THESIS

# INTRODUCING EFFICIENT **WASTE WATER TREATMENT** AND RE-USE TECHNIQUES IN NORTH CYPRUS

by

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**INTRODUCING EFFICIENT WASTE WATER TREATMENT AND RE-USE TECHNIQUES IN NORTH CYPRUS**

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“A drop of water is worth more than a sack of gold to a thirsty man.”

Anonymous

“Do not waste water even if you were at a running stream.”

Hz. Mohammed

*To my beloved unbeknown country…*

## i. Abstract

Due to its geographical location Cyprus has semi-arid climate. This fact makes water more vital and vulnerable. For all of its time Cyprus has had a lack of and low quality water, if we count the yearly average rainfall ~ 500 mm. Rainwater coming from the Trodos mountains on the South side (largest mountain range of Cyprus-peak 1,952 meters), with the Besparmak mountain and Girne mountains on the North side, is collected in big tanks and distributed to the public. However for many years water has been supplemented to NC from Turkey with tanks and balloons. In summer time people still have water shortages. "Water became more vital during last 20 years in all parts of the world. It is estimated that two billion people in the world live in areas with extended water shortages" (Duraiappah, 1998). In addition to water scarcity, water pollution is a problem that has affected every continent of the world (Sampat, 2000).

Another enormous problem in Cyprus is the negative effects of developing tourism close to the sea. There are ~ 220 accommodation complexes in TRNC and this number is increasing every year. According to official numbers, TRNC had tripled its tourist capacity in 10 years. Apart from its positive effect on the economy, unfortunately there are negative effects too. Due to lack of efficient technology, many hotels (especially located near the sea) have been, and if we don't prevent it; will still discharge their waste water directly into the sea without and/or lack of any treatment or refinement. This stands as a big problem for the endangered marine habitat (for example *"caretta caretta"*, *"Cheloina mydas"* to name two). It is not only harming the habitat but also affects tourism in a negative way due to its dirty and blurry view of the sea. A number of samples taken from the sea near the "Rocks Hotel & Casino" have been analyzed by a private laboratory and the results determined that the *e-coli* bacteria in the water are much more than it should be.

Besides tourism another big contributor to the income of the island is agriculture. Because of the water shortages many projects involving agriculture are cancelled or put on hold. People take water by opening a well in their gardens or in their crop fields. This is totally illegal and harms the underground water resources by creating holes in the ground and allowing infiltration of the sea water in the potable water resources. So the question is; "in a country where water is a major issue, why waste water and also harm the environment instead of re-using the waste water for agriculture, landscape irrigation and other needs?"

ii. <u>Table of Content</u>

iii. Key Words

**WWTP**

Waste Water Treatment Plant

**NC, SC, TRNC**

North Cyprus, South Cyprus, Turkish Republic of North Cyprus

**Biochemical Oxygen Demand (BOD)**

BOD is a measure of how much organic material is in the wastewater plant effluent calculated by the amount of oxygen used by microorganisms in the oxidation of organic matter. If the amount released in the effluent is too high, microorganisms in the receiving waters will eat the organic material utilizing dissolved oxygen as they do so. This depletes the dissolved oxygen available to aquatic life and results in fish kills, invasions of weeds, and changes in the body of water (www.sheffy6marketing.com).

**Coliform bacteria**

Coliform bacteria are found in abundance in raw waste water but their numbers are reduced through the disinfection step of the treatment process. These organisms do not normally cause disease but are used as an indicator for disease-causing organisms called pathogens. If a wastewater plant's effluent contains large numbers of coliform bacteria, it is likely that a large number of pathogens are also being released into the environment. These pathogens can present a major health hazard (www.sheffy6marketing.com).

**Aerobic**

Aerobic means "requiring air", where "air" usually means oxygen.

**Anaerobic**

Anaerobic means living “without air”, as opposed to aerobic.

**E.coli**

Escherichia coli

iv. <u>Aim of Paper</u>

The aim of this study is to enhance the quality of life, quality of water, save the endangered species and re-use the waste water in agriculture, landscape or other purposes in North Cyprus. Presenting various systems of waste water treatment and proposing applicable techniques for North Cyprus is the main aim of this paper. As a result of population growth, tourism development and a higher quality of life, water demand in Mediterranean countries is increasing every day. “It is estimated that by 2020, water demand in Cyprus will increase to 313.7 cubic meters, mainly as a result of a rise in the use of domestic water and tourism development”(Water Development Department and FAO, 2002).The water supply depends mainly on the rainfall which may only be twice a year or not at all.

Another problem is, people are consuming water without any legal rights in order to irrigate their agricultural sites and this causes the underground water aquifers to salinize. The topic must be enlightened and precautions have to be taken before the island runs out of water.

Despite the priority that waste water usage is given in the large urban centers, small communities must be able to implement and get benefits from developing technology.

The attitude of government and the political side of water management will be discussed and also the awareness of the public about waste water treatment will be investigated. Probably this paper cannot solve all the problems about water in North Cyprus but it can be a heartening step to lead young people to stand for their country’s future and increase the consciousness in public.

v. <u>Methodology</u>

The study consists of 2 main parts. The first part which is dominant and creates the major part of the study is about the theory and techniques about the waste water and the second part is the design part, which aims to create an open green space in the heart of the city with the application of the waste water treatment system.

First part starts with the introduction about the country, especially the north part of the country. Then it continues with information about wastewater. Furthermore is about the possible water treatment systems for Cyprus and detailed explanation of each system. Then political structure about the water of the country is discussed. Redesign of the Kyrenia Park and further planning explained and lastly there are topics about the water scarcity, European Union’s attitude and further solutions about the water scarcity problem.

The study is structured as one main body, introducing the sustainable solutions for the sustainable Cyprus and suggestions of applications from one of these systems is shown in order to courage associations to apply those solutions in their hotels, cafes etc.

vi. Resources

During the research, benefits are mostly taken from the Phd thesis on the internet, some other thesis in the Goethe Universität and also doctorate reports. Sustainable architecture magazines like Topos are used. Another important source was the local newspapers of Cyprus. Working in a landscape office where sustainability is an important issue was also helpful for me to proceed.

vii. Difficulties

The biggest difficulty during the study was to obtain healthy information and data from the North Cyprus authorities. Many reports are missing and/or not allowed to be shared. Due to the political situation of Cyprus it was very hard to be in contact with institutions about the political attitudes of the government regarding water problems and solution options with the South part of the island. Apart from that, the lack of opportunity to contact with wastewater treatment experts was another disadvantage for me.

1. PART I

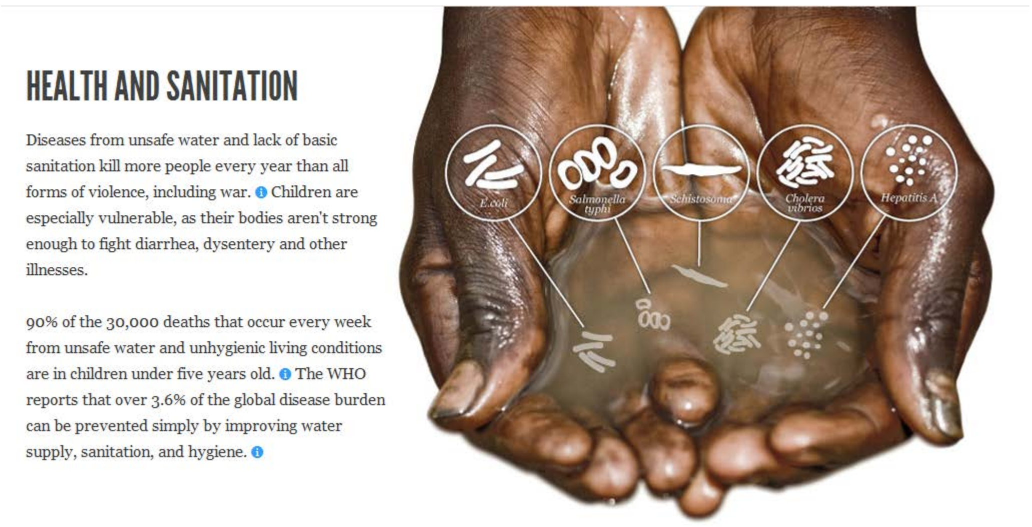
1.1. Introduction

Water is the most abundant compound on the earth's surface, covering about 70 percent of the planet. In nature, water exists in 3 different forms; liquid, solid, and gaseous states (http://en.wikipedia.org/wiki/Water). More than 3.4 million people die each year from water, sanitation, and hygiene-related causes. Nearly all deaths, 99 percent, occur in the developing world (WHO, 2008).

A staggering 97% of the water on planet Earth is salt water and un-drinkable by humans. Of the remaining 3%, 2% is locked into ice in the form of glaciers, which means only a measly 1% can be easily accessed by the human population (Yeo Kevin, Cost Analysis of Membrane Bioreactors to Reverse Osmosis Filters, 2010).

Water is a vital element to processes in our lives and all people on earth should have the same equal right to access drinking quality water. Due to the changing environment and mostly from human contribution water becomes more precious than before. It seems that to preserve the existing sources of water is not enough, also the re-using of these sources has to be considered in order to leave a healthy environment to future generations and keep the cycle of life. However the existing water sources do not always mean safe water but also can mean unsafe water including dangerous bacteria.

Fig. 1.1: Possible bacteria in the water




Source: www.who.int/healthinfo/global_burden_disease/GBD_report_2004update_part2.pdf

With its pleasant weather, virgin beaches and unique landscape, Cyprus is one of the most attractive tourist destinations in the world. According to the legend, Sezar gives Cyprus as a present to his great love “Cleopatra”. The Goddess of love and beauty Aphrodite is believed to have been born in Paphos, Cyprus.

With climate change and high demand for water, unfortunately this beautiful island will be on the list of water scarcity countries in the near future. Some leading factors of the problem are: Low amount of rainfall, evaporation, increasing number of tourist arrivals, the need for more agricultural production, lack of sufficient technology and budget to re-new waste water or renovate the existent dams, increased demand for luxury villas with the pools, unconscious drawing of underground water reservoirs by people and most importantly the unconscious public attitude about the topic. The country is facing a serious drought problem.

This dry lake bed in southern Cyprus used to be one of the island’s main reservoirs.

Fig. 1.2: Dry Lake in Cyprus


Source: http://www.greenprophet.com/wp-content/uploads/2010/09/Dry-Cyprus-lakebed.jpg

Table 1.1: Countries experiencing water scarcity in 1955, 1990 and 2025 (projected), based on availability of less than 1000 m³ of renewable water per person per year (Stikker,1998).

| **In 1955** | **In 1990** | **By 2025 under all UN population growth projections (added)** | **By 2025 only if they follow UN medium or high projections (added)** |
|---|---|---|---|
| Malta | Qatar | Libya | **Cyprus** |
| Djibouti | Saudi Arabia | Oman | Zimbabwe |
| Barbados | United Arab Emirates | Morocco | Tanzania |
| Singapore | Yemen | Egypt | Peru |
| Bahrain | Israel | Comoros | |
| Kuwait | Tunisia | South Africa | |
| Jordan | Cape Verde | Syria | |
| | Kenya | Iran | |
| | Burundi | Ethiopia | |
| | Algeria | Haiti | |
| | Rwanda | | |
| | Malawi | | |
| | Somalia | | |

Here are some photos explain the water problem on the island:

Tar effluence in the sea due to lack of control while transporting petrol from Turkey

Source: Cyprus Newspaper 04.07.12-Gazimagusa

Direct discharge of the waste water from the hotel into the sea

Source: Author 15.04.12 – Girne

Authorities warned people not to swim in Alagadi Beach, the color of the water has changed.

Source: Haberkibris.com

Waste water discharge in Güzelyurt threating the Public health and cause diarrhea.

Source: barisgazetesi.com

New born *CarettaCaretta*'s

Source: Author

Alagadi is ovulation nest for *Caretta Caretta*'s

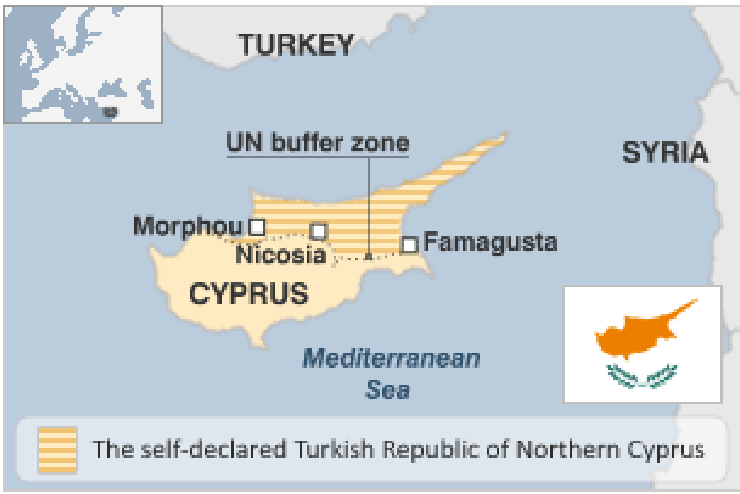

Source: Yabantv.com

## 1.2. Overview about Cyprus

**Cyprus,** Greek: Kýpros,Turkish: Kıbrıs is the 3rd largest island in the Mediterranean Sea after Sicily and Sardinia. However, the Republic of Cyprus is *de facto* partitioned into two main parts; the area under the effective control of the **Republic of Cyprus** (Greek), comprising about 59% of the island's area, and the Turkish-controlled area in the north, calling itself the **Turkish Republic of Northern Cyprus** and recognized only by Turkey, covering about 36% of the island's area. The international community considers the northern part of the island as occupied territory of the Republic of Cyprus by Turkish forces. Cyprus joined the European Union on 1 May 2004 (https://en.wikipedia.org/wiki/Cyprus). There are 2 British Sovereign Base Areas of the United Kingdom in Dhekelia and Aktorini, known as United Nations buffer zones. Cyprus has the last divided capital city in the world. According to 2011 data shown in Wikipedia the population of the island is 1.117 million. Comprising 789,300 in the territory controlled by the government of the Republic of Cyprus and 265,100 in Northern Cyprus.

The population of Northern Cyprus includes some 150,000-160,000 Turkish immigrants who are regarded as "illegal settlers" by the Republic of Cyprus government and are not included in the population statistics of the Republic of Cyprus Statistical Service. Due to its de facto administration is recognized only by Turkey, NC always suffered from foreign financing while the foreign investors hesitate to invest in unrecognized country.

Fig. 1.3: Division map of Cyprus



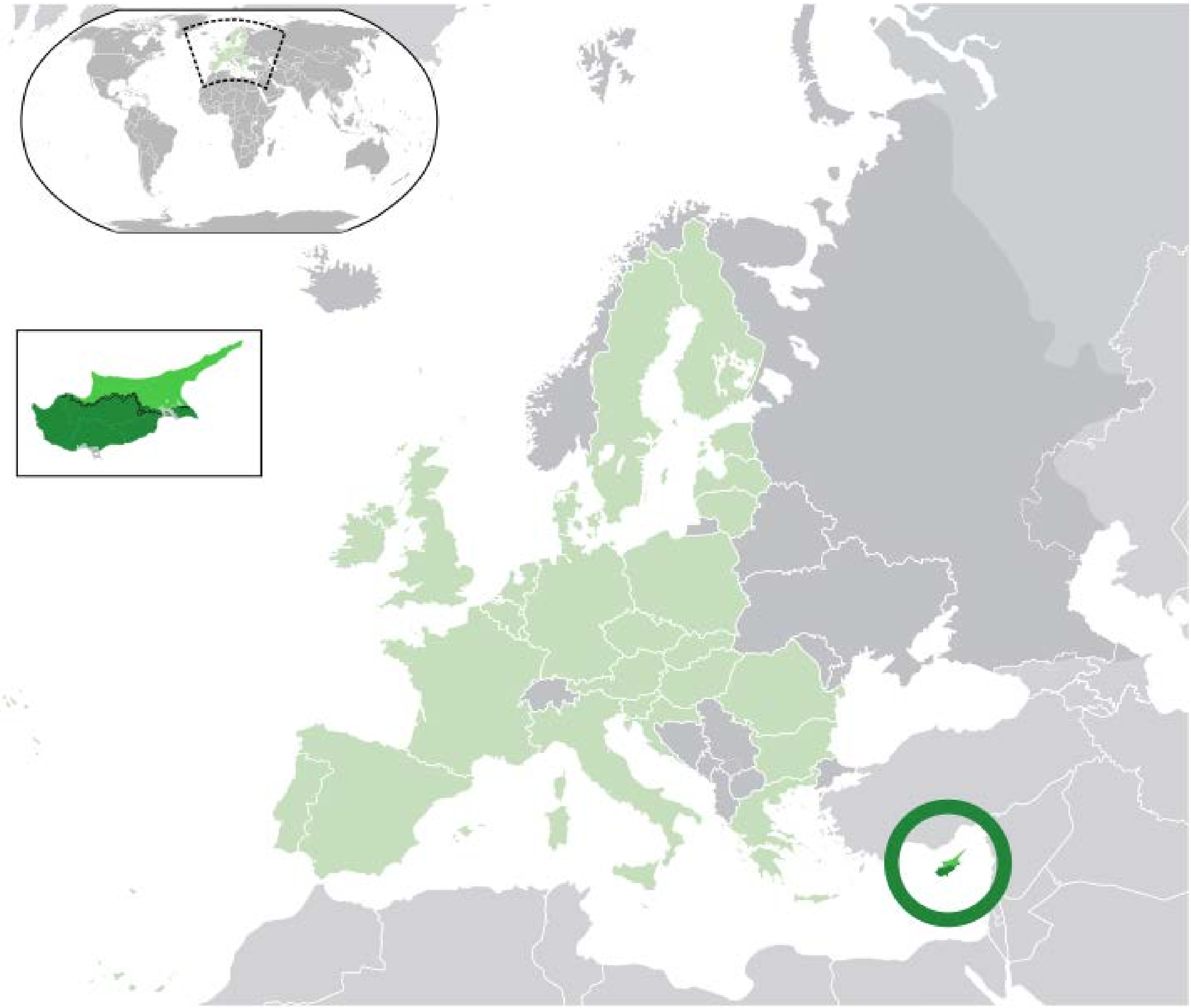

Source: http://www.bbc.co.uk/news/world-europe-17217956

There are 6 big cities in Cyprus; Girne (Kyrenia), Gazimagusa (Famagusta) on the North, Lefkosa (Nicosia) shared city, Limassol, Larnaca and Paphos on the South. The most attractive part in the North is Girne when Paphos is considered as the most beautiful city on the South.

### 1.2.1. Location

With an area of 9,251 $km^2$, Cyprus is the third largest Mediterranean island after Sicily and Sardinia. It is located at the east of Greece 380 km, south of Turkey 75 km, west of Syria 105 km and Lebanon, northwest of Israel and the Gaza Strip, and north of Egypt (medisland plant.eu). Despite its limited size Cyprus has always been important due to its geographical location and strategically importance in the Middle East. The island is forming a bridge between East and West.

Fig. 1.4: The location of Cyprus in the world



Source: en.wikipedia.org

### 1.2.2. History

The earliest known human activity on the island dates to around the 10th millennium BC. Archaeological remains from this period include the well-preserved Neolithic village of Khirokitia.

As a strategic location in the Middle East, it was subsequently occupied by several major powers, including the empires of the Assyrians, Egyptians, and Persians, from whom the island was seized in 333 BC by Alexander the Great. Subsequent rule by Ptolemaic Egypt, the Roman Empire, the Byzantines, Arab caliphates for a short period, the French Lusignan dynasty, and the Venetians, was followed by the Ottoman conquest in 1571. It remained under Ottoman control for over three centuries.

Cyprus was placed under British administration in 1878 until it was granted independence in 1960, becoming a member of the Commonwealth the following year. In 1974, seven years after the intercommunal violence between Greek Cypriots and Turkish Cypriots the establishment of a separate Turkish Cypriot political entity in the north part of island was realized (http://en.wikipedia.org/wiki/Cyprus).

