Deliverable 1.4

Lessons learnt from Israel and Cyprus success stories

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Executive Summary

SuWaNu Europe thematic network was created to bridge some of these gaps in order to accelerate the uptake of research results in the field of water reuse in agriculture and increase the reuse of treated wastewater in agriculture. One of the main goals of the project is to learn from existing knowledge, good practices and regional experience. The deliverable presented here includes an analysis of the reasons behind the high rate of water reuse in both Israel and Cyprus, both located along the Mediterranean and practice reclamation for agriculture at rates far exceeding the regional average.

To identify best practices that can lead to increased reuse and assess the reasons behind the successful reuse in both countries, a series of fact sheets was created to cover various aspects of reuse which highlight the main considerations required for successful application of reuse for agriculture. The fact sheets can also be used to identify commonalities and differences behind the successful application of reuse in both countries as the same topics as reviewed for both case studies.

Fact Sheet 1 - Water demand and supply: facts and figures reveals the fundamental common denominator for the successful application of reused water in general, particularly in the agriculture sector: in the national level in both countries **water demand exceeds the available water supply**. To enable growth prosperity, both countries had to identify additional sources of water for both drinking and agriculture. Another commonality is the small size of both Israel and Cyprus, only 2-5% the size of Spain. The small size of both countries along with recognition as a national problem allows reuse to be managed at a national level, with supportive regulations, implementation of efficient irrigation practices at a national level, and centralized decision on construction of large scale water infrastructure projects.

Fact Sheet 2 - Wastewater treatment and reuse shows some differences in reuse practices in both countries: in Israel most of the reuse is for agriculture purposes, while is Cyprus it is split between agriculture reuse and aquifer recharge, excess effluent (mostly during winter times) being diverted to the sea.

Fact Sheet 3 - Projects and infrastructure to tackle water shortage again shows many commonalities in terms of the infrastructure required to enable reuse for agriculture in a large, national level. Both countries commissioned national water allocation projects that were needed to allow reclaimed water to reach the region where they are needed for agriculture reuse. This Fact Sheet also highlight other commonalities in handling water shortage in both countries, such as using desalinized seawater for supplementing drinking water supply.

Fact Sheet 4 - Quality control of treated effluent and *Fact Sheet 5 - Code of practice for agricultural irrigation* introduce the regulatory framework for effluent quality control and agricultural reuse in both countries. As can be expected, the regulations have similarities in some topics and differences in others. These Fact Sheets were intended to be an example of available regulatory approach and to shine a light on regulatory modifications that might be needed for practicing reuse in agriculture.

Fact Sheet 6 - Pricing system for irrigation water shows the competitive pricing of reclaimed water used in both countries as an incentive for their reuse in agriculture. Other aspects of the pricing mechanisms are quite different between the countries, stemming from differences in locally adapted approaches for managing the water sectors. Cyprus, for example, uses subsidies to lower reused water prices and is aided by the EU to fund some of its large scale infrastructure projects. In Israel, on the other hand, the water sector is managed as a closed market with local water tariffs used for funding the development of infrastructure.

Fact Sheet 7 - Stakeholder involvement again highlight the two different approaches to managing decision making in the water sector applied in both countries.

Fact Sheet 8 - Public acceptance highlights the difference between promoting reuse in agriculture nowadays (Cyprus) as compared to ca. 40 years ago, when large scale reclamation was first introduced in Israel.

Water reuse will be increasingly relevant in the near future and European countries must be prepared for the necessary changes that need to be implemented. Understanding the considerations behind successful application of effluent reuse for agriculture is crucial for effectively advocating for reuse in new markets throughout Europe, which is the main interaction and contribution of the products of this deliverable to the rest of the project.

1 Introduction

Wastewater, when treated according to appropriate standards and methods, has a strong potential to complement conventional water resources used in agricultural irrigation. This is relevant throughout Europe, but especially in water scarce areas where the lack of irrigation water is limiting agricultural production, economic growth and jobs creation, and jeopardizes the sustainability of the agricultural sector. This leads to a gap between the water and agriculture sectors, where on one hand the agricultural sector has a high water demand that is not met, all while the water treatment sector is producing water and nutrients which exceed existing demand and are therefore discharged to the environment, potentially deteriorating the quality of water resources available for agriculture use.

SuWaNu Europe thematic network was created to bridge some of these gaps in order to accelerate the uptake of research results in the field of water reuse in agriculture and increase the reuse of treated wastewater in agriculture. One of the main goals of the project is to learn from existing knowledge, good practices and regional experience. The deliverable presented here includes an analysis of the reasons behind the high rate of water reuse in both Israel and Cyprus, both located along the Mediterranean and practice reclamation for agriculture at rates far exceeding the regional average.

To identify best practices that can lead to increased reuse and assess the reasons behind the successful reuse in both countries, a series of fact sheets was created to cover various aspects of reuse. The selection of topics to be covered by the fact sheets was carried based on commonalities between the cases for Cyprus and Israel. While local choices and practices vary between the two case studies, similar considerations were recognized as the basis for the successful implementation of extensive reuse for agriculture in both countries, which is the reason for the same topics being covered for both case studies. The local variability in driving forces and mechanisms for promoting the adaptation of new regulations and practices exists not only between Israel and Cyprus and can be viewed as unique for each locality attempting to implement reuse for agriculture as a new practice. By reviewing similar topics in two separate case studies, the reader is exposed to different approaches and is given the inspiration to seek a solution that would be the best available fit for the unique circumstances that make the background conditions of his or her locality.

Fact sheets topics were also selected to provide a wide knowledge base to be used by regional work groups set forth by the SuWaNu Europe consortium to inform and inspire discussions on various actions, approaches and considerations that should be taken into account to enable an increase in the extent and acceptance of water reuse for agriculture.

The 16 fact sheets created for this purpose (eight fact sheets created by each country) and included in this deliverable cover the following topics:

1. Water demand and supply
2. Wastewater treatment and reuse
3. Infrastructure
4. Quality control
5. Agriculture code of practice
6. Pricing
7. Stakeholder involvement
8. Public acceptance

Each factsheet represents a necessary component underpinning Israel and Cyprus success stories. While some of the factsheets highlight commonalities, mainly long standing water shortage as a driving force for early application of reuse as a common practice in both locations, other factsheets display differences between the case studies, primarily in topics related to local regulations and the structure and management practices of the water sector in both countries (e.g., reclaimed water quality control regulations, agriculture code of practice, pricing, stakeholder involvement).

For all the reasons mentioned above, the 16 factsheets should not be seen isolated but knowledge package that presents driving forces for water reuse, suggesting two forms of adaptation from two different localities, and can only transferred if other aspects are also taken into account. To present this idea of unity between the different aspects of successful reuse, an additional summary fact sheet titled "Keys for Success" is being created as part of WP3 of this project and will be included in D3.1 (see attached in Annex 1). This fact sheet summarizes and highlights the commonalities behind the successful reuse in Israel and Cyprus.

2 Lessons learned from successful reuse in Israel

2.1 Water demand and supply: facts and figures

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

SUWANU EUROPE

The Success Story of Israel

Fact Sheet 1 - Water demand and supply: facts and figures

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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 16 factsheets that describe the successful reclamation practices of Israel and Cyprus in order to learn and boost implementation of solutions adapted to the European context. Our ultimate goal is to enhance acceptance and awareness to an alternative source of an increasingly scarce resource, water.

The State of Israel is located on the edge of the desert, with a climate that varies between Mediterranean and arid. The average annual rainfall in the north of the country is about 1,000 mm in rainy years, and in the south, rainfall ranges between 30 mm (in Eilat, the southmost point of Israel) and 200 mm multi-year average. In addition, the rainy season is short, usually only 5 or 6 months, between October and March, concentrating most of the rainfall between December and February (20, 25 and 21% respectively). Around 60% of rainwater evaporates, 30% infiltrates to the groundwater, and 5 to 10% flows through rivers.

The distribution of natural water sources is directly related to rainfall. Thus, it is possible to see that the greatest amount of water resources is concentrated in the North region of the country and that the South is almost completely desert (see Figure 1 and Figure 2).

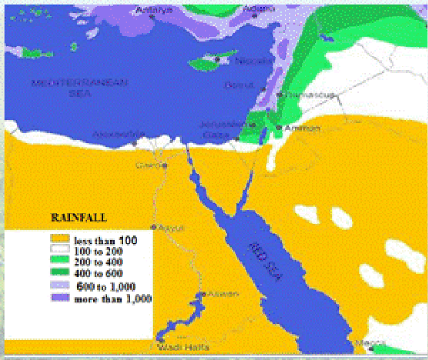

Figure 1 - Distribution of precipitation in the Middle East

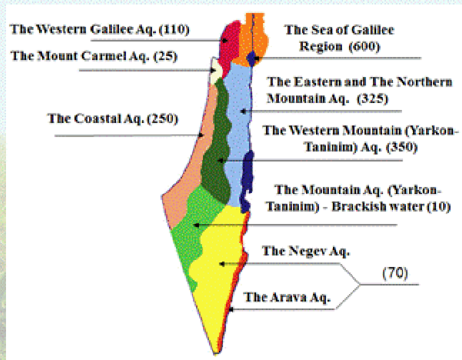

Figure 2 - Distribution of water resources in Israel. The annual natural recharge, in Millions of m³, is presented for each source in parentheses

According to the Water Law, drafted in 1959, all water resources belong to the public and any water use requires a permit (or license of use) and is regulated by the Water Authority. It is worth highlighting that the term "all water resources" also includes non-traditional sources for the time when the law was drafted, such as treated effluents and desalination water. This centralized control structure was and is used as the basis for managing water resources in Israel: how much water can be extracted from each of the available resources during the different times of the year, as well as the amount of water allocated to the different consumers. To efficiently manage the water sector, an extensive monitoring and measurement system was implemented, which includes monitoring of the volume extracted from each source, water quality, groundwater levels, etc.

The current consumption in Israel (2018) is around 2,200 Million m^3 per year, of which approximately 1,200 Million m^3 is used for agriculture (55%), 850 Million m^3 for domestic use (38%), and 150 Million m^3 are used by industry (7%). The domestic supply also includes some 100 Million m^3 supplied to the Palestinian Authority and to the Kingdom of Jordan.

In Israel, approximately 85% of wastewater is treated and reclaimed for agriculture use with different qualities and in accordance with the most demanding standards. The incorporation of treated effluents in agriculture had a very large impact on the national water balance. Mainly, it allowed reallocating more of the drinking water resources to domestic use, to a degree where today these freshwater resources make up less than 50% of the water used in agriculture.

In 1955 was drafted the Water Measurement Law and Israel started to meter all the water consumed, included the water supplied to the agricultural sector. Figure 3 shows the history of water consumption by sectors since the establishment of the State of Israel in conjunction with population growth. The same chart shows three fundamental milestones in the history of water in the country: the operation of the National Water Carrier (1964), the beginning of the reuse of effluents in a massive way (mid-1980s) and the beginning of large-scale desalination, all of which will be discussed in greater detail below.

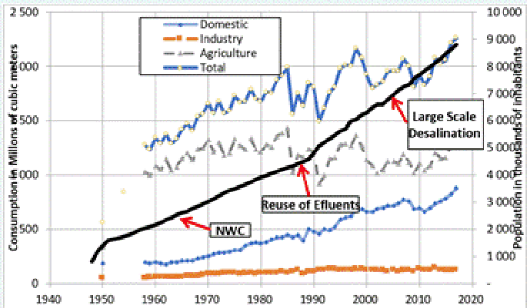

Figure 3 - Total water consumption by sector (in millions of m^3 per year) since 1950 and population of Israel (in thousands of inhabitants) since the establishment of the State in 1948

CLOSING REMARKS

Water supply in Israel sets an example of the importance of clear policies and centralized water management for creating a sustainable water sector where all aspects of water use and reuse are considered under the same roof. This management philosophy makes it easier to invest in large scale infrastructure projects, implement technological innovations, and introduce water of various cost to match the different needs that exist throughout the water sector.

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2.2 Wastewater treatment and reuse

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

The Success Story of Israel

Fact Sheet 2 - Wastewater treatment and reuse

Water demand & supply | **WW Treatment & reuse** | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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To comply with increasing demand for drinking water, major parts of the agriculture sector were gradually shifted to irrigation based on reclaimed effluent, mostly during the 1980s. Currently, more than 85% of the treated wastewater produced in Israel is reclaimed for agriculture use (Figure 1), and potable water make less than 50% of the water consumed for agriculture (Figure 2). The local golden standard for wastewater treatment and reclamation is the Shafdan, the wastewater treatment plant of the Tel Aviv metropolitan area. Shafdan, the largest WWTP in Israel, is owned by Igudan (Association of Dan Region Cities for Sewerage and the Environment) and serves a population of more than two million people in Israel's most densely populated area. The plant is considered one of the largest and most advanced of its kind in the Middle East, treating 130-145 Million m³ of wastewater per year and is currently being expanded to reach a treatment capacity of 160 Million m³. Mekorot has been the operator of the Shafdan WWTP for more than 40 years.

