Fit-for-purpose' treatment

4. Benefits and risks:

There are several benefits linked to the use of reclaimed water in agriculture mentioned in studies and verified on farms using this resource:

- Reclaimed water irrigation improves soil nutrient conditions;
- Reclaimed water irrigation improves significantly soil microorganism activities;
- Minimum or inexistent costs for the wastewater.

Salts, nitrogen and pathogens are the major risk sources for using reclaimed water in agricultural irrigation, while risks associated with heavy metals and emerging contaminants are low. Other risks could be the eutrophication, groundwater contamination, antibiotics or even odor, but, given the huge potential benefits, the risks can be controlled by proper field management. These facts must not neglect that irrigation with reclaimed water should face more stringent quality requirements in order to minimize risks.

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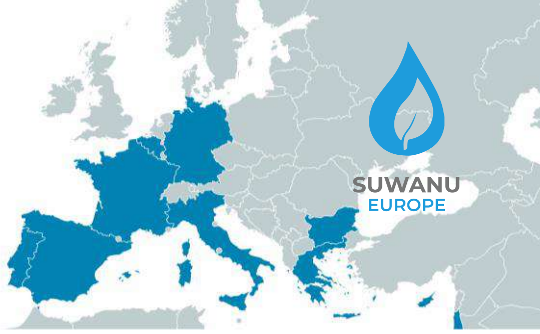
2 **Fact Sheet 5.2 –** Organoleptic studies of agricultural products irrigated with reclaimed water.

Factsheet summarizes the findings related to the impact of reclaimed water use on the organoleptic properties of agricultural products (sight, smell, taste, or touch). Different studies conducted on different agricultural products are discussed. Such as the study done on irrigation of olive trees with both rainfed water and reclaimed water comparing the differences of olives and olive oil in both cases. Furthermore, the study done on irrigated vineyards with reclaimed water with regards to the positive or negative effects on grapes and wine is reviewed. Lastly, the studies done on the use of reclaimed water on other crops and their organoleptic quality are discussed and the necessary recommendations are made.

Sustainable **Water treatment** and
Agricultural reuse options in Europe



Info-package 5
Consumers and General Public

Fact Sheet 5.2 – **Organoleptic studies of agricultural products irrigated with reclaimed water.**

Environmental benefits of irrigation with reclaimed water | **Organoleptic studies of agricultural products irrigated with reclaimed water** | Public perception and consumer acceptance | AKIS & Stakeholders analysis | Communicating the use of reclaimed water

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 5 aimed at consumers and general public, that describe important aspect of consumer perception of agricultural product that are irrigated with reclaimed water.

1. Introduction:
Consumers are very sensitive to anything related to food, especially what they give to their children. This is also one of the reasons why you are wary of the food put on the table. When choosing one or another agricultural product, despite the trademark, one relies on his or her own perceptions – sight, smell, taste, touch. These perceptions are known as the organoleptic properties of the agricultural product concerned and are particular senses for each person. The use of reclaimed water (RW) for irrigation in agriculture is part of the measures to adapt to climate change, water scarcity and drought. Some of the consumers are worried about the influence of irrigation with RW on the organoleptic properties of the agricultural product. To avoid any doubt about existence of additional changes in organoleptic properties among other reasons, European Parliament and the Council accepted the EC proposition concerning minimum requirements for water reuse, where the quality standards for irrigation water in relation to the corresponding class and type of crops are defined [1]. This Factsheet summarizes some of the findings known so far about the organoleptic studies of agricultural products irrigated with RW.

2. Irrigation of olive trees:
Different studies have been conducted to investigate the effect of irrigation with RW on organoleptic properties of olives and olive oil. In one of the studies with olive trees [2] comparing products from rainfed trees and irrigated with RW no significant differences were found in the fruity attribute within treatments. In addition, the bitter and pungent attributes were more pronounced in olive oil obtained from rainfed trees as compared to that obtained from irrigated trees (RW or fresh water), suggesting relation with higher water quantities used for the irrigations. No pathogenic microorganisms nor heavy metals were detected in the oil samples tested. In that sense, no negative characteristics were found in oil obtained from the irrigated with fresh water, reclaimed water or rainfed trees and they all were all classified as *extra virgin grade*.

Although the EU regulations do not require analysis of pigmentation of olives, the color is one of the basic attributes for determination of olive oil characteristics. There are contradictory results in terms of chlorophyll, carotenoid, polyphenol levels and the free acidity, as consumers associate them with product quality. In some cases the irrigation with RW resulted in higher fruit yield, but oil yield was not increased [3,4].

The use of appropriate management practices may exhibit RW use potential to support olive oil production and to decrease the water stress produced by the scarcity and droughts.

3. Irrigation of vineyards:

Several studies confirmed that vinery RW use for irrigation of vineyards had minimal or none impact on the winemaking, while the grapes may show lower concentrations of total phenolics, which in the finished wines would not be expected to lead to quality differences. The impact of RW on grapes or even wine could also be influenced by many factors such as the type of source of RW (Table 1), elemental content, soil type and structure, cultivar, rootstock and many others.

The researchers recommended more strict wastewater (WW) treatment for the irrigation of young grapevines as an alternative water source secured protection of environment, plant health and fruit quality [5].

Table 1: Positive or negative effect of irrigation with secondary or tertiary treated RW on some characteristics, in comparison with tap-water.

	Secondary treated WW	Tertiary treated WW
Fruit color	X	✓
Plant growth	✓	✓
Pathogens	X	✓
Heavy metals	✓	✓

4. Irrigation of other crops:

In general, there is little evidence about the effect of RW irrigation on the organoleptic quality of vegetables. Most of the papers discussed the effect of RW on nutrient content, presence or absence of toxic elements or pathogens. In some studies we can only draw indirect conclusions about the appearance or color of vegetables as a consequences of the authors' results about the size of the fruit or the amount of yield from a crop. In some cases, is suggested that high salinity of RW (above 2 dS/m) may lead to enhance acidity flavor of tomato fruits [6].

Although the feasibility of using RW is demonstrated it has to be performed with appropriate management, because of the evidences of decrease in fruit load, fruit size, yield and water productivity of citrus [7,8], that may conduct to changes in taste and visual perceptions.

The organoleptic properties are not included in the adopted "Proposal for a Regulation of the European Parliament and of the Council on minimum requirements for water reuse" [1] as a parameter that should be observed. Nevertheless, they are very important in order to present the agricultural product on the market and should be taken into account to ensure sustainability of product yields and quality.

Reference/further readings

[1] Regulation of the EU Parliament and of the Council on minimum requirements for water reuse, 2018; [2] Ayoub et al. 2013 J Agric Sci Technol A 3: 105-112; [3] Romero-Trigueros et al. 2019 Front Plant Sci 10: 1243; [4] Bedbabis et al. 2015 Agric Water Manag 160: 14-21; [5] Petousi et al. 2019 Sci Total Environ 658: 485–492; [6] Cuertero J & Fernández-Muñoz R, 1998 Sci Horticult 78: 83-125; [7] Nicolás et al. 2016 Agric Water Manag 166: 1-8; [8] Romero-Trigueros et al. 2020 J Sci Food Agric 100: 1350-1357.