Water management has been problematic since the 1960s due to the limited development of water infrastructure for domestic and irrigation supplies (T Zachariadis, Water, 2010). People found out that boiling water would have diminished the biological risks of poor quality water. During the Roman Empire many aqueducts had been built, also sewage and storm water management were other great accomplishments by the Romans on the island.

In 1960's under the motto "not a drop of water to the sea" Cyprus was one of the leading countries in the dam construction.

Fig. 1.5: An old Aqueduct in Agia Napa, Cyprus (Photo: P. Juuti).

Source: iwawaterwiki.org

Fig. 1.6: Historical water cistern in NC

Source: http://www.mimarsinan.gen.tr/wp-content/uploads/2011/07/tarihi-su-sarniclari.jpg

Fig. 1.7: Old techniques of Water Carriage in old Cyprus

Source: http://arid.chemeng.ntua.gr/Project/Uploads/CyprusConf/Closing_Session/PDF/Iacovides_I.-The_Cyprus_experience_in_planning_water_resources_management-Past_and_future.pdf

### 1.2.3. Vegetation

Cyprus has Macquis vegetation, mainly consisting of drought-resisting scrub and conifers, pine, carob, cypress, and acacia. The vegetation is adapted to the climate. In historical times Cyprus was covered with very rich forests but ancient conquerors cut down many of these trees for the need of timber for their sailing vessels.

Cyprus has about 2000 species of plants many of which are endemic plants, such as the Cyprus orchid, tulip and crocus.

Maquis vegetation which grows from the coast up to a level of 300-400 m is predominantly characterized by Pistachio Nut Tree *(Pistacia vera),* Myrtle *(Myrtus communis),* Eastern Strawberry Tree *(Arbutus andrachne),* Calabrian Oak *(Quercus infectoria),* Kermes Oak *(Quercus coccifera),* Carob *(Ceratonia siliqua)* and Olive *(Olea europea).* Reaching higher, above 500-600 m the Kyrenia Range is dominated by Calabrian Pine *(Pinus brutia)* and Common Cypress *(Cupressus sempervirens) (*http://www.northcyprusonline.com/North-Cyprus-Online-Flora-trees.php). More than 125 endemic plants are found on the island including the endangered Cyprus cedar *(Cedrus brevifolia)* and the Cyprus oak *(Quercus alnifolia)* (http://worldwildlife.org/ecoregions/pa1206).

Fig 1.8: Some plant photos taken by the Author in Arapköy, North Cyprus, April 2012

Olea europaea

Ceratonia siliqua

Prunus dulcis

A view to conifer forest

1.2.4. Topography

Cyprus has 3 main physical regions; the main one is the Trodos mountain range dominant in the south part of the island, the second one is Girne (Kyrenia) Range on the North coast and the last one is called the Mesaoria Plain running from Güzelyurt to the west of Magusa.

Fig 1.9: 738 meters high, view from St. Hilarion castle

Fig. 1.10: Kyrenia Harbor

Source: Author

The image 1.11 acquired by NASA's Terra satellite on 30 January 2001, shows the three distinct geologic regions of the island. In the central and western part of the island is the Troodos Massif, a mountain range whose surface layer is mostly basaltic lava rock, and whose maximum elevation is 1,952 metres (6,404 ft). Running in a thin arc along the northeast margin of the island is Cyprus's second mountain range, a limestone formation called the Girne Range. The space between these ranges is home to the capital Nicosia, visible as a grayish-brown patch near the image's center. Figure 1.12 is the altitude map of the island shows the highest and the lowest points.

Fig. 1.11: Space photo of Cyprus

Source: Nasa

Fig. 1.12: Altitude map of Cyprus


Source: Cyprus.properties.com

- **Soils and Substrates**

Except in the ravines and on the foothill terraces, soils are thin, overlying porous rock, is neutral or slightly alkaline. The common soil types are the calcariclithosols. The combination of a topography that favors quick run-off and harsh climatic conditions has resulted in a semi-arid type of landscape which makes erosion an effective factor in the formation of this particular type of landscape. Summer droughts greatly reduce soil moisture and parch the soil, exposing it to the subsequent autumn rains, leading to soil erosion (Makhzoumi & Pungetti, 1999).

1.2.5. Marine Habitat-Endangered Species

One of the most important species in the Mediterranean is *Caretta caretta* (longhead turtles and *Chelonia mydas* (green turtles) also that of the meadows of *Posidonia oceanica*. Posidonia is a sea grass endemic to the Mediterranean. The meadows it forms support a large variety of species of flora and fauna and provide one of the most important reproductive habitats for many animals, as well as refuge for many others. They enrich seawater with large quantities of oxygen, stabilize the sea bottom and in general sustain the ecological balance of the sea. Moreover, *Posidonia* is an important biological indicator, as it is a pollution-sensitive species and any environmental disturbance has an effect on the *Posidonia* ecosystem as a consequence. The Monk seal, marine turtles, pen shell and many others, are listed as species of particular ecological and conservation interest in the Mediterranean. Besides marine turtles (*Chelonia mydas* & *Caretta caretta*), monk seal (*Monachus monachus*), endemic grass snake (*Natrix natrix cypriaca*) etc. are other endangered aquatic species on the island (http://www.moa.gov.cy). (*Dermochelys coriacea*) are also occasionally found in the waters of Cyprus.

Fig. 1.13: Nest for Carettacaretta's, Alagadi beach, NATURA 2000 site

Source: North Cyprus Ministry of Forestry

Exploitation of turtles in the Mediterranean, from the 1920s to the 1970s, has decimated turtle populations. Tens of thousands of turtles, mainly green turtles, were shipped from the north-eastern Mediterranean, to Egypt, where there was a market for them, and to Europe where there was great demand for turtle soup. The intensive use of beaches, for tourism and recreational purposes, is now threatening turtles in the Mediterranean by depriving them of their nesting grounds. It is tentatively estimated that the current annual nesting population of turtles is about 500 female Green turtles and about 3,000-5,000 Logger heads (*Caretta caretta*). Both Green and Loggerhead turtles have been declared, by the World Conservation Union (IUCN), as Endangered. Obviously the Green turtle in this sea is more endangered due to its smaller population. Both species are protected under the Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats (Bern

Convention). They are also protected under the Barcelona Convention (UNEP) and an Action Plan for their conservation has been approved by Mediterranean States within the Mediterranean Action Plan (MAP). The Convention on Migratory Species (CMS) and the CITES Convention also protect turtles. Cyprus has ratified these. The European Union has listed both species as Priority Species for conservation in the Annexes of the Habitats Directive (http://www.aboutcyprus.org.cy/en/turtles-and-conservation-in-cyprus). Picture 1.15 shows the habitat importance and protected area by NATURA 2000. SEPA (Special Environmental Protected Area) project is funded by European Union and aims to protect and monitor the surrounding habitat for their healthy ovulation and continuing generation.

Fig. 1.14: *Caretta carettas* are endangered species in many international protection lists.

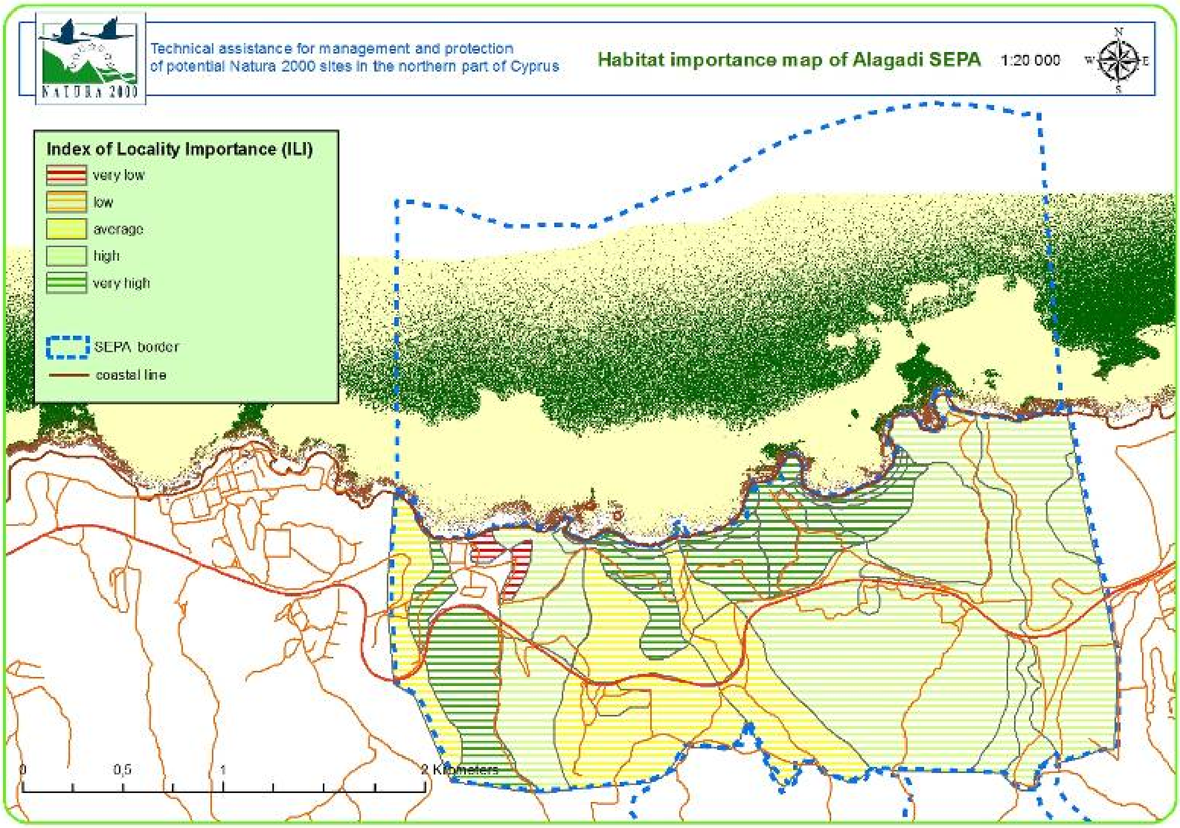
Source: http://resimler.manzara.gen.tr/caretta-caretta-39014.htmlcaretta/caretta_08.jpg

Source: http://www.goldenmoonhotel.com/picts/

Fig. 1.15 down shows the habitat importance map of Cyprus, specifically Alagadi zone where endangered species gives birth twice a year. Mostly the coast zone is the most sensitive area. When we go into the city importance lessens but still continues, unfortunately you can see these protection area mostly polluted by humans with plastic bottles or bags. Although Greenpeace members and some schools arrange an annual trip to clean the beach, the pollution continues.

After hatching out of their eggs, baby turtles rush into the brightest point which is mostly the moon reflecting on the sea. It is not possible to survive if they rush into another light which is lighter, into opposite direction of the sea. On the way many challenges wait for them, like rubbish, broken glass, wild animals or careless people walking on them.

Fig. 1.15: Habitat Importance map of Alagadi SEPA




Source: North Cyprus Ministry of Forestry

*Chelonia mydas* lays eggs only on the island, the south eastern coasts of Turkey and sometimes in Israel. They ovulate between May and August. Alagadi Beach, one of the beaches they lay eggs, is now being protected.

Once it gets dark after sunset, adult females with a shell thicker than 100 cm look for a place to ovulate. They lay between 65 and 110 eggs depending on their kind. Each turtle lays five or six eggs once in every 10 or 15 days. Once ovulation is completed, the female gets tired and goes back to the sea. And two years later, she revisits the same beach in order to ovulate. In order to help them, ecologists and students are making observations on sea turtles that are about to go extinct (Piabellahotel.com).

The Society for the Protection of Turtles (SPOT) also works with teams from British universities to study nesting sites and release baby turtles securely into the sea.

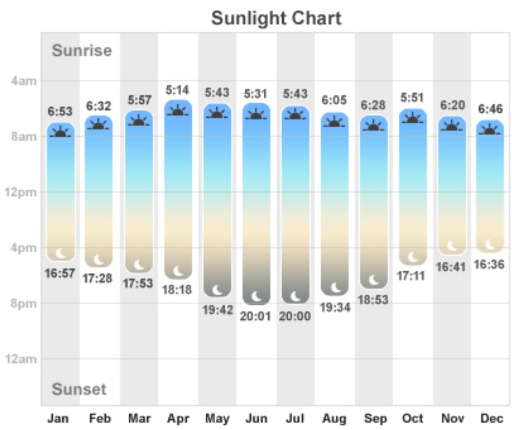
### 1.2.6. Climate

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average maximum temperature - measured in centigrade | | | | | | | | | | | |
| 15 | 15 | 19 | 24 | 29 | 34 | 37 | 37 | 33 | 27 | 22 | 17 |
| Average minimum temperature - measured in centigrade | | | | | | | | | | | |
| 5 | 5 | 7 | 10 | 14 | 18 | 20 | 20 | 18 | 14 | 10 | 7 |
| Average monthly rainfall in millimetres | | | | | | | | | | | |
| 87 | 47 | 39 | 18 | 21 | 8 | 0 | 0 | 11 | 17 | 31 | 88 |

Source: http://travel.saga.co.uk/holidays/mediaLibrary/

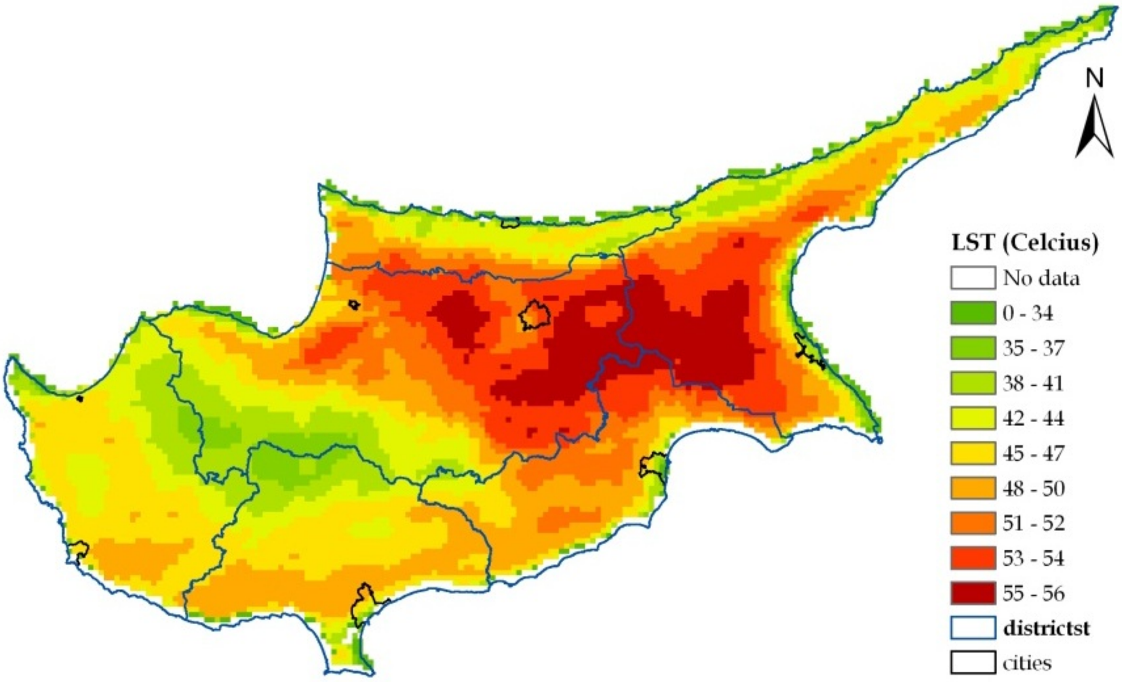
Cyprus has a Subtropical climate - Mediterranean and Semi-arid type (in the north-eastern part of island) - according to Köppen climate classification, with very mild winters (on the coast) and warm to hot summers. As shown in the Fig. 1.17 the central parts of the island are the hottest areas. Snow is possible only in the in the central part of island usually on the Trodos Mountains. Rain occurs mainly in winter, with summer being generally dry. Cyprus has the warmest climate (and warmest winters) in the Mediterranean part of the European Union. Generally the summer holiday season lasts about 8 months, although also in the remaining 4 months temperatures sometimes exceeds 20 °C. During the last decades, climate change is the biggest reason for the island’s water scarcity.

Fig. 1.16: Sunlight hours of Cyprus




Source: http://www.rentcyprus.co.uk/images/cyprusweathersunlight.jpg

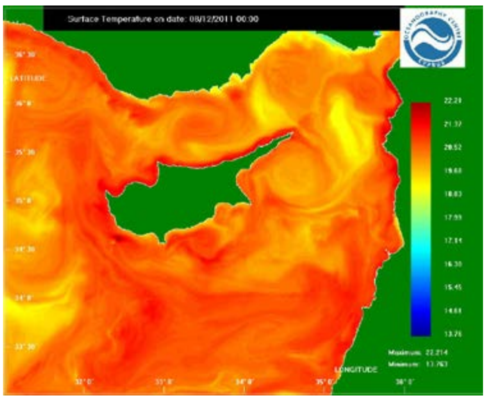
Fig. 1.17: Heat map of Cyprus




Source:http://www.intechopen.com/source/html/45144/media/image13.jpeg

Hot, dry summers from mid-May to mid-September and rainy, rather changeable winters from November to mid-March are separated by short autumn and spring seasons.The higher mountain areas are cooler and moister than the rest of the island. They receive the heaviest annual rainfall, which may be as much as 1,000 millimeter (1cm).The average rainfall is 450-500 mm and relative humidity of the air is on average between 60% and 80% in winter and between 40% and 60% in summer.

Fig. 1.18: Surface temperature Map



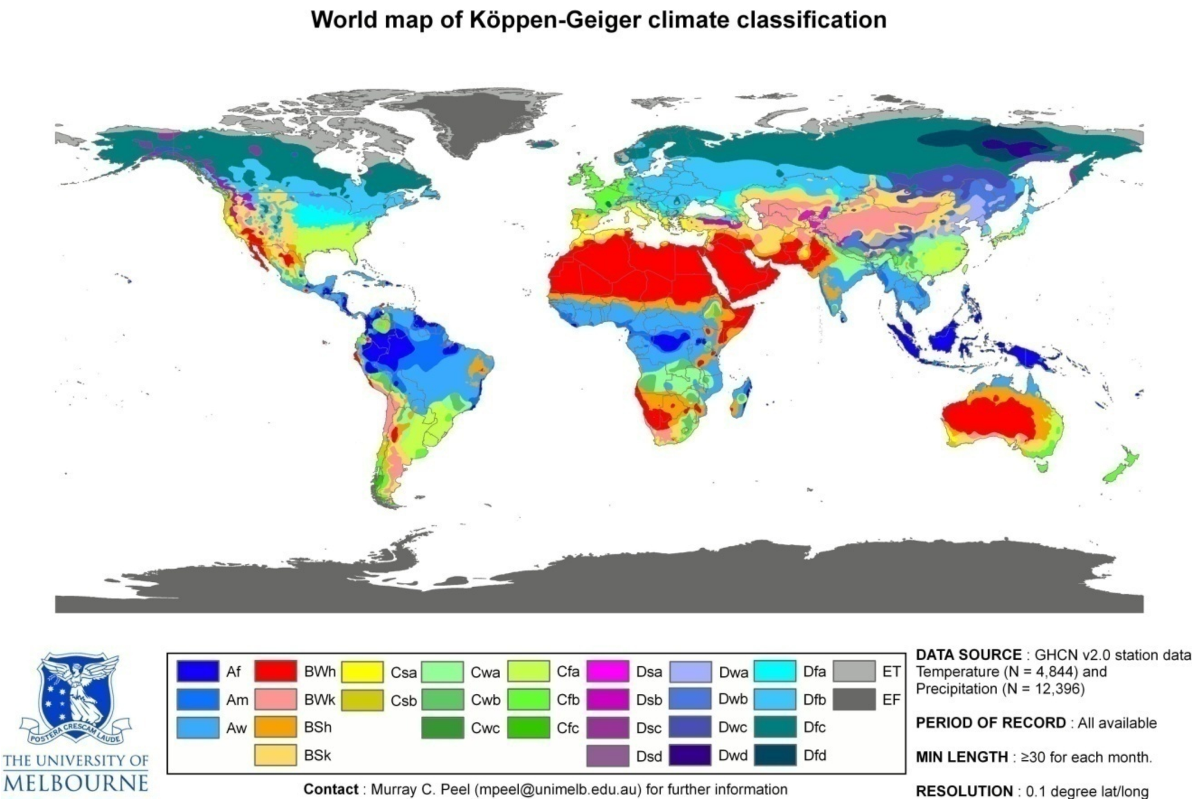
Source: rentcyprus.co.uk

Fig. 1.19: World map of Koeppen-Geiger Climate Classification

A: Tropical Climate D: Continental Climate

**B: Dry Climate** E: Polar Climate

C: Temperate Climate (Cyprus classified in Zone B- Dry Climate)




Source: https://upload.wikimedia.org/wikipedia/commons/7/7f/World_Koppen_Map.jpg

## 1.3. Water Resources in North Cyprus

North Cyprus potable and agricultural usage water sources are almost totally (98%) dependent on the rain (Cypriot Biologists Nature Research and Protection Association 2005-13). The main water resource is groundwater with a safe yield of 74.1 MCM (European University of Lefke). There are many lakes to collect rain water. Unfortunately in the last decades, the total capacity of water in these lakes was under 45%.

