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Project funded by the EUROPEAN UNION

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NAWAMED

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Survey on the potential for greywater separation and reuse in each country

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This publication has been produced with the financial assistance of the European Union under the ENI CBC Mediterranean Sea Basin Programme.
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Nature Based Solutions for Domestic Water Reuse in Mediterranean Countries

NAWAMED

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NAWAMED

1. Introduction

1.1. Background

The Mediterranean region stands as one of the most sensitive to climate change, both in terms of warming and drying. Although global climate models vary in many ways, they agree on this: the Mediterranean region will be significantly drier in coming decades, potentially expecting 40% less precipitation during the winter rainy season[1]. A robust and clear picture of climate change over the Mediterranean emerges, consisting of a pronounced decrease in precipitation, especially in the warm season, except for the northern Mediterranean areas (e.g. the Alps) in winter. A pronounced warming is also projected, maximum in the summer season and a greater occurrence of extremely high temperature events. The intensity and robustness of the climate change signals produced by a range of global and regional climate models suggest that the Mediterranean might be an especially vulnerable region to global change[2]. Therefore, the impacts of water scarcity are likely to be exacerbated in the future, with predicted increases in the frequency and severity of droughts, driven by climate change. In many locations in the Mediterranean region, including southern Europe, overexploitation by a range of economic sectors is already posing a threat to water resources and demand often exceeds availability leading to reduced river flows, lowered lake and groundwater levels and the drying up of wetlands[3]. A sustainable management of water resource is therefore essential.

A water supply is an essential requirement for all people. Determining how much is needed is one of the first steps in providing that supply. People's needs are not always predictable. To establish how much an individual needs, standard quantities are estimated and broken down into categories. Figure 1 reports the amount of water that is required for domestic purposes, according to the World Health Organization. It is worth noting that as demand for water increases, generally the quality needed for each use is not the same: water for cleaning a floor does not have to be of drinking water standard, and water for growing subsistence crops can be of a lower quality still.

Tourism can markedly increase 'urban/domestic water' use, particularly during the peak summer holiday months and especially in southern European coastal regions already subject to considerable water stress. Income is an important driver of public water use and as GDP increases, the proportion of households connected to public supplies increases. Higher household income is also linked to greater *pro capita* water use often linked to an increased capacity of water appliances (e.g. showers, toilets, water heaters, dishwashers, washing machines, sprinklers and swimming pools). Moreover, the size of households, in terms of the number of occupants, is also a key driving force. Water use related to, for example, car washing, gardening and laundry is tied more closely to the household than the individual. As a result, an economy of scale exists whereby larger households use less water per capita than smaller households. In Europe for example, while the population has slowly

[1] *A. Tuel, E. A. B. Eltahir. Why Is the Mediterranean a Climate Change Hot Spot? Journal of Climate, 2020; 33 (14): 5829 DOI: 10.1175/JCLI-D-19-0910.1*

[2] *F. Giorgi, P. Lionello. Climate change projections for the Mediterranean region. Global and Planetary Change. Volume 63, Issues 2–3, September 2008, Pages 90-104*

[3] EEA Report No 2/2009. Water resources across Europe — confronting water scarcity and drought

increased over recent decades, the number of households has grown at a faster rate due to a general decrease in household size, triggered by demographic shifts such as an increase in the number of people living alone[3].

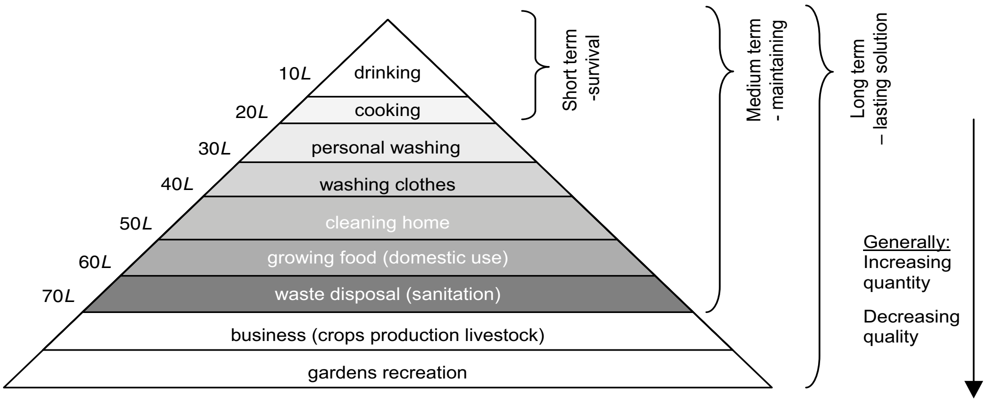

Figure 1 Hierarchy of water requirements. Source: WHO

Alternative and potentially more sustainable means of ensuring water supply have become increasingly important in recent years. These methods include, besides water saving behaviour and appliances, rainwater harvesting, re-use of treated wastewater and re-use of greywater (household wastewater other than that from toilets). Although none of these methods reduces water use, all have the potential to decrease abstraction from conventional sources and to increase the local availability of water for non-potable uses, supporting health, hygiene standards, and comfort.

As reckoned in the European Environmental Agency report "Water resources across Europe — confronting water scarcity and drought"[3], greywater reuse and rainwater harvesting can play a fundamental role, the former will convert a significant fraction of wastewater from a waste to a valuable water resource, while the latter will not only reduce household use of treated public water supplies but can also make a small contribution to lessening the severity of storm discharges. Both practices help to diminish demand from the public water supply and, therefore, the energy requirements associated with providing clean water. Furthermore, they have minimal detrimental environmental impacts. Water recycling is also increasingly implemented in various industrial sectors leading to clear improvements in water use efficiency and reduced water expenses.

1.2. Objectives

This report provides an overview of the potential for greywater separation and reuse in each country hosting a NAWAMED pilot plants, estimating the quantity of water that could be recovered thanks to the use of the proposed solutions at large scale. The targeted sector is that of domestic/urban use and estimations are at country (IT, JO, LB, TN) scale with some insights for the two Italian regions involved in the project. The report will also address the main obstacles for a large scale greywater reuse strategy (technical, economical, legal, cultural) and propose solutions to overcome them.

1.3. Outline

This report is divided into three main sections, and each section details the information gathered concerning the countries hosting a NAWAMED pilot plants, i.e. Italy, Jordan, Lebanon and Tunisia.

Section 1 reports the availability of natural water resources, amount of rain and annual rain pattern, the share of water used for urban/domestic purposes, the percentage of population covered by sewer system, main problems related to water management (overexploitation, pollution due to urban wastewater, etc.).

Section 2 describes the 2/3 most important settlement typologies (including refugee camps) of each country, putting into evidence the differences in relation to urban/domestic water management and sanitation facilities.

Section 3 provides basic information about the legal and administrative frameworks and focuses on the feasibility of greywater reuse according to possible barriers such as the permits issuing system, social or cultural barriers, water pricing systems able to incentive (or disincentive) greywater reuse, availability of national/regional funding schemes for water reuse.

2. Water and wastewater data

2.1. Italy

Urban water use in Italy is affected by two major problems. First, the excess of water withdrawal: due to the poor performance of the distribution network nearly 40% of water withdrawn is lost on the way and does not reach the final users. The problem has become worse in recent times: that is why in 2008 the total water volume withdrawn increased, while the volume delivered decreased. Secondly, the high per capita water consumption and, consequently, the dilution of the wastewater collected (BOD5 concentration is very often below 150 mg/l), affect the pollution removal capacity of the treatment plants, which usually work better when more concentrated liquids are to be treated. Moreover, the "centralised" wastewater treatment approach adopted in the past decades results in the discharge of huge mass fluxes at a single point. Thus, even the outflows which respect legal concentration limits, discharge at a very large flow rate and, consequently, contain a large amount of pollutants[4].

2.1.1. Water availability

Yearly water availability in Italy is relatively abundant: 296 km^3 (billion of cubic meters), which, after evaporation, lead to 155 km^3 of surface water and 13 km^3 of underground resources. According to the Water Research Institute (IRSA) the total "renewable" resources (which are renewed every year) would amount to 168 km^3, which corresponds to approximately 2,800 m^3 per inhabitant, a figure higher than countries like Great Britain or Germany. However, not all surface resources are available: apart from the Alpine basins, most of the rivers present a significant flow only in the period from October to March. To use this flow during the course of the year - and particularly in the summer period when irrigation uses are concentrated - reservoirs have been built[5]. According to the criteria of the International Commission of Large Dams (ICOLD) there are currently about 570 large dams in Italy together with numerous smaller reservoirs. At the beginning of the second millennium the resources available from surface flow amounted to about 40 Km^3, in addition to 12 km^3 of groundwater.

Almost 53% of the utilisable surface resources are in northern Italy, 19% in central Italy, 21% in southern Italy, and 7% in the two largest islands. About 70% of the underground resources is in the large flood plains of northern Italy, while groundwater in southern Italy is confined in the short stretches of coastal plains and in a few inner areas. Water is particularly scarce in Apulia, Basilicata, Sicily and Sardinia, a fact that could be aggravated by the effects of climate change[6].

In Italy, apart from the irrigation sector, which is responsible for more than 25 km^3 of water withdrawal (around 50% of the country's water use), the excessive use of water concerns the

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[4] G. Conte, Bolognesi A., Bragalli C, Branchini S., De Carli A., Lenzi C., Masi F., Massarutto A., Pollastri M. and Ilaria Principi. Innovative Urban Water Management as a Climate Change Adaptation Strategy: Results from the Implementation of the Project "Water Against Climate Change (WATACLIC). *Water* 2012, 4, 1025-1038;

[5] Conte G. "Dopo il referendum: la gestione pubblica riuscirà ad affrontare i problemi delle acque italiane?". SVIMEZ-Il Mulino *Rivista Giuridica del Mezzogiorno*. 4/2012, pp. 821-854

[6] ISTAT. "Utilizzo e qualità della risorsa idrica in Italia". 2019

domestic and urban sector. Urban water does not only include the supply to households but also to small businesses, hotels, offices, hospitals, schools and some industries.

2.1.2. Urban water supply[7]

The volume of water withdrawn for potable use in Italy stands at 9.49 billion cubic meters (Figure 2 and Table 1). Such a consistent supply corresponds to **a withdrawal of 428 litres per day per inhabitant**, equals 156 cubic meters per year per capita. The volume withdrawn for potable use has grown steadily over the past years, i.e. compared to 1999, in 2015, there was an increase in the volume withdrawn by 6,9 per cent.

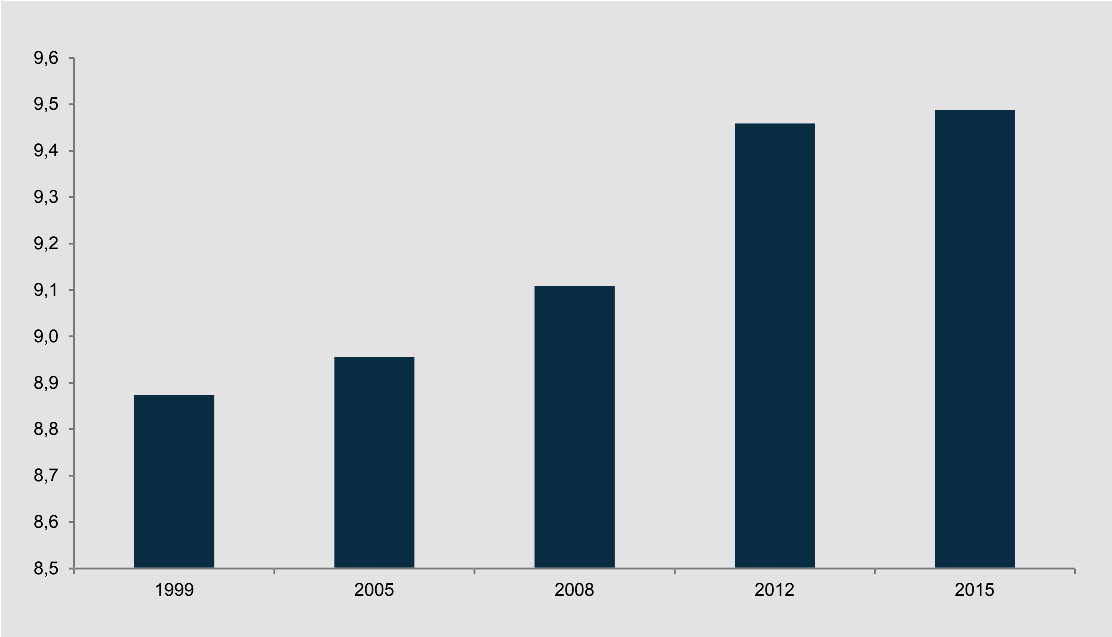

Figure 2. Water withdraw for potable use in Italy. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

The sources of withdrawal depend on the characteristics of the water bodies used for drinking water supply. Data related to 2015, reports that 84.3 per cent of the national withdrawal of water for drinking use was from groundwater (48.0 per cent from wells and 36.3 per cent from springs), 15.6 per cent from surface water (9.9 per cent from artificial reservoirs, 4.8 per cent from surface watercourses and 0.9 per cent from natural lakes) and the remaining 0.1 per cent from marine or brackish waters (Figure 3)(Table 1).

[7] All the data reported are referred to the year 2015 and taken from the National Statistics Institute (ISTAT) report: "Utilizzo e qualità della risorsa idrica in Italia". 2019

Table 1. Water withdraw for potable use and sources, detailed for the two regions hosting the NAWAMED plants and at the national level. Unit: millions of cubic meters and litre per habitant per day. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

	Springs	Wells	Surface water bodies	Natural lakes or artificial reservoirs	Marine or brackish waters	Totals	Total per capita
Lazio	823.3	309.0	3.8	38.7	-	1,174.9	546
Sicily	167.5	455.9	2.4	124.6	10.3	760.7	410
ITALY	3,444.3	4,549.5	456.0	1,026.6	11.2	9,487.7	428

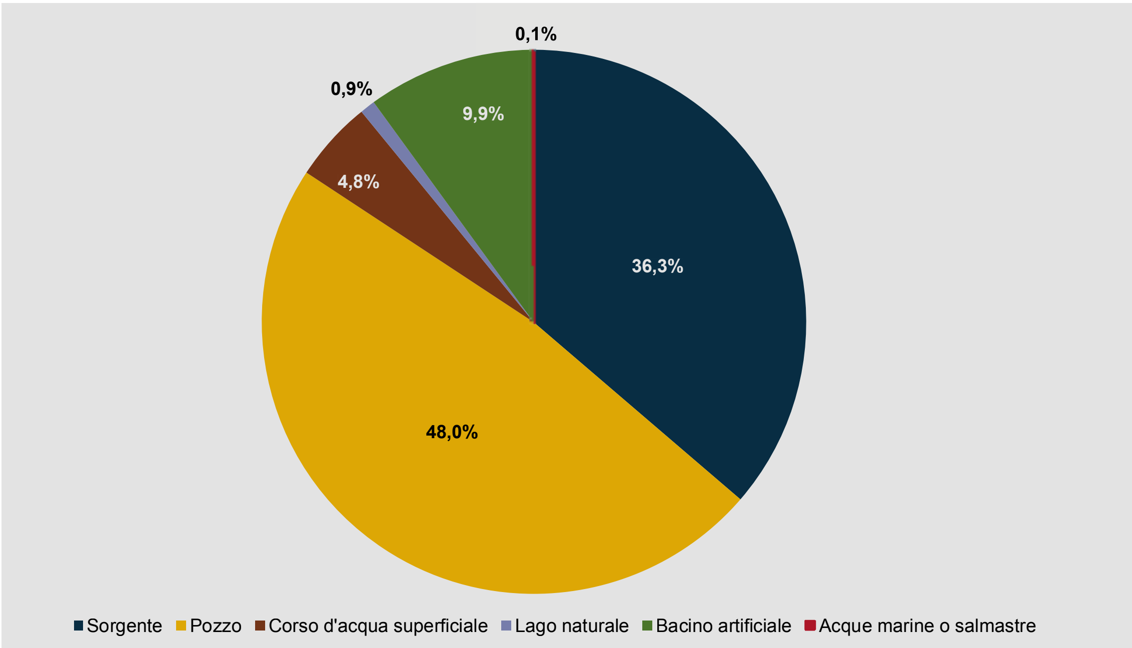

Figure 3. Water withdraw for potable use and sources at national level. Legenda: Sorgente/spring – Pozzo/well - /Corso d'acqua superficiale/surface water body – Lago naturale/natural lake – Bacino artificiali/aritifical reservoir – Acque marine o salmastre/marine and brackish waters. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

The management of the distribution service, in Italy is in charge of some 2,000 entities, which includes large private ones (375 entities managing over 92% of volumes) but also services managed by the municipalities. Overall, 70.8 percent of the volume of water fed into the network is metered.