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3 **Fact Sheet 5.3 –** Public perception and consumer acceptance of agricultural products irrigated with reclaimed water.

The factsheet presents the most relevant elements linked to public's acceptance in water reuse in agriculture and provides useful tips to build a positive relation with the community. The key elements and factors influencing the public perception are summarized. The review of past reclamation projects, both successful and failed, provide an insight to the key points to be considered in order to gain the communities trust and support. The recommendations are made to achieve a long lasting and fruitful relationship between the community, the public authorities and the stakeholders involved in the project.

Sustainable **Water treatment** and
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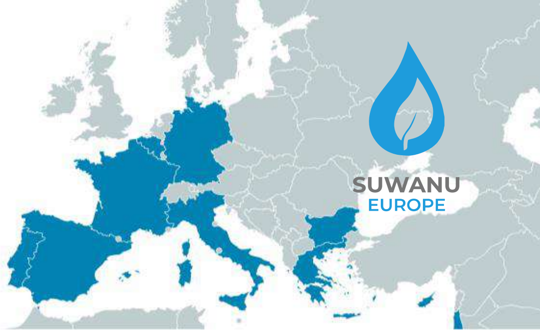


Info-package 5
Consumers and General Public

Fact Sheet 5.3 – **Public perception and consumer acceptance of agricultural products irrigated with reclaimed water**

Environmental benefits of irrigation with reclaimed water → Organoleptic studies of agricultural products irrigated with reclaimed water → **Public perception and consumer acceptance** → AKIS & Stakeholders analysis → Communicating the use of reclaimed water

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 5 aimed at consumers and general public, that focuses on public perception's relevance in the use of reclaimed water in agriculture, analyzing the main factors influencing it and the public outreach strategies that can be implemented to build a positive response to this type of projects.

1. Introduction

Reclaimed water has been used in the past 50 years around the world for diverse purposes, from non-potable to drinking water. The experience of these projects shows that public acceptance is a key element to ensure the success of the initiatives. Moreover, many failed projects have demonstrated that a negative public perception can frustrate a technically well-developed project. Thus, this fact sheet presents the most relevant elements linked to public's acceptance in water reuse in agriculture and provides useful tips to build a positive relation with the community.

2. Factors influencing public perception

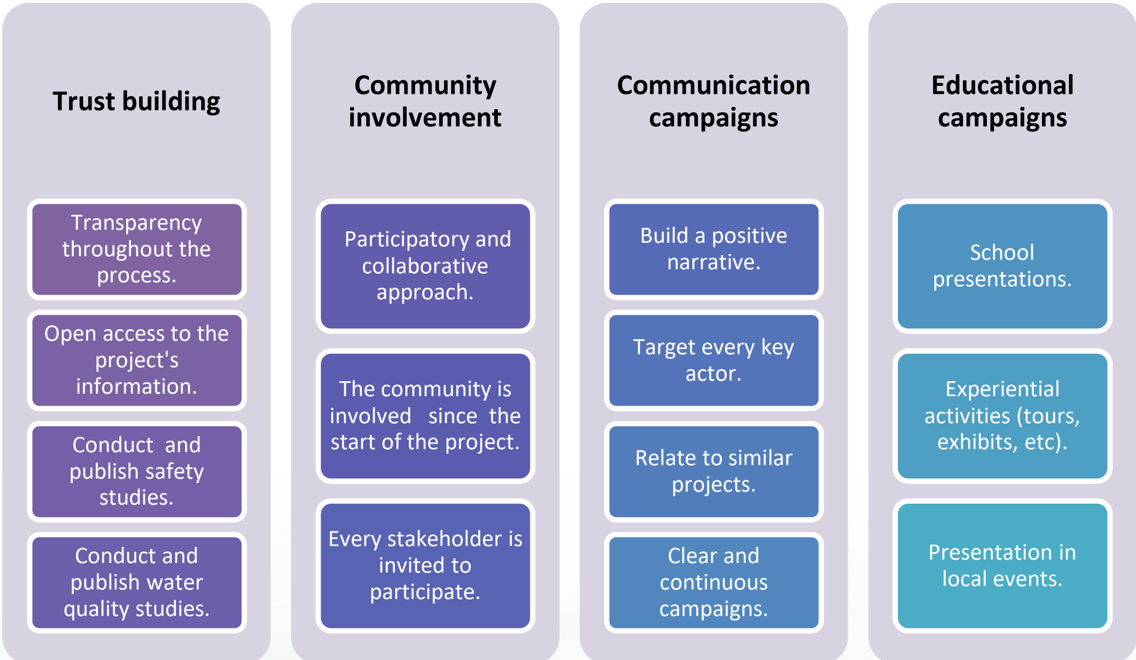
The existing research provides a general picture of the key elements involved in public perception. They are interrelated and can vary considerable in every context. The table below summarizes the main factors.

Factor	Characteristics	Response from the policy makers
Yuck Factor	Psychological barrier produced by the repulsion /disgust emotion related to the source of the water. Difficulty to separate the source (treated wastewater) to the final product (reclaimed water).	Create a positive narrative, avoiding the reference to wastewater.
Risk concerns	Public health concerns, especially with children's consumption of crops irrigated with reclaimed water. Fear of the potential long time unknown effects.	Carry out safety studies on reclaimed water with prestigious and recognized organizations (scientific institutions, universities, etc.)
Source and quality of the water	Distrust of reclaimed water due to the lack of knowledge and control over the source and the quality of the water.	Circulate the criteria and methodology used to measure water quality. Explain the water reclamation process.
Effects on edible crops	Better reaction to crops not oriented to human consumption. The type of process required before consumption - cooking, peeling, etc.- influences the acceptance.	Carry out safety studies on crops irrigated with reclaimed water with recognized organizations .
Trust in public authorities	The public is more willing to accept reuse when the institutions in charge are trustworthy, responsible and concerned with public welfare.	Ensure the transparency and fairness of the reuse projects. Establish alliances with the main stakeholders .
Water scarcity	Areas facing scarcity are more receptive to water reuse, especially if social awareness is already existing	Raise awareness on water scarcity and the benefits of non-conventional sources.
Water Cost	The public has the expectation to pay less, because the water is consider of lower quality.	Analyse the marketability of crops and work with the growers to ensure their commitment.

A great number of studies are focused on demographic characteristics, however the variability of the results could not relate public acceptance to a certain demographic criteria. A similar result was obtained with the study of environmental attitudes, where high environmental awareness did not implied a positive attitude towards the use of reclaimed water. Furthermore, the literature highlights the lack of in-depth research on the factors influencing public perception given the relevance of public acceptance in the success of water reuse projects.

3. Public outreach strategies

The review of past reclamation projects, both successful and failed, provides an insight on the key points to be considered in order to gain the communities trust and support. The figure below illustrates the guidelines to build a strong public outreach strategy.