Apart from that, there are 41 dams in North Cyprus in order to collect the rain coming from the streams (Sidal, 2006).

Fig.1.20: Güzelyurt Dam

Source: http://www.adabasini.com/resimler/2/6891.jpg

The biggest ones are the Güzelyurt, Lefke, Girne and Magosa aquifers and have a capacity of 60,12 and 2,1 million m³/year (Alkaravli,2002). According to up to date information from the Cypriot Biologists Association, including the Besparmak aquifer and Yesilirmak stream the total amount of underground water assumption is 95 million m³/year and 22 million of this amount is collected from streams and lakes.

There are 30 lakes in the Turkish part of Cyprus, 18 are for agricultural use and 12 for nourishing the underground water sources. The capacity of 18 lakes for agriculture is around 16.5 m m³/year. Consequently these lakes have no distribution units and due to evaporation, unused water collected in the lakes turns to saltwater.

During the British colonial rule an extensive and complex network of wells were built to use the underground water resources. The British also introduced strict laws about water usage during the dry summer months.

However, the corrupt Turkish Cypriot leadership in North Cyprus and the political situation in Cyprus generally do not allow adequate partnership and collaboration on water resources leading to the salinization of underground water resources. This is now a very serious problem and many households receive domestic water which is practically unusable. This water is not very suitable for farming either. Unplanned and corrupt management of existing wells dried up the underground reserves. This led to the invasion of the water-beds by the sea-water because of the pressure difference. Some pictures showing main agricultural fields of Cyprus, potatoes fields and vineyards.

Source: cyprusprofile.com

Source: modeland-project.eu

Eighteen dams were built but only one serves agriculture, however the others merely contain water evaporating out and the water in them becomes salty. Denser water accumulates calcium and other materials down on the base and pollutes land; it closes all orifices which feed the aquifer.

Then new water flowing into the dams mixes with a highly condensed salty water that makes dams useless for any purpose. Furthermore, the animosity between Turkish Cypriot/Turkish and Greek Cypriot/Greek leaderships did not allow joint programs to develop to tackle this problem. This is not only an environmental problem but also a very humanitarian problem. There are many sources of funding and various methods that have been successfully employed in the region. These should have been an utmost priority for the leaderships to implement in Cyprus, however, they could not see beyond their nationalist, self-serving rhetoric and interest (http://www.cyprusaction.org/humanrights/environment/waterresources/) Unfortunately many springs that used to flow down from Besparmak Mountain range have dried out due to uncontrolled and illegal shrinkage. As a result of this, the Famagusta aquifer is desalinated and nowadays is the biggest aquifer on the island (Güzelyurt aquifer) but it is in danger. Apart from Girne, the other 3 big cities of Cyprus get their potable water and also water for agriculture from this aquifer. (There are 6 big cities in Cyprus and the Güzelyurt aquifer plays a very important role in terms of providing water. Based on the information from the Turkish Council of Environmental Engineers, if this situation doesn't change this aquifer will be irreparably damaged forever due to lack of rain and uncontrolled water consumption. The table 1.2 presents one optimistic, one pessimistic view, and two different scenarios about what may happen if the precautions on water consumption are taken or the existing situation continues.

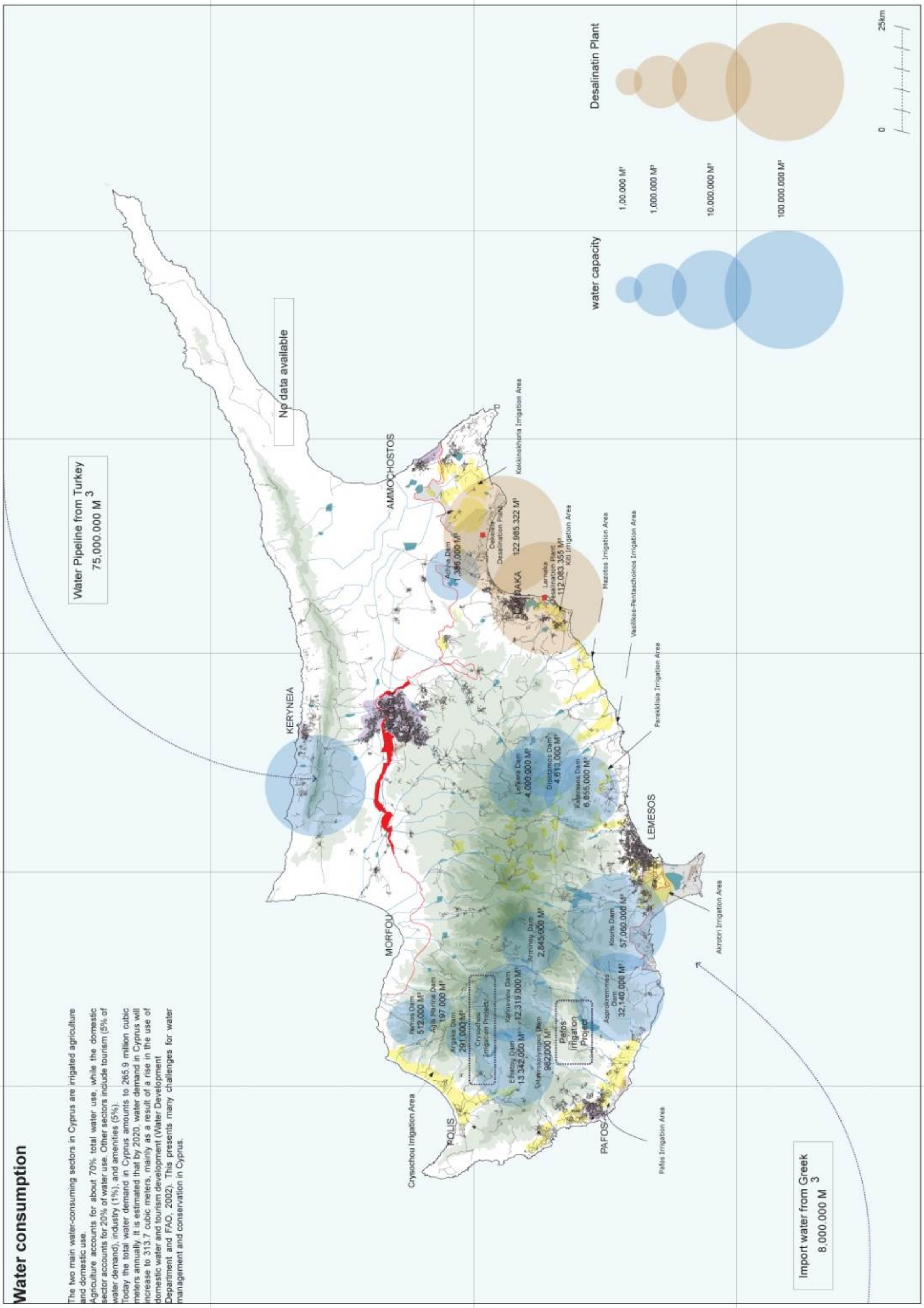
Table 1.2: Total water consumption Forecast in TRNC (10x6 $m^3$/year)

| SCENARIO | | ***2010*** | ***2020*** | ***2035*** |
|---|---|---|---|---|
| Optimistic | Arid | 91.95 | 119.95 | 149.98 |
| | Marshy | 115.41 | 149.92 | 187.71 |
| Pessimistic | Arid | 85.93 | 110.97 | 138.60 |
| | Marshy | 142.33 | 184.99 | 232.94 |

Source: Elkiran, 2006

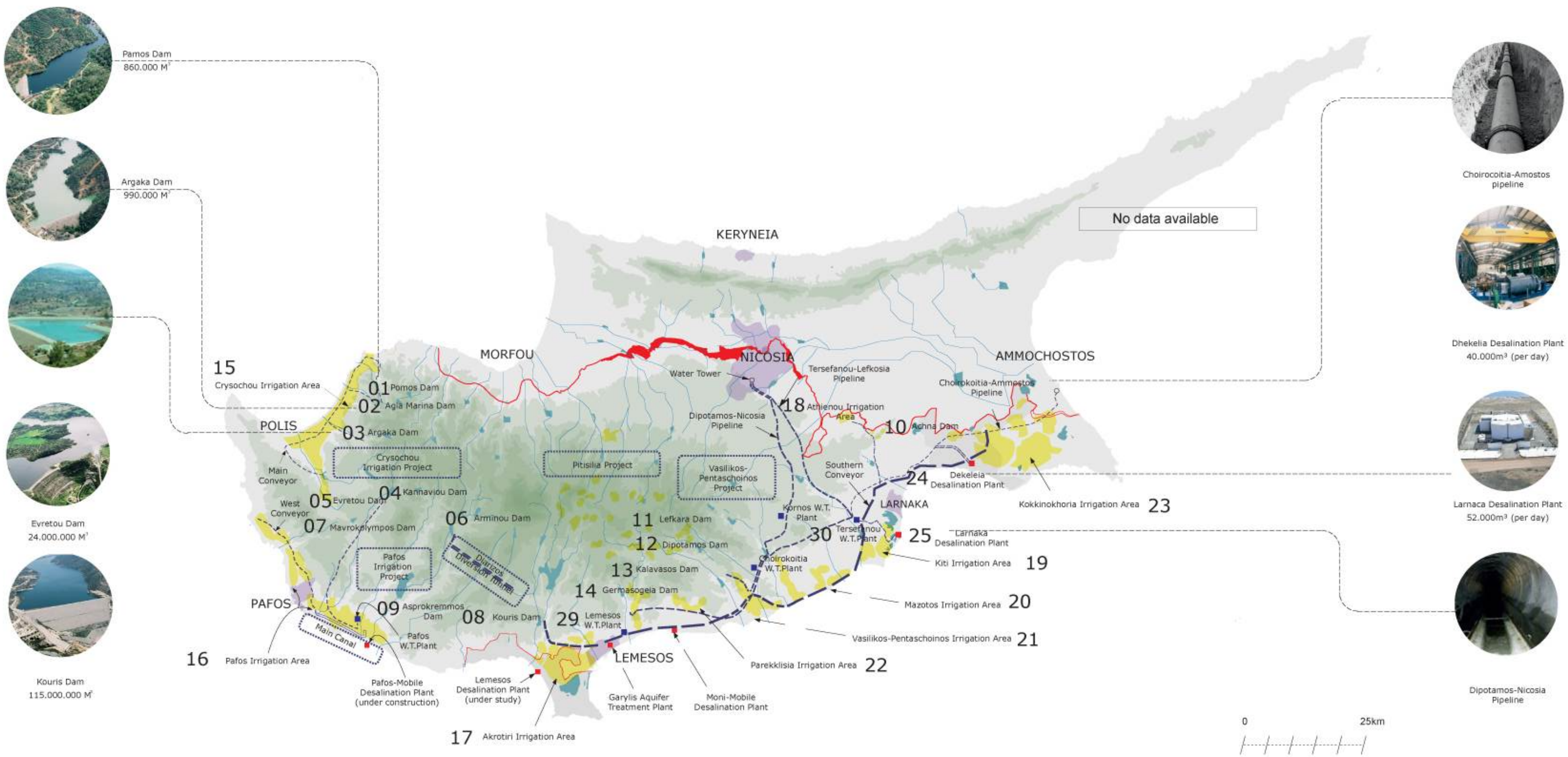
As the table explains water is much more used than it is supposed to be. According to the Turkey State Hydraulics Department, in 2010 the TRNC water need was 36 million $m^3$/year but if we assume no precautions have been taken since then around 84 million $m^3$ water was used in 2010. Also if we compare the existing water reservoirs capacity which is 95 million $m^3$/year, in any scenario, Cyprus will suffer from water scarcity in 2020.

The following 2 posters show the water consumption amount on the island and existing and water works done and still going on the island. As it can be seen from the water works poster, North Cyprus has very weak conditions about developing water works. Precautions which have already been discussed have to be implemented immediately. All the water shrinkage should be monitored and using waste water should be considered, existing waste water plants should be revitalized as well as the historical dams, a comprehensive research and analysis must done by the experts in order to build new plants on the available sites. Governmental structure of drought management should build up in the near future. We should be aware that the water is not an endless spring and one day we may have to pay much more than we should have now.




Source: projectsreview2011.aaschool.ac.uk – water consumption map of Cyprus

## Water works




| Dam | | | | | Conveyance Systems | | | |
|---|---|---|---|---|---|---|---|---|
| 01 Pomos | 860.000 M³ | 10 Achna | 6,800,000 M³ | 18 Athienou | 451 hectares | 26 Diarizos diversion tunnel | 14,5 Km | Irrigation area |
| 02 Agia Marina | 990.000 M³ | 11 Lefkara | 13,850,000 M³ | 19 Kiti | 1.206 hectares | 27 Southern Conveyor | 110,0 Km | City |
| 03 Argaka | 120.000 M³ | 12 Dipotamos | 15,500,000 M³ | 20 Mazotos | 615 hectares | 28 Tersefanou - Nicosia conveyor | 36,5 Km | Mountain |
| 04 Kannaviou | 18,000,000 M³ | 13 Kalavasos | 17,100,000 M³ | 21 Vasilikos-Pentaschoinos | | **Water Treatment Plants** | | Aquifer |
| 05 Evretou | 24.000.000 M³ | 14 Germasogeia | | 22 Parekklisia | 351 hectares | 29 Limassol | 40.000 m3/day | w.t plants |
| 06 Arminou | 4,300,000 M³ | **Irrigation Project** | | 23 Kokkinokhoria | 9.270 hectares | Future Extension | 80.000 m3/day | |
| 07 Mavrokolympos | 2,180,000 M³ | 15 Crysochou | | **Desalination** | | 30 Tersefanou | 60.000 m3/day | desalination plants |
| 08 Kouris | 115.000.000 M³ | 16 Pafos | | 24 Dhekelia | 122.985.322 M³ | Future Extension | 90.000 m3/day | conveyor |
| 09 Asprokremmos | 52,375.000 M³ | 17 Akrotiri | 46 hectares | 25 Larnaca | 112.083.355 M³ | | | |

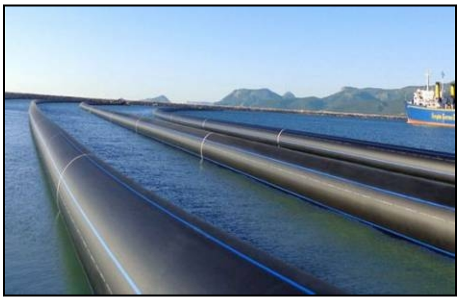
Source: projectsreview2011.aaschool.ac.uk – water works

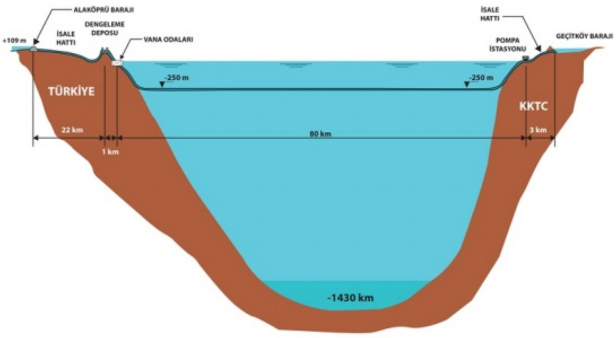
### 1.3.1. Cyprus Water Supply Project from Turkey

It is known that Turkey is the guarantor country of North Cyprus. For any Turkish people N. Cyprus is the daughter of Turkey. Due to the water problem in NC, during many years clean water has been carried from Turkey by balloons or water tanks. However, none of these techniques were long-lived and a sustainable solution.

On 7th of March 2011, construction of the “TRNC Water Supply Project” so called -Project of the Century- was started. With this project 75 million m³ water per year will be carried by underwater pipelines to the island. In the scope of this project 2 dams have been built; Alaköprü dam in Adana, Turkey and Gecitköy dam in Girne, North Cyprus. The pipes will be fixed at 250 meters below the sea and have a 1.600 m radius and 80 km length. The pipes will be monitored with censors fixed on each pipe and by this method the rate of damage will be minimized.

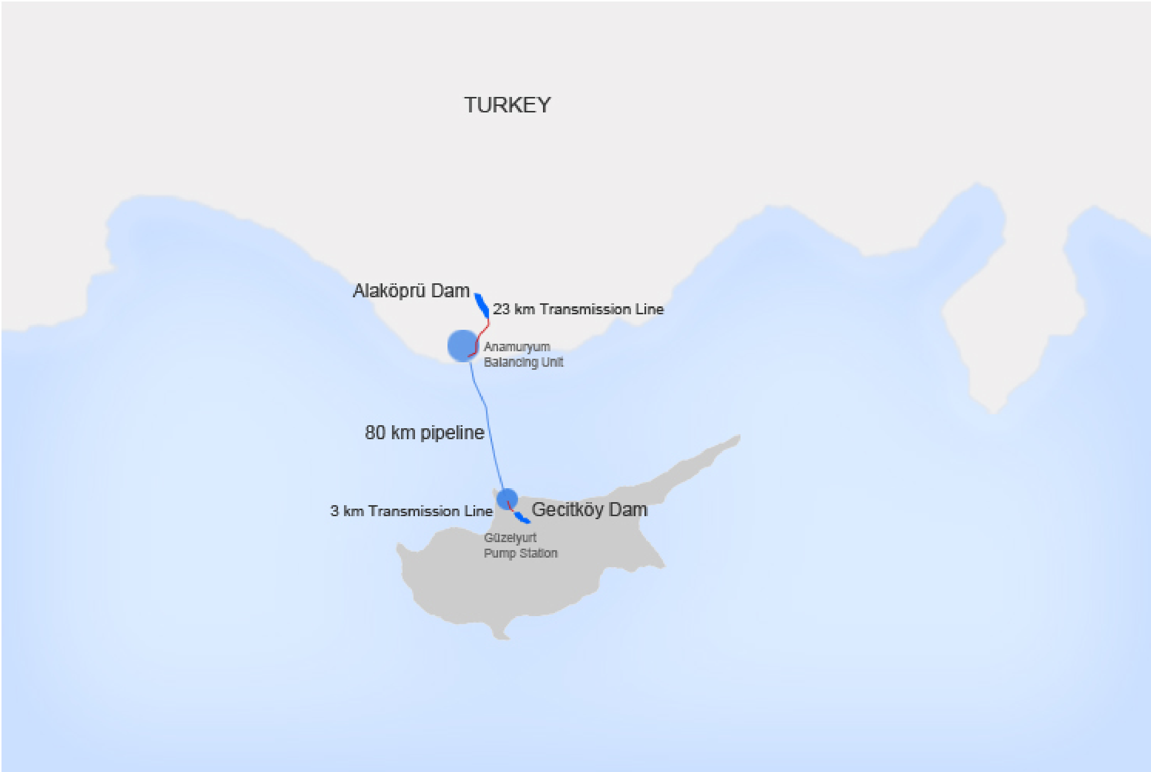
Fig. 1.21: Water pipes used for the transportation






Source: dsi.gov.tr

From the 75 million m³ of water, 37,70 m. m³ (%50.3) is planned as potable- usage water, and 37,24 m. m³ (%49.7) for agricultural use. By this way the biggest plain of the island – the Mesoria plain, 4824 ha- will be used efficiently in wet agriculture and expected to bring high income to the economy. The Project has no other applied examples in the world. Unfortunately the project will only be capable of supplying limited water for the following 50 years. That means this project is also not sustainable and durable.