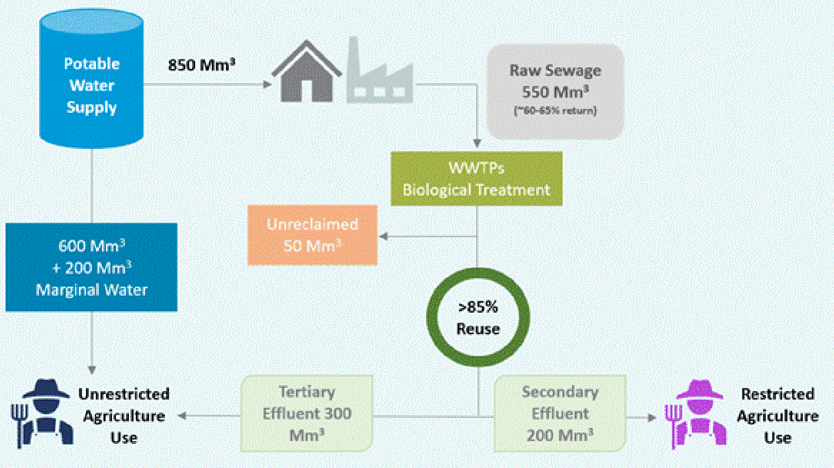

Figure 1 - Wastewater Recovery Scheme

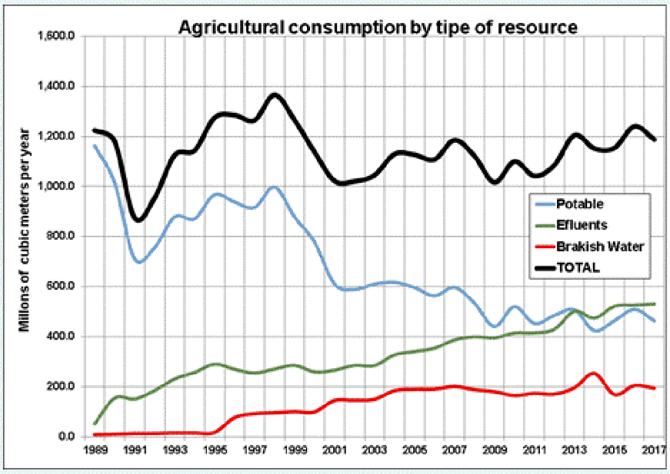

Figure 2 – Agricultural consumption according to the type of sources since 1989.

The Shafdan treatment scheme includes activated sludge with partial nitrification-denitrification. The sludge undergoes thermophilic anaerobic digestion, which produces Class A sludge that can be directly applied for agriculture without the need for further treatment. The secondary effluents produced by the Shafdan undergo Soil Aquifer Treatment (SAT) and disinfection before being supplied for agriculture use.

In the SAT, secondary effluent is infiltrated to a limited area of the Israeli Coastal Aquifer through dedicated spreading basins in the area surrounding the Shafdan. During the infiltration, treated wastewater pass through the upper layers of the soil where changing oxidation conditions provide a wide range of physical-chemical and biological processes (Figure 3). These processes significantly improve the quality of the effluent by removing pathogens, organic matter, and other undesirable compounds, producing reclaimed water of very high quality that meet most of the local requirements set for drinking water. The reclaimed water is then used strictly for unrestricted irrigation, primarily in the Negev region in the south of Israel. This practice of infiltrating secondary effluents makes that region of the aquifer into a seasonal and multi-year storage basin for large quantities of reclaimed effluent.

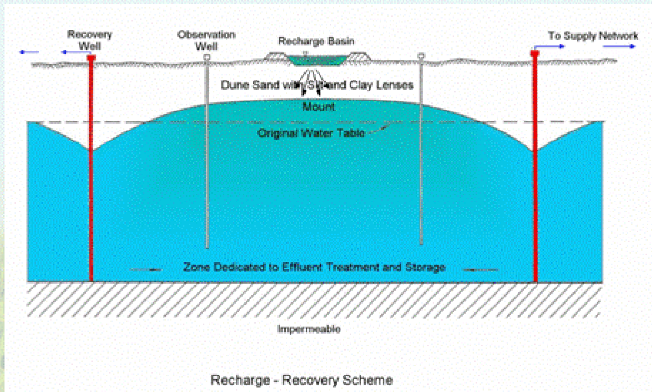

Figure 3 - Wastewater Recovery Scheme at the Shafdan Plant

The isolation of the area of the aquifer where SAT is practiced from the rest of the aquifer is achieved by employing a controlled pumping regime through more than 140 dedicated wells constructed around the infiltration basins. The wells are operated to create a hydraulic low at the perimeter of the manages region where reclaimed effluents are mixed with potable water, preventing effluents from escaping the pre-defined perimeter and reaching regions of the aquifer dedicated to potable use.

Mostly during the dry months, these reclaimed effluents are extracted from the aquifer and conveyed through the Third Line to the Negev for irrigation. Due to their extremely high quality the extracted water is suitable for the irrigation of all agricultural crops, without restrictions, prioritized by demand without creating any health risk.

Future Plans

Population growth, lifestyle, and connecting new localities to the Shafdan, are expected to increase the amount of secondary effluent produced by the Shafdan and to increase the demand for SAT basins which exceeds their current capacity. Since real estate value does not allow assigning additional land resources for SAT, Mekorot has been seeking engineered based solutions for treating excess secondary effluent that cannot be infiltrated at the SAT basins to a level that will be considered by the regulators to be equivalent to that currently produced by the SAT.

These days, Mekorot is designing a pilot plant to test a treatment train that is expected to meet these goals. The treatment train includes a tertiary (low loaded) Membrane Bio Reactor (to complete the nitrification process), followed by ozonation (disinfection, Trace Organic Compounds – TorCs – removal), Biologically Active Carbon filtration (TOrCs removal) and UV disinfection. The pilot is expected to become operational during the summer of 2020 and is planned to operate for a year before decisions are made regarding the suitability of the selected technologies for the predefined goals. Pilot design and testing is being done in close collaboration with the local regulators. An emphasis is made to assure the water produced by the pilot meet international regulations and standards for Indirect Potable Reuse (IPR), although the water will be used exclusively for irrigation.

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2.3 Projects and infrastructure to tackle water shortage

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

The Success Story of Israel

Fact Sheet 3 - Projects and infrastructure to tackle water shortage

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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The history of water resources management in Israel can be divided into 4 times periods (Feitelson, 2013):

1) Hydraulic projects (1948-1964): the construction of regional projects that were later connected to a National System. During this period a national, independent water sector was developed, isolated from neighboring countries, supporting the growing nation and agricultural settlement. Many of the projects initiated during that time were driven by political needs and were not economically feasible and were therefore **subsidized by the government through different mechanisms** (e.g., by subsidizing the price of water for agriculture).

2) "Wise" management of existing resources (1959-1990): improving the efficiency of using all available resources, for example by minimizing water losses in the national distribution network (currently less than 3%) and in urban networks (currently around 12%). In the 1960s, small scale brackish water desalination plants were constructed along the Arava region and the city of Eilat to provide potable water for remote communities isolated from the national grid. The incorporation of drip irrigation in the early 1970s significantly lowered water consumption for agriculture while leading to an increase in agricultural production. During the 1980s, the Shafdan WWTP began infiltrating secondary effluents in dedicated basins for Soil Aquifer Treatment (SAT) to produce high quality effluents suitable for unrestricted irrigation. In 1989 **reclaimed effluents produced from the SAT started being distributed through a dedicated supply system to the south of the country for agriculture use.**

3) Deliberations (1990-2005): Restructuring the Israeli water sector to its current form. This process was driven by consecutive droughts at the beginning of the 1990s, and by a 20% population increase due to an immigration flux from the former USSR. During this period, it was decided that **water pricing should reflect different water uses, and that infrastructure must be developed to start desalinizing water for drinking purposes.** More WWTPs were constructed throughout the country and their reclaimed effluents diverted to agriculture reuse according to the quality of the treatment. The Israeli Water Authority was established in 2005 to allow centralized management of all water resources throughout the country as a self-financed closed market.

4) Large Scale Desalination (since 2005): Construction of large seawater desalination plants on the shores of the Mediterranean and their connection to the National Supply System. Continued improvement of WWTPs nationwide to treat more water at a higher standard.

Mekorot, Israel's national water company, was founded in 1937, 11 years before the creation of the State of Israel. The company was established to supply water to the entire population, for any given need, at any given time, 24 hours a day, 7 days a week.

In its early years, the main source of drinking water in Israel was a fresh water lake (the Sea of Galilee) in the north of the country, along with water from its coastal and mountain aquifers.

To supply water from these resources to southern parts of the country it was decided to construct a National Water Carrier (NWC), completed in June 1964 (Figure 1). Though all the water flowing through the NWC are potable, in its early years 80% of the water was delivered by the NWC were for agriculture use and only 20% for drinking purposes. Most of Israel's water plants are connected to the NWC to allow efficient centralized control and management of water resources, regulation of water supply, and water delivery to the most remote places in the country.

Population growth increase in water consumption per capita and depletion of renewable water resources (groundwater) created a need for locating additional water resources to be used for non-potable applications. The answer to the increased need was found in shifting some of the agriculture sector, primarily in the Northern Negev area in the south of the country, to irrigation based on reclaimed effluent. This shift lead to two simultaneous changes: the proportion of water delivery for agriculture by the NWC decreased to 20%, and the construction of **The Third Water Line** to supply reclaimed effluents from the Shafdan WWTP to agriculture reuse in the Negev.

Further changes were made to the NWC in order to accommodate desalinized water and allow its distribution throughout the country. In addition to the construction of new water lines to connect the desalination plants, the system was modified to allow flow in all directions instead of an exclusively north-to-south gravity driven flow.

Figure1 - The National Water Carrier (NWC)

The National Water Carrier: Facts and Figures

- Delivers surface water from the Sea of Galilee at a flow of 20 m^3 per second from a maximum depth of 215.5 meters below sea level to a height of 151 meters above sea level, facilitated by two large pumping stations: Sapir and Tzalmon.
- The average annual energy demand accounts for 2% of Israel's total electricity consumption.
- Its overall length is 130 km, originating at the Sea of Galilee in the North and reaching the Hayarkon Springs station in Rosh Haayin where it connects to the two Yarkon – Negev lines, to form a continuous system that reaches Mitzpe Ramon in the south.
- The construction provided employment to more than 4,000 workers during a time when local population grew by 50%: from 1.6 to 2.5 million.
- The cost of construction was about 420 million Israeli liras (in 1964 prices), accounting for 5% of the GDP at that time.
- The NWC was not economically feasible in its beginnings and became sustainable only after a few decades of operation.

Nowadays, drinking water in Israel are sourced primarily from desalination plants combined with a decreasing portion of groundwater, eliminating the need to use the NWC for conveying water from the Sea of Galilee to the rest of the country (Figure 2).

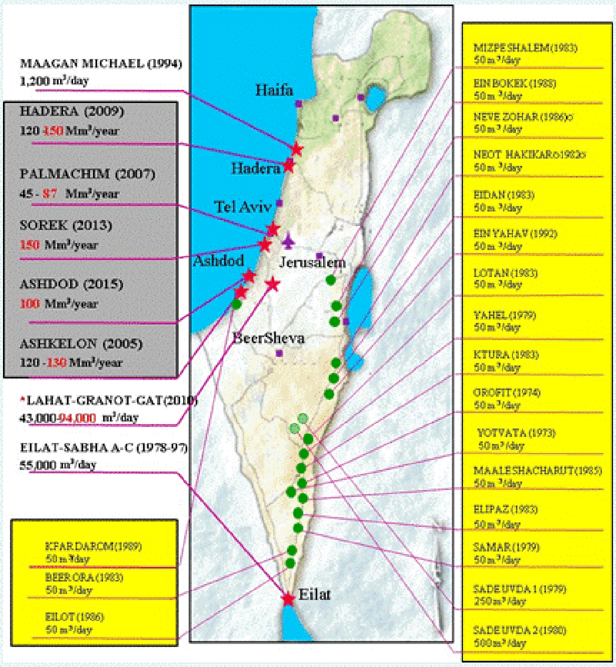

Figure 2 - Desalination plants in Israel

This allows using the NWC to deliver surplus desalinated water to the Sea of Galilee, to support and sustain its unique ecosystem which has priceless value both ecologically and historically.
The incorporation of desalinated water in the system reduce the hardness of the supplied water, thereby lowering scaling rates of water heaters, equipment, appliances and piping, reducing the consumption of detergents and lime-removal chemicals, and improving the quality of laundering and dishwashing. This also improved the quality of urban effluents (in terms of chloride contents) and therefore that of the reclaimed effluent used for agricultural, reducing required irrigation rates, improving crop productivity, and reducing salt accumulation in soils irrigated with reclaimed effluent.

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Feitelson (2013) "The Four Eras of Israeli Water Policies". In "Water Policy in Israel: Context, Issues and Opinions", Becker (ed.), Springer.

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2.4 Quality control of treated effluent

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

The Success Story of Israel

Fact Sheet 4 - Quality control of treated effluent

Water demand & supply | WW Treatment & reuse | Infrastructure | **Quality control** | Ag code of practice | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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Israel has strict regulations (Public Health Regulations for Effluent Quality and Sewage Treatment, 2010) determining minimum quality criteria for treated wastewater, more specifically for reclaimed water intended for irrigation. The regulations define three main categories of reclaimed water:

- Reclaimed water for Restricted irrigation – typically produced by a smaller reclamation facility receiving sewage of quality typical for less than 5,000 person equivalents (BOD<300 mg/L; COD<500 mg/L).
- Reclaimed water for Unrestricted irrigation – typically produced by a larger reclamation facility receiving sewage of quality typical for greater than 5,000 person equivalents (BOD>300 mg/L; COD>500 mg/L).
- Reclaimed water intended for discharge into streams (regardless of the size of the WWTP).

A designated sampling method is specified for each parameter, as well as a defined sampling frequency which varies based on the size of the WWTP. Additionally, specific criteria are defined for selected watersheds setting maximum concentrations allowed for discharge within these watersheds. These watershed specific criteria are less stringent than the requirements for unrestricted irrigation, but in some cases more stringent than those required for restricted irrigation.