As every region and context are different , the strategy has to contemplate the specificity of the community involved and the characteristics of the reclamation project. The key of these guidelines is to understand that public outreach requires a multidimensional and participatory approach, in order to achieve a fruitful and long-lasting relationship between the community, the public authorities and the stakeholders involved in the reclamation project.

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4 **Fact Sheet 5.4 –** AKIS & Stakeholders analysis: Improving knowledge transfer channels to foster innovation: facts and figures.

The stakeholder assessment and analysis were carried out following the Agricultural Knowledge and Innovation System (AKIS) methodology. The stakeholder consultation was performed in order to gather, process and evaluate information of stakeholders with a role in the water reuse and agricultural sectors. This work enables the identification of stakeholders and the assessment of their knowledge, interests, influence, existing and potential alliances and conflicts, impact of their activity, etc. Specific attention has been paid to the identification of the effective communication channels used by each stakeholder in each region. The Actor Linkage Mappings show important differences together with highlighting the special features of each target region. Specific guidelines and areas of improvement are presented to improve AKIS.

Sustainable **Water treatment** and
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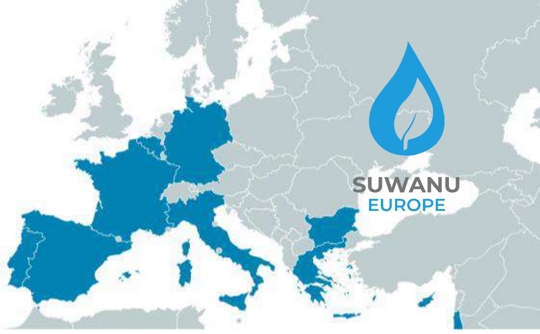

Info-package 5
Consumers and General Public

Fact Sheet 5.4 – **AKIS & Stakeholders analysis: Improving knowledge transfer channels to foster innovation: facts and figures**

Environmental benefits of irrigation with reclaimed water | Organoleptic studies of agricultural products irrigated with reclaimed water | Public perception and consumer acceptance | **AKIS & Stakeholders analysis** | Communicating the use of reclaimed water

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 5 aimed at consumers and general public, that describe the knowledge flow and the effective information and communication channels, used by key stakeholders in each region, regarding water reclamation and reuse.

1. Introduction:

In the frame of SUWANU EUROPE, a stakeholder assessment was carried out following the Agricultural Knowledge and Innovation System (AKIS) methodology. The AKIS team performed a stakeholder consultation in order to gather, process and evaluate information of stakeholders with a role in the water reuse and agricultural sectors. This work enables the identification of stakeholders and the assessment of their knowledge, interests, influence, existing and potential alliances and conflicts, impact of their activity, etc. Specific attention has been paid to the identification of the effective communication channels used by each stakeholder in each region. The main aims of AKIS are the following:

- Identification of stakeholders in each target area (Universities, Research Centers, RTDs, Public Authorities, Associations, NGOs, Opinion Leaders, etc.).
- Assessment of their knowledge, interests, influence, existing and potential alliances and conflicts, impact of their activity, etc.
- Identification of the effective communication channels used by each stakeholder in each region.
- Classification and characterization of stakeholders in a matrix (Typology).
- Development of a database of stakeholders in each target area.
- Design and description of knowledge transfer and flows in each target area.

2. Methodological framework:

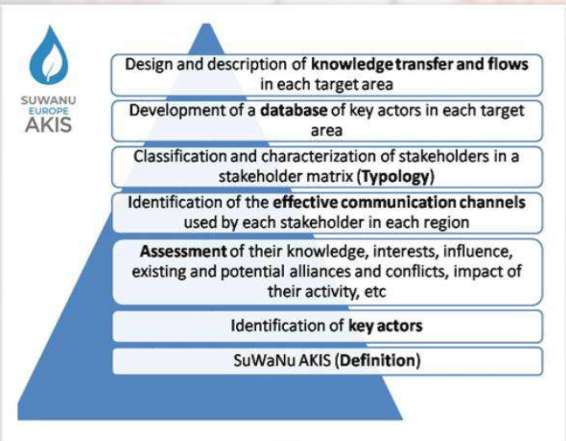

Figure 1: General methodological framework

3. WR² AKIS definition:

Figure 2: SuWaNu Europe adaptation of AKIS

4. Target Regions:

Nine (9) EU regions included as target case studies in the WR^2-AKIS : (a) ANTWERP AND LIMBURG (BELGIUM), (b) PLOVDIV (BULGARIA), (c) OCCITANIE (FRANCE), (d) Braunschweig (GERMANY), (e) THESSALONIKI (GREECE), (f) Po Valley (ITALY), (g) Alentejo (PORTUGAL), (h) Andalusia (SPAIN) & (i) NICOSIA (CYPRUS)

Figure 3: SuWaNu Europe Target Regions

5. Discussion and Conclusions:

WR^2-AKIS consists on a novel system to reveal information and knowledge transfer opportunities and weaknesses regarding water reclamation and reuse. In this Task nine (9) case studies have been analyzed in detail in order to synthesize the WR^2-AKIS. A total of 88 key players were involved in the whole WR^2-AKIS survey with a response rate exceeding 95%. More details about the countries of origin and the specific category of each key player are given in the following figures 4 & 5.