Source: dsi.gov.tr, visualization by Author

## 1.4. Agriculture

After tourism, the agriculture sector is one of the main income sources for North Cyprus's economy. Currently, the agricultural sector consumes 70% of available freshwater resources and 93% of water consumption worldwide (Turner et al, 2004; Tanji and Kielen 2002). The water withdraw from the underground water sources causes salty sea water to leak into clean underground water and results in low quality of agricultural products. Consequently farmers use more and more chemicals and hormones in order to give an attractive look to their products.

Due to its climate mostly dry resistant products are grown in NC. Mostly cereals like wheat and barley, pulses, industrial crops, potatoes, tomatoes, leafy or edible Vegetables, grape & similar fruits, nuts, citrus fruits and other tree crops (almond, banana, carob, olives, peaches..) Production is mostly dependent on the rainfall which affects the amount of vegetables and fruits. Irrigated crops account for half of the agricultural production.

Barley (Hordeum vulgare L.)  Chickpeas (Cicer arietinum)  Molohiya (Corchorus olitorius)

Tomatoes (Solanum lycopersicum)  Almond (Prunus dulcis)  Lemon (Citrus)

Due to the lack of water supplies many of the products which can be produced on the island are imported from Turkey. For the water needs of agriculture, Waste Stabilization Ponds (reasons are explained in Part III, 3.1.1 WSP) are recommended. Also to be able to keep the heavy and sudden rainfall in safe and clean storage, constructed wetlands also can be suggested for agricultural use in Cyprus.

## 1.5. Tourism

Tourism is without a doubt the country's major income. "Sea, sun and sand" is the motto to attract tourists. Besides its positive effect on the financial situation of the island, it also provides locals with work possibilities and creates a cultural bond between North and South. Tourists usually visit South Cyprus due to its being part of the European Union and then pass through the border to the North. "With over 2 million tourist arrivals per year, Cyprus it is the 40th most popular destination in the world" (http://en.wikipedia.org/wiki/Tourismin_Cyprus).

Table 1.3: Tourist Arrival Countries

| | | | |
|---|---|---|---|
| ***Arrivals by Country*** ***2009*** | | | |
| 1 | Britain | 1,069,190 | 49.93% |
| 2 | Russia | 148,734 | 6.95% |
| 3 | Greece | 131,871 | 6.16% |
| 4 | Germany | 131,158 | 6.13% |
| 5 | Sweden | 108,247 | 5.06% |

According to information from TRNC Tourism and Culture Ministry, the capacity of beds in Turkish Cyprus hotels is 19.019 and 12.818 of them are located in Girne, the most attractive tourist city in the North. Here are some photos taken at the famous corners of Cyprus.

Pic1 & 2: Janos Csatlos, pic 3,4,5,6,7: Sergej Lysionok

1.5.1. Impacts of Tourism on Economy

Tourism has a great effect on economy. The economy of Cyprus is classified as a high-income economy by the World Bank. With its high quality life standards, moderate prices and local goods Cyprus is an attractive route to tourists from all around the world. However the last decades have been not as positive and progressive to the economy due to bank crises on the South part of the island, causing a bruising to their reputation. In the North part, tourism is still a significant income issue since the area has some difficulties with foreign investors; they hesitate to start a business because of the island's unclear legal situation and embargo on its ports.

The number of tourists visiting the TRNC during January–August 2006 was 380,000, up from 286,901 during January–August 2003. The number of tourist beds increased to 17,000 in 2011. Tourism revenue in 2011 was USD 400 million. The number of tourists visiting Northern Cyprus: January–August 2003: 286,901; January–August 2006: 380,000; 2010: 437,723 (Tourism statistics for the period January-August 2003: North Cyprus Ministry of Economy and Tourism).

Of course tourism has its negative effects too. Increasing number of tourists means increasing number of hotels which means less green areas, less nature and more concrete. On the other hand, hotels constructed next to the beach will continue to discharge their wastewater into the sea without a sustainable solution and it will keep causing the marine habitat go instinct and disturb the *caretta carettas* coming to give birth on these beaches.

## A. Summary of Part I

By the legend the birthplace of the ancient Greek Goddess of love Aphrodite, Cyprus is the third biggest island lying on the Mediterranean Sea with the total area of 9,250 km². Cyprus is divided into two since 1974, Greek dominance on the South covering 70 % of the island and Cypriot Turkish with 30 % on the North. Its population is slightly over 1 million in total. Christians make up the majority of island whereas most Turkish people in the North are Sunni Muslim.

Hot dry summers starts from mid-May till mid-September and mild cold winters from November till mid-March with low amounts of rain and some snow on the Trodos Mountain. The spring and autumn are very short and summer is the longest season. The yearly rainfall is ~ 500 mm which makes the island a water scarce country. Tourism is the biggest income of the country, followed by agriculture. The economy is classified as a high-income economy by the World Bank.

Being a subtropical island and getting very low rainfall results in dangerous water problems on the island. The number of dams and lakes are not enough and unfortunately application of sustainable solutions is not very common. The water shortage in the North part will be supplied for the following 50 years with bringing water from Turkey project and the South part is being supplied by the European Union’s support and recycling solutions.

# 2. PART II

## 2.1. Information about Waste Water

Waste water is the water discharged from households, industries, office and retail building, agriculture etc. In brief, any type of water that has lost its primary quality after use. We can call waste water a liquid waste. Very common examples of waste water are liquid sewage. These sewages contain human contaminant, urine, food remnants, pathogens, metals, dissolved solids, dirty water from washing machines, bath water etc.

However, due to increasing populations in the settlements, wastes inevitably overwhelms the ability of the waterways to assimilate the decomposing organic matter, as a result of that oxygen levels dropped and marine habitat began to disappear. Sewage systems are built to filter these solids and maintain the oxygen level in the sea at its higher level.

Water leakage from underground septic tanks to the groundwater also can be classified as wastewater.

## 2.2. Techniques of Treating Water

Satisfactory quality of waste water depends on the treatment. There are many techniques that have been developed dating back to 2000BC. “In ancient Greek and Sanskrit (India) writings dating back to **2000 BC**, water treatment methods were recommended. People back then knew that heating water might purify it, and they were also educated in sand and gravel filtration, boiling, and straining. Turbidity was the main driving force between the earliest water treatments.” (http://www.lenntech.com/history-water-treatment.htm).

There are 3 types of treatment processes; physical, chemical and biological treatment.

### 2.2.1. List of Waste Water Treatment Technologies

- Activated sludge systems
- Advanced oxidation process
- Aerated lagoon
- Aerobic granular reactor
- Aerobic granular sludge technology
- Aerobic treatment system
- Anaerobic clarigester
- Anaerobic digestion
- Anaerobic filter
- API oil-water separator
- Distillation
- Desalination
- EcocyclET systems
- Electrocoagulation
- Electrodeionization
- Electrolysis
- Expanded granular sludge bed digestion
- Facultative lagoon
- Fenton's reagent
- Fine bubble diffusers
- Flocculation-sedimentation
- Flotation process
- Froth flotation
- Humanure (composting)
- Imhoff tank
- Iodine
- Parallel plate oil-water separator
- Reed bed
- Retention basin
- Reverse osmosis
- Rotating biological contactor
- Sand filter
- Sedimentation
- Sedimentation (water treatment)
- Septic tank
- Sequencing batch reactor
- Sewage treatment
- Stabilization pond
- Submerged aerated filter

- Anaerobic lagoon
- Bioconversion of biomass to mixed alcohol fuels
- Bioreactor
- Bioretention
- Biorotor
- Carbon filtering
- Cesspit
- Coarse bubble diffusers
- Composting toilet
- Constructed wetland
- Dark fermentation
- Diffuser (sewage)
- Dissolved air floatation
- Ion exchange
- Lamella clarifier (Inclined Plate Clarifier)
- Living machines
- Maceration (sewage)
- Microbial fuel cell
- Membrane bioreactor
- Nanotechnology
- NERV (Natural Endogenous Respiration Vessel)
- Treatment pond
- Trickling filter
- soil bio-technology
- Ultrafiltration (industrial)
- Ultraviolet disinfection
- Up flow anaerobic sludge blanket digestion
- Wet oxidation

Source: http://en.wikipedia.org/wiki/List_of_waste-water_treatment_technologies

## 2.3. Levels of treating water- Primary (Physical) Treatment

There are 3 steps-methods for treating wastewater;

**- Primary (Physical) Treatment**: "is designed to remove gross, suspended and floating solids from raw sewage. It includes screening to trap solid objects and sedimentation by gravity to remove suspended solids."(www.water.worldbank.org). Primary treatment can reduce the BOD of the incoming waste water by around 20-30%. It is the first step of the treatment and all the other processes are added later on.

Physical Treatment is any type of contribution to the plant to clarify the wastewater. The aim is **to clean all gross** and **larger entrained objects** and sedimentation.

Settling of these large objects with the help of gravity during sedimentation and removing the clean water is one type of physical method. “While sedimentation is one of the most common physical treatment processes that are used to achieve treatment, another physical treatment process consists of aeration -- that is, physically adding air, usually to provide oxygen to the wastewater. Still other physical phenomena used in the treatment consist of filtration. Here waste water is passed through a filter medium to separate solids. An example would be the use of sand filters to further remove entrained solids from treated waste water.” (water.me.vccs.edu/courses/ENV149/methods.htm).

### 2.3.1. Secondary (Biological) Treatment

**- Secondary (Biological) Treatment**: the step after primary treatment, removes the dissolved organic matter that escapes primary treatment. “This is achieved by **microbes consuming the organic matter** as food, and converting it to carbon dioxide, water, and energy for their own growth and reproduction. The biological process is then followed by additional settling tanks “secondary sedimentation", to remove more of the suspended solids. About 85% of the suspended solids and BOD can be removed by a well run plant with secondary treatment. Secondary treatment technologies include the basic activated sludge process, the variants of pond and constructed wetland systems, trickling filters and other forms of treatment which use biological activity to break down organic matter” (www.water.worldbank.org). Biological Treatment aims to clean the waste water quality with the use of micro organisms, mostly bacteria. As a result of formation these micro organisms, solid wastes turn into water, carbon dioxide and biomass. Generally biological treatments divide into two; **aerobic** (with oxygen) and **anaerobic** (without oxygen) depending on the type of bacteria. Activated Sludge System is the most known and used type of biological treatment. Membrane Bio-reactor (MBR), Sequencing Batch Reactors (SBR) is also examples to the biological treatment.

### 2.3.2. Tertiary (Chemical) Treatment

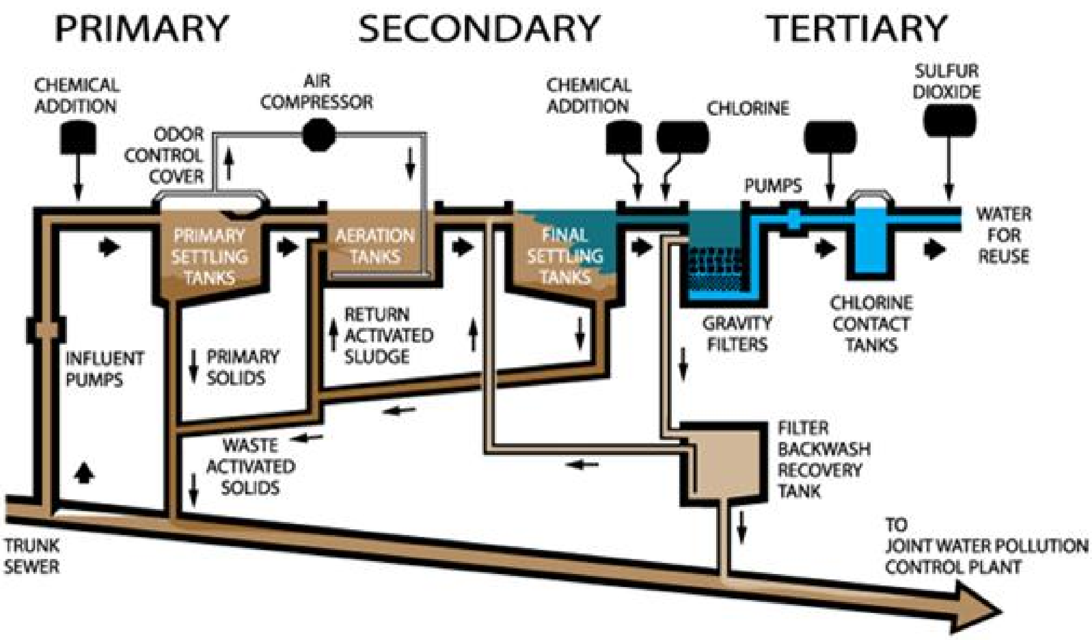
**- Tertiary (Chemical) Treatment**: is an additional system added to secondary treatment. This system can remove 99% of all impurities from the sewage and it produces water with the quality of potable water. The treatment technology is very expensive and needs professional know how and a well trained operator. We can give the modification of a conventional secondary treatment plant **to remove additional phosphorus and nitrogen** as an example to tertiary treatment step.

In most developed countries like in Northern Europe, waste water treatment is achieved up to tertiary treatment level (http://water.me.vccs.edu/courses/ENV149/methods.htm).

Chemical Treatment is an array of processes to expedite disinfection with the help of chemicals. It is the most common method for removing dissolved metals from waste water solution containing toxic metals. “To convert the dissolved metals into solid particle form, a precipitation re-agent is added to the mixture. A chemical reaction, triggered by the re-agent, causes the dissolved metals to form solid particles. Filtration can then be used to remove the particles from the mixture” (http://www.thomasnet.com/articles/chemicals/wastewater-chemical-treatment). Fig. 2.1 explains how these three levels of system are connected.

In the first (preliminary) phase, the solids are settled to the bottom of the settling tank. Then at the secondary phase microbes use air to breathe while they dissolves organic material in the aeration tanks, by that microbes settle out in the secondary settling tanks. At the tertiary, last phase, sand and coal filter out leftover particles in the filters. Here is the phase where most nutrients are dissolved.

Fig. 2.1: Typical Flow Schematic of Water Reclamation Plant



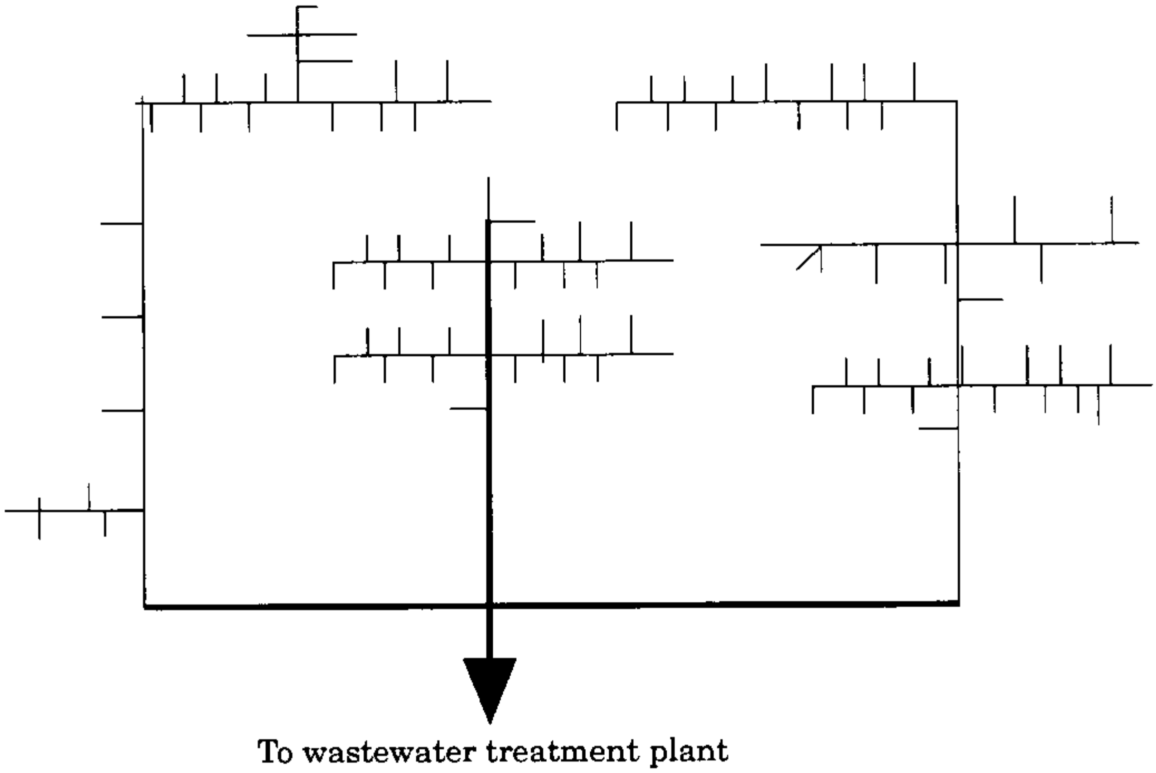

Source: http://www.lacsd.org/images/LCwrpSch_1.jpg

## 2.4. Centralized vs. Decentralized

**Centralized waste water management system** consists of a centralized collection system (sewers) that collects waste water from many waste water producers: households, commercial areas, industrial plants and institutions, and transports it to centralized waste water treatment plant in an off-site location outside the settlement, and disposal/re-use of the treated effluent, usually far from the point of origin (Wilderer and Schreff, 2000; Crites and Tchobanoglous, 1998).This system was invented in 19th century, at that time human waste was deposited in the streets and resulted in increases of diseases like **cholera**, **typhus** and other **fatal diseases**. As a solution, experts came up with an idea to collect the waste water in a main sewage system and carry it to outside the area, to be treated and purified there. The system accomplished the elimination of diseases and became more famous in USA after Europe. Since the carried waste water discharged into surface water the self-purification of the receiving water body re-ceded and potable water quality decreased, however the waste water treatment systems had to develop.

Trickling Filters was the dominant technology until the end of the 1950's when it was taken over by the Activated Sludge technology (Hartmann, 1999; Wilderer and Schreff, 2000; Burian et al, 2000).