Table 1 – Minimum water quality requirements for irrigation and discharge to streams

Parameter	Units	Unrestricted irrigation			Restricted irrigation			Discharge to streams		
		Max monthly average	Max	Min	Max monthly average	Max	Min	Max monthly average	Max	Min
Faecal coliforms	count/100ml	10	50					200	800	
BOD	mg/L	10	15		20	30		10	15	
TSS 105°c	mg/L	10	15		30	45		10	15	
COD	mg/L	100	150		100	150		70	100	
NH_4	mg/L	10	15		50	60		1.5	2.5	
TN	mg/L	25	35		60	75		10	15	
Ptot	mg/L	5	7		12	17		1	2	
Cl	mg/L	250	280		250	280		400	480	
EC	dS/m	1.4	1.8		1.4	1.8				
F	mg/L	2	3		2	3				
Na	mg/L	150	200		150	200		200	240	
DO	mg/L			0.5			0.5			3
pH			8.5	6.5		8.5	6.5		8.5	7
Mineral oil	mg/L							1	1.5	
Residual Cl	mg/L	1	2.5	0.8	1	2.5	0.8	0.05	0.1	
Anionic detergents	mg/L	2	3		2	3		0.5	1	
SAR	$(Mmol/L)^{0.5}$	5	6.5		5	6.5				
B	mg/L	0.4	0.5		0.4	0.5				
Hg	mg/L	0.002	0.005		0.002	0.005		0.0005	0.0025	
Cr	mg/L	0.1	0.25		0.1	0.25		0.05	0.25	
Ni	mg/L	0.2	0.5		0.2	0.5		0.05	0.25	
Se	mg/L	0.02	0.05		0.02	0.05				
Pb	mg/L	0.1	0.25		0.1	0.25		0.008	0.04	
Cd	mg/L	0.01	0.025		0.01	0.025		0.005	0.025	
Zn	mg/L	0.2	5		0.2	5		0.2	1	
As	mg/L	0.1	0.25		0.1	0.25		0.01	0.05	
Fe	mg/L	2	5		2	5				
Cu	mg/L	0.2	0.5		0.2	0.5		0.02	0.1	
Mn	mg/L	0.2	0.5		0.2	0.5				
Al	mg/L	5	12.5		5	12.5				
Mo	mg/L	0.01	0.025		0.01	0.025				
Vd	mg/L	0.1	0.25		0.1	0.25				
Be	mg/L	0.1	0.25		0.1	0.25				
Co	mg/L	0.05	0.125		0.05	0.125				
Li	mg/L	2.5	6.25		2.5	6.25				
CN	mg/L	0.1	0.2		0.1	0.2		0.005	0.01	

Using reclaimed effluent for irrigation – circular chemistry and the bigger picture

One implication of using reclaimed effluent for irrigation is that residuals found in commonly used domestic products might reach the effluent and effect the crops grown using these effluents. In those cases, the chemistry of our common household products might affect the chemistry of the water used for irrigation, which in turn might affect the yield or quality of the produce. One example for such circular chemistry can be given by examining the Israeli case for the content of the mineral Boron in laundry detergents.

The main polishing treatment process applied to secondary effluents prior to reuse for irrigation at the Shafdan, Israel's largest WWTP serving the greater Tel Aviv area, is filtration through a Soil Aquifer Treatment (SAT). In this process, secondary effluents are spread in dedicated basins over Israel's phreatic coastal aquifer south of the city of Rishon Le'Tziyon. During infiltration through the natural sand dunes the effluents undergo both mechanical filtration/adsorption by the sand and biological degradation by naturally occurring soil bacteria. The resulting reclaimed effluent quality is so close to potable quality that irrigation with these effluents is carried under the principles typically used for irrigation with potable water. In this treatment scheme, no specialized treatment is applied for removing specific target constituents.

A key component of domestic effluents comes from washing machines and includes chemical residues from commonly used detergents. These chemicals, mainly sodium and boron, are not removed by the SAT. Furthermore, these elements have two potentially harmful effects:

- Both elements can deteriorate the water quality of the aquifers underlying fields irrigated with reclaimed water: more than 130,000 tons Na and more than 260 tons B were annually released into the domestic collecting system from the use of laundry detergents.
- Boron is toxic to many plants at low concentrations.

It became evident that to make water reuse for agriculture the new normal, lower B and Na levels must be achieved in the domestic effluents. According to a survey published in 1997, Na released from laundry detergents accounted for 40% of the Na in the effluents, and the released B made for 80-90% of the B in the effluent. To lower the concentrations of B and Na in the effluents, a new approach was needed for managing the composition of laundry detergents in Israel. A survey conducted on contaminants in effluents showed a wide variability in B concentration in different types of laundry detergents, ranging from 0.2-0.5 gr B/kg detergent in compact liquid detergents to 8.4 gr B/kg detergent in regular powder (non-liquid) detergents (the maximum allowed at the time). That survey also showed that by lowering the concentration of B in non-liquid detergents from 8.4 to 0.5 gr B/kg detergent, the amount of B released annually to domestic effluents from the use of laundry detergent can be lowered from 260 tons to only 14 tons per year.

To lower B content in laundry detergents, a decision was made to create a new Israeli Standard (IS438): cleaning detergents – requirements for assuring environmental protection and proper marking of information: Laundry Detergents – 1998. This new standard required lowering Na content in the detergents by 33%, and B content by 94% within 8 years of its establishment. Monitoring during the early 2000s showed B concentrations in the reclaimed water are decreasing in agreement with the model-based predictions (Figure 1).

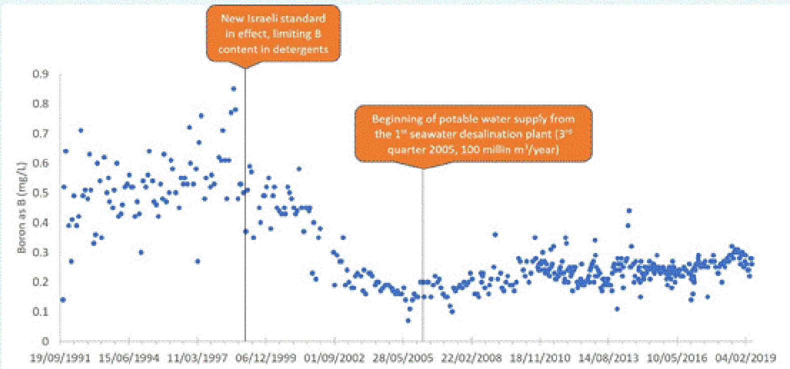

Figure1 – Dramatic changes in B concentration in secondary effluent of the Shafdan WWTP over time in response to drastic changes in regulation

The decision to implement large scale sea water desalination as a source for potable water introduced a new source for boron in drinking water (and domestic effluent) as sea water are naturally rich in B. To limit the potential increase in B concentration in the reclaimed effluent resulting from treating domestic sewage, the water quality requirements defined for the desalination plants include a maximum allowed level for B. The allowed B levels (0.3-0.4 mg/L) are set to comply with the water quality requirements for irrigation and discharge to streams (Table 1). The commissioning of the first desalination plant in late 2005 and other plants that followed are evident in Figure 1, where a distinct increase in B concentration in the secondary effluents of the Shafdan WWTP can be observed beginning in late 2005.

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2.5 Code of practice for agricultural irrigation

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

The Success Story of Israel

Fact Sheet 5 - Code of practice for agricultural irrigation

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | **Ag code of practice** | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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Two main challenges exist when irrigating with reclaimed water: assuring the water chemistry (e.g., salinity, nutrients) is suitable for the irrigated crops, and making sure the irrigation practice does not pose a public health risk. The concern for creating a public health risk can be split in two:

- General public – a concern regarding contracting an effluent-associated infection from consuming produce irrigated with reclaimed effluents
- Growers and agriculture workers – a concern regarding growers contracting effluent-associated infections from handling reclaimed effluents

The concern over a public health risk is often given as an added chance of illness. For example, the WHO guidance for irrigation with effluents states that irrigating fruits that are eaten raw with effluents containing up to 1,000 fecal coliforms per 100 ml would create a 2:1,000,000 chance of illness – meaning for every million people eating these fruits, two will contract a coliform infection. This is compared to a chance of 1:10,000 of contracting an illness from potable drinking water (Table 1). The Israeli regulations for reclaimed water for unrestricted irrigation allows for no more than 10 f.coli per 100 ml (as a monthly average), which translates to a 2:100,000,000 chance of illness (5,000 times lower than the chance of illness from typical drinking water).

Table 1 - Risk of illness from drinking water and from consuming fruit irrigated with reclaimed water

Water type	Chance of illness	Comments
Drinking water	0,0001:1	US EPA
Eating fruit irrigated with reclaimed water	2:1,000,000	Reclaimed water containing <1,000 *f.coli*/100ml

To prevent public health risks from irrigating with reclaimed effluents, a series of physical barriers are placed to distance the reclaimed effluents from food crops. The number of barriers required is set according to a combination of crop type and the quality of the water used for irrigation (Table 2). These barriers can be generally distinguished into three types:

1. Pathogen removal – e.g., media filtration with effluent turbidity <5 NTU or effluent TSS <10 mg/L; long term reservoir storage (>30/60 days for terminal/flow through reservoirs); mixing with natural water in a reservoir (up to 10% effluents/20% chlorinated effluents); disinfection (contact time ≥30 min; residual concentration > 1 mg/L); etc.
2. Physical barrier between reclaimed water and food crops – e.g., drip irrigation (the number of barriers granted depends on the distance between the fruit and the irrigated soil); soil cover; subsurface drip irrigation; etc.
3. Other barriers – e.g., heat treatment (wheat); cooking of crops not eaten raw (potatoes); fruit with inedible peel (citrus, bananas, nuts).

Table 2 - Barriers allowing irrigation by effluent quality

Unrest. Irri.	High qual Eff.	Medium qual eff.	Crop	Sand filt. /or long storage /or 10% effluent	Effluent disinfection[1]		Meets min distance req. from drip irrigation[2]	UV resistant cover sheet	Shallow inserted drip line	Inedible peel	Not eaten raw
Number of barriers needed					Must	Can					
0	2	3	Veg. consumed raw; above ground (e.g., peper, tomato, zucchini)	+	+			+	++		
0	2	3	Veg. consumed cooked W/peel (e.g., squash, eggplants)	+		+		+	++	+	+
0	2	3	Root veg. consumed cooked (e.g., potatoes)	+		+					+
0	2	3	Citrus	+		+	++		++	+	
0	2	3	נשירים	+		+	++		++		
0	Not allowed	Not allowed	Public gardening								

[1]effluent disinfection is obligatory for all vegetables eaten raw
[2]50m distance is considered two barriers; 25m distance is considered one barrier
[3]vegetables cannot be irrigated with medium quality effluents
[+]number of barriers provided

Crops that do not come in contact with the general public or that are grown in a manner that inherently prevents the survival of pathogenic microorganisms do not require barriers. These include for example:
- Crops meant for industrial use (e.g., cotton) and fodder.
- Crops dried in the sun for more than 60 days after ultimate irrigation (e.g., sunflower seeds, wheat, popcorn-corn)
- Groves forbidden for public access.

To prevent the contamination of water sources or resources, rules have also been placed to regulate where and how irrigation with reclaimed water can be practiced. For example:
- To avoid groundwater wells contamination, irrigation with reclaimed water is forbidden (unless a specific permit is granted) in a protective radius defined by the regulator (Figure 1).
- To avoid contamination of the National Water Carrier (NWC), irrigation with reclaimed water is forbidden in the natural preservation area surrounding the NWC.
- To avoid contamination of potable water, irrigation with reclaimed effluents underlaid by potable water infrastructure is only allowed when the reclaimed effluents meet the required disinfection demand, the infrastructure is in good condition and is not in the risk of experiencing negative pressure.
- Reclaimed effluents that do not meet the disinfection requirements can be used at a distance greater than 3m from the edge of the irrigated area, so long as it has been shown that surface runoff from the irrigated area cannot reach the area overlying the potable water infrastructure.

To protect public health, additional precautions are taken for parks and landscape irrigation using reclaimed water. For example:

- The reclaimed effluents must be suitable for unrestricted irrigation
- A visible sign must be posted to notify that the water source is non-potable reclaimed effluents
- In areas accessible to the public, reclaimed effluents can be used for irrigation only when the area is not accessible to the public (e.g., nighttime, closed) or using subsurface drip irrigation
- Properly signed water fountains must be available for public use in areas accessible to the public and irrigated with reclaimed effluent

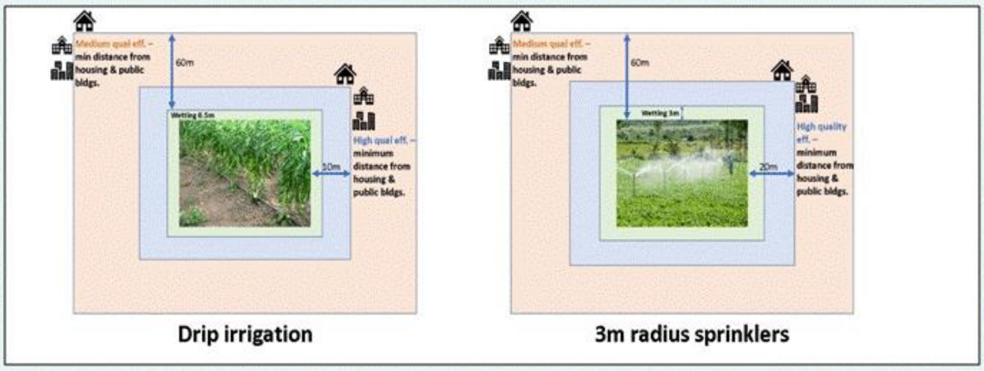

Figure1 - Two examples of protective area based on irrigation type, effluent quality, and land use

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2.6 Pricing system for irrigation water

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

The Success Story of Israel

Fact Sheet 6 - Pricing system for irrigation water

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | **Pricing** | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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Water pricing in Israel is complex and comprised of different rates for home (and small business) use and for agriculture. Home use rates are tiered, depend on the number of persons living in a dwelling unit, and represent the real cost of water supply and sewage treatment, including operating, maintaining, and developing municipal water supply and sewage treatment systems. The basic rate applies for a use of up to 3.5 m³/month per person and no less than 7 m³/month per dwelling unit (Table 1). Water consumption exceeding this quota is charged the higher tier 2 rate.

