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Water harvesting and water collection systems in Mediterranean area. The case of Malta

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Abstract

This paper focuses on how the Mediterranean countries have dealt with the water shortage problems through different systems of water collection and water harvesting, developing appropriate solutions to meet the specific needs of their ancient and present-day inhabitants by using traditional knowledge, building skills, and local resources, leading to solutions that to different extents, fit into the existing environment. This research helps to understand the different approaches in each country, resulting from climatic, geographical, socio-economic, and cultural conditions, as well as those related to spatial planning and urban development. Malta's case can be seen as a particular approach to this problem, which has led to a new source of water harvesting for common use. Malta has always been characterized by underground and rainwater shortages due to the intense but short rainfalls. It increasingly harvests and collects the resource through the use of highly technological seawater desalination systems. The Reverse Osmosis process (RO) provides the water to its inhabitants from a strongly present and easily available resource, the surrounding seawater of the Mediterranean. At the same time it boosts the use of tanks throughout the territory which reduces harmful water withdrawals from the underground, helps control the runoff phenomenon and ensures better management of water in agriculture and households.

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1. Introduction

Nomenclature

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FAO	Food and Agriculture Organization of the United Nations
MEPA	Malta Environment and Planning Authority
RO	Reverse Osmosis
SDI	Silt Density Index
UNESCO	United Nations, Educational, Scientific and Cultural Organization
WSC	Water Services Corporation
WWF	World Wildlife Fund

1.1. The water problem

Contemporary society faces today the necessity to reduce its consumptions: energy consumption is increasingly followed by water consumption. The sometimes-indiscriminate use of the water resources must face the problems of shortage and droughts occurring in several countries, especially in the Mediterranean area. Less than 1% of the water on the planet is drinkable. The water of atmospheric derivation which corresponds to rainwater, water from the melting of snow and from the fog, has always been considered an important source of supply, although this type of water needs to undergo certain treatments in order to meet the legal requirements of potability, under the chemical, microbiological and sometimes precise bacteriological profiles. The main issues emerging from several world reports (WWF, Living Planet Report, 2010) on the planet's health and water consumption concern the qualitative and quantitative conditions of the resource: limited availability, uneven distribution on the territory and increasing pollution which are being aggravated each year by the growth of the world population, the indiscriminate rise of the consumption and by the lowering of water aquifers due to excessive withdrawals and the poor management of the territory.

1.2. Traditional and modern water harvesting and collection systems

Awareness and efficiency in the management of the water resources are addressed in different ways in countries of the world, depending on the presence and availability of the resource in each country. Countries with a good presence of underground, surface or atmosphere water have always shown a minor sensitivity in the use of the resource compared to countries that have for long dealt with serious shortages or total lack of water for their population. This has led to a different development over time of water harvesting and water collection systems that would provide for their needs. Traditional and modern harvesting systems used for the collection of atmospheric water in the Mediterranean area have always met the different requirements and needs of the historical period they belonged to, but they both result from the interaction of different factors and disciplinary fields they were characterized by over time, as well as the considerable capacity to manage the available local resources (Laureano, 2001). Moreover, through time changes have occurred in their use, building materials and technologies. Traditional knowledge has ensured the appropriate use of resources over the time, resulting in positive changes and often leading to actual rural or urban ecosystems. Moreover, in most cases, such knowledge gave architectural and aesthetic values to each system through harmony with the landscape and responsiveness to the traditional decorative aesthetic.

2. Mediterranean area

2.1. Countries with different needs and knowledge

The Mediterranean area consists of countries which are characterized by different climatic conditions due to the different geographical position, the topographical situation and the resulting weather conditions. As far as water is concerned, these countries differ each other through the presence of the resource in the atmosphere and underground, and for this reason they have dealt with the problem of water harvesting and supply in different ways. Traditional and modern systems of each country have many similarities in the design solutions implemented and in the used materials. This is due to the different cultural influences from invading countries over the time, which has led changes and additions to the building technologies and the traditional established skills.