Fig. 2.2: Schematic diagram of centralized wastewater collection and treatment (off-site)




Source: Bakir, 2001:323

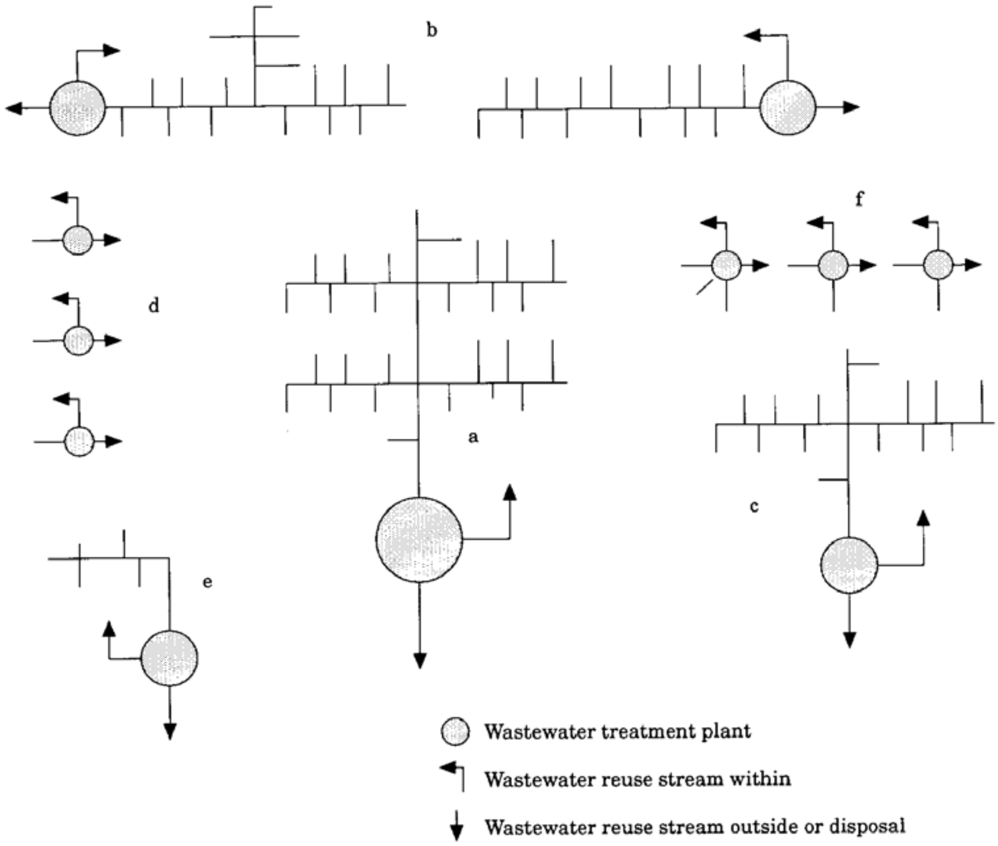
"Centralized waste water management - as the preferred choice of planners and decision makers, is often applied also to smaller communities"(Bakir, 2001). In Germany, for example, waste water management is the responsibility of the municipalities. If they are too small to address the financial and technical complexity of this task, they form inter-municipal joint-ventures. In France municipalities commonly establish joint-ventures to carry out the task of waste water management (WHO/UNEP, 1997). There are 2 approaches for centralized waste water management: intensive and extensive.

**Intensive treatment** also referred as biological treatment is the most common approach with the use of the Activated Sludge System and requires smaller space then extensive treatment but also requires skilled experts to design, construct and maintain.

**Extensive treatment** also referred to as natural treatment includes methods like lagoons, stabilization ponds and constructed wetlands. The system is easy to operate and low in cost but the main disadvantage is large amount of land area requirement.

**Decentralized waste water management system (DEWATS)** is another concept of managing waste water. It is also referred as on-site management. This system was common until the invention of centralized systems. In this case containers were placed beneath the seats of privies to collect human excrement and once full – containers were emptied at a disposal location near the residence. This system entailed potential use of the waste as fertilizer on nearby farmland (Sharon Hophmayer-Tokich, unknown date). However, there is a new approach to decentralized systems in the last few decades. “The interest in these technologies was renewed as it became apparent that the centralized strategy is not feasible in many places, or simply not the most cost-effective alternative in some cases. Due to their high costs and complexity of construction, operation and maintenance, or the fact that they require high and reliable water consumption, centralized systems may be less suitable for places such as low-income areas, rural areas with low population density, water-scarce areas, areas with an unreliable water supply system, etc.” (Bakir, 2001; UNEP/GPA, 2000; Jackson, 1996).
The decentralized systems can be applied on different scales. It can be applied to (1) individual households; (2) a cluster of homes; (3) a neighborhood; (4) public facilities; (5) commercial area; (6) industrial parks; and (7) small portions of large communities
(Bakir, 2001; Crites and Tchobanoglous, 1998). Septic tanks, anaerobic reactor, planted gravel filter can be some examples to the system.

Figure 2.3: Schematic diagram of decentralized wastewater management (on-site) (a) subsystem for residential and commercial center; (b) subsystems for residential neighborhoods; (c) subsystems for industrial development; (d) subsystem for individual residence; (e) subsystem for new development; (f) subsystems for establishments or clusters of homes;




Source: Bakir, 2001: 323

## 2.5. Cost of Treating Waste water

The cost of water treatment depends on many aspects such as:

-design cost

-equipment cost

-installation

-piping

-construction cost

-running system costs (maintenance, cleaning, chemicals, electricity, labor etc.)

-monitoring and documentation cost

For the cost estimation of wastewater, EPA (Environmental Protection Agency) had done many researches and set the numbers for cost estimation. For a specific system in specific area it is hard to give a number without analysis and the capacity of the system. For the suggested design park in Girne, further analysis and calculation must be done in order to find out the capital cost of the treatment plant.

B. Summary of Part II

Waste water means used or contaminated water, as a result of this usage; water does not have the same quality as before. Waste water contains solid organic matter which decreases the oxygen level when drained into the sea and can cause fish death. The sewage system is built up to filter these dissolved solids and decrease the harm to a minimum for the marine habitat and also human health.

There are nearly 70 types of treating waste water and technology develops every day. 3 steps of treatment are applied, these are; primary treatment which is the first step and filters the large solids to decrease the BOD level of coming waste water, secondary treatment is biological and catches the solids escaped from the primary treatment with the help of microbes, tertiary treatment is an additional system which can remove 99% of all impurities from the sewage and produce a potable water quality.

Primary (Physical) Treatment is named because of the physical contribution to the system and cleaning water with the sedimentation of large objects with the help of gravity. Besides from sedimentation, aeration- putting air into the water is another common physical treatment. The third most used method would be filters where the particles like sand are used in drainage.

Secondary (Biological) Treatment is to use the microbes to smash the solids and convert them to liquids, gas or biomass. This type of treatment is divided into two, aerobic (with oxygen) and anaerobic (without oxygen).

Tertiary (Chemical) Treatment is a series of processes to speed up the disinfection with the help of chemicals. Mostly used for removing dissolved metals in the waste water which include toxic composition. After a chemical reaction, filtration can be used to remove unwanted solids in the water.

# 3. PART III

## 3.1. Possible Waste Water Treatment Systems for North Cyprus

In order to implement a waste water plant it is not enough to point out the appropriate places to construct the plant but mostly to consider the context of the land, impacts on the environment, cultural background of the nation, advantages and disadvantages on the country's economy, people participation etc. Also these plants have to be designed, built, proceed and controlled by professionals, governmental institutions and maintained by the public.

Despite the scarcity of rain, flooding may occur in Cyprus. Due to poor infrastructure and increased areas of non-permeable spaces, rain water rises up in the streets. With its flat topography Güzelyurt and Lefkosa are two big cities affected from flooding the most. When heavy rain occurs, the island has not enough capacity to keep it, dams and lakes overflow. As a result of this, storm water mixes with the wastes.

The last big flood event happened in 19 January 2010. It rained all day long and the storm water from Trodos Mountain arrived on the hard surfaces in the city. The water level was up to 5 metres in some areas. While water mixing with the wastes and running to the underground water bodies, the politicians were blaming the authorities in the South of Cyprus. In my point of view, the problem is that island does not have enough dams or the high capacity wetlands which are ready for heavy and sudden rain.

According to sudden and heavy rains, Constructed Wetlands can operate effectively to keep the water for a long time and distribute it back to the buildings for usage, agriculture lands and the rest for supporting the existing water bodies.

### 3.1.1. Waste Stabilization Ponds (WSP)

It is natural way for waste water treatment with man-made water bodies. Stabilization ponds can be applicable to North Cyprus since they are well suited to tropical and sub-tropical countries because the intensity of the sunlight and daily temperature are key factors for the efficiency of the removal processes.

It is also recommended by the WHO for the treatment of waste water for re-use in agriculture and aquaculture, especially because of its effectiveness in removing nematodes (worms) and helminth eggs. According to a World Bank study carried out in Sana'a, Yemen using a stabilization pond technique on the land cost of upwards of US$ 7.8/m2. For Cyprus it is an expensive system to use. (http://en.wikipedia.org/wiki/Stabilization_pond). Table 3.1 shows the advantages and disadvantages of this system.

Table 3.1: Advantages and disadvantages of Waste Stabilization Ponds

| Advantages | Disadvantages |
|---|---|
| - High reduction in pathogens.<br>- Can be built and repaired with locally available materials.<br>- Construction can provide short-term employment to local labourers.<br>- Low operating cost.<br>- No electrical energy required.<br>- No real problems with flies or odours if designed correctly. | - Requires expert design and supervision.<br>- Variable capital cost depending on the price of land.<br>- Requires large land area.<br>- Effluent/sludge require secondary treatment and/or appropriate discharge. |

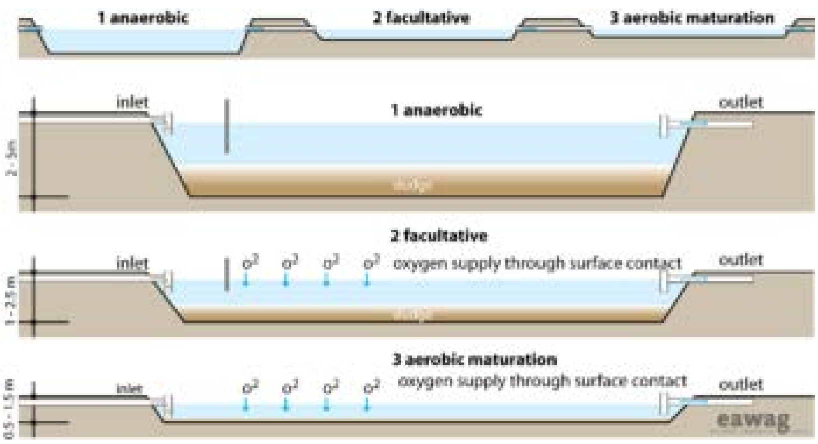
Source: http://akvopedia.org/wiki/images/thumb/5/5b/Waste_stabilization_ponds

The performance of waste water stabilization ponds in achieving the goals for developing countries appears to be satisfactory in many cases. At loading rates of 180–500 kg biological oxygen demand (BOD) per acre per day in the tropics, removal efficiencies of BOD, nitrogen, phosphorus and indicator bacteria have been reported to be 75–90; 30–50; 20–60 and 60–99%, respectively (Canter et al., 1982, Shuval et al., 1986 and Von Sperling and Marcos, 1996). Most importantly, well-designed and well-operated stabilization ponds can achieve almost total removal of helminthes (99.99%), enteric bacteria and viruses (99%), leaving an odor free effluent which is attractive for agriculture (Shuval et al., 1986).

In a **Facultative Pond**, water is transferred into a lined impermeable basin. As water settles, three separate layers tend to form: an upper aerobic layer, a middle mixed layer and a bottom anaerobic layer. BOD levels are reduced through treatment in the upper aerobic layer due to two main reasons: oxidation and decomposition of oxygen-demanding organic matter.

Oxidation occurs when dissolved oxygen, introduced by algal photosynthesis and wind action, reacts with organic matter in the wastewater, thereby reducing the BOD. BOD is further reduced by decomposition as aerobic microorganisms consume the organic matter for food. Organic matter is also broken down in the middle layer, where facultative microorganisms exist. Facultative organisms are those that can adapt and survive in environments with very small to large concentrations of dissolved oxygen (LSM, 2003).

Fig. 3.1: Linked series of Stabilization ponds




Source: http://iati-test.akvo.org/wiki/images/thumb/5/5b/Waste_stabilization_ponds.png/350px-Waste_stabilization_ponds.png

Considering the cost and land factor, stabilization ponds tend to be a cheaper option which requires large areas. According to the IRC International Water and Sanitation Centre stabilization pond technology is the most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms. Land availability is a more important case than the land cost.

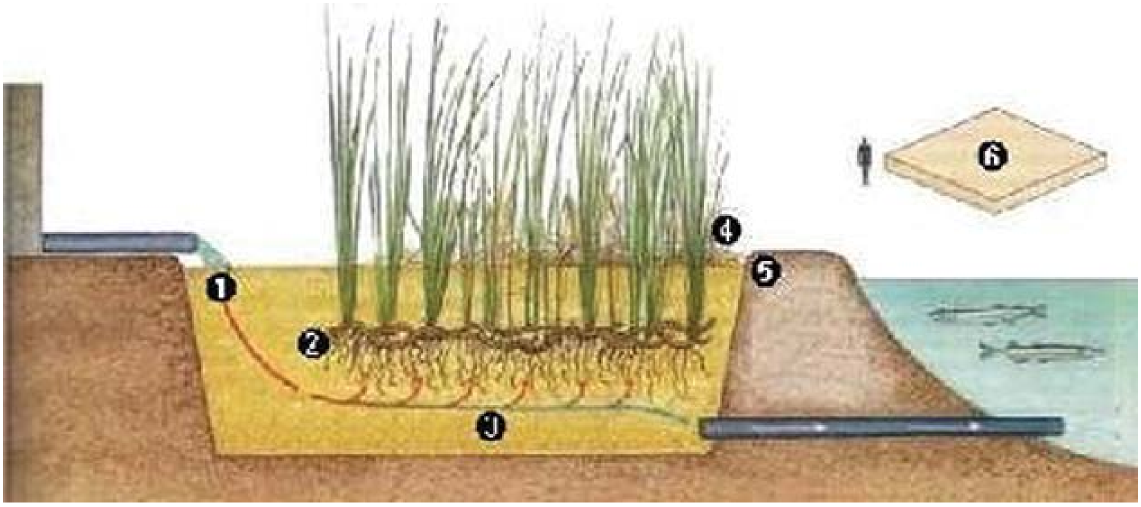
### 3.1.2. Constructed Wetlands (CW)

Constructed wetlands are man-made wetlands built to remove pollutants in the water with the help of plantation and various types of soils aside from protecting the wildlife habitat. We can say they are the imitation of the natural wetlands. CWs are not only there to provide purifying water with vegetation but also by letting the micro organisms grow since these micro organisms cleans the organic compounds from the waste water. (Wolverton, 1987) pointed out that the scientific basis for waste water treatment in a vascular aquatic plant system is the cooperative growth of both the plants and the micro organisms associated with the plants.

All three steps of treatment (primary, secondary, tertiary) are applied in this system. Removal can be achieved by the chemicals or by plantation. There is a septic tank to remove the solids from the waste water liquid. They require little or no energy to operate. Waste water Garden (WWG) is one type of constructed wetland.

Natural wetlands have been used for waste water treatment for centuries. In many cases, however, the reasoning behind this use was disposal, rather than treatment and the wetland simply served as a convenient recipient that was closer than the nearest river or other waterway (Wentz, 1987). But studies show that CWs are more popular and easy to practice and operate.

Fig. 3.2: Artificial wetlands for sewage and industrial waste



Source: http://fourthcornernurseries.com/images/articles/frers2.jpg

1. Sewage flows into the constructed wetland, which is an excavated cell filled with sand that serves to filter out odors.

2. The filter consists of a large vegetative planting, in this case rushes, whose roots in the sand are fed by the wastewater.

3. The nutrients in the water are absorbed by rushes (Juncus), which sequester them in their tissues as they grow.

4. The nutrients absorbed are eliminated with vegetative dieback of the rushes, whose remnants form an insulating layer.

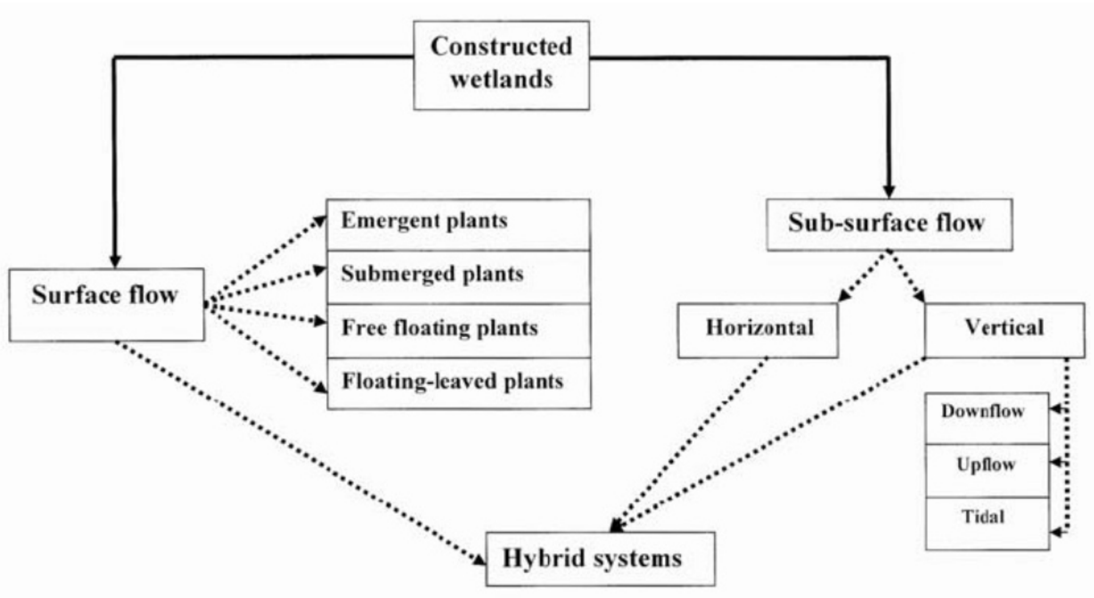
5. The purified water filters from the wetland into the lagoon.

6. Proportioning a wastewater treatment wetland: The area required is proportional to the size of the residential population and is calculated as follows: 1 person = around 5 m2.

Why applicable for Cyprus?

According to an article published in Universal Journal of Environmental Research and Technology, Constructed Wetlands especially SFCW systems showed an increase rate of contaminant take up in warmer climates, therefore this treatment has been expected to operate more efficiently in tropical regions which makes it applicable for North Cyprus. Also a wetland system needs low maintenance and no equipment is necessary.

Fig. 3.3: Classification of constructed wetlands for wastewater treatment




Source: http://de.scribd.com/doc/6888132/Wastewater-Treatment-in-Constructed-Wetlands-with-Horizontal-SubSurface-Flow

Watson et al. (1989) and Kadlec and Knight (1996) have discussed the advantages of using wetland technology for waste water treatment. Compared to conventional treatment systems, wetland technology is cheaper, more easily operated and more efficient to maintain. Minimal fossil fuel is required and no chemicals are necessary. An additional benefit gained by using wetlands for waste water treatment is the multi-purpose sustainable utilization of the facility for uses such as swamp fisheries, biomass production, seasonal agriculture, water supply, public recreation, wild life conservation and scientific study (Santer, 1989, EPA, 1993, and Knight, 1997). Being low-cost and low-technology systems, wetlands are a potential alternative or supplementary system for wastewater treatment in developing countries.

Fig. 3.4 shows the preparation process of the man made wetland, the tank is set underground, the pipes connected to the wetland lets the wastewater flow into the pool. In Fig. 3.5 there are a series of constructed wetlands surrounded by farmland. CWs mostly work well with agricultural wastes by filtering the runoff from cropland, feed lots and aquaculture operations.