Table 1 - Water and sewer rates for domestic consumers during the years 2010-2019. All prices are in NIS, per m³, including VAT. All rates were recorded on the 1st day of the month. Data obtained through the Israeli Water Authority website, accessed February 5, 2019. Rates assume 1 €=4.0 NIS

Date	Tier 1 rate €	Tier 2 rate €
January 2019	1.72	3.24
July 2018	1.65	3.11
January 2018	1.64	3.08
July 2017	1.64	3.08
January 2017	1.92	3.08
January 2016	1.92	3.09
July 2015	1.99	3.21
January 2015	2.01	3.24
July 2014	2.22	3.57
January 2014	2.22	3.58
July 2013	2.32	3.73
January 2013	2.28	3.66
September 2012	2.21	3.56
July 2012	2.19	3.53
January 2012	2.16	3.47
July 2011	2.16	3.47
January 2011	2.16	3.12
July 2010	2.16	3.12
January 2010	2.03	2.99

Many elements are considered for calculating the price of water, including costs incurred by the water supplier, purchasing desalinated sea water, costs incurred by Mekorot, subsidies and more (Figure 1). Previous pricing mechanisms did not account for real costs, making it difficult to account for actual development and operational costs. The current pricing system allows continuous updating each of these elements, for example as a result of commissioning a new sea water desalination plant. This pricing system also allows for allocating funds for future investments, thus increasing the sustainability of the water market. The unified average rate is subsequently updated frequently and reflects the predicted weighted average for domestic consumption of water under tiers 1 and 2.

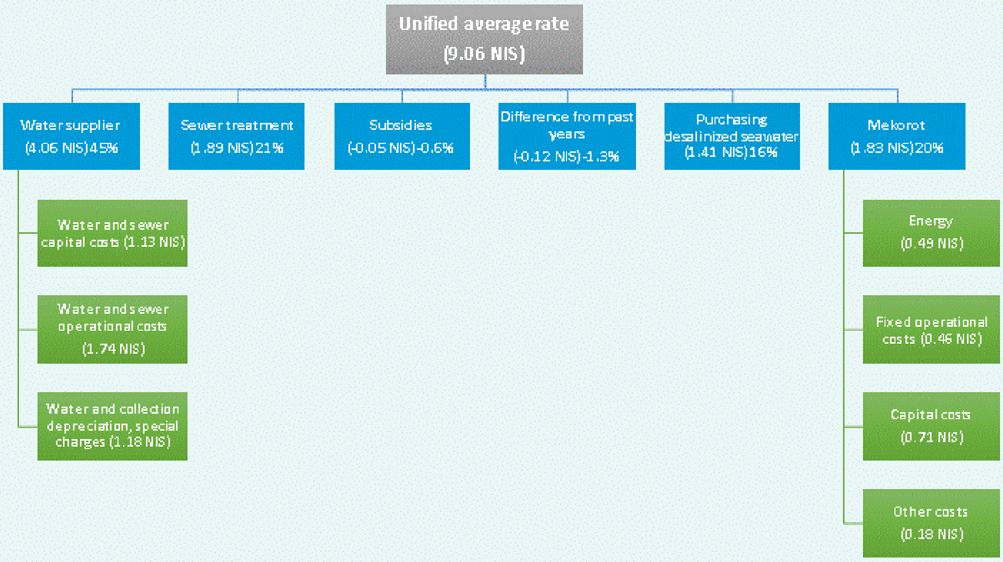

Figure 1 - Domestic water and sewer rates as of January 2019 (Israel Water Authority website, accessed February 5th, 2019)

Agriculture use rates are different and do not account for sewage treatment costs. Current costs are generally fixed throughout the country and vary primarily according to the quality of the water and the amount used with respect to pre-approved quotas (Table 2). Pricing of the different water sources available for agriculture is used, in addition to covering actual costs of water production, to regulate the consumption of different water types and provide incentives to using lower quality water when possible. For example, fresh water is the most expensive – clearly because the regulator and the managers of the local water market are interested in minimizing the use of this high-quality resource and prefers it is used for consumption. The next most expensive water for agriculture are saline water deemed as a potential threat to other water sources – clearly the motivation for the elevated prices is to prevent farmers from irrigating with such water (even if they are the ones most readily available) in order to preserve other natural resources. Similarly, the direct use of low-quality fresh water is discouraged by assigning a relatively high-water price (to preserve the resource for other applications). Using these same waters for mixing with effluents is encourage (assigned one of the lowest prices) because it allows the reuse of a resource which would otherwise be deemed waste.

Table2 - Sample water rates for agriculture. Rates vary according to water quality and the amount used (relative to the amount allotted). Rates assume 1 €=4.0 NIS

Water type	Cost €/m^3, VAT not included
Fresh Water	
Within quota	0.57
Up to 10% above quota	0.90
More than 10% above quota	1.50
Shafdan Reclaimed Water	
Within quota	0.28
Up to 10% above quota	0.83
More than 10% above quota	1.43
Effluent for Unrestricted Irrigation	
Within quota	0.30
Up to 8% above quota	0.37
More than 8% above quota	0.45
Lower Quality Effluent	
Within quota	0.26
Up to 8% above quota	0.32
More than 8% above quota	0.38
Brackish or Saline Water	
Saline	0.38
EC between 1.9 and 2.65 dSm	0.34
EC between 2.65 and 3.4 dSm	0.32
EC between 3.4 and 4.1 dSm	0.29
EC between 4.1 and 4.8 dSm	0.26
EC between 4.8 and 5.2 dSm	0.25
EC between 5.2 and 10 dSm	0.23
EC greater than 10 dSm	0.21
Low Quality Fresh Water	
Direct irrigation	0.45
For mixing with effluents	0.25

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2.7 Stakeholder involvement

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

The Success Story of Israel

Fact Sheet 7 - Stakeholder involvement

Water demand & supply → WW Treatment & reuse → Infrastructure → Quality control → Ag code of practice → Pricing → **Stakeholders** → Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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National level management of the water sector

The management of water resources in Israel is governed by the Water Law, enacted in 1959. According to this Law, there is no private ownership of water in Israel as all water resources are considered public property. This includes springs, streams, rivers, lakes, and all other surface and sub-surface water resources, including drainage and sewage. Water allocation is set at a national level with the main purpose of supplying local demand and enabling development. Property rights exclude the rights to any water resources within that property, yet the right of all persons to receive and use water is stated and protected.

Traditionally, water management in Israel was decentralized and spread among different ministries. The Water Commission, operated under the Ministry of Agriculture, was charged with allocating water from the various available resources for the different customers. Pricing for agriculture use were set by the Ministry of Agriculture and for domestic consumption by the Ministry of the Interior. During that era, water pricing was not considered a mechanism for managing the water sector.

In 2007, a reform in the structure of the water sector established the Israeli Water Authority, a new government authority set as the primary organization responsible for water related planning, regulating, and policy making. The Water Authority is a department within the Ministry of Energy. Its decisions and policy making require subsequent authorization by the Water Authority Council (WAC), a forum chaired by the Water Authority with high level representation of five ministries (Finance, Environment, Interior, Agriculture, Energy), and representatives of public interest groups (Figure 1). Although it does not have an official role in the WAC, the Ministry of Health (MOH) is a key stakeholder in decision making related to the water sector. The MOH has an integral role in the discussions, strategic planning, and subsequent changes that affect different aspects of the water sector, acting as the protector of the public's right to safe water at suitable quality for all uses.

Multi-discipline involvement in setting water quality regulations

Drinking water regulation in Israel is set by the Ministry of Health, typically joined by external advisory committees that include members of the academia and institutions related to water supply and treatment such as Mekorot. Regulations for effluent treatment and reuse, published in 1992 and updated in 2010, are also set by the MOH, with additional involvement from the Ministry of Agriculture, Mekorot, and additional stakeholders as mentioned above. Reclaimed effluent produced after Soil Aquifer Treatment of the Shafdan WWTP effluents (serving the greater Tel Aviv area) are excluded from this regulation as, due to their superior quality, they are referred to as potable water for considerations related to irrigation practices.

The regulations for using reclaimed effluents are set by the Ministry of Agriculture which, through an advisory committee led by a former high official in the MOH, created a directive for the safe use of reclaimed effluent that covers all the different applications where such use is permitted. To meet this regulation, each farmer is required to obtain a permit for using reclaimed water. The permit is specific and allows the use of effluent only for the crops requested by the farmer, under the specific irrigation conditions defined in his or her request. This regulation is enforced by the Israeli Nature and Parks Authority, which has the authority to audit farmers and assure they adhere to the letter of their permits.

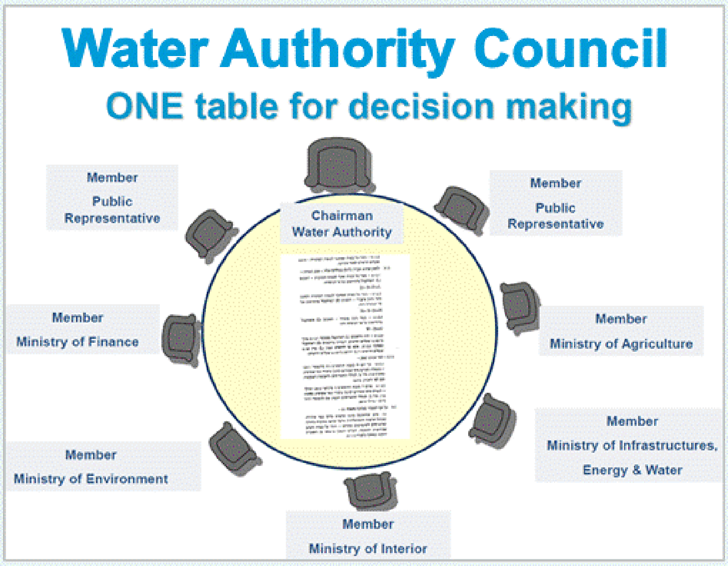

Figure1 - Structure of the Water Authority Council, responsible for authorising decisions and policies set by the Water Authority and any ministries.

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2.8 Public acceptance

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

The Success Story of Israel

Fact Sheet 8 – Public acceptance

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | **Public Acceptance**

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Israel has been facing water shortage since before its establishment due to the local climate, precipitation patterns, and natural geographical dispersal of its water resources. This shortage has created a local state of mind that readily accepts the notion of water conservation and recycling. Water conservation is and has been promoted through various outlets, such as street signs (Figure 1) and TV and radio infomercials. Outreach efforts to encourage the public to conserve water are planned at the national level by the Water Authority (and before its establishment – by the Water Commission) and target various water uses, e.g., encouraging shorter shower times, calling to keep the tap closed while soaping and tooth brushing (Figure 2), and increasing the awareness to the shortage in available water resources (Figure 3).

Figure 1 - Signs from the 1960s calling for water conservation (the left sign reads "every drop counts"; the right sign reads " save water; every drop counts")

Figure 2 - A sign at a beach shower in Tel Aviv calling to keep the faucet closed while soaping

Figure 3 - "If you don't turn off (the faucet) we will run out of water"

Initial attempts to increase awareness and create public acceptance for water conservation and reuse date to the 1940s, where for a prolonged period of time the residents of Jerusalem had to make due with only 10L per day (Figure 4). Water shortage lead to commercial reuse for restricted irrigation as early as the 1960s, reusing oxidation ponds effluents (40-60 mg BOD/L, 60-90 mg TSS/L). Public Health Regulations for Effluent Quality and Sewage Treatment were first published in 1992 (then updated in 2010), establishing maximum allowed BOD (20 mg/L) and TSS (30 mg/L) concentrations in treated effluent. This required that all WWTPs be converted from oxidation ponds and other technologies to a more robust activated sludge treatment, increasing effluent quality and creating new opportunities for effluent reuse.

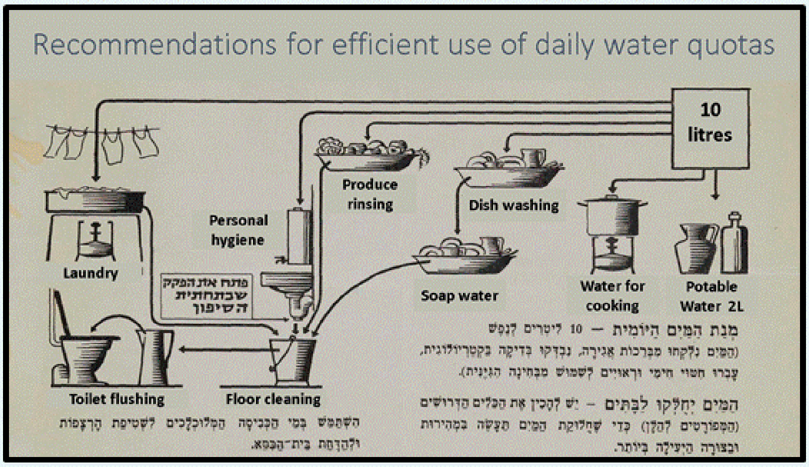

Figure 4 - Detailed instructions explaining basic concepts of domestic water use and reuse (Jerusalem, 1948).

Regulatory and other measures to increase reuse for agriculture

The common practice in Israel grants each farmer a water quota to be used for irrigation. Until 1989, these quotas were strictly based on potable water. The construction of the Third Line to the Negev (see Fact Sheet 3) made a new source of water available to farmers in the dry south region of the country, suitable for unrestricted irrigation.