In the year 2015, to guarantee water availability to the population, the total volume of water fed into the drinking water distribution networks was equal to 8.32 billion cubic meters, i.e. 375 litres per day per inhabitant (Table 2). While the volumes of water delivered for use amount to 4.9 billion cubic meters year, which accounts for a daily supply of water for drinking use of 220 litres per inhabitant (80 cubic meters per year). Overall, the volume of total water losses in the drinking water distribution network amounted to 3.45 billion cubic meters, corresponding to a daily dispersion of 9.4 million cubic meters.

Table 2. Water fed to the networks and water used detailed for the two regions hosting the NAWAMED plants and at national level. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

	Water fed to the network (thousands of cubic metres)	**Water used (thousands of cubic metres)**	**Water fed per capita (thousands of cubic metres)**	**Water used per capita (litre per habitant per day)**
Lazio	972.540	458.342	452	213
Sicily	683.146	341.567	368	184
Italy	8.320.061	4.874.673	375	220

In most Italian cities, the water infrastructure is subject to severe ageing and deterioration. Real water losses from the drinking water network, obtained as the difference between total and apparent losses (volumes stolen without authorization), are estimated at 3.2 billion cubic meters, about 100,000 litres per second, equal to 144 litres per day per inhabitant. These losses represent the physical component of the losses due to corrosion, defective joints, deterioration or breakage of the pipes, and correspond to the volume of water that escapes from the distribution system and is dispersed underground. The percentage ratio between the volume loss and the volume fed into the network is the most frequently used indicator for measuring the performance of a distribution network. In 2015 it was 41.4 per cent, an increase of four percentage points compared to 2012 confirming the state of persistent inadequacy and inefficiency of the water infrastructure and the scarce investments in terms of maintenance and development (Table 3).

Table 3. Total water losses (percentage) detailed for the two regions hosting the NAWAMED plants and at the national level. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

	2012	**2015**	**Difference (2015-2012)**
Lazio	45.1	52.9	7.8
Sicily	45.6	50.0	4.4
Italy	37.4	41.4	4.0

Rationing

Rationing in the supply of water is periods of reduction or suspension of the supply of drinking water for domestic use adopted at the municipal level to make up for water shortages or infrastructural difficulties. Water rationing in Italy is not common. In the year 2017, a critical year for water availability in Italy, these measures affected 11 municipalities, which were all located in the southern regions area, except for the municipality of Latina.

2.1.3. Wastewater[7]

On the national territory, there still is a small number of municipalities without the public sewage service. In total, those suffering from this lack of wastewater infrastructures are 40, with a population of 385,249 residents (0.6% of the total population). In some of these municipalities, the sewer system is present but has not yet been put into operation. In these cases, each building is equipped with autonomous waste disposal systems (for example, septic tanks).

In 2015, 17,897 urban wastewater treatment plants were operating in the national territory. The plants are distinguished on the basis of the type of treatment carried out, or rather with respect to the percentage of abatement of the polluting loads. They are grouped, from the simplest to the most effective, in the following types: Imhoff tank, primary, secondary (includes all biological treatments) and advanced (includes refinement phases such as nitrification-denitrification and dephosphating, as well as final filtration) (Figure 4)(Table 4). In relation to the total quantity of potential polluting loads of civil origin generated in the area, only 59.6% is actually treated in secondary or advanced purification plants.

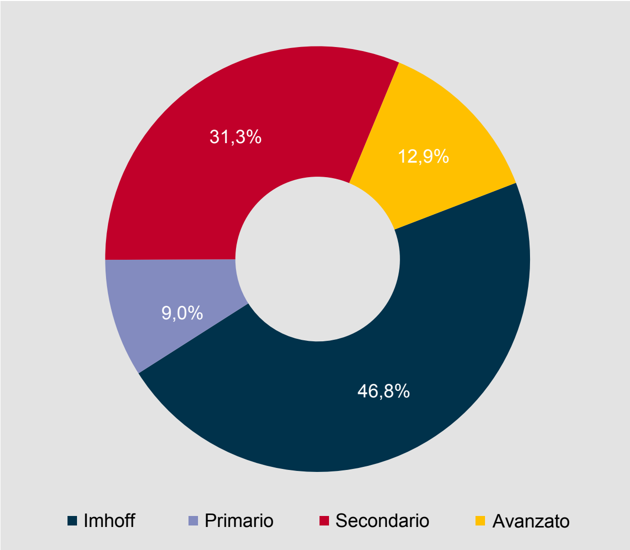

Figure 4. Wastewater treatment plants per type of treatment. Legenda: Imhoff/Imhoff – Primario/primary – secondario/secondary – Avanzato/advanced. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

Table 4. Operating wastewater plants per type of treatment, detailed for the regions hosting the NAWAMED pilots and at the national level. Source: Censimento delle acque per uso civile, anno 2015. ISTAT

	Imhoff		**Primary**		**Secondary**		**Advanced**		**Total**
	number	**%**	**number**	**%**	**number**	**%**	**number**	**%**	
Lazio	32	0.7	56	1.4	405	67.1	142	30.8	635
Sicily	63	1.6	55	6.9	239	71.2	57	20.4	414
Italy	8,377	1.6	1,607	2.4	5.604	29.3	2,309	66.7	17,897

2.2. Jordan

2.2.1. Water availability

Jordan is one of the world's most water-scarce countries. The available water resources – especially groundwater – have been heavily over-used for years. The sources of water in Jordan are 27% surface water, 14% treated wastewater and 59% groundwater. Less than 100 m³ of renewable water resources is available per capita per year. The available renewable water resources for different purposes is around 853 Million of Cubic Meters (MCM) annually, while the estimated water demand quantity for all sectors is 1412 MCM in 2017, in which 54% is used for agriculture sector, 52% for domestic sector, and 3% for industry sector[8].

[8] Ministry of Water and Irrigation of Jordan, Jordan Water Sector: Facts and Figures, 2017.

According to the historical trend analysis, rainfall across the country is significantly spatially and temporally distributed, where 90% of the country falls within arid to semi-arid classes. Climate change impacts in Jordan resulted in a shorter rainy season with lower amounts of precipitation and the number of rainfall events. The overall annual rainfall tended to decrease significantly ($P<0.05$) by time with an average reduction rate of 1.1 mm per year. Although the overall trend for most of the rainfall stations was decreasing, individual annual rainfalls analysis indicated the possibilities of extreme events to occur at some locations. The overall trend showed that more frequent drought seasons are expected[9]. The Rainfall Volume for 2016/2017 year was 8165 (MCM). The evaporation accounts for 93.5% of the rainfall volume8.

The available water resources – especially groundwater – have been heavily over-used for years. At the same time, pressure on water resources continues to grow due to population growth, the impact of climate change and economic development. Inefficient agricultural irrigation also contributes significantly to the depletion of groundwater resources. In recent years, the situation has been worsened considerably by the refugee crisis, which led to a 40% increase in the domestic water demand for northern governorates. In combination, this constitutes an enormous burden on Jordan's water resources, infrastructure and the financial position of sector institutions.

The High rates of water loss (about 50%), which can be traced back to physical leakages (technical losses) as well as water theft and incorrect billing (administrative losses), increase the pressure on water resources and significantly reduce the economic efficiency of the Jordanian water sector. In some districts in the northern Governorates, water losses are estimated at over 70%.

About 50.3% of the Jordanian population has 24 h/week of piped water supply or less and 49.7% of Jordanians were listed with higher than 24 h supply/week. It estimated that 42% of households do not have a sewer connection; in rural areas, only 6% have a sewer connection.

Another major problem in the water sector beside water scarcity is the high electricity consumption for water pumping and other water services, which accounts for 14.9% from generated electricity in Jordan. This is because that 90% of the drinking water supplied to the capital comes for sources distanced 125 to 325 km away and elevate up to about 1200m with 5 pumping stages, while 42 % of the drinking water supplied to northern governorates comes from sources distanced 20 to 76 km away and elevated up to about 1200m with 4 pumping stages in elevation (translated into higher cost for water supply).

2.2.2. Water Use in Jordan

According to data published by the Ministry of Water and irrigation, the water consumption in 2017 was 469.7 MCM for domestic purposes, 544.7 MCM for Agriculture purposes, and 32.1 MCM for industry purposes.

The indoor water-use patterns obtained from the end use metering conducted by USAID for 95 residential units in 2008-2011[10] study are illustrated in Figure 5.

[9] Salahat M., Al-Qinna, 2015. Rainfall Fluctuation for Exploring Desertification and Climate Change: New Aridity Classification, Jordan Journal of Earth and Environmental Sciences. Volume 7, (Number 1), (ISSN 1995-6681), Pages 27 – 35.
[10] USAID-IDARA, (2014). Water Residential Guide.

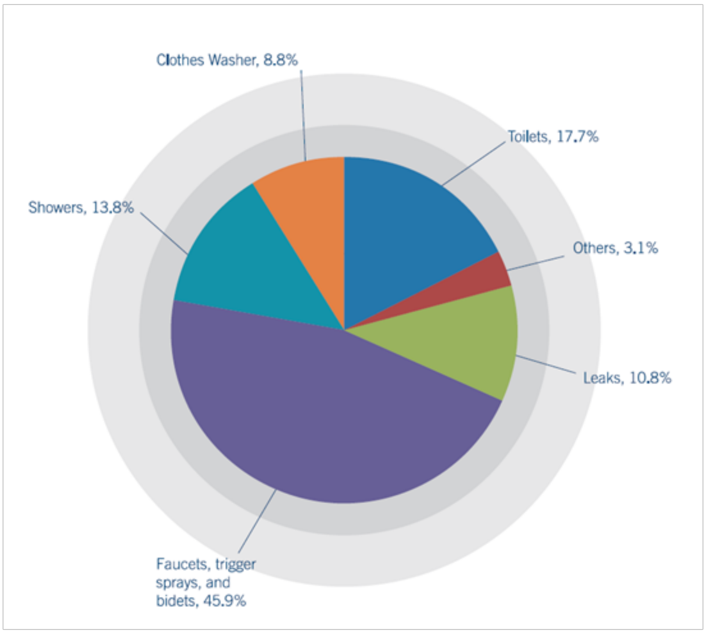

Figure 5 Residential indoor water-use profile for Jordan

There are three water supply companies in Jordan, namely Miyahuna Company, Yarmouk Water Company, and Aqaba Water Company. Billing data of these companies show that the residential sector water-use accounts for approximately 87, 86 and 29 percent of the non-agricultural water consumption in the service areas of Miyahuna, Yarmouk Water Company, and Aqaba Water, respectively. Figure 6, Figure 7, and Figure 8 illustrate water use for nonagricultural water users by the three companies[10].

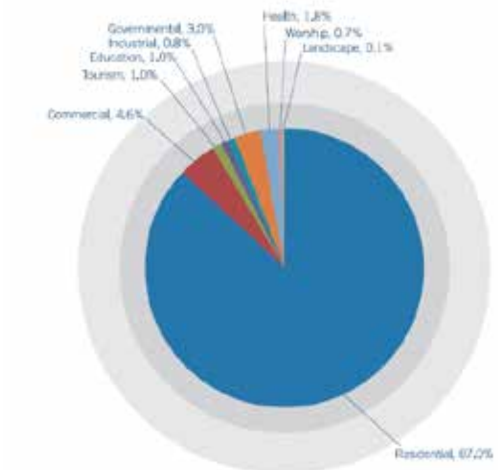

Figure 6 Water consumption for non-agricultural water users in Miyahuna service area

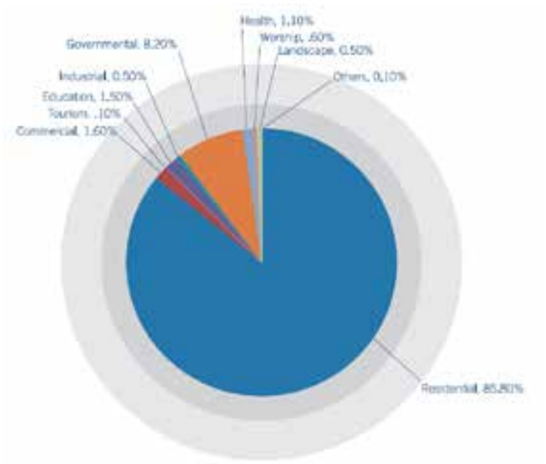

Figure 7 Water consumption for non-agricultural water users in Yarmouk Water Company service area

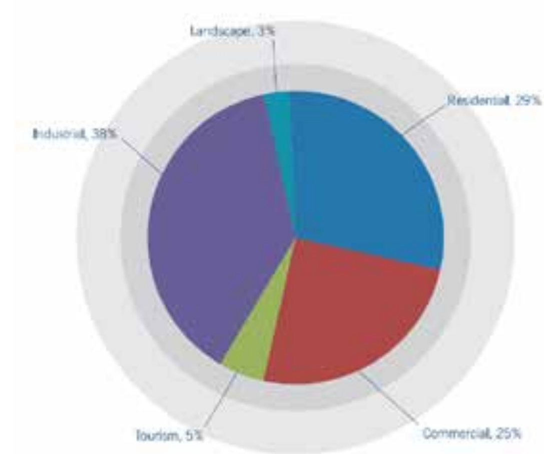

Figure 8 Water consumption for non-agricultural water users in Aqaba Water service area

2.2.3. Wastewater

Wastewater collection has been practised in Jordan in a limited way utilising primitive physical processes. Septic tanks and cesspits were mostly used with grey water often discharged to gardens. This practice created major environmental hazards, where many groundwater aquifers were polluted. Currently, there are 33 different Wastewater Treatment Plants (WWTP's) discharging approximately 137 MCM per year of effluent. Modern technology to collect and treat wastewater was introduced in the late 1960s when the first collection system and treatment plant was built at Ain Ghazal utilizing the conventional activated sludge process. The treated effluent was discharged to Seil Zarqa.

2.3. Lebanon

Water resources in Lebanon are under increased and continuous stress from a growing population, rapid urbanization, economic growth, pollution, climate change, mismanagement and ineffective water governance; thus posing serious short and long-term challenges to the water sector, necessitating the immediate application of proper management including good governance practices and integrity in managing water resources (Farajalla et al. [11], 2014, Ministry of Energy and Water, 2010[12]).