Fig 3.4: Preparation process of the manmade wetland

Source: http://upload.wikimedia.org/wikipedia/commons /thumb/d/dd/Newly_planted_constructed_wetland.jpg/

Fig. 3.5: Series of constructed wetlands

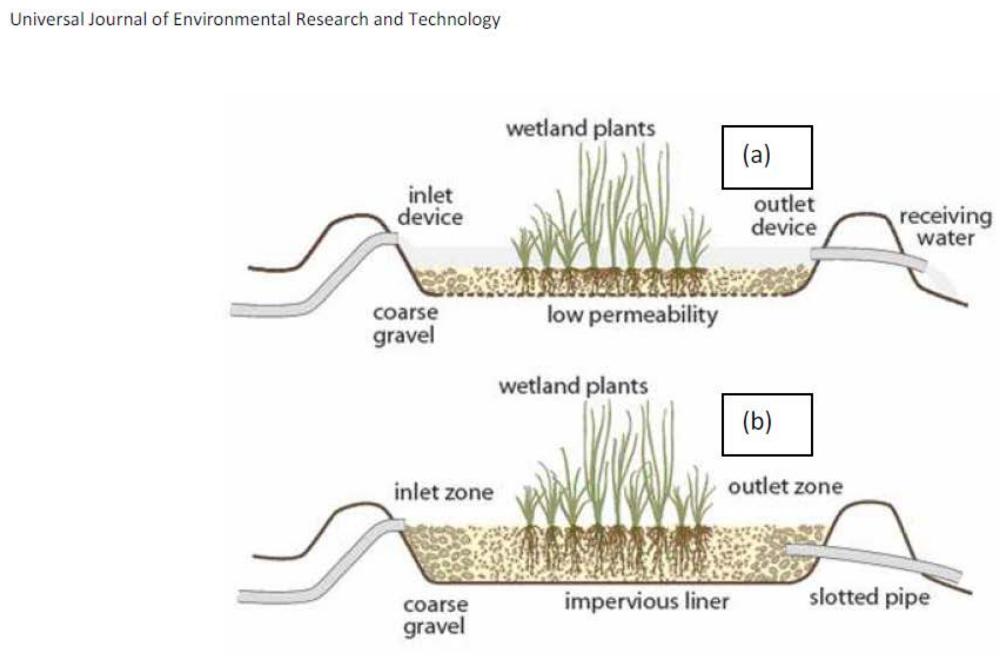
Source: http://www.mda.state.mn.us

Hammer and Bastian (1989) have reviewed the functions of natural wetlands. Wetlands support a rich diversity of wild life and fisheries by being stopping-off points and nesting areas for migratory birds and spawning grounds for fish and shellfish. Those along the coasts, river banks and lake shores stabilize shorelines and protect them from erosion. Some wetlands may function as discharge areas for surfacing ground waters, allowing stored groundwater to sustain base-flow streams during dry seasons. Above all, wetlands are ‘natural purifiers of water’.

An example of a constructed wetland serving the purpose of treating waste water and supporting wildlife with a potential for recreation is found in Nairobi, Kenya. The 0.5 ha wetland designed for 1200 people has been reported to function well in terms of wastewater treatment with removal efficiencies of 98, 67–99, 94–98, 99.4–99.9, 87–90 and 88% for BOD, TSS, COD**,** fecal coliforms, TN, and TP, respectively (Nyakang'o and van Bruggen, 1999).

Constructed wetlands could be classified according to the various parameters but the two most important criteria are water flow regime (surface and sub-surface) and the type of macrophytic growth (Fig. 3.6). Different types of constructed wetlands may be combined with each other (so called hybrid or combined systems) in order to exploit the specific advantages of the different systems. The quality of the final effluent from the systems improves with the complexity of the facility (Jan &Lenka WWT in CW with FWS, 2008). Apart from having advantages of being economic, low construction, maintenance and operation cost, low energy requirements and capacity of recycling there are also some disadvantages such as large land requirement, possible odor spread, and lack of knowledge about maintaining the system considering the wild life ecology in tropical countries.

Fig. 3.6: Classification of Constructed Wetlands, Type of Constructed Wetland (A) Free Water Surface (B) Sub surface Flow (Adopted from Gearheart, 2006)



3.1.2.1. Surface Flow Design (FWS)

Constructed wetlands with surface flow (*free water surface constructed wetlands, FWSCW*) consist of basins or channels, with soil or another suitable medium to support the rooted vegetation (if present) and water at a low flow velocity, and presence of the plant stalks and litter regulate water flow and, especially in long, narrow channels, ensure plug-flow conditions (Reed et al., 1988). One of their primary design purposes is to contact wastewater with reactive biological surfaces (Kadlec and Knight, 1996). The FWS CWs can be classified according to the type of macrophytes (Fig. 3.3).

Fig. 3.7: FWS constructed wetland at Leystad, the Netherlands , planted with Scirpuslacustris. Photo by Hans Brix

Surface-flow wetlands move effluent above the soil in a planted marsh or swamp, and thus can be supported by a wider variety of soil types including bay mud and other siltyclays.Plantings of reedbeds are popular in European constructed wetlands, and plants such as cattails (*Typha spp*.), sedges, Water Hyacinth (*Eichhornia crassipes*) and *Pontederia* spp. are used worldwide (although Typha and Phragmites are highly invasive). Recent research in use of constructed wetlands for subarctic regions has shown that buckbeans (*Menyanthes trifoliata*) and pendant grass (*Arctophila fulva*) are also useful for metals uptake (http://en.wikipedia.org/wiki/Constructed_wetland).

#### 3.1.2.2. Sub Surface Flow Design (SFCWs-RBTs)

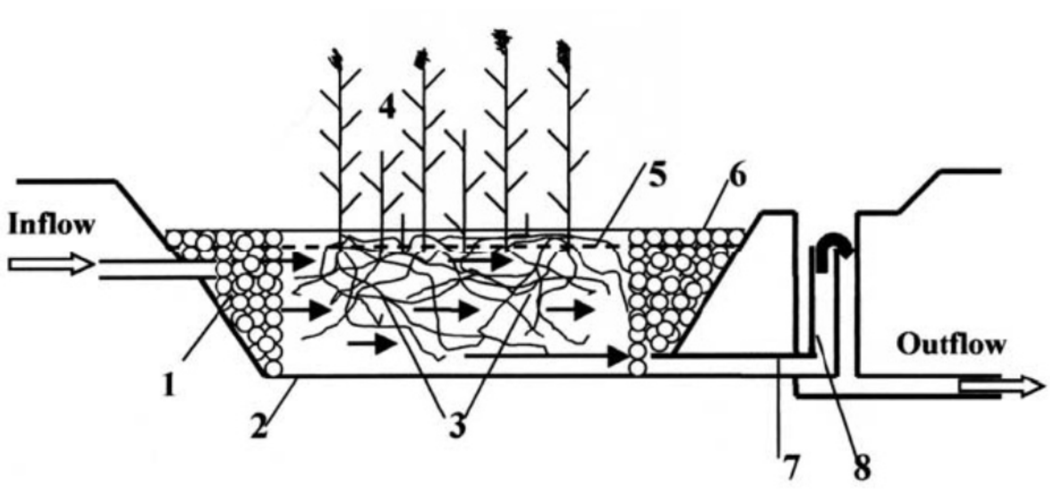
The sub surface system is divided into two according to direction flow; horizontal flow (HF or HSF) and vertical flow (VF) Fig. 3.3.

Horizontal Flow:

Figure 3.8 shows a typical arrangement for the constructed wetland with a horizontal sub-surface flow. It is called horizontal flow because the wastewater is fed in at the inlet and flows slowly through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone where it is collected before leaving via level control arrangement at the outlet.

During this passage the wastewater will come into contact with a network of aerobic, anoxic and anaerobic zones. The aerobic zones occur around roots and rhizomes that leak oxygen into the substrate (Brix, 1987b; Cooper et al., 1996). In Europe, HSF constructed wetlands are commonly called "Reed beds", in the United Kingdom also "Reed bed Treatment System" (RBTS) coming from the fact that the most frequently used plant is Common reed (*Phragmites australis*). In the United States, the team "Vegetated Submerged Bed" (VSB) was also adopted. This term, however, is very unfortunate as it resembles systems with submerged plants and therefore, we strongly recommend that is not used (Jan &Lenka WWT in CW with FWS, 2008).

Fig. 3.8: Schematic representation of a constructed wetland with horizontal sub-surface flow. 1- Distribution zone filled with large stones, 2- Surface of the bed, 3- Water level in the bed, 4- Impermeable liner, 5- Medium (e.g. gravel, crushed stones), 6- Collection zone filled with large stones, 7- Collection drainage pipe, 8- Outlet structure for maintaining of water level in the bed. The arrows indicate only a general flow pattern.




Source: Vymazal (200 la), Backyus Publishers.

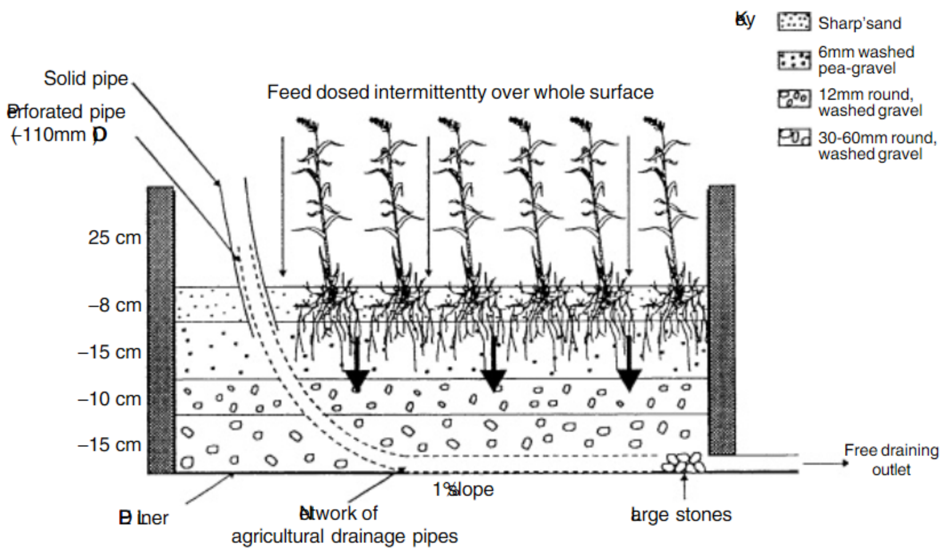
Vertical Flow:

A Vertical Flow Constructed Wetland is a filter bed that is planted with aquatic plants. Wastewater is poured or dosed onto the wetland surface from above using a mechanical dosing system. The water flows vertically down through the filter matrix. The important difference between a vertical and horizontal wetland is not simply the direction of the flow path, but rather the aerobic conditions.

Down flow:

VF constructed wetlands are primarily used to treat domestic or municipal sewage. However, in recent years VF systems have also been used to treat other types of wastewater (Table 3.2). VF constructed wetlands are also often used as part of hybrid systems treating various types of waste water. Typical arrangement of down flow VF system is shown in Fig. 3.9.

Fig. 3.9: Typical arrangement of a down flow vertical – flow constructed wetland




Source: Cooper et al., 1996

Table 3.2: The use of VF systems for various types of wastewater other than sewage

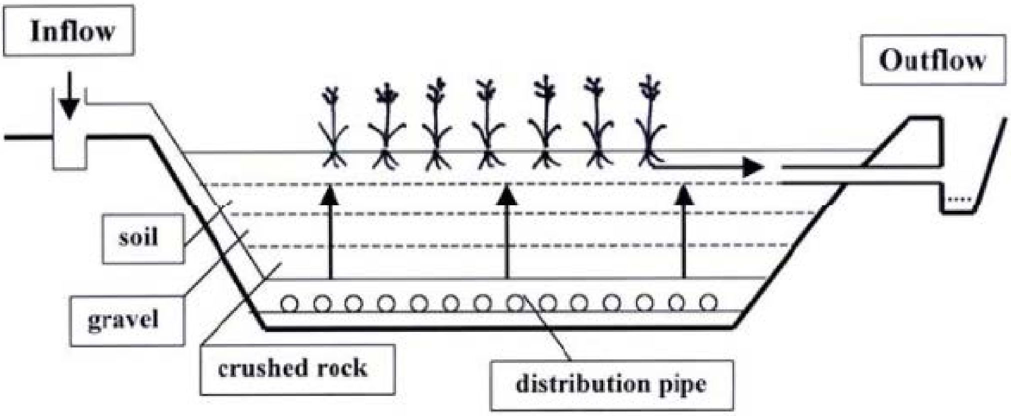
| **Waste type** | **Country** | **Reference** |
|---|---|---|
| Perchlorate | USA | Tan et al. (2004) |
| Phenanthrene | Germany | Machate et al. (1997) |
| PAH | France | Cottin and Merlin (2006) |
| Herbicides | UK | McKinlay and Kasperek (1999) |
| Sulfides | Colombia | Giraldo and Zárate (2001) |
| Airport runoff | Canada | McGill et al. (2000) |
| Landfill leachate | Australia | Headley et al (2004) |
| Dairy | The Netherlands | Veenstra (1998) |
| Cheese dairy | Germany | Kern and Idler (1999) |
| Abattoir | Canada | AQUA TT |
| Mushroom farm leachate | Canada | AQUA TT |
| Composting leachate | Germany | Lindenblatt (2005) |
| Surface water | The Netherlands | Bloom and Verhoeven (2006) |
| Refinery wastewater | Pakistan | Aslam et al. (2007) |
| Aniline and N-compounds | Portugal | Novais and Martins-Dias (2003) |

Source: Jan &Lenka WWT in CW with FWS, 2008

Up flow:

In vertical-up flow constructed wetlands the wastewater is fed on the bottom of the filter bed. The water percolates upward and then it is collected either near the surface or on the surface of the wetland bed (Fig. 3.10).These systems have commonly been used in Brazil (Salati, 1987; Manfrinatoet al., 1993; Salati et al., 1999) since the 1980s. The beds are filled with crushed rock on the bottom, the next layer is coarse gravel and the top layer is soil planted with Rice (*Oryza sativa*) (Jan &Lenka WWT in CW with FWS, 2008).

Fig. 3.10: Schematic representation of a constructed wetland with vertical up-flow




Source: Vymazal (200 la), Backhuys Publishers

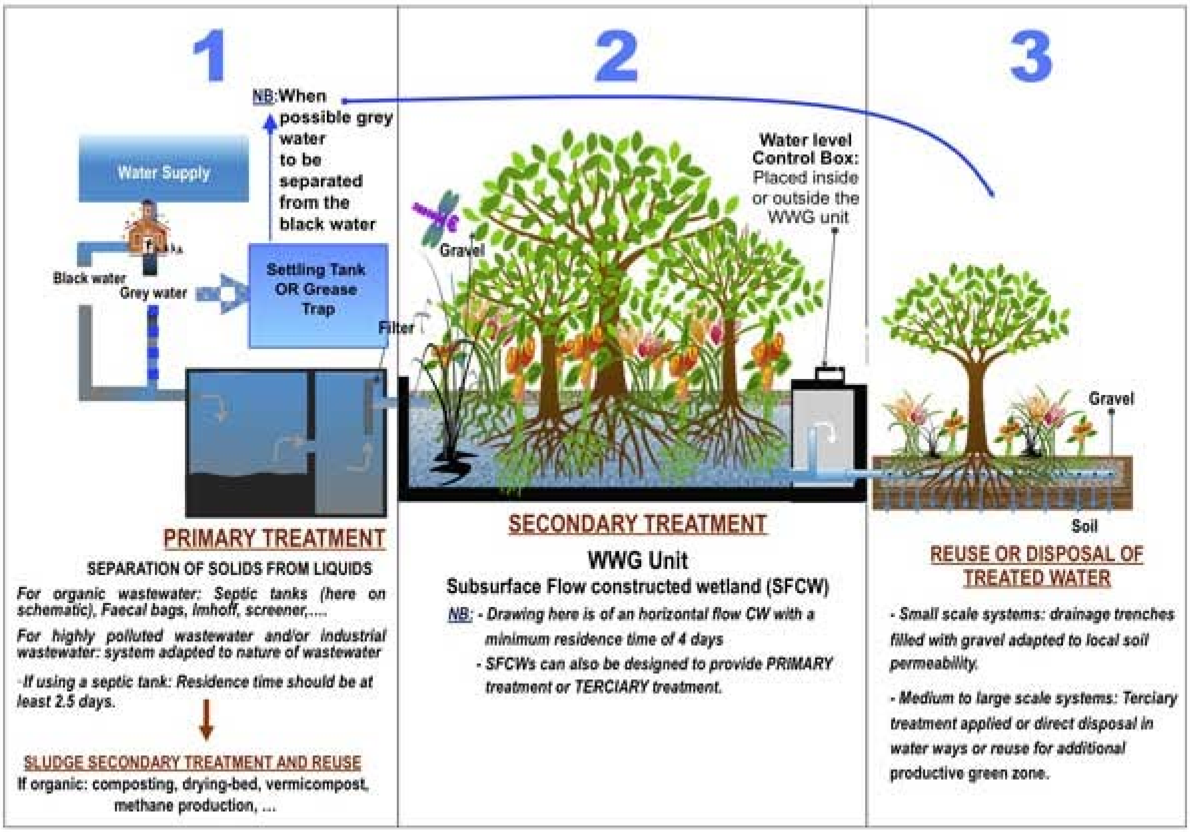
Tidal flow:

Tidal flow systems are a new form of VF system (Green et al., 1997;Revitt et al., 1997; Sun et al., 1999a,b; Zhao et al.,2004a;Cooper & Cooper (2005) pointed out that tidal flow systems developed to try to overcome some of the problems that were seen in theearly forms of VF systems related to clogging of the surface. Up flow systems have been were used for about 20 years but they suffer from the problemthat distribution is below the surface and hence hidden from the observers. Intidal flow systems at the start of the treatment cycle the wastewater is fed tothe bottom of the bed into the aeration pipes. It then percolates upwards untilthe surface is flooded. When the surface is completely flooded the pump isthen shut off, the wastewater is then held in the bed in contact with themicroorganisms growing on the media. A set time later the wastewater isdrained downwards and after the water has drained from the bed thetreatment cycle is complete and air diffuses into the voids in the bed (Cooper, 2005).

### 3.1.2.3. Waste Water Garden (WWG)

Waste water Garden is a type of constructed wetland. What WWG units do is reproduce the conditions of natural wetlands, called by scientists the “kidneys of the Earth” for their high capacity of water recycling in the biospheric cycles. Unlike many natural wetlands however, WWG belongs to the family of subsurface flow designs, which means that at no moment is the sewage water in contact with the air, thus preventing all bad smells, mosquito breeding or accidental human contact (http://www.wastewatergardens.com/1en_overview.html). The system can be used in public parks, office buildings, hotels/cafes, schools and rural areas.

Fig. 3.11: WWG system detail




Souce:www.tamanpetanu.com/_/rsrc/1336389181271/development-plans/wastewater-management/WWG_Complete2Sldg_CutIn3.ppt.jpg

Fig.3.12: Xpu-Ha Eco-Park, Restaurant, handling wastewater for 1500 people

Source: http://www.wastewatergardens.com/5en_photos2.html

In this system basically, the aquatic plants are planted in order to purify the waste water or storm/runoff water. The plants clean the pollutants in the water; the top part of the plant observes the oxygen and carries it to the roots which enable the microorganisms to live. Wetlands also provide important habitat for many animals. Apart from that, CWs are constructed on the gravity-flow means no need for pumps, electricity or additional effort. It is one of the cheapest solutions to clean the water. For Cyprus it is recommended for the rural areas for usage of agricultural production. The ecologic system can encourage farmers to produce their products without the concern of rain amount or season.

### 3.1.3. Membrane Bioreactor

Membrane bioreactor (MBR) is the combination of a membrane process like microfiltration or ultra filtration with a suspended growth bioreactor, and is now widely used for municipal and industrial wastewater treatment with plant sizes up to 80,000 population equivalent (i.e. 48 million liters per day). When used with domestic wastewater, MBR processes can produce effluent of high quality enough to be discharged to coastal, surface or brackish waterways or to be reclaimed for urban irrigation. An added benefit of membrane bioreactors is its ability to allow complete nitrification to occur or operated in denitrification mode, which allows the choice of leaving all the nitrogen in the sewage water or taken out (Gaglardo *et al.* 2001).

“A MBR can best be described as one part of a biological process where small microbes degrade pollutants before being filtered by a collection of submerged membranes.” (http://www.treatmentequipment.com/files/mbr/mbr_brochure.pdf). Physical, chemical and organic processes are used in this technology in order to remove the contaminants in the wastewater. The main disadvantage of MBR is high need of energy for aeration.