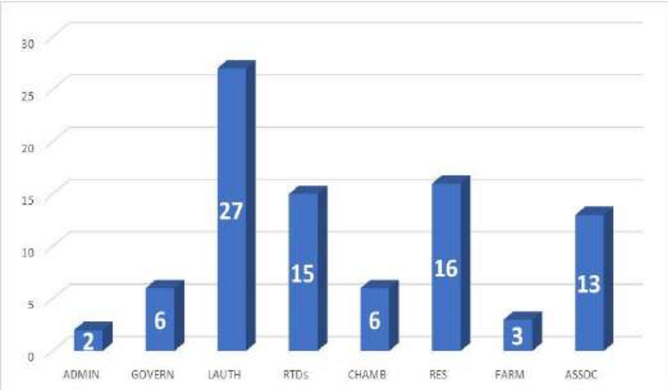

Figure 4: Key players per category

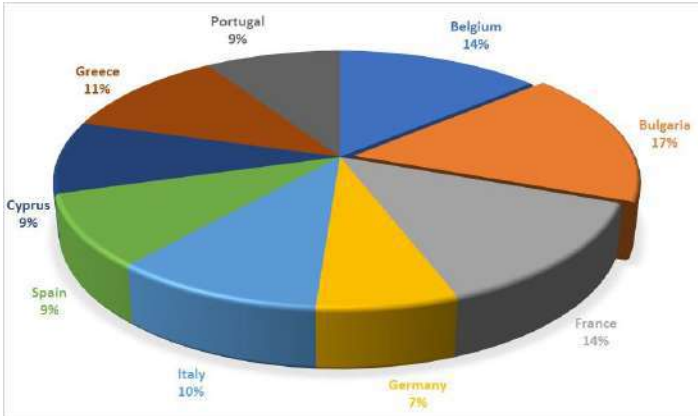

Figure 5: Key players per country

Concluding, the WR^2-AKIS analysis reveals that four of the target regions have established an increased communication and cooperation network (Germany, Italy, Spain and Cyprus) while almost all of them presents communication dynamics (except Greece). On the other hand, the typologies of the Actor Linkage Mappings cover a wide range of possible scenarios. Although, there are some similarities in case of the leading key players in the national networks (Type II: Bulgaria, Italy and Cyprus & Type IV: Germany and Greece) the whole mappings presents important differences and have to be analyzed more carefully taking advantage of the special features of each target region. An AKIS can be an adequate vehicle for empowering farmers and reclaimed water users to investigate new options to make their business more sustainable. An AKIS should be able to propose and develop practical ideas, to support innovation, knowledge transfer and information exchange. In an ideal world AKIS would function as a closely related and interconnected system. However existing AKIS are often fragmented. This raises coordination issues. Education is often weakly connected to research, extension and business. Applied research is often reviewed on scientific output (which places great emphasis on peer reviewed publications), much less on practical relevance (research is often not sufficiently related to farm).

Reference/further readings

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SUWANU EUROPE

ARISTOTLE UNIVERSITY OF THESSALONIKI

5 **Fact Sheet 5.5 –** Communicating the use of reclaimed water for agricultural irrigation: How to transfer a positive image of using reclaimed water.

Since water scarcity is driven in part by the agricultural use of freshwater, the advantages of using reclaimed water are discussed. Reclaimed water can be an alternative to conventional water resources for agricultural irrigation. The high potential for the use of reclaimed water in agriculture irrigation and its contribution to a Circular Economy is presented. The advantages of increase use of reclaimed water are shown, one of which is the reallocation of freshwater resources to domestic use, thus decreasing the pressure on this scarce resource.

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Info-package 5
Consumers and General Public

Fact Sheet 5.5 – **Communicating the use of reclaimed water for agricultural irrigation: How to transfer a positive image of using reclaimed water**

Environmental benefits of irrigation with reclaimed water → Organoleptic studies of agricultural products irrigated with reclaimed water → Public perception and consumer acceptance → AKIS & Stakeholders analysis → **Communicating the use of reclaimed water**

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 5 aimed at consumers and general public, that describe the benefits of reclaimed water in irrigation and the public perception and acceptance towards the use of reclaimed water.

1. How much water do we have on Earth:
Everyone knows water is a finite and precious resource. Even though 72% of Earth's Surface is covered with water, less than 1% is accessible for direct human use. Water scarcity is driven by two main factors: water demand, which continues to rise across Europe by a growing population and socio-economic developments, and climate conditions, that control the renewal of freshwater resources and the seasonality of water supply, which are even more affected by climate change.

2. How much water agriculture needs:
Agriculture is the sector that exerts the highest pressure on renewable freshwater resources, accounting for 59% of total water use on an annual average in Europe. In the Mediterranean region alone, agriculture can account for as much as 75% of total water used in agriculture.
If wastewater is treated according to appropriate standards and methods, the resulted effluent (i.e. reclaimed water) can be an alternative to conventional water resources for agricultural irrigation.

3. Advantages of using reclaimed water in agriculture:
The main advantages of using reclaimed water can be grouped as follows:

- Reclaimed water may substitute freshwater in many cases.
- Reclaimed water contributes to agricultural irrigation to address the global water deficit.
- Nutrient-rich reclaimed water is a valuable resource to farmers.
- Reclaimed wastewater is safe for agricultural use when adequately treated.
- Health and environmental aspects are very sensitive issues and important prerequisites.

Water reclamation and reuse is perceived as being more risky than beneficial. There is no "Zero Risk" solution, but existing and innovative technology offers high potential in safety issues.

The water reclamation and reuse activities in the European Union (EU) are guided by the EU Water Framework Directives promulgated in 2000 under the European Community Commission Directive (91/271/EEC). There has been many success stories of reuse of reclaimed water in agricultural irrigation, which were collected within the scope of SUWANU EUROPE project, and that can be followed in https://suwanu-europe.eu/database/.

4. Potential for the use of reclaimed water in agriculture irrigation and contribution for a Circular Economy:

More tan 40,000 million m^3 of wastewater is treated in Europe every year, but only 964 million m^3 of this treated water is reused as reclaimed water. The increase in the use of reclaimed water in agriculture is a goal to be set. It is expected that by 2030 reclaimed water reuse will reach 1.66% (>25 km^3 per year) of the total water use. Globally, more than 20 million ha of land are irrigated with reclaimed water, enhancing circular economy. The amounts are about to increase in the next decades as water scarcity intensifies. Agricultural irrigation is the main application for water reuse with 32% of the reclaimed water used for this purpose. Also, the use of reclaimed water in agriculture allows the reallocation of freshwater resources to domestic use, thus decreasing the pressure in this scarce resource. An increase in the use of reclaimed water may lead us to:

- Manage and use water sustainably.
- Be independent from climate fluctuations.
- Control water on regional scale.
- Contribute for quality and safe products.
- Reduce ecological footprint.
- Meet regulations and standards for constant water quality.
- Reduce cost in long term use.

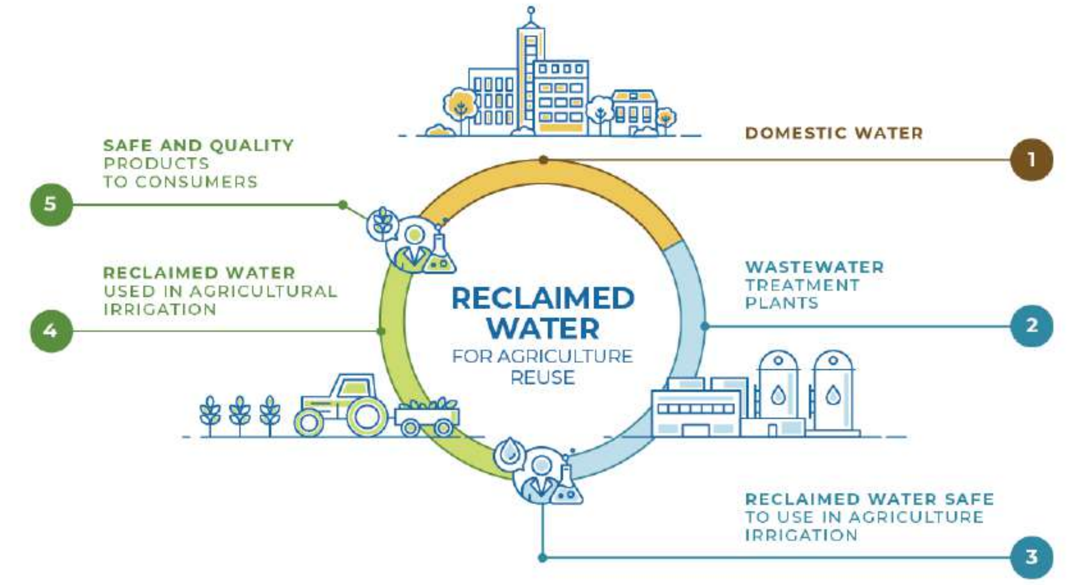

Figure 1: Circular Economy in using Reclaimed Water for agriculture reuse

Reference/further readings

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Pros & Cons Of Water Recycling, Reuse & Reclamation, 2020, Betters Meets Reality

SUWANU Europe, 2020, https://suwanu-europe.eu/water-development-projects-europe/

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Info-package 6: Authorities and policy makers

6 **Fact Sheet 6.1. –** New Eu Regulation on reclaimed water for agricultural irrigation.