The following measures were taken to increase the acceptance and willingness of farmers to use reclaimed effluent for irrigation:

- Consultation events were organized where information was provided to the farmers regarding advantages and safety aspects of irrigating using reclaimed water.
- Farmers were offered a 20% increase to their water quota for the portion they were willing to replace with reclaimed effluent (i.e., for every 100 m³ of potable water quota relinquished, the farmer would receive 120 m³ quota of reclaimed effluent).
- The quality of reclaimed effluent from the Shafdan WWTP (see Fact Sheet 2) far exceeds that of tertiary effluent. Irrigation with these effluents is regulated by the Ministry of Health according to the criteria set for potable water, eliminating the bureaucratic burden of applying for a permit for irrigating with reclaimed effluents.
- For similar reasons, crops irrigated with Shafdan reclaimed effluent are considered to be grown using potable water for the purpose of international export.

Over time farmers realized that reclaimed effluents contain valuable nutrients (N, P) which reduce their fertilization cost, creating another motivation for effluent reuse.

Nowadays the demand for reclaimed effluents in general, particularly for those of the high Shafdan quality, far exceeds the amount of effluents available for supply. Mekorot works constantly to increase its reuse rates and to provide farmers with more high quality Shafdan reclaimed effluents for irrigation.

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3 Lessons learned from successful reuse in Cyprus

3.1 Water demand and supply: facts and figures

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

The Success Story of Cyprus

Fact Sheet 1 - Water demand and supply: facts and figures

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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Cyprus, an island country located in the eastern Mediterranean Sea, has a semi-arid climate that offers mild winters and hot dry summers because of the varying topographic characteristics arising from the island's mountainous terrain. It has a total land area of 9254 km^2. The annual temperature in the country ranges from 14 to 17 °C during the winter period and 30 to 37 °C during the summer. The wet season extends from November to March, with approximately 60% of the rainfall between December and February. The average annual precipitation is 480 mm, with the highest and lowest values being recorded in the higher altitudes of the Troodos Mountains (1100 mm) and in the eastern coast (300 mm), respectively (Figure 1).

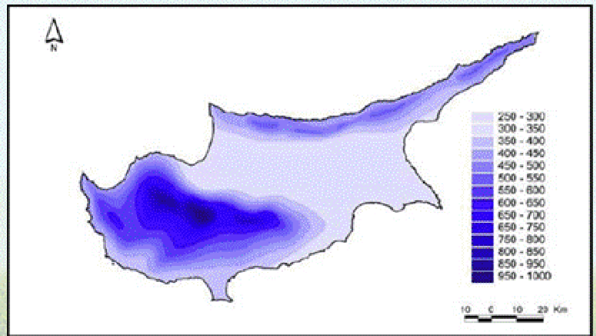

Figure 1 - Annual rainfall in Cyprus
(Source: Cyprus Water Development Department, 2019)

Agriculture and domestic utilization are the main economic sectors of water demand in Cyprus. Agriculture is likely to encounter the most serious threats due to water scarcity, as it is the major consumer of water in Cyprus (Christou et al., 2017). Water demand for irrigation (agriculture and landscape) is around 160 million cubic meters (MCM) (59% of the overall water demands), while 29% of the overall water demand is for domestic use, 5% for tourism, 3.3% for livestock farming and 3% for industrial use.

Dams and desalination provide 85-90% of the total drinking water, while up to 40% of irrigation water is provided by dams and water recycling (Figure 2). Groundwater serves 10-15% of the total drinking water and up to 60% of the total irrigation water. However, it should be noted that groundwater aquifers which used to be the most obvious and easily accessible water source in the country, are highly overexploited and deteriorated.

Moreover, piezometric levels decrease rapidly, resulting in seawater intrusion with water quality effects such as increase of salinity of ground water along coastal areas.

Thus, the increasing water demand for both irrigation and human consumption has led to the development of large infrastructure projects, such as:

- the construction of over 100 dams with total storage capacity of 332 MCM of water;
- urban wastewater treatment plants/water reclamation plants (UWTPs);
- water reallocation projects (e.g. large-scale water distribution networks and drilled boreholes for domestic and irrigation purposes) to store, process and transfer water throughout the island and specifically to supply adequate irrigation water to agricultural areas.

Picture 1 – Image of an irrigated field area with reclaimed water in Nicosia, Cyprus

Furthermore, several agronomic and policy measures have been adopted towards the alleviation of the irrigation water demand, with the most important being the reuse of reclaimed water for irrigation (Picture 1), the extended use of advanced irrigation systems and the adoption of the recycling nutrient solution in greenhouses.

Another set of action measure taken by the Cyprus government to help alleviate the increasing problem of water scarcity and to eliminate the dependency of the domestic water supply on annual rainfall was:

- To proceed with the construction of seawater desalination plants. Consequently, at present, these contribute up to 72 MCM per year. However, the desalinated water production varies according to the domestic water abstracted from dams per year (Figure 2).
- To replace freshwater used in agriculture by tertiary-treated urban wastewater effluents. Reclaimed water is used to satisfy part of the existing irrigation needs. Today, 15% of the irrigation needs are covered by reclaimed water, and in 2025 it is expected to cover 25% of the irrigation needs.

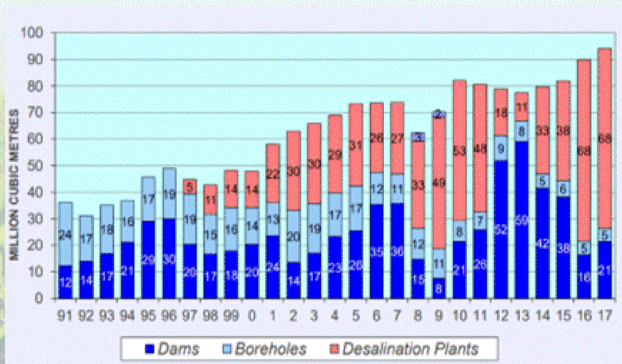

Figure 2 - Drinking water supply from Governmental Water Works (1991-2017)
(Source: Water Development Department, 2019)

CLOSING REMARKS

The water demand in Cyprus exceeds the overall water supply, and as a result various important centralized agronomic, infrastructure and policy measures have been adopted towards the alleviation of the overall water demand. The most important measures concern the creation of dams, the utilization of existing and creation of new boreholes and reservoirs, desalination plants, the reuse of reclaimed water for irrigation and the extended use of advanced irrigation systems and recycling of nutrients in greenhouses.

An organized, centrally-governed framework that combines all of the above water stress-mitigation measures, achieves the successful management of the water supply in a manner that serves the needs of urban and agricultural areas, even under conditions of high water stress.

REFERENCES:

Christou, A., Dalias, P. and Neodeous, D., 2017. Spatial and temporal variations in evapotranspiration and net water requirements of typical Mediterranean crops on the island of Cyprus. The Journal of Agricultural Science, 155 (8), 1311-1323.

Water Development Department (WDD), Information and Data on Water Resources, Water Use and Wastewater Treatment Plants Provided by the Water Development Department, Cyprus, 2019.

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3.2 Wastewater treatment and reuse

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

The Success Story of Cyprus

Fact Sheet 2 - Wastewater treatment and reuse

Water demand & supply | **WW Treatment & reuse** | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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The increasing water stress and the semi-arid climate of Cyprus make reclaimed water a growing water resource to meet the water demands of the island. Today, Cyprus water demands by sector are 59% for irrigation, 29% for domestic use, 5% for tourism needs, 3.3% for livestock farming and 3% for industrial purposes.

More than 30 million cubic meters (MCM) of reclaimed water are being produced today, while by 2027 up to 74 MCM are expected to be produced. Reclaimed water is mainly used to satisfy part of the existing irrigation needs. In detail, today, 15% of the total irrigation needs are covered by reclaimed water, a percentage which is expected to reach 25% by 2025.

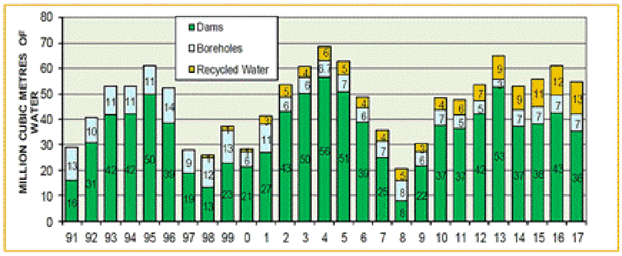

Figure 1 - Irrigation water supply, 1991-2017.
(Source: Cyprus Water Development Department, 2019)

In more detail, reclaimed water in Cyprus is utilised for the following purposes:

- **Irrigation of crops, grass and green areas** - the irrigation is done under the Code of Good Agricultural Practice: K.D.P. 263/2007.
- **Infiltration in dry river beds** - the reclaimed water enters about 22 shallow ponds constructed by the Cyprus Water Development Department, through which it reaches the aquifer.
- **Enrichment of aquifers** - Aquifers of reclaimed water are used as storage reservoirs mainly in winter. The water from the aquifers is then extracted and used for irrigation. Main examples of aquifers' recharge:
  - Limassol: the water is used for the recharge of Akrotiri aquifer in winter when there is surplus of reclaimed water.
  - Paphos: all the reclaimed water in Paphos is used for the recharge of Ezousa aquifer
- **Discharge into the sea** - due to the seasonal demand of water for irrigation and limited surface/ground storage capacity, unused reclaimed water is discharged into the sea and Polemidia dam, where it may be used for irrigation during the winter months.

To date, reclaimed water satisfies the needs of 5000 ha in total, through existing and new irrigation networks. Since 2004, reclaimed water has also been used for artificial recharge of aquifers with water of low quality (natural high sulphate and boron concentrations). This water is pumped again from the aquifers, and through the irrigation pipes, for distribution for irrigation in water-stressed agricultural areas.

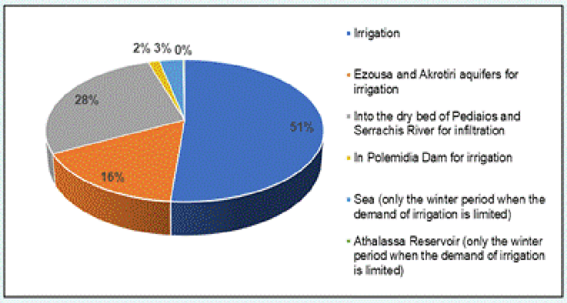

Figure 2 - Treated wastewater reuse for 2016 (for agglomerations with ≥2.000 P.E.)
(Source: Cyprus Water Development Department, 2019)

Artificial recharge with reclaimed water can be considered as a good case study, which can be applied in areas with similar geological conditions to Cyprus, suffering from droughts, since (i) seawater intrusion is controlled, (ii) it provides storage of effluent water for subsequent retrieval and reuse, (iii) the aquifer serves as an eventual natural distribution system, (iv) further purification of effluent water is made (reducing biological load) and (v) saving of equal quantities of freshwater for domestic use.

There are six (6) main urban wastewater treatment facilities (UWTPs) (> 2000 P.E.) in the government-controlled areas of Cyprus, serving the big urban centers of the island (Table 1). Due to the Cyprus political situation, the Mia Milia WWTP serving part of the Nicosia area, is not included in this fact sheet, since it is not managed by the Cyprus Government.

Moreover, eight (8) rural UWTPs serve communities with P.E. higher than 2000, five (5) rural UWTPs serve communities with PE below 2000, three (3) plants serve refugee housings, three (3) plants serve hospitals, nine (9) plants serve military camps and one (1) plant serves the Immigration Detention Centre at Menoyia (Water Development Department, 2019).

Table 1 - Capacity of the main UWTPs in Cyprus and technologies applied
(Source: Water Development Department, 2019)

WWTP	Capacity (m^3/day)	Capacity (Person Equivalent (PE))	Biological treatment process applied	Tertiary treatment process applied
Anthoupoli	13000	130000	Membrane Bioreactor (UF)	-
Vathia Gonia (NSB)	22000	202000	Membrane Bioreactor (MF)	UV disinfection
Larnaca	18000	100000	Membrane Bioreactor	Sand filtration - Chlorination
Moni Limassol	40000	272000	Conventional Activated Sludge	Sand filtration - Chlorination
Paphos	19500	160000	Conventional Activated Sludge	Sand filtration - Chlorination
Paralimni – Ayia Napa	21000	125000	Conventional Activated Sludge	Chlorination
Total	**133500**	UF: Ultrafiltration; MF: Microfiltration		

In conclusion, Cyprus is a good example of water reclamation and reuse, as there are reclamation facilities in all major cities, thus treating the majority of the island urban wastewater. Moreover, water reuse schemes have been long implemented and have been briefly described in this fact sheet, showcasing the ways in which water reuse can be successful and effective in serving the needs of water stressed areas following of course the Code of Good Agricultural Practice.

REFERENCES:

Water Development Department (WDD), Information and Data on Water Resources, Water Use and Wastewater Treatment Plants Provided by the Water Development Department, Cyprus, 2019.

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3.3 Projects and infrastructure to tackle water shortage

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

The Success Story of Cyprus

Fact Sheet 3 - Projects and infrastructure to tackle water shortage

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | Public Acceptance

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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The increasing water demand for both irrigation and human consumption, during the past century, has led to the development of large infrastructure projects in Cyprus, such as: 1) dams (e.g. construction of over 100 dams with total storage capacity of 332 MCM of water), 2) urban wastewater treatment plants/water reclamation plants (UWTPs), 3) water reallocation projects (e.g. large conveyors/reservoirs and drilled boreholes for domestic and irrigation purposes) to store, process and transfer water throughout the island and specifically to supply adequate irrigation water to agricultural areas and 4) desalination plants (Water Development Department, 2019).

The annual inflow of water to the Cypriot dams (Figure 1) for the years 1987-2017 are presented in Figure 2, with an average value of 79 MCM/year, while the annual water to the dams for the year 2016-2017 was 48.9 MCM. Concerning surface water, the water corresponding to the total surface of the government-controlled area of the island is 2792 MCM (average from 2000 to 2017), while the inflow of surface and groundwater is 279 MCM (Water Development Department, 2019).