As shown in Figure 9 an average year in Lebanon yields about 2,700 MCM (million cubic meters) of available water while annual total demand ranges between 1,473 and 1,530 MCM per year (Ministry of Energy and Water, 2010b). Theoretically, the available water should exceed the needs of Lebanon

[11] Farajalla, N., Kerkezian, S., Farhat, Z., El Hajj, R., & Matta, M. (2015). The Way Forward to Safeguard Water in Lebanon - Nation Water Integrity Risk Assessment. Retrieved from https://www.aub.edu.lb/ifi/Documents/publications/research_reports/2014-2015/20150429_CC_Water_Summary.pdf

[12] MoEW. (2010). National Water Sector Strategy. Retrieved from http://www.databank.com.lb/docs/National%20Water%20Sector%20Strategy%202010-2020.pdf

until the year 2035 given current trends of growth. In 2010, the Ministry of Energy and Water (MoEW) estimated Lebanon's annual available water per capita from renewable sources at 926 m^3, which is lower than the 1,000 m^3 widely used Falkenmark benchmark for water scarcity.

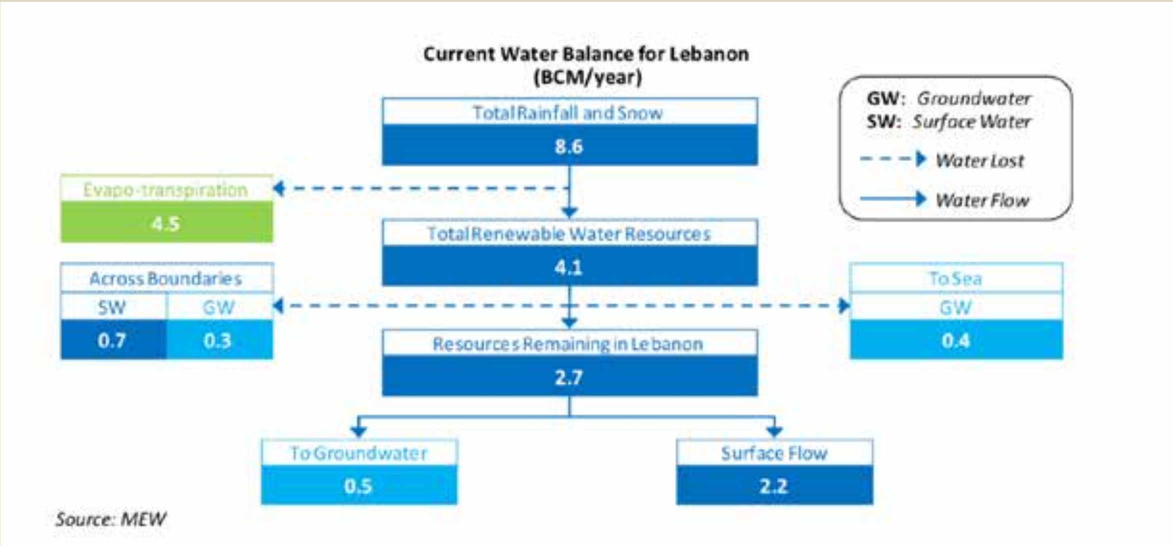

Figure 9 Summary of the current water balance in Lebanon (Ministry of Energy and Water, 2010b

2.3.1. Sources of Water

Rainfall

The estimated average rainfall in Lebanon is around 860 mm per year[16 13 18], ranging from 600 to 900 mm along the coast; to 1,500mm in Mount Lebanon dropping as low as 200 mm in north-eastern Beqaa[16 18]. The annual snow cover is abundant, covering approximately 2,500 km^2 of the Lebanese area (25%), and yielding an annual water equivalent of about of 2,800[13]. Figure 10 Lebanon rainfall map illustrates the rainfall distribution over Lebanon.

Lebanon is drained by 17 perennial and several seasonal rivers. Almost all of the perennial rivers are coastal with only three found in the interior of the country: Litani, Assi, and Hasbani. Furthermore, Lebanon shares three rivers with neighboring countries: the Kebir and Assi with Syria and the Hasbani with Israel. Flow from perennial and seasonal streams and rivers is estimated at around 4,000 million cubic meters (MCM) per year (Ministry of Environment, 2001).

[13] ECODIT. Strategic Environmental Assessment for the New Water Sector Strategy for Lebanon. Regional Governance and Knowledge Generation Project. 2015

Table 5 identifies the major perennial rives and their direction of flow. Major surface storage structures such as reservoirs are not very abundant in Lebanon. The only major reservoir on a river is the Qaraoun Lake which is formed by the rockfill dam on the Litani Rivera. This river which is about 170 km long with a catchment of 2175 km^2, drains the Beqa'a before discharging into the Mediterranean (Comair 2005). The river's average annual flow rate is nearly 700 MCM and the total reservoir capacity is 220 MCM (Hajjar 1997[14]). There are plans for dams on the Kebir and Assi rivers; however, these have not yet been executed.

Figure 10 Lebanon rainfall map

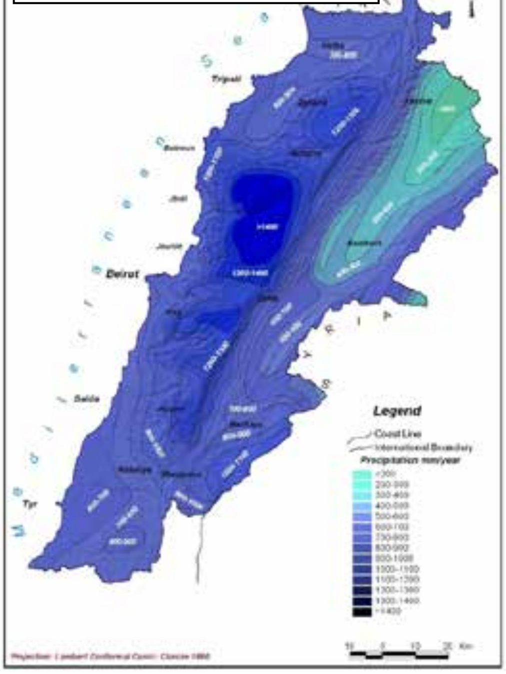

*Table 5. Mean flow rate of major perennial rivers (adapted from Comair 2005 and Hajjar 1997) * Total flow of all 13 rivers listed*

River	Annual Flow Rate (MCM)	Description
Major Coastal Rivers	2,470*	Flow west from their source in the Mount Lebanon range: Ostuene, Aaraqa, El Bared, Abou Ali, El Jaouz, Ibrahim, El Kalb, Beirut, Damour, Awali, Saitani, El Zahrani, Abou Assouad
Kebir River	190	Flows west and traces the north border of Lebanon with Syria
Litani River	946	Drains the southern Beqa'a plain and discharges into the sea north of Tyre
El Aassi River	400	Flows north into Syria draining the northern Beqa'a plain
Hasbani River	140	Crosses the southern border and forms one of the tributaries of the River Jordan

Fissured karstic limestone covers more than 65% of Lebanon (Hajjar, 1997[14]), which has allowed for the formation of a substantial number of high yield aquifers (Figure 11). Sustainable development of groundwater may yield between 400 and 1,000 MCM per year[15]. A 1970 report by the UN

[14] Hajjar, Z. (المياه اللبنانية والسلام في الشرق الأوسط). 1997. Beirut: دار العلم للملايين

[15] Abdulrazzak, M. and L. Koubeissi, 2002. UNDP-ESCWA Initiative on National Framework for Water Resources Management in Lebanon, presentation at the 2nd Water Demand Management Forum: Water Valuation in the Middle East and North Africa, June 2002.

estimates the potential maximum exploitable amount of groundwater to be around 3,000 MCM per year (Hajjar, 1997[14]).

Data on water resources are conflicting and inconsistent given the outdated measurements, rendering water balance figures only an estimation. Annual precipitation in Lebanon amounts to 8,600 MCM, with 50 percent of it being lost through evapotranspiration. Other losses include those from rivers flowing to neighbouring countries (summing up to 700 MCM), and those recharging groundwater resources (700 MCM) (MOEW, 2010).

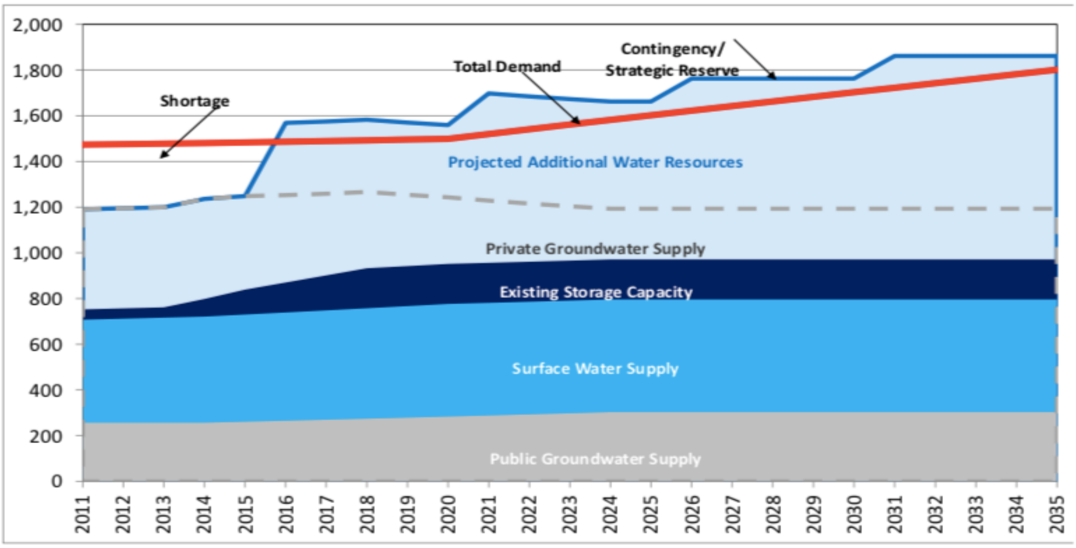

Figure 11. Primary distinct water sources in Lebanon

Surface Storage Capacity

The surface storage capacity is depicted by the amount of water accumulated in dams. Lebanon is profitably using two major dams in Lebanon: the Qaraoun Dam located in the Beqaa Valley and the Chabrouh Dam situated in Mount Lebanon[16]. The Ministry of Energy and Water (MoEW) estimates the capacity of each dam (Qaraoun and Chabroun) in static conditions to be 220 MCM and 8 MCM, respectively. Under dynamic conditions, the dams' capacities reach roughly 180 MCM and 15 MCM, correspondingly. The total capacity of the dams is estimated to be 235 MCM of which 45 MCM are used for water supply and irrigation purposes; however, the remaining quantity is mostly used for hydropower. Hydropower generation takes place mostly in Qaraoun Lake along with water stowing, compensating for water shortages during the drought season. Another minor dam, Al Qaisamani Dam, with an estimated 1 MCM storage capacity, supplies potable water to 35 villages in the Matn area[16 17].

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[16] AHT-Group-AG. Identification and Removal of Bottlenecks for extended Use of Wastewater for Irrigation or for other Purposes. Management and Engineering, Lebanon Country Report, Final Version, MEDA-Countries (Egypt, Lebanon, Morocco, Syria, and Tunisia). 2009

[17] MoEW. (2010). National Water Sector Strategy. Retrieved from http://www.databank.com.lb/docs/National%20Water%20Sector%20Strategy%202010-2020.pdf

Non-conventional Water

The rate of water renewal is much slower than the consumption rate, rendering a ratio of 1:1.5 according to recent estimations. Water scarcity has caused overexploitation of the available resources leading to seawater intrusion of coastal aquifers, worsening the quality of groundwater resources. This has led to the need to look for alternative water to compensate, to some extent, the losses and deteriorated state of water resources[18].

Globally, wastewater treatment and reuse along with desalination of seawater are currently used and considered as nonconventional sources of water; however, they are, to a large extent, not practised in Lebanon[16]. The reuse of wastewater, both black and grey water, is a topic worth stressing on for its potency to decrease the exploitation of natural water resources and its ability to yield water in great amounts if properly implemented. About 165 MCM /year of wastewater is mostly generated in Lebanon; 130 MCM / year are from households, and the remaining are industrial discharges[18] . The average rate of wastewater treatment was 4% in 2009, with no reuse of water; water desalination is also limited to the private sector (4.5 MCM) and Electricite du Liban (5.5 MCM)[16].

2.3.2. Impacts of the Syrian Crisis on Water Use in Lebanon

The Syrian crisis has resulted in massive inflows of displaced persons into Lebanon and across the region. Lebanon hosts almost 37% of the total Syrian refugees which is equivalent to nearly one third of Lebanon's population. This led to a significant increase in water demand; for example, the population served by the Beka'a Water Establishment nearly doubled between 2011 and 2014 from nearly 500,000 to about 1,000,000. Similar trends were observed in most other parts of the country to varying degrees[19].

2.4. Tunisia

2.4.1. Water Availability

The average rainfall ranges from less than 100 mm in the south to more than 1,500 mm in the northern region of the country. Challenges and conflicts will arise for Tunisia due to the expected drop of the water share per capita per year, down to 360 m^3 for the year 2030 compared to the current figure of 450 m^3 estimated to be already below the baseline of 1,000 m^3, thus indicating an absolute water scarcity. To cope with water shortage, Tunisia has launched a strategic study for the whole water sector called "Water 2050"[20]. Amongst the priorities aiming at using non-conventional water resources, the study will promote the use of wastewater. For that purpose, a thematic group on "wastewater reuse" was established. One of the fundamental statements is the need for wastewater to be used/recycled. In fact, today, Tunisia is facing serious water deficiency.

[18] Karam, F., Mouneimne, A. H., El-Ali, F., Mordovanaki, G., & Rouphael, Y. (2013). Wastewater management and reuse in Lebanon. Journal of Applied Sciences Research, 9(4), 2868-2879.
[19] El Amine, Y. Lebanon Water Forum - Rethinking Water Service Provision in Lebanon. Paper presented at the Lebanon Water Forum, Issam Fares Institute. 2016 https://www.aub.edu.lb/ifi/Documents/publications/conference_reports/2015-2016/20160526_oxfam_confererence_report.pdf
[20] ITES, 2019. Tunisie: Eau 2050.

Groundwater extraction often exceeds natural recharge, resulting in a progressive decline of the groundwater table and a deterioration of the water quality. The situation is expected to worsen due to population growth and urbanization as well as the effect of climate change on the availability and variability of water resources. With two-thirds of the population already living in urban areas on the coast (33% live in rural areas), it is expected that the water demands of this population will be partly satisfied by interregional and desalination measures.

2.4.2. Water use in Tunisia

According to the last statistics of the Tunisian Ministry of Agriculture, Water Resources and Fisheries (MARHP)[21], 87% of water use was intended to agriculture, 19% for domestic uses, 3% and 0.1% respectively for industrial and other different sectors such as tourism. With the priority given to the development of the irrigated sector in the agricultural policy, the irrigated areas increased from 398,000 ha in 2000 to 435,000 ha in 2018. On another hand, the increased scarcity of the resource is experienced as a result of over-consumption of groundwater during years of scarcity, so the water resource is often the limiting factor in the extension of irrigation.

Regarding domestic water[22], a population of some 9.724 million inhabitants is served by SONEDE, which takes 708 Mm^3 of which 680 Mm^3 is produced. The produced volumes come mainly from surface water (58%), from the renewable aquifers (36%) and 4% was produced by desalination. The average of the water consumption ranges between 20 and 80 l/d/inhabitant in rural areas compared to 110 l/d/inhabitant in urban areas.

More than 86% of the urban population is connected to sanitation network (17180 KM). According to official data[23], more than 90 % of wastewater collected by ONAS is treated, and more than 20 % of treated wastewater is recycled. Treated wastewater used in irrigation must conform to the Tunisian Norms for reuse (NT 106.003). It is used mainly to irrigate crops (excluding vegetables that might be consumed raw), green spaces, and golf courses. Hence, the WWTPs are producing secondary treated effluents estimated at 270 Mm3 /year; only a few WWTPs are equipped with tertiary treatment which is hardly operating. The majority of WWTP is more than 30 years old. The National sanitation office (ONAS) has started a policy of rehabilitation of these plants.