Fig. 3.13: Example of MBR Unit

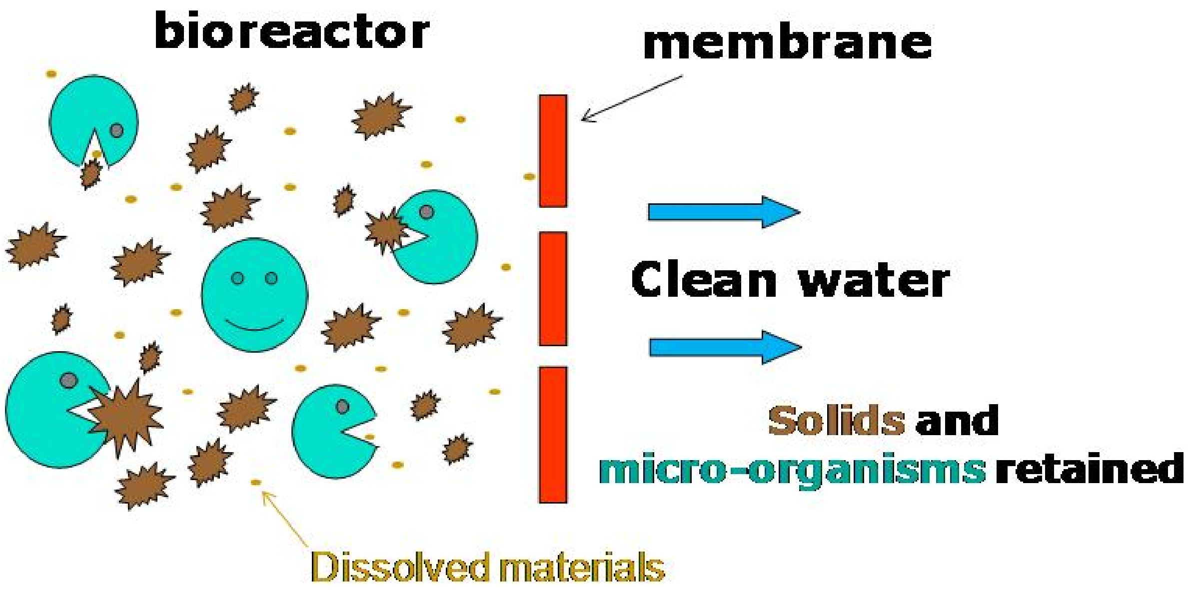

Source: http://www.treatmentequipment.com/files/mbr/mbr_brochure.pdf

MBR configurations are divided into 2 types: internal/submerged, where the membranes are immersed in and integral to the biological reactor; and external/side-stream, where membranes are a separate unit process requiring an intermediate pumping step (http://en.wikipedia.org/wiki/Membrane_bioreactor). The idea to submerge the membranes in the bioreactor came from Japanese scientist Yamamoto and co-workers in 1989. The system is first used in 1990 in USA. Both the (internal and external) MBRs showed successful performance for chemical oxygen demand (COD) removal efficiency (98% average), color (98%), and nutrients (86% for total nitrogen and 86–89% for total phosphorus

(http://en.wikipedia.org/wiki/Membrane_bioreactor#Internal.2Fsubmerged). The system is one of the most used wastewater treatment system which is becoming popular and attractive every day, the other most used technique is Reverse Osmosis (RO) and they are considered as last step in wastewater treatment. On the other hand, the system is very similar to conventional activated sludge system (CAS) but more developed version.

Compared to CAS MBR does not need extra clarifier for expansion, just increasing the number of membranes would be enough. Also MBR can operate at higher biomass concentrations (MLSS) than conventional systems.

Fig. 3.14: Simple schematic describing the MBR process

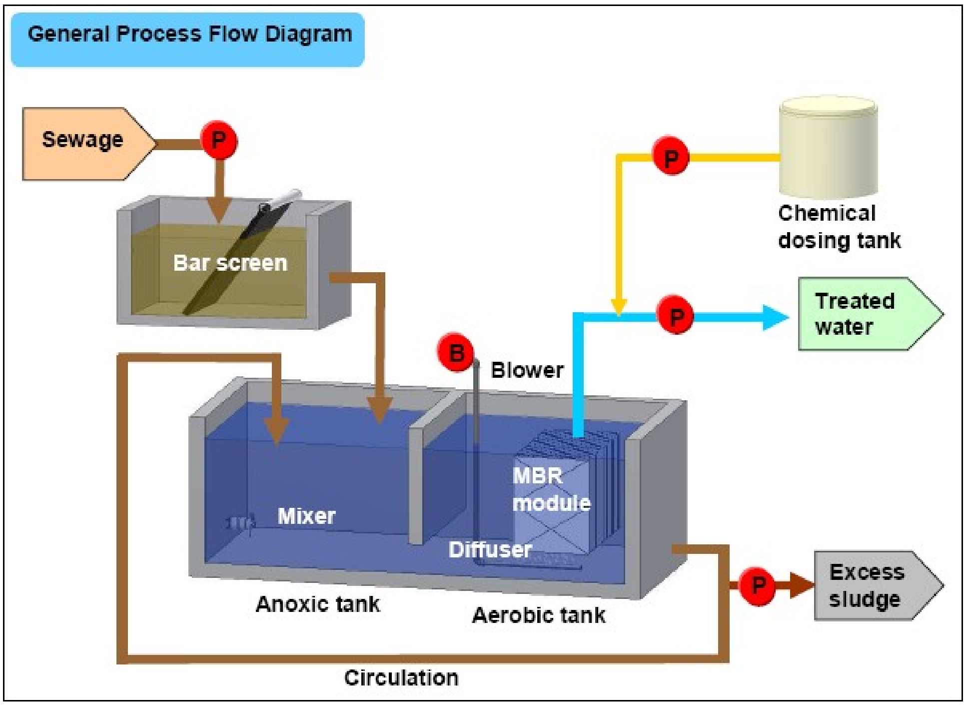



Source: http://en.wikipedia.org/wiki/File:MBR_Schematic.jpg

MBRs have emerged as an alternative bioreactor configuration in cases where space and water resources are limited (2006 Water Environment Foundation).

With the membrane directly immersed into the bioreactor, submerged MBR systems are usually preferred to side-stream configuration, especially for domestic wastewater treatment. The submerged configuration relies on coarse bubble aeration to produce mixing and limit fouling. The energy demand of the submerged system can be up to 2 orders of magnitude lower than that of the side-stream systems and submerged systems operate at a lower flux, demanding more membrane area. In submerged configurations, aeration is considered as one of the major parameter on process performances both hydraulic and biological. Aeration maintains solids in suspension, scours the membrane surface and provides oxygen to the biomass, leading to a better biodegradability and cell synthesis. (http://en.wikipedia.org/wiki/Membrane_bioreactor#Internal.2Fsubmerged). Fig 1.1 shows how internal and external MBRs work.

Fig. 3.15: General Process Flow Diagram of MBRs

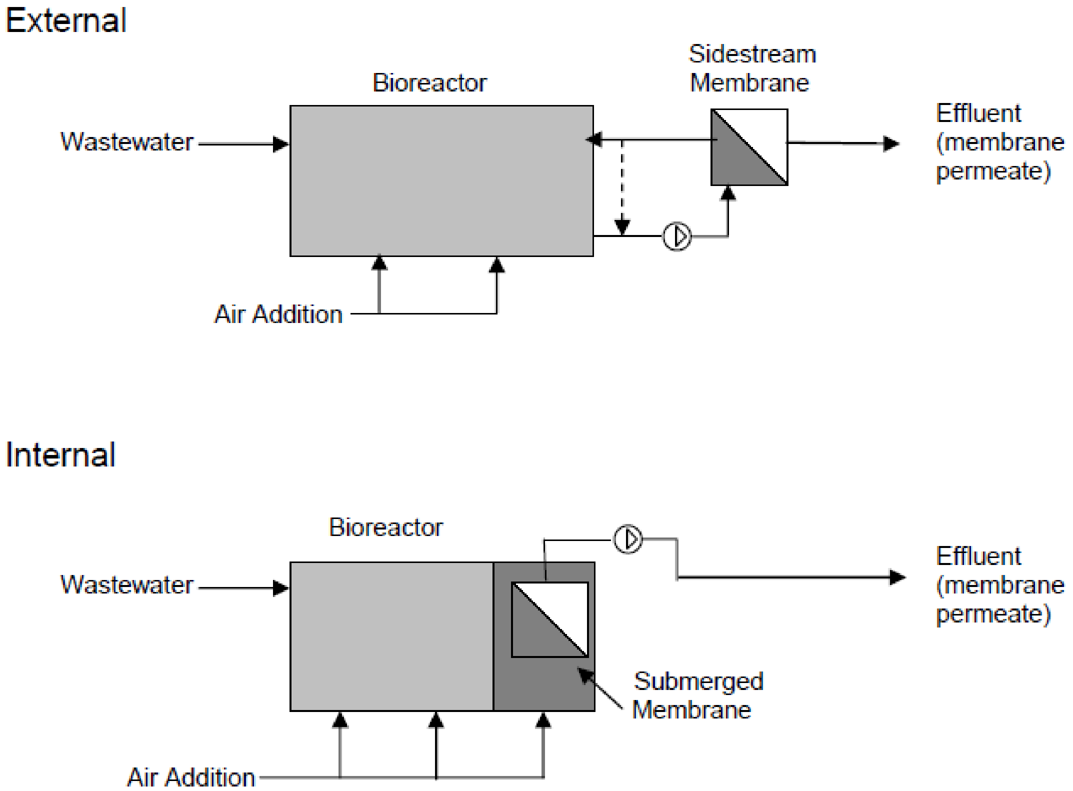



Source:http://nature.berkeley.edu/classes/es196/projects/2010final/YeoK_2010.pdf

Membrane bioreactor systems are one of the last steps of treatment technology. I personally recommend submerged membrane bioreactors for the Kyrenia Park and other available lands in North Cyprus. Since the major need of this system is oxygen, aeration problem without creating odors has to be solved. In this proposed park, the pipe of the MBR system is recommended to be connected to the building or high stores hotel next to the park and extend the pipes parallel through wall and till the end of the roof floor.

The cost of the system is of course dependent on the population of users, amount of water to be recycled and size and the number of the reactors. Further studies for the cost and installation of the system to be built in North Cyprus must be done. According to gained information from “Winery Waste water Treatment and Reuse Project” the estimated cost of the whole treatment system is costly differing from $1 to 1.8 million dollars, reactor cost $300,000 to $600,000 and $50,000 for the membrane replacement every 5 years. If we consider the system proposed to be build for Girne (Kyrenia Park), due to small number of users and the small size of the land, the system is supposed to be less costly.

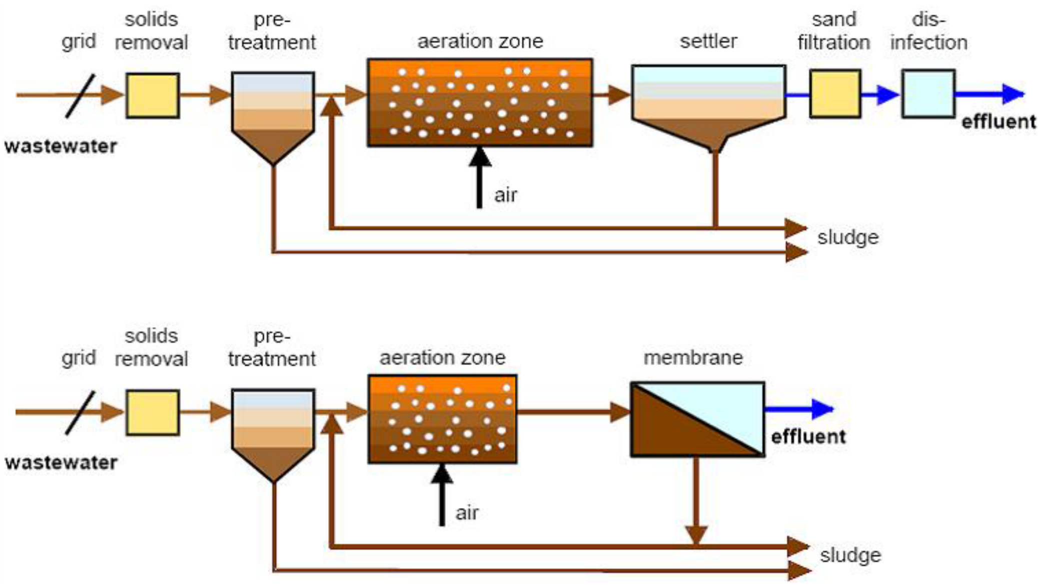
Fig.3.16: Simplified Schematics Depicting MBR Configurations




Sour

Source: 2006 Water Environment Foundation

Fig.3.17: Schematic of conventional activated sludge process (top) and external (side-stream) membrane bioreactor (bottom)

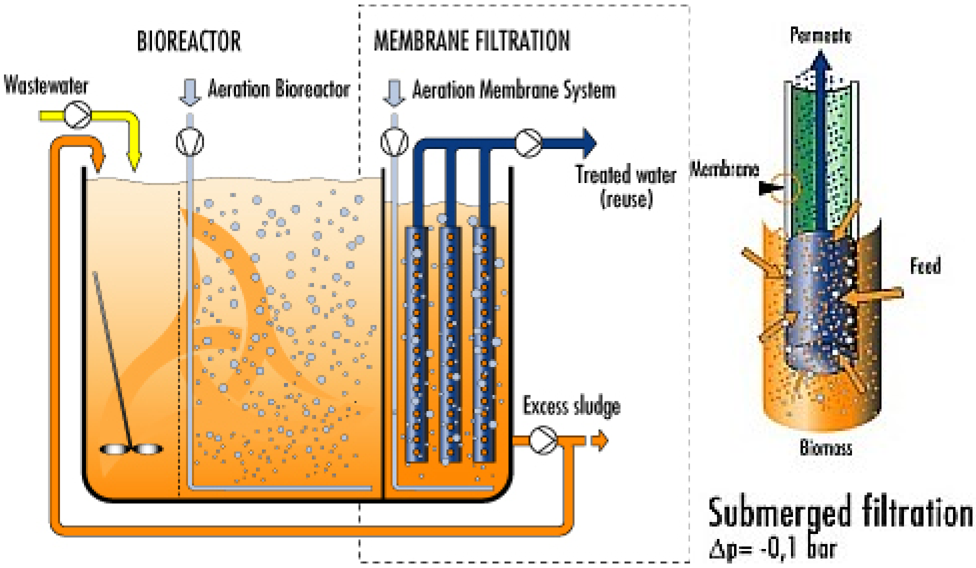



Source: http://en.wikipedia.org/wiki/File:MBRvsASP_Schematic.jpg

**Internal membrane configuration:** In the immersed (submerged) or internal membrane MBR system (Figure 3.18), the membranes are directly submerged in the bioreactor mixed-liquor, preferably located in compartments or a separate tank coupled to the bioreactor to minimize membrane cleaning efforts. This configuration typically involves the use of polymeric membranes. The membranes are either vertically or horizontally oriented hollow fibers contained in a rectangular or tubular support structure, or vertically oriented flat sheets contained within a support structure.

The mixed-liquor is located on the shell side of the membranes and the effluent is extracted into the lumen of the membrane. The driving force across the membrane is typically achieved by creating negative pressure on the lumen or permeates side of the membrane. The membrane component of this configuration involves substantially more membrane area per unit volume relative to the membrane component of the external MBR configuration, operates at a TMP typically 28 to 56 kPa and operates at an effective cross-flow velocity of less than 0.6 m/sec (Lei and Bérubé, 2004). Fig. 3.18 is an example to submerged MBRs, the wastewater insert to the bioreactor and the sedimentation of solids realizes, the membranes are submerged to the reactor with a separate tank, with the vacuum technique, filtration takes place. Flow of coarse air bubbles keeps the membranes clean.

Fig.3.18: Example of submerged (internal) membrane bioreactor




Source: http://www.lenntech.de/prozesse/submerged-mbr.htm

For the Kyrenia park irrigation, the submerged systems tempt to provide better solution considering the low energy consumption and limited land area.

**External membrane configuration:**

The filtration elements are installed externally to the reactor, often in a plant room. The biomass is either pumped directly through a number of membrane modules in series and back to the bioreactor, or the biomass is pumped to a bank of modules, from which a second pump circulates the biomass through the modules in series. Cleaning and soaking of the membranes can be undertaken in place with use of an installed cleaning tank, pump and pipe work (http://en.wikipedia.org/wiki/Membrane_bioreactor#Internal.2Fsubmerged).

As an applied example of the system, Guangzhou has the largest underground MBR system in China. According to Guangzhou Daily on 28 September 2010; Mr. Zhang Guang Ning: "The Jing Xi MBR water and wastewater treatment plant is an engineering feat which is most suitable for a densely populated city like Guangzhou. It takes up minimal ground area and uses advanced technology that has little impact on residents living in close proximity."

C. Summary of Part III

In this section different possible solution for the sustainable usage of water has been reviewed. In order to implement a WWTP, many analyses must be done. The performance or the quality of the system is not very important if it doesn't fit the context. For Cyprus one of applicable solution is waste water stabilization ponds. The system can be applicable in the large agricultural lands in the country. Since the removal system is related to the amount of sunlight, the system is very appropriate for Cyprus. Cost of the system can vary dependent to the scale of the project.

Since Cyprus is developing country and not very strong in economic terms, another low cost, high performance and suitable for the tropical regions system is constructed wetlands. CWs are the natural purifier of the water and can be used as storage of the groundwater by being constructed close to the shore or sea. The natural plantation helps cleaning the water and generally CWs provide a home to different type of habitats just like natural wetlands. Apart from that CWs are constructed in a gravity basis which means no need or very low need of pumping or electricity. There are 2 types of CWs, Surface Flow Design and Sub Surface Design. WWG is one type of CW belonging to subsurface design. This means no contact of waste water with the air which prevents the odor and any human contact. WWGs are wide used in Europe and in the world with their high capacity of recycling in the biospheric cycles.

Another recommended system is Membrane Bio Reactors. MBR is the last step of the technology. It requires minimal land area and the advanced technology is used. After recycling, you can decide to keep the nitrogen in the water or not. It is highly used in municipal or industrial wastewater treatments. It has 2 types, external and internal. In case of the limited land, internal systems are recommended due to size of the system is smaller. For Girne Park, MBR systems are very suitable with minimum ground area and utmost technology in cleaning water.

## 4. PART IV

### 4.1. WWT and Governmental Structure of Water in Cyprus

- **South Cyprus**

With its participation to European Union in 2004 South Cyprus has been developing itself in terms of many cases. The economy of Cyprus is classified by the World Bank as a high-income economy. However banking and financial crises in 2012-13 had affected the South side of the island's economy in a negative way and caused many banks such as Laiki to shut.

Since its independence from the British in 1960, in order to cope with water drought SC gave an utmost effort to develop not only existing dams but also to construct waste water plants also desalination plants.

At present, there are eight sewage treatment centers in operation in Cyprus that supply treated water for crop irrigation, although not for vegetables, which are consumed fresh. They churn out some 14.5 million liters of water annually. There are currently two desalination plants operating on the island, in Larnaca and Dhekelia, which are expected to produce 30 million cubic meters this year. They supply the Nicosia, Larnaca and Famagusta districts. (http://www.cyprusresalesdirect.com/news/ news_08aug07/). There are also plans for extra 3 water desalination plants all arranged to be completed by the end of 2013. Besides this the Agriculture Ministry Fotiou has announced that a temporary, floating plant, should be ready to commence operations by May next year, as a temporary measure.

The largest development project in Cyprus since independence was the Southern Conveyor Project, which collected surplus water from the southwestern part of the island and conveyed it by a 110-kilometer long water carrier to the central and eastern areas (http://en.wikipedia.org/wiki/Agriculture_in_Cyprus).