Figure 1 - A map of the dams of Cyprus.
(Source: Water Development Department, 2019)

In 2017, 55 MCM were used for irrigation purposes, from which 36 MCM were from dams, 7 MCM from boreholes and 13 MCM from tertiary-treated effluents.

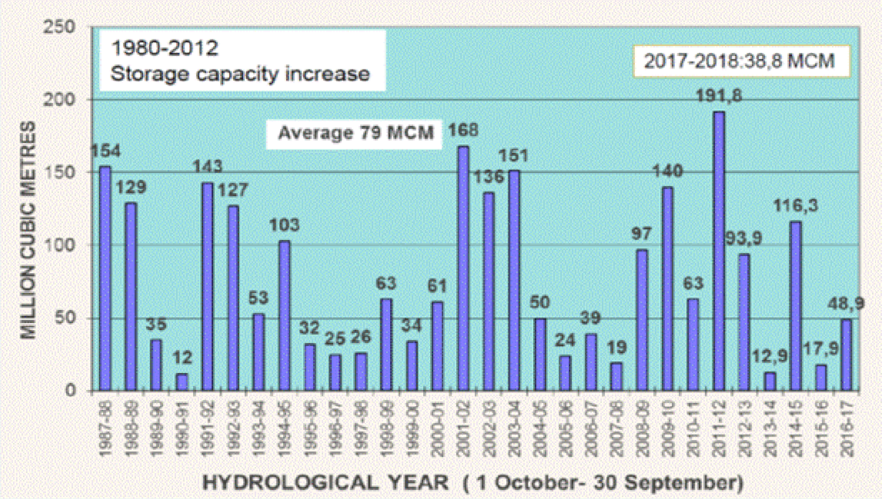

Figure 2 - Inflow of water to the Cypriot dams (1987-2017).
(Source: Water Development Department, 2019)

Despite the development of the conventional surface and underground water sources, Cyprus continued to face an acute water shortage problem. Therefore, in order to eliminate the dependency of the domestic water supply on annual rainfall, the Cyprus Government decided:

- To proceed with the construction of desalination plants (in total 4 desalination plants in Larnaca, Dhekelia, Vasilikos and Limassol, with total yield of 220.000 m³/day or 80 MCM/year);
- To replace freshwater used in agriculture by reclaimed water (1995). To date, reclaimed water satisfies the needs of 5000 ha in total, through existing and new irrigation networks (Figure 3).

There are six (6) main UWTPs (> 2000 P.E.) in the government controlled areas of Cyprus, serving the big urban centers of the island (i.e. Limassol, Anthoupolis, Vathia Gonia, Larnaca, Paphos, Ayia Napa - Paralimni Sewage Boards) and another one (i.e. Mia Milia) in the non-government controlled areas (with a capacity of 30000 m³/day, which applies a membrane bioreactor treatment method). The latter WWTP also serves a large part of Nicosia that is controlled by the government of the Republic of Cyprus.

The capacity of the main UWTPs and the technologies applied in each UWTP are presented next. The six UWTPs serving the big urban centers of the country, today have a total capacity of 133500 m³/day and consist of a primary, a secondary and a tertiary stage.

According to the Cyprus Law, sewage treatment is of Tertiary Degree, which is higher than the requirements of the EU Directive 91/271/EEC, which states that "treated wastewater shall be reused whenever appropriate", leaving too much room for interpretation as to what can be considered as an "appropriate" situation to reuse reclaimed water.

<u>Tertiary Treatment in Cyprus consists of</u>:

- Activated Sludge with Sand Filtration and Chlorination (3 facilities – Limassol, Paphos and Paralimni - Ayia Napa)
- Membrane Bioreactor with Chlorination (1 facility – Larnaca)
- Membrane Bioreactor with UV disinfection (1 facility – Vathia Gonia (Nicosia))
- Membrane Bioreactor (Ultrafiltration) (1 facility – Anthoupoli (Nicosia))

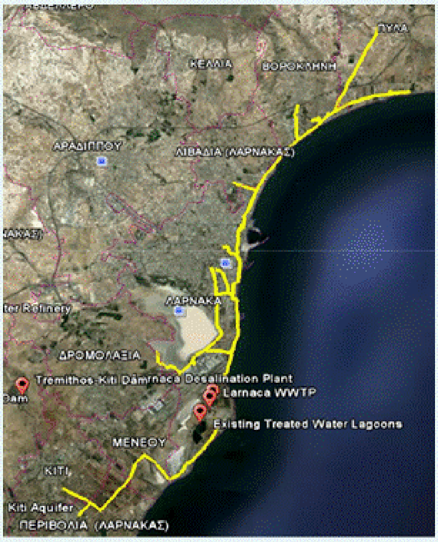

Figure 3 - Larnaca area treated effluent irrigation schemes.
(Source: Water Development Department, 2019)

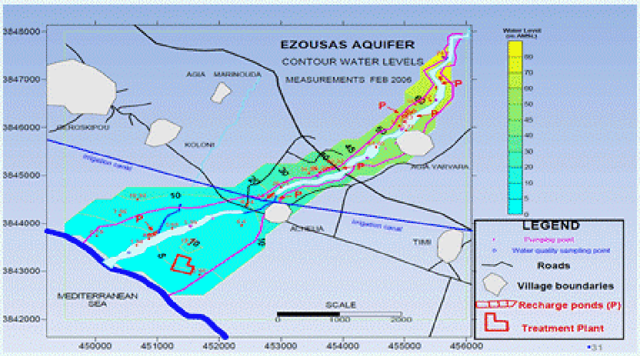

Figure 4 - Artificial recharge of Ezousa river alluvial aquifer (Paphos) with reclaimed water.
(Source: Water Development Department, 2019)

CLOSING REMARKS

In conclusion, Cyprus is a very good example of water treatment and reuse, as there are reclamation facilities in all cities covering the majority of the urban areas, thus treating the majority of the island coverage. Moreover, water reuse schemes have been long implemented and have been briefly described in this fact sheet, showcasing the ways in which water reuse can be successful and effective in serving the needs of water stressed areas.

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3.4 Quality control of treated effluent

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

The Success Story of Cyprus

Fact Sheet 4 - Quality control of treated effluent

Water demand & supply | WW Treatment & reuse | Infrastructure | **Quality control** | Ag code of practice | Pricing | Stakeholders | Public Acceptance

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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Quality Control of the reclaimed water in Cyprus is dictated clearly in legally binding instruments.

- "Water Pollution Control Law (106(I)/2002 to 2009)"
- and the "Ministerial Decree of small-scale UWTPs (KDP 269/2005)".

According to the Article 12 of the Directive 91/271/EEC referring to Urban Wastewater Treatment, "treated wastewater shall be reused whenever appropriate". Based on the Code of Good Agricultural Practice issued with a decree within the framework of Cyprus Water Pollution Control Laws, the use of recycled wastewater of appropriate quality is required and is an environmentally accepted solution, given the dry climate and reduced rainfall in Cyprus.

A. Quality Control for Urban and Rural Agglomerations above 2.000 person equivalents (P.E.):

Sampling and analysis are being executed by:

- Urban Sewerage Boards (USBs): Assure the quality of treated effluent according to the requirements of their Discharge Permits (Law 106(I)/102);
- Water Development Department (WDD): is responsible of the disposal of the treated effluent produced by the Urban Sewerage Boards (government policy);
- Department of Environment (DoE): is responsible for issuing the Discharge Permits. Moreover, the DoE follows up whether every UWTP meets the requirements of their Discharge Permits.

The quality characteristics of recycled water are included in the terms of discharge and disposal permits (Table 1).

Table1 – Effluent quality characteristics included in disposal permits of UWTPs above 2000 P.E. and frequency of controls by WDD and USB (*WDD: Water Development Department, USB: Urban Sewerage Board) (Source: Cyprus Water Development Department, 2019).

A/A	PARAMETERS	MAXIMUM PERMITTED VALUE	FREQUENCY OF ANALYSIS - BY WDD	FREQUENCY OF ANALYSIS - BY USB
1	BOD5	10 mg/l	4/year	1/15 days
2	COD	70 mg/l	4/year	1/15 days
3	Suspended Solids (SS)	10 mg l	4/year	1/15 days
4	Conductivity	2500 pS/c m	4/year	1/15 days
5	Total Nitrogen (TN)	15 mg l	4/year	1/15 days
6	Total Phosphorous (TP)	10 mg l	4/year	1/15 days
7	Chlorides (Cl)	300 mg/l	4/year	1/month
8	Fat and Oil	5 mg/l	4/year	1/month
9	Zinc (Zn)	1mg/l	2/year	2/year
10	Copper (Cu)	0,1mg!l	2/year	2fyear
11	Lead (Pb)	0,15 mg/l	2/year	2/year
12	Cadmium (Cd)	0,01 mg/l	2/year	2/year
13	Mercury (Hg)	0,005 mg/l	2/year	2/year
14	Chromium (Cr)	0,1mg/l	2/year	2/year
15	Nickel (Ni)	0,2 mg/l	2/year	2/year
16	Boron (B)	1mg/l	2/year	2/year
17	E.Coli	5 E.Coli / 100ml	4/year	1/15 days
18	Eggs of Intestinal Worms	Nothing	4/year	4/year
19	Residual Chlorine	1mg/l	4/year	1/15 days
20	pH	6.5-8,5	4/year	1/15 days
21	Toxicity		1/year	1/year

Information on the frequency of analyses by the Water Development Department (WDD) and the Urban Sewage Boards (USBs) is also included in the disposal permits.

B. Quality Control for Rural Agglomerations less than 2.000 P.E.:

Sampling and analysis are being executed by the Water Development Department.

In addition, specific terms for reclaimed water disposal apply for all WWTPs serving a capacity of P.E. of 2000 residents (P.E.) or below. Based on these, treated wastewater could be reused for irrigation or stored in reservoirs for further use. The exact areas to be irrigated need to be identified and disposal and use of reclaimed water should be in accordance to the Cyprus Code of Good Agricultural Practice (Table 2).

Table2 – Dramatic changes in B concentration in secondary effluent of the Shafdan WWTP over time in response to drastic changes in regulation

A/A	Species allowed to be irrigated	BOD_5 (mg/L)	Suspended Solids (mg/L)	*E. coli / 100 mL*	Intestinal worms ***
1	All crops and green areas with restricted use (a)	10*	10*	5*	N/L
				15**	
2	Green areas and cooked vegetables (b)	10*	10*	50*	N/L
		15**	15**	100*	
3	Green areas with restricted use by the public	20*	30*	200*	N/L
		30**	45**	1000*	
4	Fodder crops	20*	30*	1000*	N/L
		30**	45**	5000**	
5	Industrial crops	50*	-	3000*	-
		70**		10000**	

* 80% of the samples, 24 samples/year
** Max acceptable value
*** sampling frequency once a year/summer months
(a) No vegetables with leaves, bulbs and condyles eaten raw
(b) Potatoes, Beetroots

Reclaimed water that will be used for irrigation must not contain toxic elements or compounds which on their own or in combination are accumulated on the edible parts of the plant irrigated with reclaimed water and have been proven to be toxic for humans.

During the winter period, reclaimed water should be stored in a tank of a capacity equal to the water quantity for at least 10 days. Storage of reclaimed water in dams is allowed only in cases when the water is used for irrigation purposes. Also, in cases where the stored water in dams is used for drinking purposes, the reclaimed water percentage should not exceed 5% total stored water content. Toxicity inspections must take place four times per year or less frequently, when the conditions allow it, while genotoxicity tests must be conducted at least once per year (Kalavrouziotis et al., 2015).

Closing remarks

The strict quality control scheme of water reclamation and reuse which is aided by the regulatory enforcement of high quality standards, encourages a very high degree of compliance of the stakeholders who make use of reclaimed water. Moreover, a high degree of coordination and communication among the governmental authorities and organizations that are in control of the water reuse schemes in Cyprus, makes the monitoring of quality and compliance, a success story.

References:

Water Development Department (WDD), Information and Data on Water Resources, Water Use and Wastewater Treatment Plants Provided by the Water Development Department, Cyprus, 2019.

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3.5 Code of practice for agricultural irrigation

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

The Success Story of Cyprus

Fact Sheet 5 - Code of practice for agricultural irrigation

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | **Ag code of practice** | Pricing | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – Lessons learned from the success stories of Cyprus and Israel

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Agricultural irrigation in Cyprus is governed by the Cyprus Code of Good Agricultural Practice (GAP) (No. 263/2007). Under this Code, the included guidelines mark the way of safe irrigation with reclaimed water.

The main provisions of the Code include, among others (Table 1):

- Restrictions on the type of crops irrigated: Irrigation of crops is allowed, except for leafy vegetables, bulbs and condyles that are eaten raw (e.g. lettuce, carrot, celery, parsley).
- Safety precautions for the proper use of reclaimed water:
  - The use is prohibited by unauthorized persons.
  - Marking pipes with red line.
  - Clear signaling to alert the public that the reclaimed water is undrinkable.
  - Hydrants and distribution systems should have protection.
- Irrigation practices according to the methods of irrigation (subsurface/drip/sprinklers) and to the kind of crops (Picture 1).
- Main uses (in order of "preference")
  - Forest trees
  - Fodder crops
  - Fruit-tree orchards
  - Green areas
  - Vegetables

Picture 1 – Image of an irrigated field area of alfalfa crop with reclaimed water in Nicosia, Cyprus

Table1 – Cyprus Code of GAP– PART IV: Use of recycled water for irrigation purposes.