Tunisia's 2050 water strategy aims at better utilizing water resources knowledge and improve the enabling environment for more effective water mobilization, including blue water, green water[24] and grey water, and efficient water use. Specifically, the strategy aims to (i) preserve and optimize the available blue water (surface and groundwater), which amounts to 4,800 MCM/yr and represents a seventh of the total amount of the rainfall received across the country, through rainwater harvesting and supplemental irrigation; (ii) maximize opportunities for green water resources, which are estimated at about 23 BCM/yr, in conjunction with technical efficiency.

[21] Ministry of Agriculture, Water Resources and Fisheries, 2017. Rapport National du Secteur de l'Eau.
[22] Drinking water (SONEDE and OTEDD, 2012)
[23] ONAS, 2017. Rapport Annuel 2017
[24] The green refers to the consumption of water contained in plants and soil, without being part of any surface or body of groundwater. The blue refers to the consumption of surface water resources and groundwater. The grey refers to polluted water resources.

The vision of the 2050 water strategy[25] is underpinned by six focal areas: (1) the preservation of the north water tower resources through adequate hydraulic works; (2) rehabilitation of water infrastructure in relation to domestic and irrigation systems; (3) more attention for rained agriculture in terms of incentives, restructuring and scientific support; (4) additional focus on artificial aquifer recharge; (5) exploration and development of technologies across the water sector, particularly in the areas of artificial aquifer recharge, wastewater treatment and desalination; and (6) optimal system management and water use efficiency for irrigation and domestic use.

[25] https://water.fanack.com/tunisia/what-does-the-future-hold-for-water-in-tunisia/

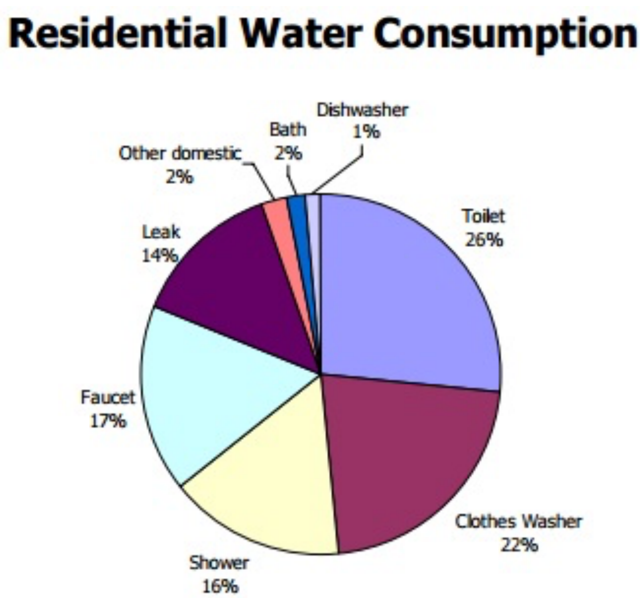
3. The possible sources of greywater and characteristics of the settlements

Greywater refers to all household wastewater other than that from toilets, i.e. wastewater from baths, showers, washbasins and the kitchen. In the simplest re-use systems, greywater is stored and subsequently used, untreated, for flushing toilets and watering gardens (other than edible plants). Greywater from baths, showers and washbasins is generally preferred to that from kitchen sinks and dishwashers since it is less contaminated. GW may represent up to 75% of total domestic WW, accounting for up to 100–150 l/PE/day in EU and high-income countries, and for smaller volumes in low-income countries[26]. While rainwater flowing from a roof or driveway can be transferred via guttering or piping to a receiving container and subsequently used for activities such as gardening and car washing.

3.1. Italy

3.1.1. Possible sources of greywater

Greywater represents 50-80% of domestic wastewater and its recovery represents a large fraction of potable water that could be saved. Out of 100 litres of drinking water used for domestic use, the potential of recovery of greywater could account for 50-80 litres. Moreover, since treating, pumping and heating water consumes significant amounts of energy, using less publicly supplied water also reduces energy consumption.



[26] Dilip M Ghaitidak 1 , Kunwar D Yadav. Characteristics and treatment of greywater--a review. Environ Sci Pollut Res Int. 2013 May;20(5):2795-809.

In Italy, the Legislative Decree no. 152 of 03 April 2006 "Disposizioni sulla tutela delle acque dall' inquinamento" / Provisions on the protection of water from pollution", and the European Community directives 91/271 (Urban Waste Water Directive) and 91/676 (Protection of waters against pollution caused by nitrates from agricultural sources) regulate the collection of civil or domestic wastewater once it reaches the public areas outside the buildings. Nevertheless, how domestic wastewater is collected within the dwellings and the buildings is not standardise at the national level. Separation of grey and black waters did not always occur; indeed, it is a relatively recent practice, which is mainly regulated by the municipalities through their building codes. In some cases, regional administrations harmonised and regulated the practice at the regional level, but still, there is a lack of national guidelines.

The current building practice is to install a double plumbing system which keeps separated grey and black waters within the dwellings. Greywater goes through a degreaser and subsequently is merged to the blackwater before both flows enter a pre-treatment system, i.e., Imhoff tank. Both systems are located in the basement of the building (multistorey or single houses) and from there they are connected to the public sewerage system.

As mentioned before, the separation of wastewater within the building has become a common practice only in the last few decades, and, for the purpose of this report, we assume it started to spread from the nineties of the last century. Based on recent statistics (2018), the number of buildings that were built after 1991 accounts to 1.531.000 units (around 15% of the total number of buildings in the country). Hence, we can assume that in these buildings, as in those that went through a large renovation in the same 1991-2018 period, greywater is collected separated from the blackwater flows and it can be recovered before it enters the pre-treatment stage.

Table 6 Year of construction of residential buildings in Italy. Source: CRESME

Year of construction	Number of buildings	% of the stock
Ante 1945	3.530.000	28,9
1946-1960	1.660.000	13,6
1961-1970	1.970.000	16,2
1971-1980	1.980.000	16,2
1981-1990	1.290.000	10,6
1991-2000	800.000	6,5
2001-2010	540.000	4,5
2011-2018	191.000	3,5

3.1.2. Housing and settlement patterns

Another aspect to take into consideration to assess the potential for the recovery of greywater is the type of settlement/dwelling. If greywater can be relatively easily collected both in single or multifamily houses, its reuse is certainly more complex in multistorey buildings. Figure 12 shows the typical dwellings in Italian territory. According to the 2001 census, the estimated number of households living in single or detached houses or in small multistorey buildings, which might be of higher interest in terms of feasibility of the recovery and reuse of greywater, stands at some 15 million units[27]. More recent statistics account the number of households to reach some 26 million, hence these estimations could be even higher.



Figure 12 Typical housing in Italy. Single house, semi-detached house, multistorey building.

Multistorey buildings are typical of densely populated areas, while the most common type of dwellings in suburbs and scattered/rural areas are single houses or small buildings hosting few households (detached houses). The algorithms developed by Eurostat (Degree of Urbanization - Degurba), mostly based on population density, represents an appropriate indicator to discriminate urban areas from rural ones. Based on the share of the local population living in urban clusters and in urban centres, it classifies Local Administrative Units (LAU or municipalities) into three types of area:

- Cities (densely populated areas) – at least 50% of the population lives in urban centres
- Towns and suburbs (intermediate density areas) – less than 50% of populations live in urban centres and less than 50% in rural grid cells
- Rural areas (thinly populated areas) – at least 50% of the population lives in rural grid cells

[27] ANACI 2° RAPPORTO CENSIS – ANACI. 2006

Table 7 Dwelling (households), buildings and families. Source: Censis servizi elaboration based on 2001 Census data (ISTAT)

Number of dwellings (households) in the building	**Number of buildings (residential use)**	**Number of multistorey buildings (residential use)**	**Number of dwellings (households)**	**Estimated number of dwellings in multistorey buildings**
1	6,902,088		6,902,088	
2	2,280,428		4,560,856	
3-4	1,031,757	103,176	3,478,593	347,859
5-8	517,100	387,825	3,223,761	2,417,821
9-15	275,263	247,737	3,117,717	2,805,945
> 16	207,333	196,966	5,985,865	5,686,572
Totals	**11,213,969**	**935,704**	**27,268,880**	**11,258,197**

Table 8 shows the number of dwellings and residential buildings to be found in the urban centres, suburbs and rural areas of the two provinces hosting the NAWAMED pilot plants and in the whole country.

Table 8. Households and buildings for the type of settlement, in Italy and in the two provinces hosting the NAWAMED pilot plants. Source: ISTAT, 2011 census.

		Latina province	**Siracusa province**	**Italy**
Densely populated areas				
	Households (number)	232,451	195,418	27,921,889
	Residential buildings (number)	88,321	104,383	10,004,446
Intermediate density areas				
	Households (number)	14,273	6,164	1,168,353
	Residential buildings (number)	9,007	4,700	724,972
Rural areas				
	Households (number)	38,905	15,185	2,117,919
	Residential buildings (number)	23,698	12,405	1,458,280
Totals				
	Households (number)	285,629	216,767	31,208,161
	Residential buildings (number)	121,026	121,488	12,187,698

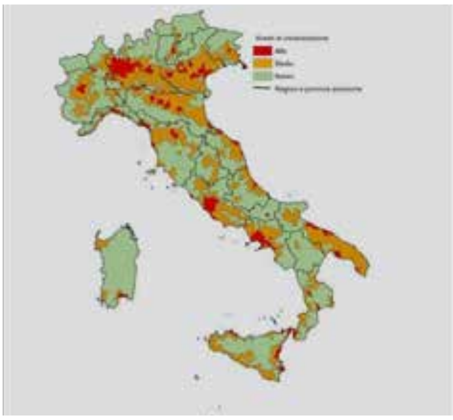


Figure 13 Degree or urbanisation of Italian municipalities. Red: hig

According to the results of the 2011 census, the Italian urban level stands at 6,7 percent for the entire national territory, and in many of the main centres, the urban area has become so large that there is no available space for new settlements that spread to adjacent municipalities. 91 percent of the Italian population lives in towns, although these represent only 6,7 percent of the Italian territory. By contrast, in the scattered houses, the population residing there is just under 6 percent, but this population is scattered within 93.3 percent of the national territory (Figure 13).

3.2. Jordan

3.2.1. Settlement patterns

Over the 2004-2015 period, the country's population grew, on average, at 6 percent a year mainly due to a 22 percent annual growth of non-Jordanians, reaching close to 9.5 million people in 2018.

There are three main types of settlements in Jordan:

- Urban settlements (Figure 14)
- Rural settlement (Figure 15)
- Bedouin settlements (Figure 16)

Some four-fifths of all Jordanians live in urban areas. The main population centres are Amman, Al-Zarqāʾ, Irbid, and Al-Ruṣayfah. Many of the smaller towns have only a few thousand inhabitants. Most towns have hospitals, banks, government and private schools, mosques, churches, libraries, and entertainment facilities, and some have institutions of higher learning and newspapers. Amman and Al-Zarqa, and to some extent Irbid, have more modern urban characteristics than do the smaller towns[28].

Figure 14 Urban settlements in Amman

Figure 15 Rural settlements

Figure 16 Bedouin settlements

[28] Ian J. Bickerton, Kamel S. Abu Jaber and Others (2020). "Jordan". Encyclopedia Britannica. URL: https://www.britannica.com/place/Jordan

There are primarily four zoning categories in Jordan for urban settlements, labelled as Residential Zones A, B, C, and D. Residential Zone A is for villas and luxurious housing, Residential Zone B lower-density, higher-end housing, and Residential Zones C and D higher-density, more-affordable housing. Over the past decade, 55.7 km^2 of the new urban area have been zoned, three-quarters of which are located within Greater Amman Municipality. Residential Zone A accounts for 5.9 percent of total new land, and Residential Zone B 23.6 percent. Land for middle to low-end of the housing market account for a relatively small portion of the new urban land—Residential Zone C accounts for 32.1 percent while Residential Zone D, the one with smallest plot size and therefore the most affordable type, accounts for a negligible 0.2 percent[29].The minimum lot size for each category is as follows: 1000 m^2 for Residential Zone A; 750m^2 for Residential Zone B; 500m^2 for Residential Zone C; and 300 m^2 for Residential Zone D in municipalities other than Amman, and 250 m^2 for Residential Zone D in Amman. Housing units built on smaller plots are much affordable than on bigger plots, as land is the most important cost factor. The generous minimum plot sizes in Jordan imply that the option of building smaller, cheaper is quite difficult.

The national water policy includes wastewater treatment as the main sanitation intervention. Sanitation coverage for both the urban and rural population is 93%. Out of which 63% are connected to the sewerage system (2014), with this expected to increase to 80% by 2030. The rest of those having access to improved sanitation use on-site sanitation solutions such as septic tanks.

In urban areas, water is usually available once a week, and less than once every two weeks in rural areas, with reduced frequency during the summer. Only 77.3% of existing sanitation systems are safely managed and only a third of schools have basic sanitation services.

The number of refugees registered in Jordan in 2019 stands at 744,795 persons of concern, among them approximately 655,000 Syrians, 67,000 Iraqis, 15,000 Yemenis, 6,000 Sudanese and 2,500 refugees from a total of 52 other nationalities. About 83 percent of refugees living outside refugee camps in urban areas[30].

Refugee camps

Za'atari refugee camp hosts around 80,000 Syrians refugees, and it is under the joint administration of the Syrian Refugee Affairs Directorate and UNHCR. The size of the camp is presenting huge challenges for infrastructure. Recently the camp was connected to water and wastewater network by a donation from Germany, through the KFW, in addition to funding from Canada, UK and US[31].

3.2.2. Households sanitation system

The Jordanian regulations governing plumbing in buildings are the 'Sanitary Wastewater System Code', and the 'Water Supply Code' (Ministry of Public Works and Housing 1988). These codes provide guidelines for the design and installation of plumbing systems in domestic properties.

The Sanitary Wastewater System Code provides guidelines for internal and external drainage and wastewater systems and gives recommendations for pipe types and dimensions and the design of

[29] World Bank (2018), Jordan Housing Sector Review.
[30] The UN Refugees agency (2020).
[31] UNICEF, 2020.

rainwater gutters. It provides extensive design guidelines for septic tanks. The codes suggest that all wastewater should be discharged using a sanitary wastewater system in accordance with the recommendations laid down in the code and prohibits wastewater discharge according to any other method. There is no explicit prohibition of the installation of a separate plumbing system for greywater. On the contrary, it is recommended that the toilet, bidet and urinals should not be connected into the same pipe as the floor drains and sinks, until outside the building. A suggested layout for a domestic wastewater system shows the wastewater from the toilet and bidet being kept separate from the shower and sink until outside the building where they are connected at a manhole. The code requires that each pipe joint, bend or change in level outside the property is facilitated by an access chamber (manhole). The code also suggests that each bathroom has its own external manhole and requires wastewater to be discharged into the municipal drain where possible, and failing this, to a septic tank.

Although greywater reuse is not expressly permitted, many of the above requirements – if implemented – could facilitate the use of greywater[32].