The fact sheet outlays the previous publications and deals made by the European Union to regulate the use of reclaimed water for agricultural irrigation. More specifically the 2012 publication of the Commission's Communication on "A Blueprint to Safeguard Europe's Water Resources" as well as the "provisional deal on water reuse for agricultural irrigation" announced in December 2019 by the Council of the EU.

The fact sheet summarizes the contents of the proposed "Regulation of the European Parliament and of the Council on minimum requirements for water reuse", which includes a series of 16 Articles and 2 Annexes, summarized with the most relevant topics.

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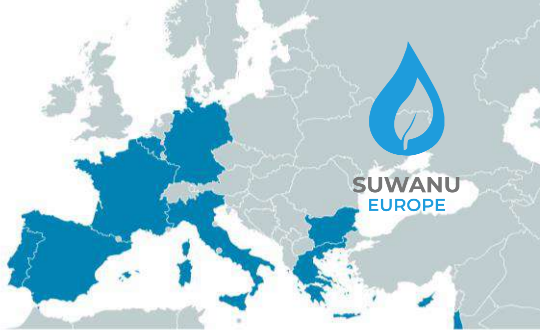

Info-package 6
Authorities and Policy Makers

Fact Sheet 6.1 – **New EU Regulation on reclaimed water for agricultural irrigation.**

New EU Regulation on reclaimed water for agricultural irrigation → Water Reuse Risk Management Plans → Water resources governance → Strategic planning for the use of reclaimed water in agricultural irrigation → Confronting barriers and promoting synergies in geographical clusters

SUWANU EUROPE is a H2020 project aimed at promoting the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water for agricultural irrigation. This is the first of the five Fact-sheet Series included in Info-package 6 that is addressed to authorities and policy makers to describe the scope and contents of the currently proposed EU Regulation on minimum requirements for water reuse in agricultural irrigation

1. Introduction

Water reuse for agricultural irrigation has been practiced in numerous European territories for centuries. Planned water reuse, complying with specific national regulations is a more recent practice, dating back to the early 1980's. The European Union interest in regulating the use of reclaimed water for agricultural irrigation became a priority by 2012 with the publication of the Commission's Communication on "A Blueprint to Safeguard Europe's Water Resources", which pointed out the need to create an instrument to regulate standards for water reuse at Union level and to remove the barriers to a widespread use of such an alternative water supply option.
In December 2019, the Council of the EU announced a "provisional deal on water reuse for agricultural irrigation" resulting from the works of the third trilogue and the Committee of Permanent Representatives. That consensus proposal was submitted for consideration by the Parliament and since then is pending for its final approval. That "provisional deal" is the reference document that has been used to elaborate this fact-sheet summary, with sentences and paragraphs taken directly from it.

2. Contents

The proposed "Regulation of the European Parliament and of the Council on minimum requirements for water reuse" (December 2019) includes a list of 44 Considerations covering the interest, the scope, the goals and the supporting information of the proposed Regulation, which is followed by a series of 16 Articles exes. The following sections summarize the most relevant topics covered by those Articles and Annexes.

3. Articles

Article 1 describes the subject matter and the purpose of the Regulation, namely:

1. *This Regulation lays down minimum requirements for water quality and monitoring, as well as provisions for risk management, for the safe use of reclaimed water in the context of integrated water management.*
2. *The purpose of this Regulation is to guarantee that reclaimed water is safe for agricultural irrigation, thereby ensuring a high level of protection of human and animal health and the environment.*

Article 2 presents the scope of the Regulation and specifically offers the possibility for Member States to decide whether agricultural irrigation with reclaimed water is appropriate in their territories:

1. *This Regulation shall apply whenever treated urban waste water is reused, in accordance with Article 12(1) of Directive 91/271/EC, for agricultural irrigation as specified in section 1 of Annex I.*
2. *A Member State may decide that it is not appropriate to reuse water for agricultural irrigation in one or more of its river basin districts or parts thereof, taking into account specifically indicated criteria.*

Article 3 presents the 15 specific definitions adopted by the Regulation when referring to and describing water reuse activities for agricultural irrigation. The most relevant terms are:

1. *'reclaimed water' means urban waste water that has been treated in compliance with the requirements set out in Directive 91/271/EEC and which results from further treatment in a reclamation facility in accordance with section 2 of Annex I of this Regulation.*
2. *'reclamation facility' means an urban waste water treatment plant or other facility that further treats urban waste water complying with the requirements set out in Directive 91/271/EEC in order to produce water that is fit for a use specified in section 1 of Annex I to this Regulation.*
3. *'point of compliance' means the point where a reclamation facility operator delivers the reclaimed water to the next actor in the chain.*
4. *'water reuse system' means the group of infrastructures and other technical elements necessary for producing, supplying and using reclaimed water. It comprises all the elements from the inlet of the wastewater treatment plant to the point(s) where reclaimed water is applied for agricultural irrigation, including distribution and storage infrastructure, where relevant.*

Article 4 summarizes the requirements applicable to reclamation facility operators and to reclaimed water quality. A first section covers the operational objectives of the operators in charge of producing a suitable reclaimed water quality (up to the point of compliance) and a second section describes the obligations of the operators to monitor reclaimed water quality to ensure compliance with applicable requirements.

Article 5 introduces one of the novelties of the Regulation: the need to establish and implement a risk management plan. This article presents the purpose of the plan, the stakeholders responsible for its development, the elements included in the plan, and a series of specific requirements.

Article 9 describes Member States responsibilities concerning information and awareness raising in relation to water reuse activities. In addition, **Article 10** describes the need for Member States to inform the public on water reuse activities. Furthermore, **Article 11** establishes the reporting schedule that Member States have to follow for reporting the results of their monitoring activities.

Finally, **Article 16** defines the time for entry into force and application of the Regulation:
"This Regulation shall enter into force on the twentieth day following that of its publication in the Official Journal of the European Union. It shall apply from ... [three years after the date of entry into force of this Regulation]."