2.2. The northern Mediterranean area

The northern part of the Mediterranean area, consisting mainly of countries of the European Union, has always had available water in the atmosphere in terms of rainfall, so the traditional and modern water harvesting and water collection systems are widely spread throughout the territory. Their design solutions and used materials are similar because of the different influences of the building skills of different populations that have passed through in different historical periods and they were generally made in large sizes, especially water storage systems. A large part of this area is also characterized by the availability of water in the underground: the possibility of water supply from underground has led to the creation of wells for the withdrawal and collection of water which exploit the water from atmosphere resources only in a complementary way to meet the requirements and needs of the local population. The supply in this area is generally guaranteed by elements that convey water to the underlying collection systems made of special waterproof coatings of the roofing and flooring, carried out with wet and dry lay technologies to allow an adequate flow and conveyance of rainwater into the collection systems. As far as collection is concerned, there are some types of underground tanks dug into the rock, connected by systems of canal and flow lines, which have assumed different conformations depending on the urban development of the place. These tank systems have developed as urban systems, such as, for example, the “Sassi” of Matera and the “Bottini” of Siena, the latter consisting of canals dug in the rock that allow the supply and conveying the water collected from rainfall but also by infiltration and condensation of the air that passes through these ducts. Each system, depending on the place it originates from, is developed and characterized by some building aspects that have modified, in part, the general system: these are cases of the tanks and wells in Venice built of especially made conical dry-laid bricks allowing rainwater harvesting after a previous step in a layer of sand filter for purification. Like many other systems, this solution has undergone changes due to the urban development of the city where it is inserted. From a mainly external and underground element located outside buildings, it was incorporated into the developing residential housing for reasons of recovery and of public land saving. There are also more punctual rainwater harvesting and collection systems: single underground, semi-underground or external tanks whose walls and roofing are built with bricks or local stone squared elements according to different dry or wet building technologies (*opus caementicium*, *reticulatum*, *incertum* and, sometimes, *spicatum*), with a roofing of round arches and vaults, often supported by pillars and faced with *cocciopesto* plaster to prevent any leakage of water from the system. These types of tanks that share characterizing elements in several cases, are present in Italy, as in the case of the *Piscina Mirabilis* or in the tank called *Cento Camerelle* of Naples. Some of them are also present in Turkey, as the famous *cisterns* of *Yerabatan* and *Binbirdirek*, in Istanbul. Other tanks that have similar characteristics are present in France and Spain,

mainly in castles and palaces or in villas as in Croatia and Slovenia, as the tanks in Brijuni, Val Catena, built with square elements of Istrian local stone. Especially in the case of Greece, there are also collection systems that take advantage even from the underground water and that have been constructed in more than one technology: they are excavated in the rockbed but also have walls and roofs which are constructed in square blocks of local stone and opus caementicium. In Greece, there are also special water supply systems such as culverts and spring taken, that draw water from underground aquifers where the soil has a right alternation of permeable and impermeable layers at different depths: those tunnels and rooms were inclined to the horizon with a minimum slope so that the water could be drawn from all the permeable layers. From this structure a branched or more lines that penetrated into the rock outcropping to collect more water and prevent stagnation.

2.3. The southern Mediterranean area

On the other hand, the southern part of the Mediterranean mainly consists of countries belonging to the African continent and western Asia. These countries' approach to the water resources has always been different from the above analyzed one: they have always faced huge shortage problems which has led to the development of specific systems for harvesting and collection. One example are the buildings that many of these countries have used to supply water, the qanat. These systems arise from Persian qanat shutters, underground drainage tunnels that intercept the ground water near the surface and allow to rise thanks to a gently sloping gravity. The tunnels were dug into the rocky terrain of the site and water collection was used in the cities and to irrigate fields. These systems can often reach lengths of hundreds of kilometers and thanks to the dug wells for their ventilation (necessary for their own construction), their maintenance is easy. Examples of qanat are present in Morocco (where they take the name of khattara), Algeria, Egypt and Libya. In the latter, the system is called foggara and it shares the same principle as qanat, but it manages to increase the quantity of the transported water drawn from the underground by adding water resulting from condensation of humid air that goes in the other direction opposite the fluid, along the inner walls of the foggara. There are however more punctual systems too: tanks built with square blocks of local stone laid by using techniques of masonry systems common of most northern Mediterranean area. Among these, some important case are those of Caravanserai of Cyrene tanks in Libya, or tanks in Morocco whose paving is made of local stone elements, laid out and chased with lead to prevent any loss. There are also examples of underground tanks dug into the local rock, often limestone, as in the case of tanks in Algeria and Lebanon or dug wells to supply water from the ground in Libya, where there are still in use tools called shaduf for the withdrawal.