In 2003 A governmental committee has been formed to examine the codes in light of the potential greywater reuse and to propose amendments that would allow the reuse of greywater more easily, in particular, to require all household plumbing to separate greywater from blackwater until outside the building. The Ministry of Public Works and Housing, in cooperation with MWI, has included greywater reuse in the new water and sanitation plumbing code. The following precautions are recommended according to the greywater chapter of the new Jordanian water and sanitation plumbing code:

- Exclude laundry water from soiled diapers or from any items soiled with faces or other excrements.
- Use grey water for garden irrigation under the following conditions:
  - ✓ Use showers and bathroom faucets grey water after on-site primary treatment to remove hair and sediments, and disinfection to prevent risk of harmful bacteria.
  - ✓ Use subsurface irrigation, installed at least ten centimetres underground, to prevent human exposure to any potential pathogens.
  - ✓ Avoid waterlogging your soil, do not irrigate after rain.
  - ✓ Divert grey water that is not used for irrigation to the sewer system.
  - ✓ Regularly monitor water quality and divert grey water to sewer system in case of water contamination or malfunction of the treatment process.

3.3. Lebanon

3.3.1. Settlement patterns

In Lebanon, most of the population live on the coastal plain, and progressively fewer people are found farther inland. There are two main types of settlements in Lebanon: Urban settlements (Figure 18) and rural ones (Figure 17). Rural villages are sited according to water supply and the availability of land, frequently including terraced agriculture in the mountains. Northern villages are

[32] Center for the Study of the Built Environment (CSBE), (2003). Greywater Reuse in Other Countries and its Applicability to Jordan.

relatively prosperous and have some modern architecture. Villages in the south have been generally poorer and less stable. Most cities are located on the coast; they have been inundated by migrants and displaced persons, and numerous suburbs, often poor, have been created as a result. It estimated that 88 percent of the population out of a total of 6,859,408 (2019 data according to World Population prospects – United Nations Department of Economic and Social Affairs) is urbanized. Lebanon's four major cities are Beirut, Tripoli, Saida and Tyre[33].

<u>Refugee camps in Lebanon</u>

According to the UNHCR, in 2015, the overall number of registered displaced Syrians in Lebanon hovered around 1.1 million. Many of the displaced Syrians still live in informal settlements in more than 3,000 locations across the country, mainly in Baalbek-Hermel and in Bekaa, the others mostly in North Lebanon and in Akka. They lack basic services like water and sanitation, and their shelters are not properly equipped for adverse weather conditions. Other vulnerable groups are affected by the Syrian Crisis, such as vulnerable Lebanese, Palestinian Refugees from Syria (PRS) and Palestinian Refugees from Lebanon (PRL), the latter of whom host most of the PRS in their camps, adjacent areas and gatherings[34]. According to UNRWA over 470,000 Palestinian refugees are registered within Lebanon, about 45 per cent of them live in the country's 12 refugee camps. Conditions in the camps are dire and characterized by overcrowding, poor housing conditions, unemployment, poverty and lack of access to justice[35]. Informal settlement and camps have negative impacts on the environment mainly in relation to the drainage of storm, grey or black waters, and the collection of solid waste.

Figure 17 Rural settlement in Lebanon

Figure 18 Urban settlement in Lebanon (Beirut)

3.3.2. Greywater in Lebanon

Increasing water shortages in Lebanon, are driving the search for non-conventional sources to complement traditional ones. The reuse of wastewater; both black and grey, offers potential in limiting environmental degradation and in delivering an alternative source of water, mainly for irrigation or non-human consumptive use. The World Bank assessed the average discharge of

[33] Paul Kingston and Others (2020). "Lebanon". https://www.britannica.com/place/Lebanon
[34] Ministry of Social Affairs (MoSA) Coordinating Agencies: UNHCR and UN-Habitat. LEBANON CRISIS RESPONSE PLAN 2015-2016
[35] https://www.unrwa.org/where-we-work/lebanon

wastewater in 2010 to be 248 MCM/year as domestic sewage and 43 MCM/year sewage from industrial facilities; however, these values are estimates as no, or very limited, exists in most areas of Lebanon[16 18].

Lebanon's wastewater sector is in a dire state. Prior to 2012, only 8% of the wastewater generated was treated, and today, this number does not exceed 30%. Adding to that the largest wastewater treatment plants such as those in Ghadir and Saida only include preliminary treatment through the removal of grit and scum, failing to adhere to standards for wastewater discharge into the natural environment.

In 2012, the national water and wastewater strategy recognized wastewater as a major environmental problem and set stringent targets to treat 80% of wastewater by 2015, and 95% by 2020 (MoEW, 2012). Similarly, the strategy set targets for increased wastewater reuse to 20% by 2015, and 50% by 2020.

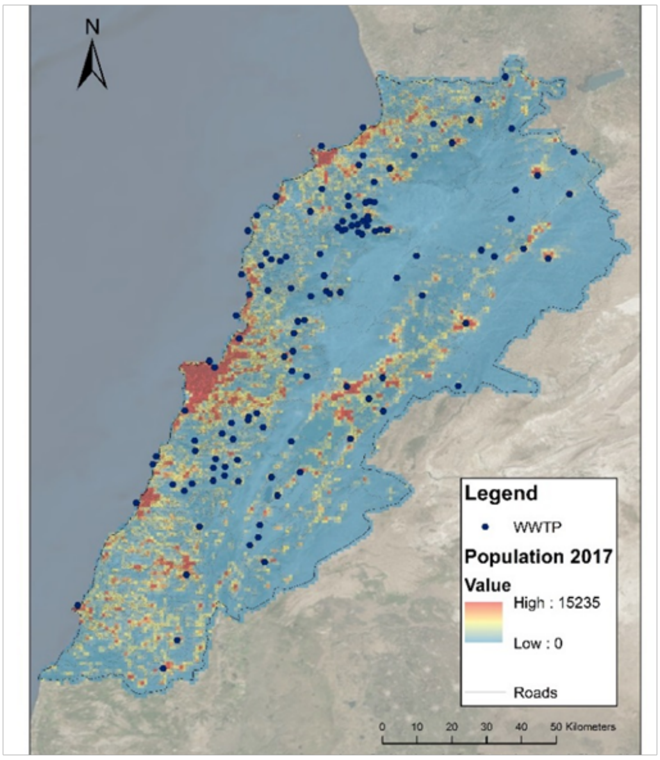


Figure 19 Wastewater treatment plants in Lebanon

Unfortunately, Lebanon is very far from meeting these targets. Although some progress was achieved in terms of constructing wastewater treatment plants (see Figure 19) with a big investment in the sector of USD 1.4 billion as of 2009, the majority of these plants remain non-functional. The consequences of the latter include among others, pollution of water bodies, damage to the aquatic environment, drinking water contamination, and spreading of diseases in communities.

3.4. Tunisia

3.4.1. Housing and settlement patterns

In Tunisia, the type of housing varies according to the environment of residence: communal or non-communal. In the following table (Table 9) the distribution of housing by type[36].

Table 9 Type of housing by environment. Source: Statistiques Tunisie

Type of housing	Dwellings (thousands)		
	Communal	Non-communal	Total
Traditional (Houch/ dar arbi/ Borj)	324.3	511.6	835.8
Twin dwelling or floor twin dwelling	1,118.1	156.4	1,274.5
Villa or duplex	646.5	269.4	915.9
Apartment	244.3	5.9	250.2
rudimentary housing	6.7	6.8	13.5
Total	2,339.8	950.1	3,289.9

As expected, the traditional housing (Houch / Dar Arbi / borj) is the most widespread in the non-communal environment representing 53.8% of the total number of housings in this area. In communal areas, the proportion of traditional housing does not exceed 13.9%. For the country as a whole, housings of this type represent a little more than ¼ of housings (explicitly 25.4%). The communal environment is characterized by modern type of housing. There were nearly 60% of all villas and 97.6% of all apartments in the country. Rudimentary housing is 0.7% in non-communal areas.

We will adopt the two settlements typologies used in Tunisia:

- The communal environment refers to "urban and built-up rural areas"
- the "non-communal environment" corresponding "dispersed" dwellings in rural areas and grouped together under this term.

<u>Urban and built-up rural areas (communal areas)</u>

Tunisia is a country of 11.3 million inhabitants (2016) of which 68% are living in the urban area. In communal area, most of the population are connected to the drinking water system (99.7% in 2017). However, regional disparities exist. However, small villages and some neighbourhoods suffer from discontinuous water supply due to high pressure on the water resource, illegal connexions or ageing network.

More than 86% of the urban population is connected to sanitation network (17,180 km)[37]. However, for the village with less than 4000Hab, the ONAS is not officially in charge of their sanitation. Only a few have a proper sanitation system connected to WWTP. For the others, partial network in the main streets is in general installed with discharge in the natural system (ex. oued).

[36] Statistiques Tunisie, www.ins.tn
[37] Rapport annuel ONAS 2018

In big cities and at the level of the household the average water consumption is about 100 to 120 l/day/hab. As example, the socioeconomic study conducted by CERTE demonstrated that for “Bardo Centre apartment” the average Water consumption during the summer can reach 300-700 l/day per apartment (household) and 70 to 300 l/day for doctor offices. The average consumption is from 120 to 170 l/day/hab. However, for urban agglomerations, individual dwellings with garden, with a more pronounced rural character, water consumption is different. As example, for CHORFECH 24, despite the presence of a few livestock farms and a few crops, the residential character of the locality is confirmed. The results on average consumption are around 130 l/day/hab.

The tables below (Table 10)[38] present water usage for the two types of settlements building (Bardo center) and village (Chorfech 24).

Table 10 Water usage for the two types of settlements building

Water use	**Bardo centre**	**Chorfech 24**
Consumption sink m3/year	3,171	945
WC consumption m3/year	7,420	2,438
Washing machine consumption m3/year	2,242	608
shower consumption m3/year	8,834	2,177
Reject air conditioner m3/year	1,057	0
Agricultural consumption m3/year	0	24
Livestock consumption m3/year	0	1,328

Dispersed / non communal settlement

The remaining population (32%) live in rural areas. Concerning domestic water, most of the population are connected to the network in the villages. According to the official data, in 2017, 68% in non-communal areas are connected at home. However, regional disparities still exist. For the "dispersed" rural areas, connexion to water was provided by the General Directorate of Rural Engineering (DGGR) and its deconcentrated services, the Regional Agricultural Development Committees (CRDA). They are in charge of the development of the water system for domestic water. Water price, in this case, is a function on the adopted water system and the distance to the users and can vary between 0.400 and 1 TND/m3. The management of the implemented water system is entrusted to local structures called Agricultural Development Groups (GDA) composed by elected members. Their role is to ensure that water is properly distributed to all the inhabitants. Some of them, are facing important management and technical issues due to lack of competences and high energy consumption. Their total number is 1,439.

However, today, according to figures from the Directorate of Drinking Water and Rural Equipment at the Ministry of Agriculture[39], there are still approximately 290,000 people, who have no access

[38] SWMED project, survey CERTE
[39] https://inkyfada.com/fr/2019/03/06/tunisie-eau-potable-chiffres/

to water: 8% of the 3.6 million Tunisians living in rural areas and 2-3% of the national population. The most concerned rural area is located in the North-West and the Centre-West. They have neither running water at home nor access to the fountains set up by the Ministry of Agriculture in rural areas.

In this type of settlement, 900,000 people use unimproved sanitation, about half use shared latrines, and the other half use mostly unimproved latrines. ONAS initiated Small Town Sanitation Program planned for the period from 2019 to 2023, having as main components the construction of 24 new wastewater treatment plants and 900 km of network.

3.4.2. Greywater in Tunisian

Greywater is water that comes from showers, bathroom faucets and clothes washers. It represents 50-80% of residential wastewater and its quality varies mainly due to the variety of detergents used in a household, and the detergents that can make treatment for reuse more difficult because they can alter the effectiveness of the chemicals used to treat the grey water.

The Tunisian sanitation system is based on sewerage system mixing grey and black wastewaters, but in the majority of cases is mixed outside of houses by two independents pipes. This situation can facilitate the recycling of grey wastewater after adequate treatment. There are some examples of reuse of grey wastewaters in hotels in Tunisia and some pilot plants for demonstration.

Urban and industrial uses are localized, and there are few mentions of greywater recycling in Tunisia.

4. The social, legal and administrative frameworks for the use of non-conventional water resources

The global market for water reuse solutions has grown significantly since the early 90s, when less than 1 MCM/d of reuse plant was installed annually, to 7 million MCM/d installed capacity during 2017 and is projected to continue to expand to over 10 million MCM /d by 2022. Industrial uses followed by irrigation (for agriculture and landscape) are still the largest global markets[40].

The need to minimise health and environmental risks of water reuse has led to the development of guidelines and regulations for the safe use of treated wastewater in an increasing number of countries. Some international and national organisations have developed reference guidelines for water reuse applications, because a consistent approach to the management of health and environmental risks from water reuse requires high-level guidance based on a majority consensus (Table 11). Such guidance is provided in the form of a risk management framework for the beneficial and sustainable management of water reuse systems. Examples include guidance provided by international organisations such as the World Health Organization (WHO), and national organisations of federal governments such as the US Environmental Protection Agency (USEPA) and, in Australia, the Natural Resource Management Ministerial Council, the Environment Protection and Heritage Council, and the Australian Health Ministers Conference (NRMMC-EPHC-AHMC)[41].

As it is set out in the EU Water Framework Directive, water pricing can be a key mechanism to achieving sustainable public use of water. Fundamental to the success of water pricing is its link to the volume of water consumed since this underpins the incentive for efficient use of water. With respect to the public water supply, meters are used in homes and business premises to quantify the volume used. Metering leads to reduced water use. Nevertheless, a further important issue with respect to domestic water pricing is the ability to pay, since it is generally recognised that no one should have to compromise personal hygiene and health in order to pay their water bill[3].

[40] Desalination and Water Reuse: Scarcity Solutions for cities & industry. Global Water Intelligence Market Report 2017.)
[41] European Commission Joint Research Centre Institute for Environment and Sustainability. Water Reuse in Europe Relevant guidelines, needs for and barriers to innovation. 2014

Table 11. Water reuse guidelines developed by international organisations. Source: European Commission Joint Research Centre Institute for Environment and Sustainability (2014).

Organization	Guidelines	Comments
World Health Organization (WHO)	"Guidelines for the safe use of wastewater, excreta and greywater" (2006)	Volume 1: Policy and regulatory aspects. Volume 2: Wastewater use in agriculture. Volume 3: Wastewater and excreta use in aquaculture. Volume 4: Excreta and greywater use in agriculture.
United Nations Environment Programme (UNEP)	"Guidelines for municipal wastewater reuse in the Mediterranean region" (2005) "Development of performance indicators for the operation and maintenance of wastewater treatment plants and wastewater reuse" (2011)	
United Nations Water Decade Programme on Capacity Development (UNW-DPC)	Proceedings on the UN-Water project "Safe use of wastewater in agriculture" (2013)	
International Organization for Standardization (ISO)	ISO/TC282 Water reuse (under development)	The standardisation of water reuse of any kind and for any purpose. It covers both centralised and decentralised or on-site water reuse, direct and indirect reuse, as well as intentional and unintentional reuse. The scope of ISO/PC 253 (Treated wastewater reuse for irrigation) is merged into the proposed new committee. Excluded: the limit of allowable water quality in water reuse, which should be determined by governments, the WHO and other relevant competent organisations.
Food and Agriculture Organization (FAO)	"Water quality for agriculture" (1994)	

4.1. Italy

4.1.1. Social and legal aspects

Requirements for reclaimed water

Agricultural irrigation by far is the largest application of reclaimed water worldwide and in Europe. In the EU, Italy is second only to Spain in terms of reuse of reclaimed water, accounting for 233 million m3 per year (2006), mostly used by the agricultural sector[42]. The source of this volume of reclaimed water is mostly treated wastewater for indirect agricultural use.