4. Annexes
Annex I enumerates the four agricultural uses (A, B, C and D) allowed for reclaimed water and the minimum quality requirements applicable to reclaimed water intended for agricultural irrigation. Finally, Annex I presents the requirement for "a validation process monitoring that has to be performed before a new reclamation facility is put into operation, and in all cases where equipment is upgraded, and when new equipment or processes are added".
Annex II covers in detail the key elements of risks management. A specific fact-sheet has been prepared on the objectives and the scope of the Water Reuse Risk Management Plant required by the Regulation.

Reference/further readings
Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge, 2017.
Regulation of the European Parliament and of the Council on minimum requirements for water reuse, 2018.
Opinion of the European Council adopted in June 2019.
Position of the European Parliament published in February 2019.

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8 **Fact Sheet 6.3. –** Water resources governance (e.g. need to incorporate reclaimed water into integrated water resources management): facts and figures.

The fact sheet focuses on the chronology of Spanish water governance and its institutions, giving an overview of the evolution of water governance in Spain. Going from the first law with regards to water management called the 1879 Water Law, as well as the renewed 1985 Water Law which led to the first cycle of River Basin Hydrological Plans, to the drought management plans, created by the 2001 National Hydrological Plan Act. An overview is given to water governance since 2000, which saw the inclusion of European Water Framework Directive in Spanish law, as well as the reestablishment of water markets which was influenced by the 2005-2008 droughts. Furthermore, the national program for irrigation modernization is explained, with water-saving techniques and other irrigation management initiatives implemented by the Spanish government. Lastly, the recent developments in implementation of water use reduction policies are explained.

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Fact Sheet 6.2 – **Water Reuse Risk Management Plans.**

New EU Regulation on reclaimed water for agricultural irrigation → **Water Reuse Risk Management Plans** → Water resources governance → Strategic planning for the use of reclaimed water in agricultural irrigation → Confronting barriers and promoting synergies in geographical clusters

SUWANU EUROPE is a H2020 project aimed at promoting the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water for agricultural irrigation. This is the second of the five Fact-sheet Series included in Info-package 6 that is addressed to authorities and policy makers to describe the provisions of the currently proposed EU Regulation concerning the risks involved in using reclaimed water for agricultural irrigation, and the elements to be included in the Water Reuse Risk Management Plan required by the Regulation.

1. Introduction.
The proposed "European Regulation on minimum requirements for water reuse" points out the need for including risk evaluation as a way to correct the limited extend that water reuse has had in the EU: "This appears to be partly due to the significant cost of waste water reuse system and the lack of common EU environmental and health standards for water reuse, and, as regards in particular agricultural products, the potential health and environmental risks and potential obstacles to the free movement of such products irrigated with reclaimed water".
Furthermore, water reuse activities should prevent deterioration of drinking water quality. "For this reason the risk management plan should pay special attention to the protection of bodies of water used for the abstraction of water intended for human consumption and/or relevant safeguards zones". The regulatory text also indicates that "Risk management should comprise identifying and managing risks in a proactive way and incorporate the concept of producing reclaimed water of a quality required for particular uses. The risk assessment should be based on key elements of risk management and should identify any additional water quality requirements necessary to ensure sufficient protection of the environment, human and animal health".
Finally, the Regulation highlights that "Education and training of the end-users are of primary importance as components of implementing and maintaining preventive measures. Specific human exposure preventive measures should be considered in the risk management plan, such as use of personal protective equipment, handwashing and personal hygiene", and proposes protective measures like "Supply of the reclaimed water should be suspended when non-compliance causes a significant risk to the environment or to human health".

2. Contents:
The proposed "Regulation of the European Parliament and of the Council on minimum requirements for water reuse" (December 2019) includes a set of provisions for identifying and quantifying the risks involved in using reclaimed water for agricultural irrigation, and particularly for elaborating the Water Reuse Risk Management Plan required by the Regulation. The following sections summarize the most relevant provisions devoted to risk issues, as required by the Regulation.

3. Articles:
Article 1 presents the subject matter and the purpose of the Regulation, with a very specific recognition of the role of risk management:

1. *"This regulation lays down minimum requirements for water quality and monitoring, as well as provisions for risk management, for the safe use of reclaimed water in the context of integrated water management".*

Article 2 presents a series of definitions specifically related to risk management:

1. *'risk' means the likelihood of identified hazards causing harm in a specified timeframe, including the severity of the consequences.*
2. *'risk management' is a systematic management that consistently ensures the safety of water reuse in a specific context.*
3. *'preventive measure' means appropriate action or activity that can be used to prevent or eliminate a health and environmental risk, or reduce it to an acceptable level.*
4. *'barrier' is any mean, including physical or process steps or conditions of use, that reduces or prevents the risk of human infection by preventing contact of the reclaimed water with the ingested produce and the directly exposed person, or other mean that, for example, reduces the concentration of microorganisms in the reclaimed water or prevents their survival on the ingested produce.*

Article 5 describes the objective of the Water Reuse Risk Management Plan (WRRMP) required by the Regulation, as well as the parties responsible for its preparation, the supporting information in which it should be based, its main regulatory provisions and the authority for future amendments:

1. *For the purpose of producing, supplying and using reclaimed water, the competent authority shall ensure that a Water Reuse Risk Management Plan is established.*
2. *The Water Reuse Risk Management Plan shall be developed by the reclamation facility operator, other responsible party(ies), and end-users as appropriate. The responsible party(ies) preparing the Water Reuse Risk Management Plan shall consult all other relevant responsible party(ies) and end-users, as appropriate.*
3. *The Water Reuse Risk Management Plan shall be based on all the key risk management elements set out in Annex II and identify the risk management responsibilities of the reclamation facility operator and other responsible party(ies). It may cover one or more water reuse systems.*
4. *The Water Reuse Risk Management Plan shall in particular:*
    a) Set out any necessary requirements for the reclamation facility operator.
    b) Identify hazards, risks and appropriate preventive and/or possible corrective measures.
    c) Identify additional barriers in the water reuse system, and set out any additional requirements after the point of compliance.

5. Annexes:

ANNEX II is entirely devoted to describe the key elements of risk management, the conditions relating to the additional requirements and the preventive measures. Key elements of risks management to be considered are: Risk management shall comprise identifying and managing risks in a proactive way to ensure that reclaimed water is safely used and managed and there are no risks to human and animal health and the environment. For this purpose, a Water Reuse Risk Management Plan is established based on the following elements:

1. *Description of the entire water reuse system.*
2. *Identification of the parties involved in the water reuse system and identification of their responsibilities.*
3. *Identification of potential hazards.*
4. *Identification of the environments and populations at risk and the exposure routes to the identified potential*
5. *Assessment of environmental risks and risks to human and animal health.*

Reference/further readings

Regulation of the European Parliament and of the Council on minimum requirements for water reuse, 2018.
Opinion of the European Council adopted in June 2019.
Position of the European Parliament published in February 2019.

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9 **Fact Sheet 6.4. –** Strategic planning for the use of reclaimed water in agricultural irrigation (the planning process to develop SUWANU EUROPE action plans): facts and figures.