TYPE OF CROPS AND IRRIGATION PRACTICES APPLIED
For **grass** and **green areas with free use from the public** irrigation must be done at night and when there are no persons on the premises. The permitted irrigation practices include subsurface or drip irrigation and sprinklers with low-pressure and high-intensity rainfall, depending on the soil type.
For **grass**, **green areas with limited use**, **agricultural crops** and **livestock farming**, the permitted irrigation practices include subsurface, drip and controlled surface irrigation as well as folding sprinklers, low-pressure sprinklers and high-pressure sprinklers (in case of complete absence of wind)
For **vineyards**, drip irrigation and sprinklers are used. In cases that the fruit is wet, irrigation is interrupted two weeks before harvest. The harvest of grapes from the ground is prohibited.
For **tree crops** the permitted irrigation practices include drip and controlled surface irrigation as well as sprinklers. **Important note:** In cases that during the irrigation the fruit is wet, irrigation must be interrupted at least one week before harvest. It is also not allowed to collect fruit from the ground, except in the case of nuts.
For **vegetables eaten raw,** drip and subsurface irrigation are permitted. **Important note:** Measures should be taken to ensure that fruits do not come into contact with reclaimed water.
For **vegetables eaten cooked**, the sprinkler, subsurface and drip irrigation techniques are permitted.
It is forbidden to irrigate with reclaimed water **leafy vegetables**, **bulbs** and **condyles that are eaten raw** (e.g. lettuce, carrot, celery, parsley).

In small reclamation facilities, specific terms for waste disposal are applied (P.E. below 2000 P.E.). Based on these, reclaimed water may be reused for irrigation or stored in reservoirs for further use. The exact areas to be irrigated need to be identified and disposal and use of reclaimed water should be in accordance to the Cyprus Code of GAP (Table 2).

Table2 – Specifications for the quality of reclaimed water used for irrigation purposes for UWTPs below 2000 P.E. the Cypriot Regulation KDP269

	Species allowed to be irrigated	BOD, (mg/L)	Suspended Solids (mg/L)	*E. coli* / 100 mL	Intestinal worms ***
1	All crops and green areas with restricted use (a)	10*	10*	5* 15**	N/L
2	Green areas and cooked vegetables (b)	10* 15**	10* 15**	50* 100*	N/L
3	Green areas with restricted use by the public	20* 30**	30* 45**	200* 1000*	N/L
4	Fodder crops	20* 30**	30* 45**	1000* 5000**	N/L
5	Industrial crops	50* 70**	-	3000* 10000**	-

* 80% of the samples, 24 samples/year
** Max acceptable value
*** sampling frequency once a year/summer months
(a) No vegetables with leaves, bulbs and condyles eaten raw
(b) Potatoes, Beetroots

The improved irrigation efficiency via the use of reclaimed water in Cyprus, has been achieved by the responsible authorities and specifically by the Cyprus Water Development Department through the following means:

- Cropping patterns selected and proposed to farmers to ensure efficient utilization of water at farm level based on water supply reliability, project economics, land resources, climatic conditions.
- Water allocated to agriculture using a quota system and penalty charges for over-consumption.
- Irrigation water in government schemes distributed through modern and highly efficient systems (e.g. closed pipes, drippers, sprinklers).
- Improved irrigation systems currently cover 95% of total irrigated area (annual water savings are of the order of 75 MCM).

Conveyance efficiencies: 90-95% | Field application efficiencies: 80-90%.

CLOSING REMARKS

Specific regulatory guidelines in the framework of the Cyprus Code of GAP, has enabled the strict monitoring of the quality of reclaimed water used for irrigation, as well as the compliance of the stakeholders to high quality criteria for use of reclaimed water for crop irrigation which may be intended for human consumption.

REFERENCES:

Water Development Department (WDD), Information and Data on Water Resources, Water Use and Wastewater Treatment Plants Provided by the Water Development Department, Cyprus, 2019.

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3.6 Pricing system for irrigation water

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

The Success Story of Cyprus

Fact Sheet 6 - Pricing system for irrigation water

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | **Pricing** | Stakeholders | Public Acceptance

KEYS FOR SUCCESS – **Lessons learned from the success stories of Cyprus and Israel**

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 16 factsheets that describe the successful reclamation practices of Israel and Cyprus in order to learn and boost implementation of solutions adapted to the European context. Our ultimate goal is to enhance acceptance and awareness to an alternative source of an increasingly scarce resource, water.

Adequate water pricing is important for the sustainable, long-term financing of high quality drinking water and sewerage services. However, there are often insufficient price differentials between reclaimed water and freshwater, which is made worse by a lack of sufficient cost recovery and the existence of public subsidies to conventional water resources in many areas of the EU.

The development of water reuse schemes, therefore, needs to be done in the wider economic context of user - polluter - and beneficiary - pays principles (Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the WFD, 2016).

In general, water reuse may be economically favorable compared to other unconventional sources (i.e. desalinated water) (UNEP, 2012) and it is important that pricing for reclaimed water is integrated with pricing in the context of wider water supply. However, competitive price rates from reclaimed water (at or below those of freshwater) have been seen as essential to drive uptake (Hidalgo and Irusta, 2005).

Low levels of cost recovery would discourage both water efficiency and reused water by failing to account for the full external costs of freshwater abstraction and wastewater discharge. Because these external costs are typically borne by taxpayers, price support measures for water reuse may be justified, to enhance its competitiveness.

This is the case for Cyprus, where water reuse schemes have significant uptake partly through the use of subsidies, together with an integrated supportive regulatory regime.

Picture 1 – Image of an irrigated field area of alfalfa crop with reclaimed water in Nicosia, Cyprus

In Cyprus, the Water Development Department (WDD) and the Cyprus Urban Sewerage Boards (Public Utility Organizations) are responsible for the construction of water reclamation facilities and the sewerage networks, while the Urban Sewerage Boards are responsible for their operation and maintenance.

Specifically, **80% of the capital cost** (construction cost) of sewerage networks, reclamation facilities/UWTPs, treated effluent storage lagoons and central irrigation networks are covered by the European Community (i.e. national Funds, co-financed by the cohesion fund of the EU and the Cyprus Government, loans from European Investment Bank (EIB) up to 50% of the required expenses and contribution of the Community).

The remaining **20% of the capital cost** and the 100% of the related cost of the operation and maintenance of the treatment facilities are covered by the Urban Sewerage Boards.

The above operation and maintenance costs are covered through taxation of the citizens, and specifically, through the:

- sewerage fee, which is paid once a year based on the value of the house, and the
- sewerage system use, which is paid every two months based on the drinking water consumption.

Reclaimed water is supplied for irrigation and landscape uses in Cyprus, with a price that is only 33% - 40% of the price of freshwater supplied for the same uses, in the same areas (i.e. freshwater price is €0.17/m³ for agriculture and €0.36/m³ for landscape, while the reused water price is €0.07/m³ and €0.17-0.23/m³, respectively). **This is one strong incentive for the end-users to accept reclaimed water as a new reliable water resource.** The water selling prices for reclaimed water and freshwater (not filtered) are presented in Table 1.

Table 1 – Irrigation water rates from Government Water Projects and from governmental networks of reclaimed water (Source: Water Development Department, 2019)

A/A	Use	Water Selling Rate: Tertiary-treated effluent	Water Selling Rate: Fresh not filtered water from government water works
		EUR /m³	EUR /m³
1	Fixed annual fee	2.40/decario	2.40/decario
2	For persons for agricultural production	0.07	0.17
3	For irrigation divisions for agricultural production	0.02	0.12
4	Industry	0.17	0.25
5	For irrigation of sport fields, parks and other green areas falling under the responsibility of State / Local Authorities	0.12	0.23
6	For irrigation of private sports fields and private green areas, hotel and house gardens	0.17	0.36
7	For irrigation of golf fields	0.23	0.36
8	For over consumption for agricultural use	Increase by 50%	0.45
9	For over consumption for the items 3 to 7	Increase by 50%	Increase by 50%

Setting an excessively low price for reclaimed water in relation to existing alternatives could over-encourage the use of this water, provoking unsuitable uses and even external costs and possibly damage the image of reclaimed water seen as "less good" than existing alternatives. A solution to this is the use of an increasing block tariff - stepped increases in tariffs as usage increments. In essence, fixing the price for reused water is always a trade-off of cost distribution between the beneficiaries, the operators and the tax payer in general (Guidelines on Integrating Water Reuse into Water Planning and Management in the context of the WFD, 2016).

CLOSING REMARKS

Adequate water pricing is important for the sustainable, long-term financing of high quality drinking water and sewerage services. As a result, pricing mechanisms must be employed by governmental bodies to encourage the reuse of water, in combination with financial incentives such as subsidies for such reuse. Strict monitoring is required to make sure that water is reused appropriately and that no misuse occurs.

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3.7 Stakeholder involvement

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

The Success Story of Cyprus

Fact Sheet 7 - Stakeholder involvement

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | **Stakeholders** | Public Acceptance

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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The management of the water resources is the responsibility of the Cyprus Government, which is framed by National and European legislation.

The competent authority for decision making regarding the management of water sources in Cyprus, is the Council of Ministers, after the proposals made by the Minister of Agriculture, Rural Development and the Environment. The Council of Ministers decides whether to take into consideration the opinion/advice of the Water Management Advisory Committee (which includes members from governmental departments, the local Water and Sewage authorities, the users' associations, the environmental organizations and other stakeholders). The Water Development Department of the Ministry of Agriculture, Rural Development and Environment is responsible for the implementation of the Government's water policy, regarding the development, management and protection of the water resources. Also, it is responsible for the management, operation and maintenance of the Government Water Works. The Local Water Authorities (i.e. Water Boards, Communities and Municipalities) are responsible for the distribution of domestic water to the end-users. Sewerage Boards are responsible for the collection and treatment of urban wastewater. The Ministry of Interior is the responsible stakeholder for the conduction of the Local Water Authorities and Sewage Boards duties.

More details about the role and the activities of the above ministries/departments/authorities are presented in this factsheet.

The **Ministry of Agriculture, Rural Development and Environment** undertakes the immense responsibility, to promote through an integrated coordination, the protection and sustainable management of the environment, natural resources, and the sustainable management of agricultural, livestock and fisheries production. The **Department of Agriculture**, the Department of Veterinary Services, the Agricultural Research Institute, the Land Consolidation Department, the Department of Fisheries and Marine Research, the **Water Development Department**, the Forestry Department, the Geological Survey Department, the Meteorological Service, the Mines Service and the **Department of Environment** fall under the jurisdiction of the Ministry of Agriculture, Rural Development and Environment.

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Picture 1 - ...

The **Water Development Department** is responsible for implementing the water policy of the Ministry of Agriculture, Rural Development and Environment with objective the national development and management of the water resources of Cyprus, in accordance with European and National legislation and within the framework of the Government water policy in force.

The Department develops and applies the water policy, after the approval of the Council of Ministers and it is also responsible for the management, operation and maintenance of the Governmental Water Works.

Main role/responsibilities: Preparation of the National Implementation Program. Reporting to EC according to the Article 17 of the Urban Wastewater Treatment Directive (UWWTD) (91/271/EEC). Preparation of design, tenders and contracts for the construction and the maintenance of all rural, sewerage collection systems and UWTPs on behalf of the Rural Sewerage Boards. Management/reuse of reclaimed water

The **Department of Environment**, which also belongs to the Ministry of Agriculture, Rural Development and Environment, is the authority that protects and enhances the environment and also aims to ensure sustainable development and improve the quality of life. Environmental protection is achieved through the rational management of resources and waste, the impact assessment, pollution control, tackle actions on climate change and halt the risk of loss of species and habitats, while helping to promote green growth within the contents of circular economy.

Main role/responsibilities: Implementation of Urban Wastewater Treatment Directive (UWWTD) (91/271/EEC) and Participation with the Water Development Department (WDD) to the European Committee (EC). Designation of Sensitive Areas in cooperation with the Water Development Department (WDD), the Department of Fisheries and Marine Research (DFMR), the Geological Survey Department (GSD) and the Department of Agriculture (DA). Reporting to EC according to the Articles 15 and 16 of the UWWTD. Effluent Quality Monitoring Programme in cooperation with the State General Laboratory and Water Development Department. Preparation of Discharge Permits for the operation of UWTPs and the effluents' discharges

The **Department of Agriculture**, which also belongs to Ministry of Agriculture, Natural Resources and Environment, is responsible for the education of farmers in all matters related to agricultural production with the use of treated wastewater effluents. The selection of crop and the irrigation system to be used, as well as preparation of irrigation schedules are amongst the responsibilities of the Department. Also, the follow up of the guidelines and the code of practice is also responsibility of the Department of Agriculture.

The **Sewerage Boards** are public utility organizations and have the responsibility of the concentration, operation and maintenance of the sewerage system which includes the pipes, the pumping stations and the UWTPs. The Boards are responsible for the collection and treatment of wastewater. Their main target is to produce treated effluent which can be used for irrigation purposes. The Sewerage Boards are under the control of the Ministry of Interior and the Chairmen of the Boards are the mayors of the cities.

The **Local Water Authorities** (i.e. Water Boards, Communities and Municipalities) are responsible for the administration at the consumers' level and the distribution of domestic water to the end-users.

The **Ministry of the Interior** is responsible for the promotion of the administrative duties of the Local Water Authorities and Sewage Boards.

It has no effect on the water management issues.

Picture 2 – A pipe carrying reclaimed water to agricultural fields for irrigation in Nicosia, Cyprus. Pipes carrying reclaimed water are painted red to be distinguished from other water pipes.

The Agricultural Research Institute is a Department under the Ministry of Agriculture, Rural Development and Environment. Its role is to act as a center of knowledge and innovation in Cyprus whilst strengthening rural development, improving the quality of life, and ensuring the sustainable use of natural resources, such as the use of reclaimed water for irrigation purposes.

CLOSING REMARKS

The stakeholder framework regarding water treatment and reuse in Cyprus is highly involved, with different players dealing with different aspects of the water treatment and disposal/discharge. As discussed in this factsheet, the existence of a monitoring mechanism of each governmental/public organization is crucial, for the assurance of the smooth operation of all organizations, in parallel.