On 12 June 2003 the Ministry of the Environment issued the Ministerial Decree 185: "Regulation containing technical standards for the reuse of wastewater in implementation of article 26, paragraph 2, of the legislative decree of 11 May 1999, n. 152". The decree:

- identifies the possible uses (irrigation, civil and industrial);
- identifies the chemical, physical and microbiological parameters of the recovered water; it provides information on dual distribution networks;
- provides information on monitoring activities;
- specifies how to address the economic costs of wastewater treatment and recovery.

The decree contains comprehensive standards developed specifically for water reuse practices. The standards D.M. 185/2003 include maximum limit values for physical-chemical parameters that have to be met for all the intended uses of reclaimed water (Table 12). Some parameters have limit values similar to those designated for drinking water, even if the reclaimed water is used for uses such as irrigation of green areas. Regarding industrial uses, limit values should, as a minimum, comply with the limit values set for water discharges to surface water (Legislative Decree 152/2006).

In terms of water Reuse Costs, the average costs for reuse, as calculated by ISPRA in a Survey of several Italian recycling plants (different plants for different uses: urban, industrial, agriculture)[43] range between 0,0083 and 0,48 €/m3. As a comparison, the costs of abstracting water from rivers and groundwater bodies is estimated at 0,015-0,2 €/m3. The high cost of recycled water is generally indicated as one of the main barriers to water reuse[44].

The decree makes no distinction between types of reuse, providing the same chemical and microbiological restrictive limits. Article 3 defines that reclaimed water can be used for: irrigation, civil purposes and industrial purposes. Irrigation: Irrigation of crops for the production of food for human and animal consumption as well as non-food crops, and for the irrigation of green or recreation and sports areas. Civil purposes: i.e. washing of roads in urban centres, supply of heating or cooling system, feeding of dual supply networks (separate from drinking water network), with the exclusion of direct use of reclaimed water in building for civil use, with the exception of toilet drain systems. Industrial purposes: i.e. firefighting, industrial processing, industrial washing and

[42] European Committee of the Regions. Water Reuse – Legislative Framework in EU Regions. 2018
[43] ISPRA. L'ottimizzazione del servizio di depurazione delle acque di scarico urbane: massimizzazione dei recuperi di risorsa (acque e fanghi) e riduzione dei consumi energetici. Rapporto 93/2009
[44] The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL). Report on Urban Water Reuse. Integrated Water Approach and Urban Water Reuse Project. 2018

thermal cycles of industrial processes, with the exclusion of the uses that involve contact between the recovered wastewater and food or pharmaceutical and cosmetic products.

Table 12. D:M: 185/2003 for water reuse, parameters and standards.

PARAMETERS	STANDARDS	PARAMETERS	STANDARDS
pH	6.0 ÷ 9.5	Sulphites [mg SO_3/L]	0.5
Sodium Adsorption Rate	10.0	Sulphates [mg SO_4/L]	500
Coarse solids	absent	Chlorine residual [mg/L]	0.2
TSS [mg/L]	10.0	Chlorides [mg Cl/L]	*250*
BOD_5 [mg/L]	20.0	Fluorides [mg F/L]	*1.5*
COD [mg/L]	100.0	Animal/vegetal oils & fats [mg/L]	10.0
Phosphorus [mg P/L] (total)	2.0	Mineral oils [mg/L]	0.05
Total Nitrogen [mg N/L]	15.0	Phenols [mg/L] (total)	0.1
Ammonia [mg NH_4/L]	2.0	Pentachlorophenol [mg/L]	0.003
EC_W [dS/m]	3.0	Aldehydes [mg/L] (total)	0.5
Aluminium [mg Al/L]	1.0	Tetra/tricloro-ethylene [mg/L]	*0.01*
Arsenic [mg As/L]	0.02	Chlorinated solvents [mg/L] (total)	0.04
Barium [mg Ba/L]	10.0	TTHM [mg/L]	*0.03*
Boron [mg B/L]	*1.0*	Aromatic solvents [mg/L] (total)	0.001
Cadmium [mg Cd/L]	*0.005*	Benzene [mg/L]	0.01
Cobalt [mg Co/L]	0.05	Benzo(a)pyrene [mg/L]	0.00001
Chromium [mg Cr/L] (total)	0.1	Org. nitr. solvents [mg/L] (tot.)	0.01
Chromium VI [mg Cr_{VI}/L]	0.005	Surfactants [mg/L] (total)	0.5
Iron [mg Fe/L]	2.0	Chlorinated biocides [mg/L]	0.0001
Manganese [mg Mn/L]	0.2	Phosphorated pesticides [mg/L]	0.00001^
Mercury [mg Hg/L]	*0.001*	Other pesticides [mg/L] (total)	*0.05*
Nickel [mg Ni/L]	0.2	Vanadium [mg V/L]	0.1
Lead [mg Pb/L]	0.1	Zinc [mg Zn/L]	*0.5*
Copper [mg Cu/L]	*1.0*	Cyanides[mg CN/L] (total)	*0.05*
Selenium [mg Se/L]	*0.01*	Sulphides [mg H_2S/L]	0.5
Tin [mg Sn/L]	3.0	*E. Coli* [UFC /100 mL] *(80% of samples)*	10*
		CWs & Stabilisation ponds	*50***
Thallium [mg Tl/L]	0.001	*Salmonellae* [UFC /100 mL]	absent

^ for any single item;
** 100 CFU/100 mL will be allowed as a maximum for a single isolated sample and for the first three years of application of the new Act;*
*** 200 CFU/100 mL will be allowed as a maximum for a single isolated sample.*

The D.M. 185/03 establishes particularly restrictive qualitative limits for the reclaimed waters, representing an obstacle to the concrete diffusion of the practice of reuse, caused by the difficult economic sustainability of the projects. In particular, the restrictive limits for microbiological parameters are a crucial element, since the very removal of microorganisms raises the costs of purification to such levels as to make reuse not convenient or economically unsustainable, which has essentially limited the larger spread of the practice of reuse up to now[45].

Italy is one of the few EU member states that establishes and standardises the practice of water reuse. In terms of investment opportunities, water reuse projects have limited economic attractiveness and are further aggravated by the unclear regulatory framework applying to them. To limit this situation, new rules, adopted by the European Parliament and the Council on 25 May

[45] G. Mancini. Luci ed ombre del riuso delle acque reflue in Italia: quali le concrete prospettive tra costi e vincoli normativi? Ecomondo. 2007

2020 (Regulation 2020/741 - Minimum requirements for water reuse[46]), establish harmonised minimum requirements for reclaimed water to be met by the Member States. The Regulation sets obligations for operators of reclamation plants, which include complying with minimum requirements of water quality, according to the four water quality classes based on target crops, microbiological factors, and physicochemical parameters. Moreover, these obligations include establishing a risk management plan, in consultation with the relevant actors, such as the suppliers of wastewater, to address potential additional hazards. The newly agreed rules will possibly stimulate the water reuse sector and provide a certain amount of clarity concerning water reuse requirements. According to the European Commission, the new Regulation could increase water reuse from 1.7 billion m^3 to 6.6 billion m^3 per year[47].

The new Regulation on minimum requirements for water reuse has entered into force. The Italian legislation described above, and the regional regulations adopted will need to be harmonised with the provisions of the EU Regulation within three years, from 26 June 2023. Major changes are foreseen, as the current legal framework does not have relevant provisions regards the differentiation of water uses into classes, the validation of monitoring protocol, Water Reuse Risk Management Plan, and Information to the public[42].

Building regulations

In Italy, according to the report produced by the ONRE (National Observatory on Municipal Building Regulations) of Legambiente and CRESME (Economical, Sociological and Market Research Centre), referring to data from 2011, 530 of the 8,092 Italian Municipalities already include in their building regulation, rules on sustainable water management. The very large part—more than 90%—of them have new regulations, approved after the year 2005. In the coming years, the building regulations of all the remaining Municipalities will be progressively updated and—considering also the need to fulfil the requirements of the new Climate Change Adaptation Plans—, they will include sustainable water management rules.

Nonetheless, it should be underlined that the process of renewing Municipality regulations including water aspects require more time than expected. Although the sustainable water management technologies and approaches are of growing interest in the scientific community and are reckoned to be effective both for single households and urban contexts, the economic crisis is progressively reducing the activities of Municipalities in the environmental sector and water now has a very low ranking in the interest of public administrations4.

4.1.2. Water pricing system

In Italy, there are different managing systems for water services. About half of the population are served through the delegated public management model. PPPs (Public Private Partnerships) cover 36% and concessions cover 5% of the population. Water services are directly provided by municipalities (direct public management) to the remaining share of the population.

[46] http://data.europa.eu/eli/reg/2020/741/oj
[47] Zbigniew Kozłowski. https://www.waterworld.com/international/wastewater/article/14177296/minimum-requirements-for-water-reuse-new-rules-adopted-by-the-eu

The tariff for water services is proposed by the local regulator (EGA - Ente di Governo d'Ambito) to the national regulator (ARERA (the Regulatory Authority for Energy Networks and the Environment)) which can approve it. If the local regulator does not act, the water company can send its proposal directly to the national regulator (ARERA) for tariff approval.

Water tariffs and the cost of water services have been key topics of public debate in Italy during the past years (the national referendum held in June 2011 established that water management services could not be operated by private companies). Tariff schemes and other economic instruments should be able to discourage high domestic consumption, guarantee infrastructure development and maintenance, and stimulate new technologies (rainwater harvesting, greywater re-use).

In May 2012 the Italian Energy Authority, after the Law n. 214/2011 assigned to the same Authority competencies on Water Services Regulation, started a public consultation on a new national water tariff scheme. In the meantime, while general public opinion is still very much worried about the possible growth of water tariffs, the environmental movement requests full application of the "polluter pays" principle, clearly saying that the huge investments in the water sector needed to fulfil the requirements of the Directive 2000/60, have to be paid by water users.

Nonetheless, the adoption of economic tools to stimulate new technologies as to include some water technologies (rainwater harvesting, greywater reuse) among the building renovation solutions that receive fiscal incentives, raised interest by Environmental NGOs but has not yet achieved public debate4.

4.2. Jordan

4.2.1. Social and legal aspects

The idea of water conservation is not new to Jordan. A report by the Centre for Development Research by 1999 estimated that 60% of households in Amman and 30% in rural Jordan reused water within the dwelling.

There are many examples throughout the Jordanian reusing their own greywater. As example, in the King Abdullah Mosque, the wastewater from the ablutions of worshippers is collected and pumped to a rooftop storage system where it is filtered and reused to irrigate some areas of plants in the grounds of the mosque. The system was installed in 1998 and has resulted in a significant saving on the mosque's water bills and the capital costs for the installation of the system were recovered within the first year of operation.

4.2.2. Barriers for constructing greywater systems in Jordan

There are some barriers to implement greywater reuse systems in an extensive way in Jordan, here are some of them:

<u>The piping systems in Jordanian houses</u>

The vast majority of houses in Jordan are constructed of reinforced concrete. Water and wastewater pipes generally are cast into the floor slabs. Access to the pipes is therefore difficult and costly. In most cases, plumbing practices are not consistent with Jordanian regulations; greywater from bathrooms should be kept separate from the toilet water until the manhole outside the house. This should make the interception and use of greywater relatively easy. However, this practice generally is not followed. The disturbance factor and cost of retrofitting a concrete house, unless it is undergoing a major refurbishment, make the economics of greywater use unfavourable in these cases since the costs saved are unlikely to pay for the plumbing and installation. It is vastly preferable therefore for new houses to be dual plumbed (i.e. plumbed with a separate plumbing line for greywater) from the beginning.

However, for new houses or where the plumbing is either separate or accessible, labour costs are low, and parts are cheap and easily available.

Characteristics of wastewater

The per capita water usage in Jordan is significantly below that of developed countries, and therefore, lower greywater is available for reuse is available with higher concentrations of different parameters. The characteristics of wastewater in Jordan are somewhat different from other countries. The average salinity of municipal water supply is 580 ppm of TDS, and the average domestic water consumption is low[48]. These results are in very high organic loads and higher than the normal salinity in wastewater. Part of the water is lost through evaporation, thereby, increasing salinity levels in the effluents to wastewater treatment plants. In addition, high organic loads impose operational problems where the plants become biologically overloaded with only a portion of their hydraulic loads.

Removing greywater from sewage systems will increase the salinity levels and organic loads in the effluents to WWTP's which impose operational problems where the plants become biologically overloaded with only a portion of their hydraulic loads.

Environmental Problems

The most positive environmental impact of greywater reuse is the reduction in demand for fresh water. However; one of the main environmental risks from greywater reuse is that of groundwater pollution. Another risk is the poisonous effects of chemicals on plants.

Jordanian people use septic tanks and cesspits to discharge greywater to gardens. This practice resulted in major environmental problems, especially groundwater pollution; the pollution problems were complicated by rapid urban growth.

However, three factors could mitigate these environmental risks. The first is that there are very small quantities of greywater in domestic contexts available for reuse. The second is that most of the water and nutrients in the greywater will be taken up by the plants themselves. Other substances in the greywater (e.g. organic matter and bacteria) will be broken down by the topsoil. The third factor is to use nature-based solutions to treat the greywater before usage. Under normal circumstances, very little of the greywater will reach the groundwater.

[48] Abdulla FA, Alfarra A, Qdais HA, Sonneveld B (2016). Evaluation of Wastewater Treatment Plants in Jordan and Suitability for Reuse. Acad. J. Environ. Sci. 4(7): 111-117.

Aesthetic Problems

Greywater reuse for flushing may cause unpleasant odour and discouloration of the toilet bowl. This could be mitigated through more treatment for greywater before reuse.

The Low Cost of Water

The water sector in Jordan is highly subsidised; the domestic consumers are not paying the actual costs of the water. The low prices of water reduce the effective 'financial savings' to be made by reusing greywater.

4.2.3. Water pricing system

Water and wastewater tariffs in Jordan (Figure 20) are approved by the Council of Ministers based on requests by the Ministry of Water and Irrigation (MWI)[49]. Current tariffs do not allow Miyahuna and WAJ to recover all their costs and as tariff stability is missing. Water and sanitation service costs are subsidized. Combined water and sewer bills amount to less than 0.92% of the total household annual expenditures[50].

■ تعرفة الإستهلاك للاشتراكات المنزلية

قيمة الفاتورة = مبلغ ثابت + الكمية الإستهلاك للشريحة X (سعر الشريحة للمياه + سعر الشريحة للصرف الصحي) X العامل

■ المبلغ الثابت وسعر الشريحة للمياه وسعر الشريحة للصرف الصحي

المبلغ الثابت	العامل	صرف صحي/ م3	مياه/ م3	شرائح الإستهلاك الربعية (م 3)
	سعر الوحدة بالدينار			
4.43	1.00	0.690	2.100	مقطوعة الحد الأدنى 0-18
8.08	1.00	0.046	0.145	19-36
9.73	1.00	0.288	0.500	37-54
9.73	1.10	0.518	0.850	55-72
11.73	1.15	0.690	1.000	73-90
11.73	1.15	0.805	1.400	91-126
11.73	1.20	0.920	1.600	127 - فما فوق

■ في حال عدم وجود اشتراك صرف صحي تكون قيمة أجور الصرف الصحي = صفر

■ المبلغ الثابت ويغطي كلفة الخدمات الإدارية غير المرتبطة بكمية الإستهلاك

■ العامل: يتفاوت ما بين 1 - 1.2 وذلك حسب شريحة الإستهلاك ...

Figure 20 Residential Water Tariff in 2019

The volumetric charge varies with consumption and is based on a complex formula set for each consumption block. The pricing system in Miyahuna is based on increasing block rates for residential users and a constant price per cubic meter consumed for non-residential users.