This fact sheet explained how SUWANU EUROPE consortium conducted their strategy for a General and Regional Action Plans to promote the use of reclaimed water in agricultural irrigation. It goes over all the approaches and stages in strategic planning: Methodological approach, analysis stage, planning stage and finally, the evaluation. The methodological approach selected was the Logical Framework Approach, by defining the objective, the analysis stage with the use of different methodologies: SWOT, PEST, AKIS and AHP methods. The planning stage with the development of an action plan with specific objectives in a hierarchy of an achievement levels. Finally, the evaluation tool selected was the use of performance indicators which inform of the project's progress.

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Fact Sheet 6.3 – **Water resources governance (e.g. need to incorporate reclaimed water into integrated water resources management).**

New EU Regulation on reclaimed water for agricultural irrigation | Water Reuse Risk Management Plans | **Water resources governance** | Strategic planning for the use of reclaimed water in agricultural irrigation | Confronting barriers and promoting synergies in geographical clusters

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 6 aimed at authorities and policy makers, that describe trajectory and current features of water governance in Spain

1. Introduction:

Agriculture is the main water user (72% of total abstractions), especially irrigated agriculture, which is 18% of the total cultivated area. Urban and industrial water supply is guaranteed and is of good quality. Moreover, southern Spain has water scarcity and prolonged droughts, leading to the growing use of seawater desalination and a lack of resources to cover water demands.

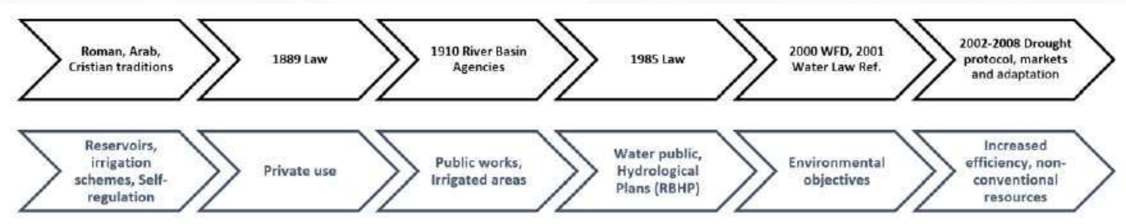

Figure 1: Chronology of Spanish water governance and institutions

2. Evolution of water governance in Spain

Spain has a long history of State intervention in water management. The 1879 Water Law regulated the private use of water both individually and through "water users' associations" (WUAs), which have a key role in Spain´s water policy. This law established administrative licences for water rights and declared water resources to be public property under the control of the State. Water agencies (River Basin Authorities - RBAs) were created in the 1920s to execute water policy, mainly through supply-side actions (reservoirs and channels). The Democratic Regime renews the water institutions with the 1985 Water Law that reinforced the public nature of water resources and raised the priority of water quality protection and ecosystem health. Additionally, this law led to the first cycle of River Basin Hydrological Plans (RBHP) which strove to implement water rights defined with supply guarantee according user hierarchy (a failure threshold below 10% for irrigation and 0.2% for urban sectors).

3. Drought management

The 1978-1984 drought probably heavily influenced the 1985 Water Law. However, the 1990-1995 'Megadrought' affected all of Spain during the first cycle of RBMPs and had a marked impact on the regulation and allocations of water under extreme conditions. As a reaction to this drought, the 2001 National Hydrological Plan Act incorporated the concept of drought management plans (DMPs) to be drawn up by the RBAs. These plans include a) drought diagnosis (definition of indicators and monitoring); b) program of measures; c) management options; and d) a follow-up system. Once a drought has been identified, the DMPs should identify the most appropriate mitigation measures, adapted to the different established drought thresholds and phases.

The environmental effects of droughts on ecosystems were not initially included in the RBMPs (1992) and were incorporated into Spanish legislation through the 2001 Water Law and were also included in the 2009 and 2015 RBMPs.

4. Water governance since 2000

The purpose of the 2001 Water Law that amended 1985 Law was to include the European Water Framework Directive (WFD) in Spanish law. WFD is mainly addressed to achieve a 'good environmental status' of all European water bodies and encourage efficient water management. The Spanish legislation incorporates the environmental criteria besides the traditional two that were: satisfying human needs and contributing to territorial and economic development. The growing scarcity due to temporal droughts and decreasing resources the last decades and the increasing societal demands (environmental flows, water masses status) and the opposition to increased supply by new reservoirs have changed the paradigm towards managing demand by increasing efficiency use and implementing economic instruments: water markets, and water tariffs.

While water markets had been traditionally used in Spain, especially in the arid southeast, they were abolished under the 1985 Water Law, but the 2005-2008 drought forced reestablishment of water markets to support high-value crops by trading between different users. However, the volume of water traded in Spain remain small and are concentrated in a few regions. Additionally, water trading occurred almost exclusively during droughts, and even under these extreme scarcity situations, trading accounted for less than 5% of total water use.

The national program for irrigation 'modernization' began in 2002 in response to the 1990-1995 drought. The national policy of subsidizing water savings and conservation technologies was considered as the core of the national plan for "drought emergency measures". The Spanish government developed the National Irrigation Program to convert the old open-channel distribution infrastructure into pressurized pipe networks to achieve annual water savings of 3,000 hm^3 (Berbel et al., 2019). Water-saving techniques are the main irrigation management initiatives in the implementation of the WFD and the RBMPs in southern Spain. National investments of EUR $4{,}0 \cdot 10^9$ have been made in water conservation technologies, which have affected $1.7\ 10^6$ ha with an estimated water abstraction reduction of 1,925 hm^3. Regarding urban water, levels of consumption (137 l/day/inh.) leave a margin for water savings.

Regarding water tariffs, those are regulated by the Law and by the WFD and should be aimed to cost recovery and should implement volumetric billing. The 'modernization' of irrigation system included volumetric metering as a condition to subsidize infrastructure and consequently a majority of the farmers pay water per volume, with an increasing cost due to the impact of pressurized networks and impact of energy expenses which is moving farmers to invest in PV systems and precision irrigation (53% of irrigated area uses drip systems).

5. Recent developments

The recent droughts, the WFD and political pressures have altered perceptions of water use, especially in urban areas. In all regions, several policies have been implemented to reduce water use, specially in the water scarce areas in Southeast and Islands The construction of desalination and water-recycling plants supplied certain municipal water use. Similarly, regulations were implemented to reduce water consumption and to incentivize urban water conservation. Reclaimed water and desalinated waster amount to 2% of total use, both sources were promoted as a response to 2005-2008 drought event. Water reuse was was regulated Royal decree1620/2007 meanwhile desalinization that goes back to 1964 and was promoted in program A.G.U.A (2007).