3. The case of Malta

3.1. Water in Malta

The archipelago of Malta, consisting of Malta, Gozo and Comino, is a country with a current population of about 400,000 inhabitants, one of the most densely populated countries in the world. Over the past 50 years it has seen a boost in the development and a consequent increase in proportional demand for water due to the great density of population and strong tourism. Today, the largest part of the demand of the resource is represented by the domestic sector due to the indiscriminate use and high living standard of the population, and by the agricultural sector, which, as its main source, uses the underground water which has led to increasingly heavy withdrawals and pollution of the ground and transiting water. Malta has always been poor in water: the island is characterized by the scarcity of the resource on the surface while the underground part has always been over-exploited, resulting in lowering and changes in

the structure of the underground aquifers. The rainfalls that are characteristic of its climate do not help either: it is usually an average of 550 mm annually, a figure that widely varies from year to year, which is manifested by sporadic events of great intensity and volume but relatively short, especially in the period between October and February, thus not so useful to meet the needs of the population during the hot and dry summer and very disadvantageous to runoff phenomena that occur especially in the more built area on the island.

3.2. Water harvesting and collection systems in Malta

This particular situation has led to the research for new water supply systems over time, that would meet the water of both residents and tourists visiting the island. Until the beginning of 1600 the water supply of Malta was related only to rain for which holes were dug in the local rock: there are the tanks Misqa (Fig 1a), whose holes dug in the limestone of the site date from the period between 4500 and 2000 BC. Some harvesting systems that date back to the same period are also present in sites recognized by UNESCO: the megalithic temples and tombs throughout the island where the community meeting places as well as and places of spiritual and religious ritual. These buildings were built with megalithic blocks of limestone of the area and consisted of two temples grouped together, located in close positions but on different heights. The temple that was generally built higher served the worship of life, whereas the lower one the cult of death. The water harvesting systems in these buildings consisted of the holes dug in the local rock or they could be underground caverns that were part of the local underground temples. There are examples of such tanks in the temples of Tarxien (Fig 1b), those of Mnajdra and Hagar Qim and in the underground Hal-Saflieni (Fig 1c).



Fig. 1. (a) Misqa water cistern; (b) water cistern at Tarxien Temple; (c) water cistern at Hal-Saflieni; (photos by the author);

The hydric needs of the Maltese population were therefore provided for by atmospheric sources water collected in such tanks dug into the limestone of the area. Today, tanks are not the most used system for the needs of the population as their water collection capacity is about only 2 hm³. Their use is however particularly efficient in terms of sustainable management of water resources during the intense and short rainfalls that characterize Malta. The intensity of the phenomenon associated to the strong waterproofing of surfaces due to the huge urban development is the cause of the runoff which that thanks to the spread of tanks mainly in urban areas, can be limited. Instead of flowing rapidly towards the sea, which could have harmful consequences on the maltese territory, the water can be channeled into these systems, supporting the existing solutions of water harvesting for common needs. Better control of such runoff phenomena as well as the improvement of the management of the water resource through the appropriate allocation of tanks for each household, can help meeting the ever growing demand for water and on the other hand, is acts as a solution in terms of sustainability for the efficient reuse of the collected

water, even though for non potable uses.

FAO explains how providing each household with 25 m³ capacity tanks would allow a recovery of around 4.5 hm³ of water in the runoff process, consequently diminishing the volume of water required and supplied by the network, covering over 40% of the demand (FAO, 2006). Even in the case of agriculture which ranks second in water demand, it would be possible to exploit the tanks to collect the rainwater from the runoff, which would diminish the underground withdrawal or the load volume required from the supply network in order to irrigate. The use of incentives to increase the number tanks and improve the management of water could help for more awareness of the resource, more respect for its use and a better management of the runoff phenomena. In the case of new constructions in particular, water harvesting related to the exploitation of the runoff is regulated by a plan drawn up in 2004 by the Malta Environment and Planning Authority (MEPA), which regulates the creation of water collecting surfaces on roofs, calculating the possible size and capacity of the tanks according to precise coefficients proportional to the surface of the roof, as shown in Table 1.