The residential Tariff formula is as follow:

*Cost of water per month = Fixed amount (JD) + (Used water per month (m3) * (Water price (JD /m3) + Sewage network usage price (JD/m3)) * Factor)s*

4.3. Lebanon

The main institutional players in the water sector are the Ministry of Energy and Water (MoEW), the four Water Establishments (WEs), and Litani River Authority (LRA). Their capacities and responsibilities are discussed in the following sections.

[49] USAID (2009).Pricing Of Water And Wastewater Services In Amman and Subsidy Options.
[50] Ministry of Water and irrigation (2016). National Water Strategy.

4.3.1. Laws and Responsibilities

In 2000, Law 221 reformed the water sector and consolidated the day to day management of the water from the 25 water authorities to four main water establishments (WEs) and the Litani River Authority (LRA), under the jurisdiction of the MoEW. The four WEs are the North Lebanon WE (NLWE), Beirut and Mount Lebanon (BMLWE), South Lebanon (SLWE), and Bekaa (BWE).

As per Law 221, the roles and responsibilities of MoEW and of WEs are summarized in Table 13:

Table 13. Roles and Responsibilities of the MoEW and WEs in the water sector (Farajalla, Kerkezian, Farhat, El Hajj, & Matta, 2015)

	Responsibilities	MoEW	WEs
Policy-making	- Definition of sector policy, institutional roles and structures - Enactment of legislation and regulation - Development of investment and subsidy policy	✓	
Planning and implementation	- Establishment of long-term consolidated planning for water, irrigation and wastewater - Evaluation of infrastructure and investment requirement • - Water rationalization - Design, construction and operation of major water infrastructures - Funding and execution of investment programs	✓	✓
Conservation and Resource Management	- Allocation of resources across regions, e.g., water reuse - Identification and promotion of water conservation campaigns	✓	
Regulation and Enforcement	- Issuance of regulations - Enforcement of regulations and standards for cost recovery, service quality, water quality, and consumer relation	✓	
Operation and Distribution	- Billing and collection of tariffs - Maintenance and renewal of infrastructure		✓
Wastewater Treatment	- Operate, maintain and renew sanitation infrastructure		✓
Control and Monitoring	- Management of all information including data collection, analysis and reporting - Implementation of service quality and contingency planning	✓	

It should be noted that the MoEW and WEs cooperatively oversee transnationally funded ventures, while the Council for Development and Reconstruction (CDR) regulates the ones held with the assistance of external sources.

The amendments in the law have not been fully executed due to certain delays (hindered and gradual approval of laws in 2004 and 2005), and to the vulnerability of certain WEs regarding their potency to act upon their privileges. The WEs often lack the technical capacity, financial autonomy and accountability, hindering them from taking full charge of operation and management (O&M) responsibilities. Therefore, O&M operations are at times outsourced or run through the CDR and municipalities. This is especially the case in the wastewater component of water services provision. Irrigation water is provided by three of the four water establishments NLWE, BMLWE, and BWE in areas north of the Beirut-Damascus highway. The LRA is tasked with supplying irrigation water and managing major irrigation projects in areas of the Beka'a south of the Beirut-Damascus highway and in South Lebanon.

Based on the Municipal Act, Law no. 118/1997, the Municipal Council is in charge, without limitation, of pubic programs for water projects, granting certificates for the routing of water connections and allowing the excavation of public roads to lay water and wastewater pipes. As part of their miscellaneous authority, municipalities can also use public properties to implement water projects. The conflicting responsibilities handed to municipalities and WEs, and the inconsistencies between legal and existing responsibilities have created institutional voids, and weakened the accountability line between policy makers and service providers (MoEW, 2010).

Another form aiming at regulating the water sector is Code de l'Eau or Water Code. In cooperation with the French government, this code was drafted to ultimately promote Integrated Water Resource Management (IWRM), and to fill any institutional voids found in Law 221 [19]. The code seeks to promote the notion of 'user pays' and 'polluter pays' and relies on the decentralization principle to water planning and management. Key constituents of this code encompass the appointment of public authorities as the main entities in charge of overseeing and regulating freshwater quality, providing safe drinking water and wastewater treatment, managing drought and floods and protecting water resources. It entails the development of a National Water Council, representing policy and planning institution for the water sector. A National Water Plan and River Basin Plan should be conducted under this draft to highlight the qualitative and quantitative needs of the water sector, allowing to assign resources accordingly. The draft code also incentivises on the participation of the private sector[19].

<u>Challenges faced by the Water Establishments (WEs)</u>

<u>Financial and Commercial</u>

<u>Sources of revenues</u>

According to the assessments done in 2008-2009, the main source of revenues of the WEs come from the water allocation and watering systems' fees (constituting 10% of the total), followed by assembly dues (connection, disconnection, reconnection fees…), meter or measure costs, maintenance charges, penalizations and wastewater fees (putatively weighed at that time). Many external grants were contributed to the RWEs, but their annual budgets are usually reviewed by concerned ministries for approval. Given the government's budget deficit, the concerned ministries allocate very small financial budget for the establishments [19].

<u>Tariffs</u>

As dictated in the law, the RWEs are responsible for the implementation of a tariff system. The current system in Lebanon considers an annual flat tariff rate, irrespective of the actual per capita consumption. Water bills mainly comprise fixed charges related to the volume of water supplied to the consumers, fixed at 1 m3/household/day, and to connect related charges [19].

As Table 14 implies, only 10% of the total connections in the four WEs are metered and their fees undergo normal lump sum tariffs instead of volumetric tariffs. This tariff strategy is primitive and isn't adopted in any of the developed countries. The absence of metering devices prevents volumetric charges and is considered inefficient since consumers are not incentivised to reduce their water consumptions.

Table 14 Percentage of metered connections in each WE

	BMLWE	NLWE	SLWE	BWE	Total
Total No. of connections	378,735	92,972	137,551	66,089	675,347
Total No. of metered connections	6,591	30,000	18,828	11,954	67,373
% metered connections	2%	32%	14%	18%	10%

Billing and collection performances

Consumers do not always pay their due bills that are collected on a yearly basis by employees or cashiers at the WEs. It should be mentioned that WEs do not follow a specific or appropriate billing method. With no monitoring of consumer compliance, uncollected subscription fees are valued at approximately 375 Billions of LBP, exacerbating furthermore the WEs' financial capabilities (MoEW, 2010).

4.3.2. Wastewater reuse regulation

The irrigation with treated wastewater is currently prohibited (Decree 8735 of 1974) and hence no standards for water reuse are established, but as reuse is envisaged for the future, draft wastewater reuse guidelines have already been prepared (Table 15). The standard proposed by FAO (2010) is quite similar to that applied in Jordan for many years. There, positive experiences have been made with treated wastewater reuse in agriculture. However, the FAO proposal is lacking the conditions in which area treated wastewater is allowed to be reused in agriculture. Because of the high pollution risks in karst aquifers, the potential reuse areas depend on the groundwater vulnerability[51].

Table 15 Draft Lebanese guideline for wastewater reuse (FAO, 2010)

class	I	II	III
restrictions	produce eaten cooked; irrigation of greens with public access	fruit trees, irrigation of greens and with limited public access; impoundments with no public water contact	cereals, oil plants, fiber and seed crops, canned crops, industrial crops, fruit trees (no sprinkler irrigation); nurseries, greens and wooden areas without public access
proposed treatment	secondary + filtration + disinfection	secondary + storage or maturation ponds or infiltration percolation	secondary + storage /oxidation ponds
BOD_5 (mg/L)	25	100	100
COD (mg/L)	125	250	250
TSS (mg/L)	60 (200 WSP)	200	200
pH	6 – 9	6 – 9	6 – 9
residual Cl_2 (mg/L)	0.5-2	0.5	0.5
NO_3-N (mg/L)	30	30	30
FC (/100ml)	<200	<1000	none required
Helminth eggs (/1 L)	<1	<1	<1

Note: Irrigation of vegetables eaten raw is not allowed

[51] A. Margane, A. Steine. German-Lebanese Technical Cooperation Project Protection of Jeita Spring. Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation. 2011

4.3.3. Lessons from a project in Lebanon

Though its supply is modest, greywater is regarded as a potential source in reducing demand for water from fresh sources [13]; however, very limited research and fewer projects have involved greywater in Lebanon. The most (maybe the only) prominent and large scale project was that funded by the Canadian International Development Research Centre (IDRC) and the Italian Government Development Cooperation and implemented between 2002 and 2008 by a local NGO, Lebanese Appropriate Technology Association (LATA) in cooperation with the consulting company Middle East Centre for Transfer of Appropriate Technology (MECTAT).

The project covered ten towns in the Beqaa and two in South Lebanon whereby houses were equipped with 3- or 4- barrel treatment systems (depicted in Figure 21 and in Figure 22). In these, anaerobic treatment of collected greywater takes place over a period a day or two after which it is pumped into a drip irrigation network installed in the garden. Between 100 and 150 m3 of irrigation water was provided per household based on a greywater recovery rate of 50 to 60% an amount sufficient for a typical home garden[52].

Figure 21 An actual 4-Barrel System[52]

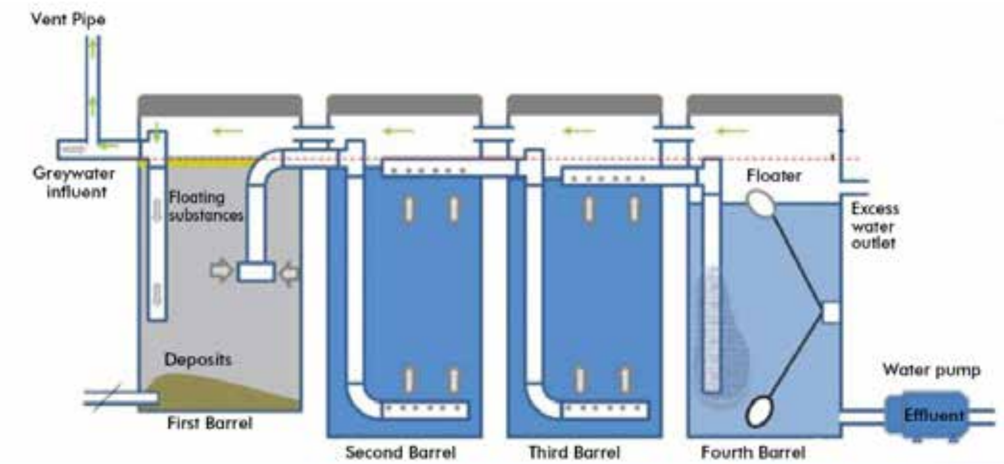


Figure 22. 4-Barrel System setup, for up a family of 6 (Ghougassian, 2013)

A Confined Trench (CT) system (see Figure 23) was also used in some locations. These systems utilize aerobic digestion of organic pollutants. A review of the treatment processes by Gemayel (2008) indicated that the CT system outperformed the barrel systems and amongst these the 4-barrel

[52] Ghougassian, B. (2013). Onsite Greywater Treatment and Reuse in Irrigation. President of LATA, 4th Beirut Water Week(Notre Dame University-Louaize), Lebanon.

system gave better treatment results. Gemayel further determined that long detention periods coupled with good maintenance produced good quality effluent. Short detention periods coupled with an absence of maintenance gave at best, average removal efficiencies.

At the time of the project, the average unit cost of 4-barrel system ranged between $250 and $350 for a household of 5-6 members while the unit cost of CT system was between $400 and $500 for a household of 7-10 members[52].

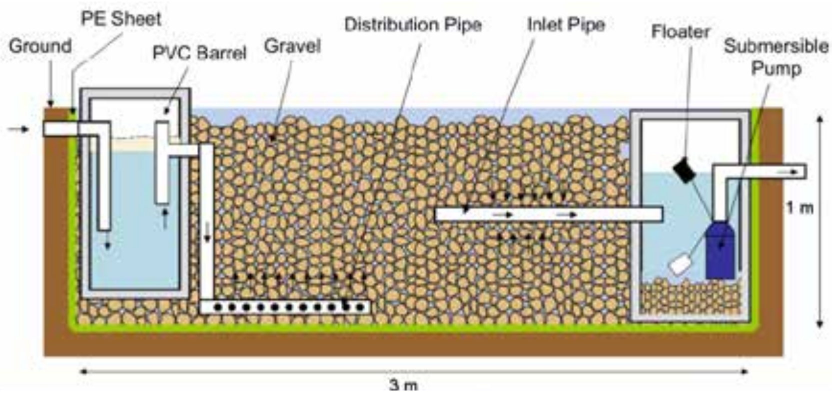


Figure 23. Confined Trench setup for maximum 10 people (Ghougassian, 2013)

Some Benefits

The successful implementation of GW related projects in Lebanon led to an average GW recovery rate of about 100 to 150 m3 of irrigation water a year per family. Bills for trucked water were reduced by 20% water and for households with no connections to the sewage system, costs related to the emptying of septic tanks were reduced by 60%.

Some Drawbacks

The effluent generated from the greywater treatment systems was found to have high faecal concentrations. Also, the removal efficiencies for each system were found to be low thus not providing the users with the effluent that could be safely used in unrestricted irrigation.

The most recurrent problems were odour; mechanical problems (mainly pump malfunctioning), system clogging and the clogging of hoses.

Some Lessons Learned

For beneficiaries to fully grasp the concept and operation of the system, along with the required maintenance, training of beneficiaries and all relevant stakeholders is necessary.

4.4. Tunisia

4.4.1. Social and legal aspects

Social aspects

There are substantial imbalances in terms of water-resource distribution between the better endowed North and the semi-arid South. If left unaddressed, deficiencies could become more severe in the coming years. Tunisia is a water-scarce country, and water supply security challenges are predicted to be exacerbated by climate change in the coming years. Opportunities for improvement are analysed and condensed into several recommendations for the way forward for the WASH sector in Tunisia[53].

Water is becoming more scarce forcing planners to consider developing non-conventional water resources including treated greywater reuse to satisfy increasing non-potable, agricultural, and industrial applications[54]. With the technical advances in greywater treatment technology, even the risks of treated greywater reuse on soil and plants can be satisfactorily and safely managed[55]. However, for various economic and social factors, the reuse of treated greywater is still limited to agricultural and industrial purposes. In fact, the qualitative characterization of treated greywater is a key aspect when trying to reuse it.

In agreement with the study done by Munoz (2016)[56], there are several barriers in Tunisia that are preventing implementation of greywater systems from being a regular structure of every building or widely accepted. One being the economic costs of the network (if we don't consider the benefit of water recycling/reuse), the initial investment to purchase and install treatment system, and annual maintenance, which can outweigh the costs savings on the water bill (depending on the system). The second being the lack of regulatory guidelines and standards. Third, there are public concerns about the potential health impacts that using grey water can cause, such as contact with pathogens causing illness and outbreaks, a concern such as this is likely to become reality if a system is mismanaged and crossing of pipelines occurs.

The public perception will have to be changed in a positive light through extensive education of the need to augment local water resource, the benefits of water recycling to the environment and the safety of using grey water. Installing greywater systems is best done when preparing design plans for a house, as opposed to during construction or retrofitting a house. In Tunisia, greywater is not greatly studied at this time and information about system installation is not easily accessible for those who wish to implement a greywater system in their homes.

Legal Aspect

The reuse of wastewater in Tunisia is regulated by a set of legislative decrees which identify conditions of agriculture use of treated wastewater, quality of treated wastewater, modalities for reuse and the list of crops to be irrigated by treated wastewater.