Reference/further readings

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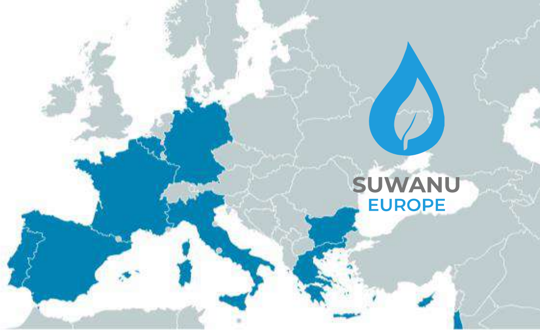
10 **Fact Sheet 6.5. –** Confronting barriers for agricultural irrigation with reclaimed water and promoting synergies in geographical clusters.

The barriers which prevent the widespread implementation of water reuse in Europe and at a global scale are discussed in this fact sheet. The key barriers and challenges are identified and were grouped into the following categories: complexity, cost, risk and production. Furthermore, the barriers were grouped in two main categories: technical and non-technical barriers, both of which were detailed in the fact sheet. Moreover, issue of overcoming the mentioned barriers is explained, with the synergistic approach discussed in detail.



Sustainable **Water treatment** and
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Fact Sheet 6.4 – **Strategic planning for the use of reclaimed water in agricultural irrigation (the planning process to develop SUWANU EUROPE action plans.**

New EU Regulation on reclaimed water for agricultural irrigation → Water Reuse Risk Management Plans → Water resources governance → **Strategic planning for the use of reclaimed water in agricultural irrigation** → Confronting barriers and promoting synergies in geographical clusters

SUWANU EUROPE is a H2020 project aiming to promote the effective exchange of knowledge, experience and skills among practitioners and relevant actors on the use of reclaimed water in agriculture. This factsheet is part of a total of 5 factsheets in Info-package 6 aimed at authorities and policy makers, that describe …

1. Introduction:

A strategic plan can be defined as a coordinated and systematic way to approach the achievement of a specific goal. Its involves the identification of concrete results, activities and actions required to reach it and allows driving an in-depth analysis of the current situation. In this fact-sheet, it is explained how SUWANU EUROPE project's partners conducted their strategic plan with the aim of developing a General and Regional Action Plans to promote the use of reclaimed water in agricultural irrigation.

2. Methodological approach:

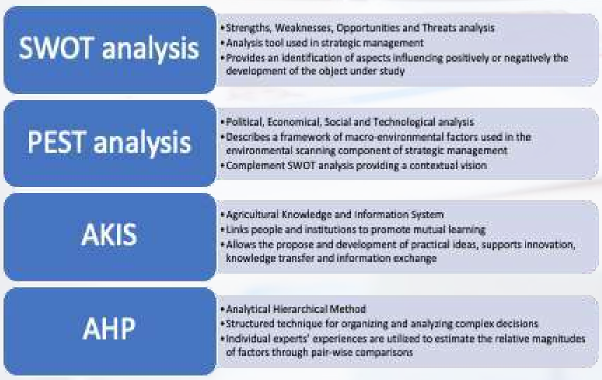
The methodological approach selected was the Logical Framework Approach (LFA), which is an analytical process that provides a set of tools for the support of goals and objective-oriented planning and management (European Integration Office, 2011). This approach consists of two phases, begins with the gathering, revision and systematization of the information available about the issue, which is called the analysis. Afterwards comes the planning, where all this knowledge is used to design an operational plan to be implemented.

The definition of the common goal or general objective was the next step, defined as follows *"to increase the use of reclaimed water in agriculture, resulting in a more resilient agricultural sector to cope with water scarcity and climate change effects."*

3. Analysis stage:

Once the objective is defined, the analysis step provides a state of the art of the situation. In this case, a state of art about reclaimed water use in agricultural irrigation to better understand the circumstances, the current implementation degree and the replicability potential for water reuse solutions. The state of art will provide a multi-actor approach including the expertise and experiences of actors involved in the process of implementing reclaimed water.

The information should face the actual infrastructure situation, institutions involved, supply-demand and socioeconomic characteristics including future plans, e.g. new research. There exist different methodologies that can be used in the analysis process, in this fact sheet we explain those used in SUWANU-EUROPE project: SWOT, PEST, AKIS and AHP.



However, once the key factors influencing the foster of reclaimed water in agricultural irrigation are identified, it is needed to evaluate its relevance. Aspects' relevance identification is fundamental to know which aspects need more or less attention. For that reason, we conducted a survey among key actors identified in the project with the aim to evaluate which aspects of the different categories from SWOT analysis were more relevant. The results were presented using a spider diagram (see [SUWANU D2.1](#)).

4. Planning stage:

With the information produced in the analysis the planning consists of the translation of the strategy into an empirical plan that can be implemented by the public authorities and the stakeholders involved. An action plan has to contemplate every single step required to achieve its goal and consider the resources and timeframe needed to have a successful implementation. The goal and its specific objectives have been selected; however a Plan might require rephrasing each of them to express very clearly an expected outcome.

The development of an Action Plan can be understood as a pyramid, where the goal is located at the pick and refers to a mid to long term vision. The specific objectives are a high-level achievement that expresses the project's direct impact and can be more than one.

The results are all the outputs that have to be reached in order to achieve a specific objective, thus there can be a number of them for every specific objective. Finally the lowest level of the pyramid is formed by every single action that has to be taken in order to accomplish a result. To evaluate if an Action Plan is coherently design it is useful to read it from the bottom up of the pyramid, to see if the fulfilment of every level will allow the achievement of the next.

The table below shows an Action Plan outline and presents some of the worked done in SuWaNu's General Action Plan.

5. Evaluation:

The evaluation is the final step of strategic planning. Its aim is to determine the real application of the objectives established in the previous steps. Different methodologies can be followed for this purpose, key performance indicators or objective matrix are some examples.

Level	Objective hierarchy	Purpose	How to express it	SUWANU EUROPE (Example)
1	Goal	The main goal of the Project, regarding the "longer vision" of the topic.	Written as a clear statement	To increase the use of reclaimed water in agriculture, resulting in a more resilient agricultural sector to cope with water scarcity and climate change effects
2	Specific objective	What we want to achieve, the intended effect of the project.	Written to express the future situation.	6. The communities involved accept the agricultural products irrigated with reclaimed water
3	Results	Expresses what we need to do in order to achieve each specific objective.	Written like tangible results.	6.1 The regional public opinion is aware of the benefits of water reuse to face water scarcity and protect the environment
4	Steps to implementation	How we carry out the project. Actions needed to achieve the results.	Written in the present tense with an active verb.	6.1.1. Develop awareness campaigns directed to local schools and universities. 6.1.2. Promote educational workshops for civil society (NGOs, consumer organizations, neighbourhood associations, etc.). 6.1.3. Create digital formative contents to disseminate on the internet and social media. 6.1.4. Build alliances with stakeholders to unify the efforts towards an environmentally aware local society.

The most common evaluation tool is the use of indicators, that inform about the project's progress in comparison with the objective established before. They measure the project's impacts and outcomes during and after the project is developed. Indicators also help to reduce the time employed in the development of the report, making easier the information gathering process. In the case of SUWANU-EUROPE, we developed specific "*indicators for successful implementation of SUWANU Action Plans*" (see [SUWANU D2.7](#)).

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