Table 1. Malta Environment and Planning Authority – policy and design guidance 2004 (source: FAO, 2006 - www.mepa.org);

Destination (in mq of the roof)	Coefficient
dwellings	0.3
villas	0.45
industrial and commercial buildings	0.45
hotels	0.60

Since 1600 and particularly under the English influence, besides the tanks, several plants to draw water from underground were built in the main cities of Malta, often supported by boiling plants to turn into potable the water drawn from aquifers. 80% of the underground water resources were extracted from the limestone rocks strongly present on the island: thanks to porosity and permeability, this type of geological formation, holds the fresh water creating underground lentiform bodies usually located above the layers of the same rock that has absorbed the more dense brackish water. But the continuous and invading withdrawal of underground water of area worsened the situation: the quality conditions of the aquifer worsened in terms of concentration of the salt in the water while the demand for drinking water was still rising. The overexploitation of these water bodies has resulted in the reduction of the same volume of the lenses and the consequent need for new sources of water supply for Malta. The water harvesting system that transform salty seawater into drinking water through a desalination process, the Reverse Osmosis process (RO), becomes an acceptable and reliable solution which guaranteed high quality drinking water. From the 80s desalination plants were built in Ghar Lapsi, Tigne, Cirkewwa and Pembroke (Fig 2).



Fig. 2. Pembroke RO plant; (photo by the author)

The desalination systems are an example of the water supply system that until recently was considered to be a new challenge: the process allows the production of drinking water from brackish water through reverse osmosis (RO), using an enormously available resource: the sea water surrounding the island.

The most important RO plant is in Pembroke. The process consists of forcing the sea water or brackish water through a multi-layer membrane by applying pressure that is generated by external pumps whose task is to win over the osmotic force which, searching for the equilibrium point, moves water in the opposite direction. The semi-permeable membrane, a key element in the process of water desalination, is made up of several layers that have different textures in order to prevent the passage of the different types of salt in the water that has to be purified, and to guarantee high resistance to pressure. The WSC mainly deals with these systems, although there are examples of private desalination systems where 1 hm³ of water can be produced. There is, however, no detailed information on it. The use of such RO systems also permits the production of water with very low energy expenditure: the process consists of simple passages of the sea water in different plants for the water to be filtered gradually. The rest of the salt water produced after the passage through the RO tanks is returned to the sea. The recovery of energy from the turbines amounts up to 80% in the different stages of the process and the simplified hydraulic do not require maintenance by operators. Moreover, the control of the amount of salts present in the drawn water through the study of the SDI index allows the preservation of the membranes, ensuring greater durability. The SDI index of the drawn water has often had the optimal value, especially in older and longer used wells, pushing for the use of existing wells and discouraging the drilling of news ones.

From the second half of the twentieth century in Malta, WSC provides for about 57% of the drinking water coming from the RO systems and the underground withdrawal plants. In the recent years the total production of water from the WSC has been set to about 30 hm³ (Fig 3).

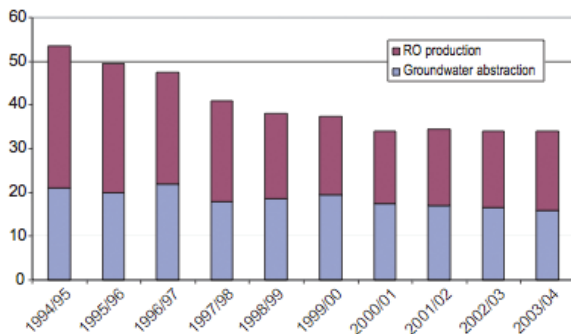


Fig. 3. Trends in WSC water production, 2003 (source: FAO, 2006)

In the near future Malta could face a drastic decline in the withdrawal of underground water due to a further deterioration of the bodies of freshwater, a consequence of the continuous withdrawal, resulting in passage of the total water production by the WSC through RO systems only. The related high costs for the production of these plants, would directly affect the Maltese citizens. However, while in the past water shortages in Malta were dealt with by allocating of a fixed quantity of water per person, with the RO systems a stricter attention to the amount of water used will no longer be necessary. This aspect is the main drawback of the RO desalination systems, along with the high cost of facilities: it leads to an indiscriminate and unlimited use of this valuable resource and does not promote the awareness towards conservation and more conscious use of water.

4. Conclusion

Malta's case shows how the water harvesting and collection systems have evolved over time and that the demand for that resource is being met by environmentally responsible systems that respect local resources. Moreover, Malta can also be an example of how modern technology searches immediate efficiency through the highly specialized skills, managed by the ruling structures that are able to mobilize environmental resources. The reliability of such systems, the low energy required for their use and the stability of the water supply for the common uses are the main advantages of this solution. It makes it possible to meet the growing demand for water with a natural method reproduced through modern technology which solves, more and more adequately, the current pressing issues of energy and water saving.

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