- Decree N° 89-1047 of 28 July 1989, modified by decree N° 93-2447 (1993) identifying conditions for agriculture reuse of treated wastewaters;
- Ministerial Decree (1995) relating the modalities and specific conditions for reuse of treated wastewater.
- NT 106.03 (1989): standards for reuse of treated wastewater for irrigation purposes. The Tunisian standard was developed based on the recommendations of FAO and WHO. From

[53] World Bank Group, Water and Sanitation for all in Tunisia
[54] Chaabane et al, 2016, DOI 10.1007/s11356-016-7471-x
[55] Lamine et al. 2012 DOI: 10.1080/19443994.2012.677553; Merz et al. 2007, DOI: 10.1016/j.desal.2006.10.026
[56] Munoz 2016, https://repository.usfca.edu/capstone/353

the perspective of micro-biological quality, the NT 106.03 only considers the number of nematode eggs while several standards recommend a limit for faecal Coliform levels in risk of contact with humans (stadium, garden)

- Decision of 28 September 1995 list of requirements for agricultural wastewater reuse implementation.
- Decision of the Minister of Agriculture (21 June 1994): list of crops that can be irrigated with treated wastewater; The list included industrial crops, cereal crops, forage crops, fruit trees and fodder shrubs (Acacia, Atriplex), Forest Trees, flowering plants.

The legislation prohibits the irrigation of vegetables that might be consumed raw (crudités). This adapted measure considering the health aspect is, however, a limiting factor for agricultural as it is eliminated crops with high economical value and against a diversified agricultural strategy.

It must be noted that all this decree is linked to the reuse of wastewater in the agricultural sector. There are no standards or specific conditions for the reuse for recreational and environmental purposes or at the industrial (water process, cooling, fire extinguisher systems…) and urban levels (toilet flushing). It is clear that the agricultural sector is using more than 80% of the water resource and the treated wastewater is more adapted to agricultural reuse due to the potential of nutrients reuse, although it is not really integrating into the strategy of reuse; however, it is important to develop a clear framework for other reuses. They can present a continuous demand for TWW which is not the case of the agricultural sector. There is no legal frame for grey water treatment and reuse.

The National sanitation office (ONAS) is in charge of sanitation and the producer of TWW. Currently, there are 122 WWTPs active in the whole territory, among which 78% are equipped with activated sludge process (with low and medium organic load). Hence, the WWTPs are producing secondary treated effluents estimated at 270 MCM /year; only a few WWTPs are equipped with tertiary treatment which is hardly operating.

Treatment is centralised and treatment process is mainly biological and stands at the second level leading to limited bacteriological quality, which is at the origin of the list of crops to be irrigated by TWW but can lead to interesting strategy of nutrient valorisation or groundwater recharge (using optimised infiltration-percolation process). Several actors control before and during the reuse of treated wastewater, mainly the Ministry of Public Health for the sanitary control of operators, the local population of irrigated areas and products. ANPE is in charge of the evaluation and approval of environmental impacts studies related to treated wastewater reuse projects. The Ministry of Agriculture ensures the distribution of TWW to farmers.

The high number of actors and their dependency on different ministries need strong coordination and the implementation of multi-decision mechanisms as well as participative approach for efficient awareness, control and reuse.

4.4.2. Water pricing system

In most of Tunisia, urban water and sewerage services are delivered by two national companies: SONEDE, the Tunisian Water Utility (henceforth the TWU) and ONAS, the Tunisian Sanitation Utility (henceforth the TSU). Water bills include either water or water plus sewerage, depending on the locality, as observed in most countries: the sewer fee is charged within the water bill issued by the

TWU which collects it on behalf of the TSU in areas with collective sanitation (exclusively urban areas). The two national operators establish their own pricing rules, but users receive a unique bill based on their water consumption.

The main operators in Tunisia's water sector are SONEDE (Société Nationale d'Exploitation et de la Distribution des Eaux), DGGR (Direction Générale du Génie Rural) and ONAS (Office Nationale de L'Assainissement). SONEDE has got a 100 percent responsibility for the promotion of urban drinking water. SONEDE together with DGGR is 90 percent responsible for the promotion of rural drinking water. ONAS was established in 1974 for the regulation of wastewater management and since 1993 additionally assigned with the protection of the water reserves. ONAS operates 80 percent of the sewage network (sewers, pump stations, cleaning plants etc.) and is supported locally by private companies.

For instance, in 2016, a user consuming between 71 and 100 m3 per quarter paid 0.770 TND/m3 by m3; a user consuming between 101 and 150 paid 0.940 TND/m3, this price does not include taxes and sanitation services(Figure 24).

Several reforms were established that led to the increase of high water price in current terms but these reforms were not sufficient to offset inflation, leading to a decrease in water prices in constant terms (Figure 25).

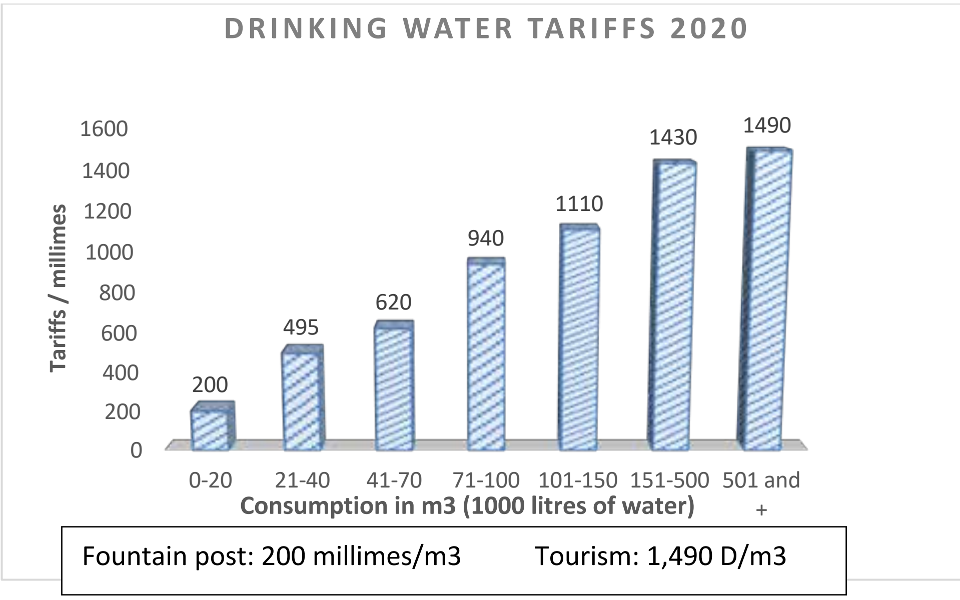


Figure 24 Drinking water tariff bands in Tunisia (SONEDE)

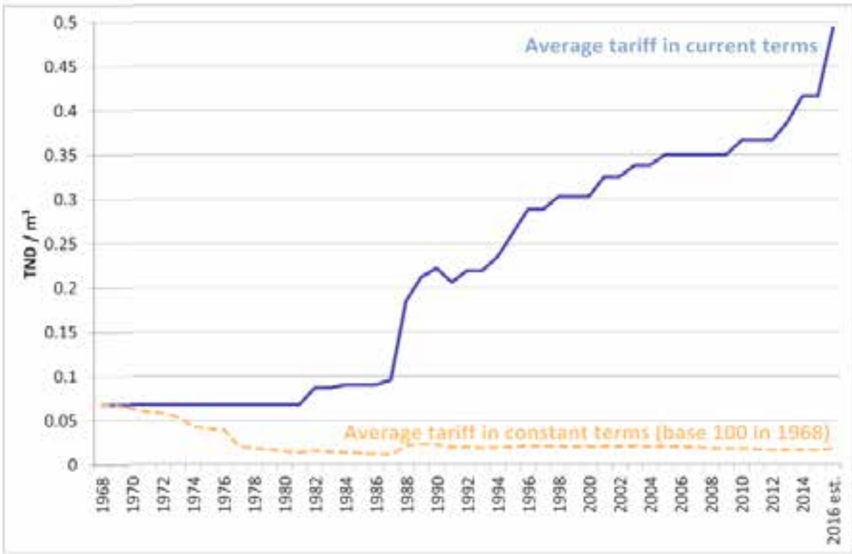


Figure 25 Evolution of average water price (excluding sewer and VAT) for a 30 m3 /quarter water consumption from 1968 to 2016 (SONEDE) (base 100 in 1968)[57].

The price for tourist subscribers was ten times the top band in 1979, only twice in 1982, and 1.8 times in 2016. Other uses have incurred a higher price since 2010, due to the change in the pricing structure toward a two-part (binomial) IBT.

Awareness-raising and communication to reassure users about the risks associated with treated wastewater (TWW) are not always sufficient. Awareness of the benefits of TWW that will lead to economic benefits is also a very important factor for social acceptability[58].

The low price of TWW in comparison with conventional resources may also influence but cannot be the only motivating factor, as the Tunisian experience shows. The symbolic tariff of 0.020 DT/ m^3 of TWW was not sufficient to motivate farmers to use this resource. For non-agricultural uses, however, such as Irrigation with conventional water is not subsidized, the price of water is a parameter important in the choice of used resources.

On the other hand, it is noted that the reuse of TWW appears to be very cost-effective for golf. As an example, the number of visitors required to have a positive gross margin is 9,000 using the waters of the SONEDE while it is 5,000 with the TWW.

The situation regarding the airport's green spaces is similar and allows the airport to save money compared to a situation without a project where Civil Aviation and Airports Office (CAAO) would use only SONEDE. Thus, the table below shows that the CAAO realizes about 5 DT million in savings over 20 years, compared to a situation where only SONEDE water would be used instead. It is

[57] Inflation rates from 1968 to 1980: World Development Indicators, 1980–2016: World Economic Outlook Database, April 2016, IMF.

[58] Hachicha, 2015, DOI: 10.13140/RG.2.1.3961.0648

interesting to note that in the case of the watering of the airport's green spaces, the investment of the CAAO is in charge of the sewerage system and the entire irrigation network and that the situation is still more profitable than appealing SONEDE[59].

In the context of the OSP study, the analysis of SONEDE's pricing system highlights certain limitations:

- The pricing system used by SONEDE is a progressive pricing system that favours households of modest socio-economic status. Nevertheless, the pricing system, and particularly the increases, is not indexed to costs, to increases in charges, or even to increases in the cost of living or income.
- A brief focus on SONEDE's cost structure, on the other hand, shows that the deficit is not only due to the reluctance to increase fares. The "energy" item is growing, today representing more than 64% of the purchases consumed. As for the "personnel costs" item, it has seen a steady increase, which has even accelerated after 2011.

The benchmarking exercise showed that the price of water in Tunisia is among the lowest. The price for water services represents 0.88% of the income of an average household, and there is still a margin compared to the maximum rate estimated by the WHO of 3.5%.

These remarks underline that price increases must be made while working in parallel on controlling the heaviest energy and personnel costs.

Drinking water pricing in rural areas

For GDAs in rural areas, tariffs per m3 vary greatly from one GDA system to another, even within the same governorate. They vary from a minimum of 0.200 TND/m3 to a maximum of 1.500 TND/m3. The averages at the governorate level range from 0.500 TND/m3 in Tataouine to 0.796 TND/m3 in Beja.

[59] WATER REUSE 2050

5. Conclusions

5.1. Greywater recovery potential

The available information doesn't allow an estimation of the greywater reuse potential at the country level, due to the uncertainty concerning the share of population living in buildings where to install the infrastructures for greywater recovery. According to the data provided in the above sections, however, reuse of greywater could be considered a positive practice in all the considered countries (Italy, Jordan, Lebanon and Tunisia). Nonetheless, it must be underlined, that the water recovery potential is significantly different from one country to another.

In Italy, domestic consumptions are quite high, ranging between 130 and more than 200 litres/inhabitant/day (l/h/d): around 70% of which is greywater. Recovering greywater in Italy would lead to an average availability of more than 100 l/h/d.

In Lebanon, the lack of a diffuse domestic consumption metering system doesn't allow to gather figures about the greywater reuse potential, however, the relatively high availability of water resources in the coastal area, where the major urban settlements are located, would suggest a high potential, not far from the one mentioned above for Italy.

In Jordan, the heavy restrictions of the water distribution due to the dramatic scarcity of water resources[60], make the households consumptions very low. According to the data provided at paragraph 2.2.2, considering a total availability of 469.7 millions of cubic meters for urban uses of a population of 9.5 million inhabitants and an average distribution loss of 50%, the average per capita consumption is 67 l/h/d, which means a residential/domestic use of less than 60 l/h/d. Greywater recovery potential in Jordan could be estimated less than 50 l/h/d.

In Tunisia – excluding rural areas where the pro capita water use ranges between 20 and 40 l/h/d – urban water consumption ranges between 80 and 110 l/h/d. Greywater recovery would allow availability of additional resources ranging between 55 and 80 l/h/d. In urban modern buildings, however, water consumption may be significantly higher (more 300 l/h/d), increasing the potential greywater recovery.

5.2. Housing and settlement patterns and greywater reuse

In all the analysed countries the housing and settlement patterns allow greywater recovery, at least on a share of the building heritage. In Italy, a precautionary estimation of the building where greywater recovery would be possible - that is the building where the greywater is piped out of the building separately from the black water - is around 15% of the total (the share built after 1991 when the separation of the two pipes became compulsory by law). In Jordan, it is not possible to clearly estimate the share of buildings to "retrofit" greywater recovery. Nevertheless, it possible to apply the technology for new buildings. It is also important to consider the high average salinity of Jordanian water, that could affect the possible reuse for irrigation. In Lebanon as well, it is not possible to estimate the potential for the "retrofitting" of greywater recovery system in existing the

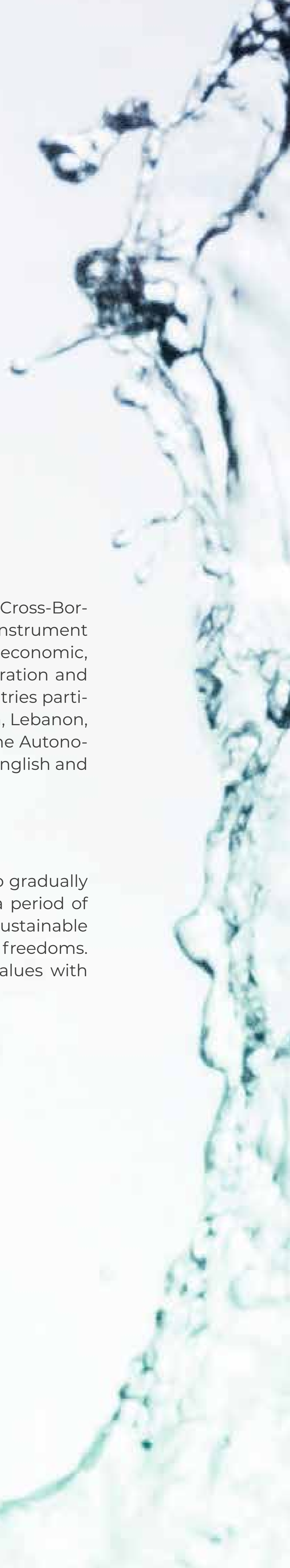
[60] In urban areas, water is usually available once a week, and less than once every two weeks in rural areas, with reduced frequency during the summer.

buildings: apparently the national water and wastewater strategy aimed at reaching more basic achievements, such as the wastewater collection and treatment infrastructure. While in Tunisia, the significant amount of one or two floors dwellings (1,118) and "villas" (646) could allow for a progressive diffusion of greywater recovery.

5.3. Possible obstacles to the diffusion of greywater reuse

In all the country considered the possible barriers to a wider diffusion of greywater recovery and reuse are similar (occurring everywhere) and can be summarised as follows:

- Technical difficulties in retrofitting existing buildings, and consequently high costs of works and nuisance for the people living the building;
- Low cost of potable water, making the payback time of a water reuse (and saving) system quite long;
- Lack of specific regulation for greywater reuse: the existing regulations on water reuse for most of the countries apply to mixed wastewater and are generally focused on reuse for irrigation.



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