REFERENCES:

Water Development Department (WDD), Information and Data on Water Resources, Water Use and Wastewater Treatment Plants Provided by the Water Development Department, Cyprus, 2019.

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3.8 Public acceptance

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

The Success Story of Cyprus

Fact Sheet 8 – Public acceptance

Water demand & supply | WW Treatment & reuse | Infrastructure | Quality control | Ag code of practice | Pricing | Stakeholders | **Public Acceptance**

Keys for Success – Lessons learned from the success stories of Cyprus and Israel

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Despite the clear need for alternative water supplies to address water security challenges, public acceptance is still a critical barrier to the introduction of recycled water schemes (Fielding et al., 2018). Thus, public acceptance is a major consideration for authorities seeking to introduce recycled water schemes, all over the world.

There are various psychological barriers to the public acceptance of reclaimed water reuse, such as the ‘yuck factor’, health risks, variable reliability of applied treatment technologies, trust in authorities to manage risks as well as an overall disbelief in science and technology. Moreover, there are environmental and pricing concerns.

The literature and the experimental research demonstrate that providing information to the public about the recycling process, the safety of the source, the benefits of the source, that water recycling is well practiced in other countries of the world, and other key aspects increases acceptance of recycled water. Information of this type is likely to be effective because it addresses known predictors of recycled water acceptance.

A lot of reaction and skepticism were observed from farmers/end-users at the early days of implementing wastewater reuse projects in Cyprus, mainly due to ignorance, misconceptions and psychological fear. In order to build trust and get support, Cypriot authorities had to initiate stakeholder awareness raising actions, consultation and collaboration activities during the development of the various wastewater reuse schemes.

In instances where the community associates a high level of risk with the wastewater reuse schemes, trust has shown to be maximised when the following conditions are met (Figure 1) (Khan and Gerrad, 2006):

Figure 1 - The main conditions to be met for increased trust in the community in water reuse
(Source: Khan and Gerrad, 2006)

In Cyprus, the local authorities gathered sufficient information before communication began with the various stakeholders and end-users, such as:

- The justification of the need for wastewater reuse in Cyprus, e.g. the context of water scarcity, including under future climate conditions;
- The costs of installing treatment and distribution systems;
- The environmental benefits, as well as the environmental drawbacks and risks;
- The social and economic benefits and drawbacks/risks;
- Transparency on exposure risks to the public, how these will be addressed and the treatment levels to appropriate standards.

All the above, were analyzed within the planning process, in order to provide a clear justification for the introduction of the Cypriot wastewater reuse scheme.

Acceptance issues were addressed by the Cypriot authorities through:

- Information / consultation campaigns;
- Education of the farmers in small groups;
- Regulating effluent reuse through the Cyprus Code of Good Agricultural Practice;
- Making recycled water cheaper than freshwater;
- Demonstrating benefits in practice.

Informational/consultation campaigns, development of awareness raising tools and dissemination of information on the various benefits of wastewater reuse among all key stakeholders in Cyprus have two main objectives:

- To build trust, credibility and confidence in wastewater reuse (addressing health risks-related concerns of the general public and workers potentially exposed to the effluent);
- To raise awareness on the benefits of reuse for the various stakeholders involved in the development of wastewater reuse schemes.

Also, Educational and Awareness raising campaigns were organized by the Water Development Department, including:

- TV and radio shows;
- School visits;
- Distribution of informational leaflets;
- Creation of website dedicated to water issues;
- Establishment of the Water Week;
- Social media posts;
- Press articles;
- Workshops/seminars/training events;
- Conferences.

When addressing the issue of public acceptance towards wastewater treatment and reuse, analysis should also include investigation around the attitude towards the environment and the concern of the public for the future generations. Scientists and water managers agree that positive community attitude regarding this alternative source is critical (Keramitsoglou and Tsagarakis, 2013) and, accordingly, informing the public about the treatment process and the resulting quality of water, becomes a success promoter for any reuse policy.

CLOSING REMARKS

Reuse acceptance strongly depends on the potential use of reclaimed water. Change in thinking cannot be acquired unless a large and disperse group of stakeholders is involved, since no individual has the capacity to implement any measures required for sustainable wastewater reuse. These challenges suggest that social learning is an important goal to facilitate stakeholders' involvement.

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4 Conclusions

SUWANU EUROPE delivers different outputs to support knowledge transfer in water reuse for agriculture such as regional action plans, info-packages or policy briefs. The fact-sheets presented in this report will complement other materials offering the opportunity to extract the most relevant information from the cases of Cyprus and Israel, two countries considered pioneers in the use of reclaimed water in agriculture. Cyprus and Israel have faced severe water stress that jeopardized the sustainability of the agricultural sector. The 16 factsheets included in this deliverable highlight the main considerations required for successful application of reuse for agriculture. Since the same topics are reviewed for both cases studies, the fact sheets can also be used to identify commonalities and differences behind the successful application of reuse in both case studies.

Fact Sheet 1 - Water demand and supply: facts and figures reveals the fundamental common denominator for the successful application of reused water in general, particularly in the agriculture sector: in the national level in both countries **water demand exceeds the available water supply**. To enable growth and prosperity, both countries had to identify additional sources of water for both drinking and agriculture. Another commonality is the small size of both Israel and Cyprus, only 2-5% the size of Spain. The small size of both countries along with recognition as a national problem allows reuse to be managed at a national level, with supportive regulations, implementation of efficient irrigation practices at a national level, and centralized decision on construction of large scale water infrastructure projects.

Fact Sheet 2 - Wastewater treatment and reuse shows some differences in reuse practices in both countries: in Israel most of the reuse is for agriculture purposes, while is Cyprus it is split between agriculture reuse and aquifer recharge, excess effluent (mostly during winter times) being diverted to the sea.

Fact Sheet 3 - Projects and infrastructure to tackle water shortage again shows many commonalities in terms of the infrastructure required to enable reuse for agriculture in a large, national level. Both countries commissioned national water allocation projects that were needed to allow reclaimed water to reach the region where they are needed for agriculture reuse. This Fact Sheet also highlight other commonalities in handling water shortage in both countries, such as using desalinized seawater for supplementing drinking water supply.

Fact Sheet 4 - Quality control of treated effluent and *Fact Sheet 5 - Code of practice for agricultural irrigation* introduce the regulatory framework for effluent quality control and agricultural reuse in both countries. As can be expected, the regulations have similarities in some topics and differences in others. These Fact Sheets were intended to be an example of available regulatory approaches and to shine a light on regulatory modifications that might be needed for practicing reuse in agriculture.

Fact Sheet 6 - Pricing system for irrigation water shows the competitive pricing of reclaimed water used in both countries as an incentive for their reuse in agriculture. Other aspects of the pricing mechanisms are quite different between the countries, stemming from differences in locally adapted approaches for managing the water sectors. Cyprus, for example, uses subsidies to lower reused water prices and is aided by the EU to fund some of its large scale infrastructure projects. In Israel, on the other hand, the water sector is managed as a closed market with local water tariffs used for funding the development of infrastructure.

Fact Sheet 7 - Stakeholder involvement again highlight the two different approaches to managing decision making in the water sector applied in both countries.

<u>Fact Sheet 8 - Public acceptance</u> highlights the difference between promoting reuse in agriculture nowadays as compare to ca. 40 years ago. Promoting reuse in the current era (Cyprus) requires much outreach and direct interaction with the public to reduce its anxiety and assure its collaboration with changes in irrigation practices. In the 1980, when these practices were adapted in Israel, such wide outreach was not required, and the practices were adapted by direct interaction with a limited sector (farmers) which was directly affected by the change. The current focus of outreach efforts remain different between the countries for these same reasons: while in Cyprus it is focused on the high quality requirements the reclaimed water must meet, in Israel the focus is less specific, highlighting the general need for water conservation.

Combining the Fact Sheets from both case studies shows that the underlying commonality between the case studies, which is the core behind their successful application of reclaimed water for irrigation, is a **water demand that exceeds the available water supply**. Another commonality is the **national management of the water sector**, and **competitive pricing to encourage the use of reclaimed water**. These three elements identified in the Fact Sheets presented above represent the minimum requirements for embarking on a quest to foster the use of reclaimed water for irrigation. Other aspects of reuse, such as **local regulations** and **public acceptance** are more site specific and are likely to require site-specific adaptation. Although the situation in terms of water availability in other European countries might be perceived as more positive when compared to Cyprus and Israel, climate change is increasing pressure on water resources and the future prospects indicate that water scarcity and droughts will be more common and more important throughout Europe, especially in the Mediterranean basin.

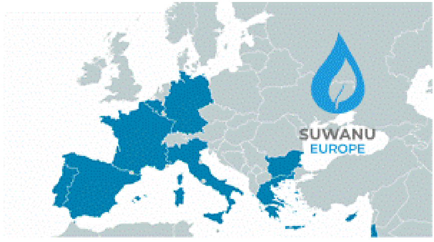
Public perception in European target regions regarding the use of reclaimed water in agriculture is one of the barriers identified in the project (see SWOT analysis from Deliverable 2.1). However, this perception is also linked to the lack of awareness regarding the real situation of common water resources. Nevertheless, participatory workshops organized within the project allowed us to identify a change of mind among the potential users of reclaimed water (i.e. farmers) and to identify consumers of agricultural products who are open to consume agricultural products irrigated with non-conventional water resources such as reclaimed water.

Therefore, water reuse relevance will be higher in the near future and European countries must be prepared to face the necessary changes that would be required. In this sense, new regulations recently adapted by the European Commission on water reuse in agriculture (COM (2018) 337 final: *REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on minimum requirements for water reuse*) will offer guarantees to users and consumers. However, even though the EU Regulation will apply directly to Member States, they would need to adapt national regulations as well as the institutional and administrative schemes, policies and strategies to enable a wider application of water reuse.

As a conclusion, it is crucial to account for the experience of countries and regions that had to deal with this situation in the past and have developed the necessary regulations, administration bodies, standards, etc to use reclaimed water as another water resource. The present fact-sheets are intended to bridge knowledge gaps and provide guidance in the adaptation of societies to climate change effects. Understanding the considerations behind successful application of effluent reuse for agriculture is crucial for effectively advocating for reuse in new markets throughout Europe, which is the main interaction and contribution of the products of this deliverable to the rest of the project.

Annex 1 –Keys for Success Fact Sheet from D3.1

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

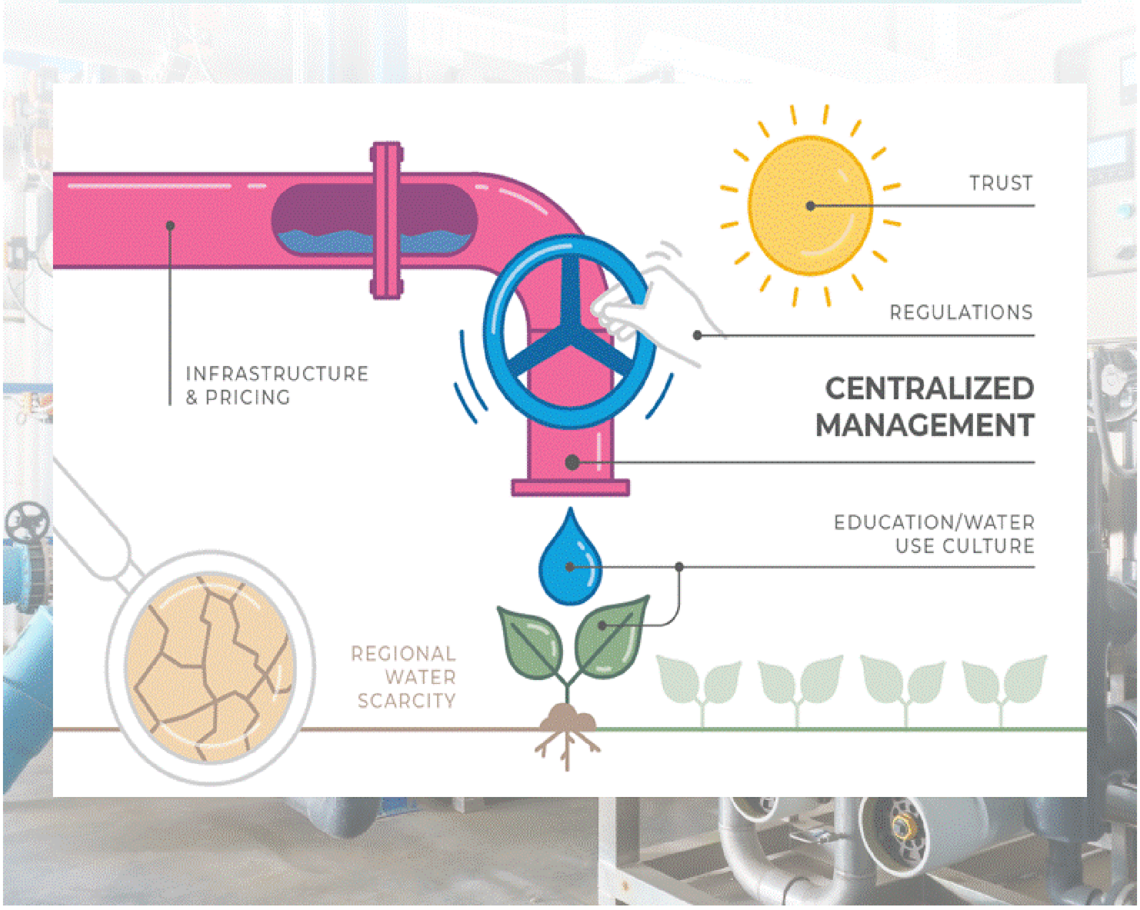


Info-package 3
Water Reclamation Operators

Fact Sheet 3.4 – **Key for success in Israel and Cyprus: 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 main factors contributing to successful implementation of reclaimed water in agriculture.



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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To learn more about the Israeli water sector: www.water.gov.il

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