Limassol desalination plant

Source: jpost.com

Dhekelia desalination plant

Source: velatia.com

- <u>Governmental Structure of Water in South Cyprus</u>

The policy control of water management in SC is at present divided between 3 divisions:

1- Ministry of Agriculture, Natural Resource and Environment

2- Geological Survey Department

3- Department of Agriculture and Environment Services

Basically water management is organized as: Ministry of Agriculture, Natural Resources and Environment in **Policy Setting Level**- Ministry of the Interior and Ministry of Finance are involved, Water Development Department (WDD) in Executive/ **Regulatory Level** and Local Water Boards, Municipal Boards and Village Boards in **User Level**. Water Supply and Sanitation, Sewerage services are managed by different water boards separately. The role of the Private Sector Involvement in Water management can only be in desalination plants and it is limited with 10 years. Apart from all, there is Drought Management Committee set up by the government with the responsibility of implementing measures of mitigating the adverse effects from drought and to mitigate water scarcity problems.

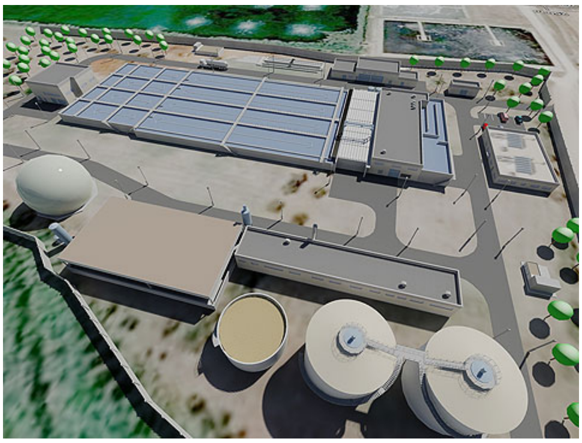
As an organizational structure, Water Development Department is established in 1896 as a Section of Public Works Department, with responsibility for domestic water supply and irrigation. Many laws are set according to the standards of EU Directives. One of the most important laws is; “The biggest challenge will be the compromise between conflicting and competing uses and at the same time protecting the resource and using it in a sustainable manner.”

- **North Cyprus**

Compared to South Cyprus unfortunately North Cyprus has very poor conditions in terms of water treatment. However with the utmost effort of the government and guarantor country Turkey, NC is developing step by step in terms of treating the waste water. In Cyprus (both South and North), the total number of the main Wastewater Treatment Plants currently in operation is 25 (European Water11/12: 63-69, 2005). 3 of these plants are used for desalination.

The biggest treatment plant in North is Nicosia Bi-communal Waste Water Treatment Plant located in Haspolat. It is the biggest plant on the island and used by both communities. The constructed completed in 2010 with the cost of €25 Million. First the project’s master plan was drawn by the Cyprus Government in 1960 aiming to connect both sides socially, economically and politically and also maintaining central sewerage system of Nicosia.

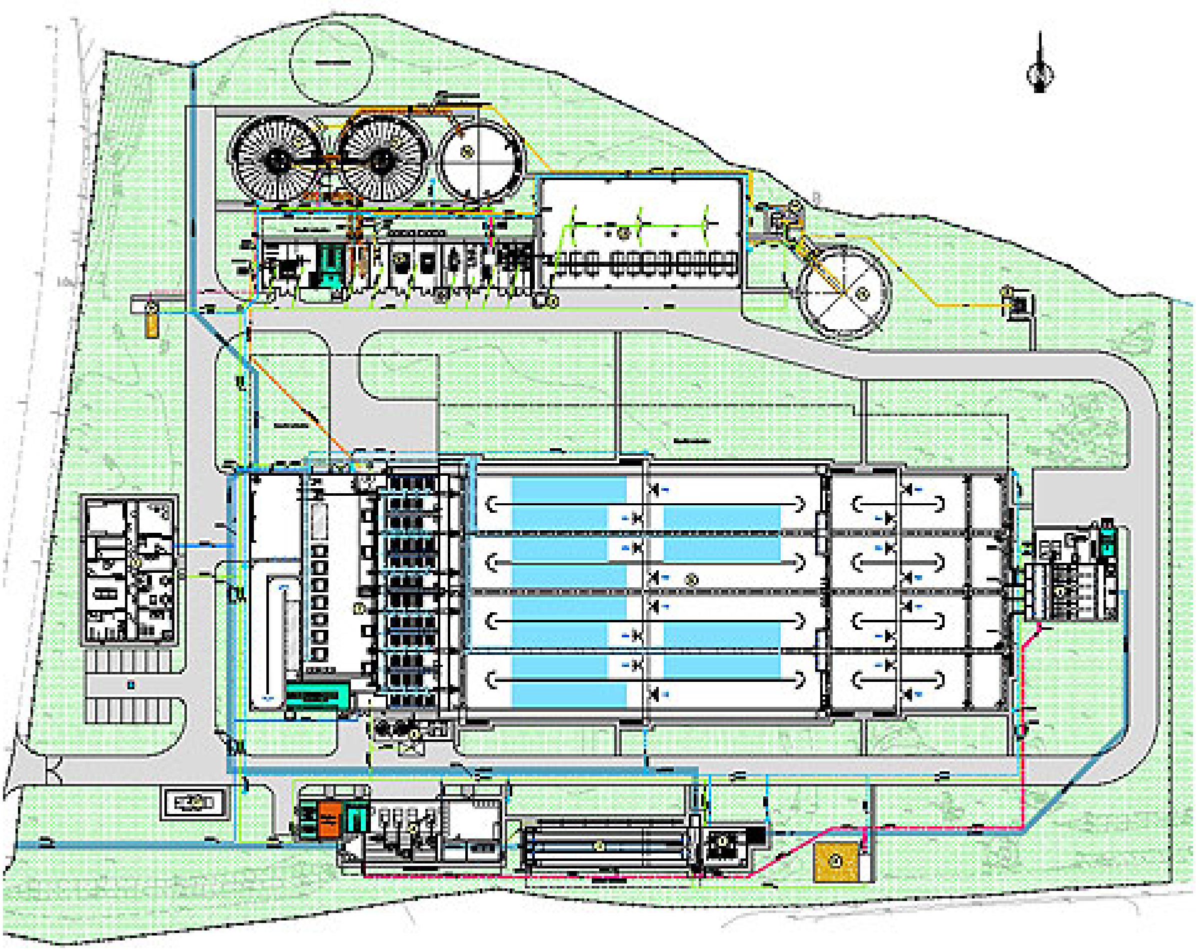
Fig.4.1: Nicosia Bi-Communal Waste Water Treatment Plant

Source: http://www.water-technology.net/projects/nicosiawastewatertre/

Around 270,000 of Nicosia's inhabitants will benefit from the treatment plant, which will be one of the largest installations based on membrane bioreactor (MBR) technology. The Nicosia plant has a capacity to produce ten million cubic meters of water a year, which will be used to irrigate agricultural land. The plant is also expected to produce 3,333t of dry bio-solids, which can be used as a natural fertilizer. Green electricity may also be generated by converting the energy content of bio-solids. A new inlet pumping station had built to connect the inlet trunk sewer. Wastewater from the inlet pumping station made to flow towards the screening system (http://www.water-technology.net/projects/nicosiawastewatertre/).

Fig. 4.2: Plan of Lefkosa WWT Plant



Source: http://www.water-technology.net/projects/nicosiawastewatertre/nicosiawastewatertre4.html

WTE Wassertechnik was responsible for designing, building, operating and transferring the system for the following 10 years. The construction carried by Turkish firm Emek Construction.

Apart from the Bi-Communal WWTP, there are many some and middle-scale plants, for example “Tahal Desalination and Purification Plant” in Bafra Holiday Village with the capacity of producing 2.000 $m^3$ water a day. Many projects planned for Girne Region are holding.

- <u>Governmental Structure of Water in North Cyprus</u>

The policy control of water management in NC is at present divided between 2 divisions:

1- Ministry of Agriculture, Natural Resource and Environment

2- Department of Water Works

Apart from that there is a Department of Harbors, controlling the imports exports, maintenance about the harbors also controlling the level of water but unfortunately there is no water section connected to this department neither there is a drought management in North Cyprus. Water scarcity might be underestimated, as a result of this whenever there is reduction in the amount of rain, the society is facing with a water shortage during days.

4.2. <u>Case Study: Romanos Hotel, Greece</u>

Romanos Costa Navarion hotel is a 5 stars hotel located in the south west of Greece. The hotel contains 321 luxurious rooms and suites, including 121 with individual infinity pools. The hotel was opened in 2010 and is operated by Starwood Hotels under their 'Luxury Collection' brand. Costa Navarino has put a strong emphasis on environmental responsibility. All properties being developed in the destination must meet strict environmental standards in order to protect the landscape for future generations. For this project, a German company for waste water technologies supply had designed 1000 $m^3$/day Membrane Bioreactor (MBR) ultra filtration system to treat the waste water. The treated water is planned to use for irrigation of the golf course and surrounding landscape.

Fig. 4.3: Romanos Hotel Visualization and WWT Handling System


Source: http://www.huber.de/huber-report/ablage-berichte/greenbuildings/romanos-hotel-greece.html?popup=1

## 4.3. Case Study: Los Cabos Hotel & Resort - Baja California, Mexico

The Pueblo Bonito Sunset Beach Hotel is a 5 star hotel and resort located in Baja Peninsula in Mexico. The hotel contains 327 bedroom suites with 10 swimming pools. Again the same German company supplied a 130 m³/day Membrane Bioreactor (MBR) ultra filtration system for waste water, which is used for irrigation. Due to water scarcity in the region, waste water treatment technologies were very important during designing process. Nowadays many hotels around the area are designed with improved water treatment technologies for sustainability and environment.

Fig. 4.4: Los Cabos Hotel & Resort WWT Application

Source: http://www.huber.de/typo3temp/pics/7af8d8deae.jpg

D. Summary of Part IV

After its independence Cyprus has been developing itself in terms of sustainability. Many dams are fixed at the south and some new desalination plants had constructed. The governmental control of the water starts from the ministry of agriculture at top, geological survey department and to the department of agriculture and environment services. Water is vital on the island for crop irrigation and fresh usage. Also south has newly structured Water Drought Management in order to focus more on water problem and produce solutions. The biggest plant on the island is located in Nicosia and shared by the both communities.

On the other hand, North Cyprus is developing itself in terms of sustainability with the financial help of Turkey. Yet, compared to South Cyprus, development in the North is slower process. The Haspolat treatment plant takes place in the North Part of Nicosia. It serves for 270.000 inhabitants of Nicosia and the system is based on Membrane Bio-Reactor Treatment. Apart from Haspolat Bi-Communal WWTP, there are few small and middle scale plants, constructed for hotels or holiday villages.

The Governmental Structure of TRNC about water is connected to Ministry of Agriculture, Natural Resource and Environment at the top level and at the second level Department of Water Works is responsible for water management. However there is a need of separate sub-division in regional level, for example Water (trafficking) Controlling Department.

# 5. PART V

## 5.1. Redesign of “Girne Kordonboyu Park” with WWT Application

The city of Girne (Kyrenia) consists of dense buildings and narrow streets. Mostly the buildings are 2 or 3 floors, the ground level used as shops and retails, the upper floors used for residence. Fast development in tourism and economy, over population and immigration results in new construction of apartments, hotels and shops. However the city is certainly in need for open, green spaces where people gather together, relax and enjoy their time.

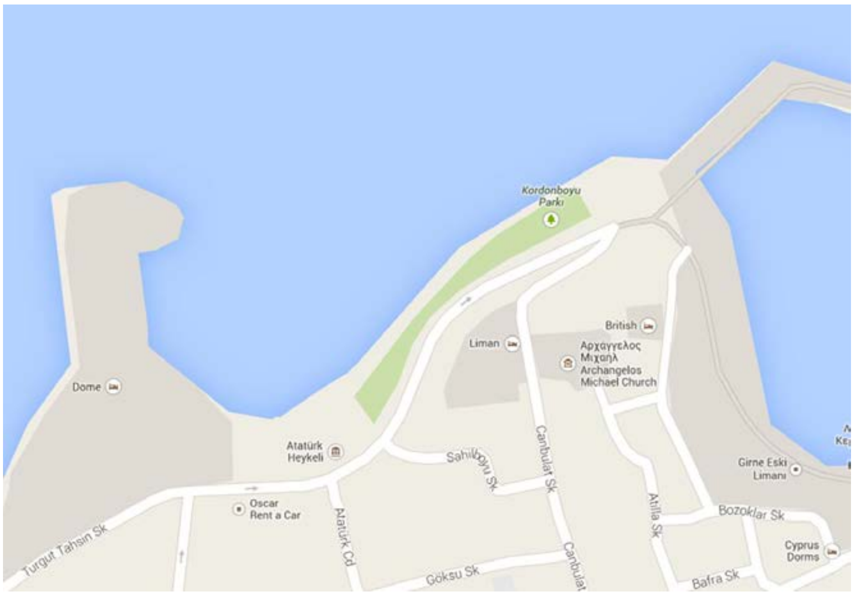
The design aims to provide an open space for the people at the same time to use water treatment technology in order to save and reuse the waste water from the surrounding hotels also to increase the consciousness in the society. Another point of the system is to protect natural marine life on the coast and prevent the endangered species die out.

### 5.1.1. Analysis of the Project Area

The area takes place in Turgut Tahsin Street, crossing with Atatürk Street, Girne-North Cyprus. It is approximately 4.700 m² and lies parallel on the harbor. The area is without a doubt the most busy and attractive part of the city. Every year many tourists who visit the TRNC are attracted in this historically variable and rich, unique quarter of the city. Also it is an indispensable destination of Cypriot families to take a walk in the park with their kids or for young people to hang out with their friends.

The height from sea level on the west part starts with nearly 3 meters and continues up to 6 meters. The depth of the sea is estimated 7 to 10 meters.

Fig. 5.1: Location of Project Area




Source: googlemaps.com

The area has its own curved shape which is adapted to the old harbor constructed by Romans for trade purposes. At the end of the harbor is the famous Girne castle from the Byzantine times, it was constructed to protect the city against Arab attacks. Mostly the buildings surrounding the horse shoe shaped harbor are constructed by Lusignans and Venetians. The buildings used to be warehouse for import and export; nowadays they protect their main characteristics with traditional yellow-stone, historical arches with keystone, wooden balconies and wood frame around windows and these buildings function as cafes and restaurants.

The existing landscape consists of palm trees, oleander, date palm, cheesewoods, cactus and similar vegetation. Though, sufficient landscaping on the area is missing due to lack of water, salt and maintenance problems. As can be seen on Fig. 7.8 the existing shrubs are ruined or died.

Fig. 5.2: Shrubs are in bad condition in the park

Source: TRNC Ministry of Forestry

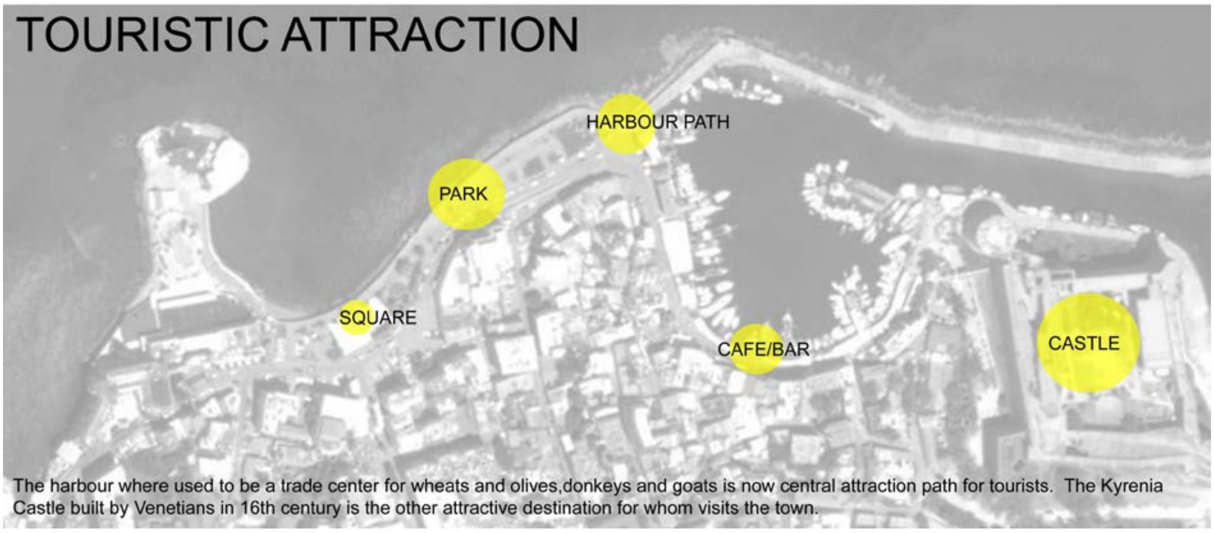
Mostly in this historical part of the city, the houses are historical and protected. Although newly built houses and hotels disturb the pattern of the area. Almost all ground floors are for commercial purposes, while the upper floors are used for residential purposes. The lack of the green in density is obvious.

Fig. 5.3: Zoning map of the Area


Source: Googlemaps.com, drawing by Author

In terms of tourism the area provides a unique selection of different style architecture, up and down topography, pleasant weather and relaxing time near the sea. The castle at the end is the most tourist receiving point. Mostly people follow the route coming from the central bus station in the center of the city, through narrow shopping streets and to the harbor, last stop is the castle. Relaxing at a café on the harbor at the evening, watching a football game is like a habit of the public.

Fig. 5.4: Tourist Attraction Points on the Area




Source: Googlemaps.com, drawing by Author

Speaking about narrow streets we must mention that traffic is one of the obstacles of the city. Generally the roads are one way or limited entry. Increasing number of taxis carrying tourist and private cars of people obstructs the traffic flow. Middle or big size vehicles are not allowed in the city roads. About the specific area, which you can see with the red line, there is a time limited entrance to the harbor. Usually on the weekends evening 1 km long lane is open to vehicles which limits the space for public and disturbs the vision.

Fig. 5.5: Traffic Map of the Area


Source: Googlemaps.com, drawing by Author

### 5.1.2. Design

"A park works if it is accepted and perceived as part of the city….. Parks mean freedom and community, repose and recreation. Parks need to be multifunctional, ecological and cultural, open to their users and even open to the city. Park design needs to become social art and collective creativity" (Topos 55, pp16, 17. 2006).

The design is mainly divided into 3 zones; on the east is a multipurpose area for events, in the middle there is a large green lawn and last part is an open hard surfaced area with rounded sitting benches. The organic form of the road represents the organic structure of the city's streets. It connects the asphalt traffic road with the historical cobblestone through the coast. The existing time-limited vehicle access into the historical center is suggested to be closed and the service delivery to the buildings facing to the sea should be provided from the backside. The children playground in the middle is surrounded by dense vegetation for the security. The slope of the site is taken into account and east part of the park is designed as continuous stairs for a nice view under shadow. The rounded benches are planted with native shrubs and palm trees in the middle. All the materials should be traditional and the vegetation should be the native plants which are drought resistant and don't require much water. Recommended plants for the Girne Park:

- Quercus ilex
- Nerium Oleander
- Prunus dulcis
- Euphorbia dendroides
- Iris foetidissima
- Olea europaea
- Acacia cyanophylla
- Begonia x benariensis
- Phoenix dactylifera

In the existing park there are: *Melia azedarach*, *Nerium Oleander*, *Washingtonia filifera*, *Tamarix articulata*, *Cycas revoluta*, *Pittosporum tobira* and *Phoenix dactylifera*.

Fig. 5.6: Phoenix dactylifera

Fig. 5.7: Melia azedarach

Source: http://www.palmdoctor.com/images/Palms/Phoenix_dactylifera2.gif

Source: http://www.dinsan.com.au/media/159289/melia-azedarach-land.jpg

Kyrenia Park Design

The MBR water cleaning tank takes place underground in the middle of the park. The pipes from the hotels and cafes around will be connected to the system and there will be an extra pipe from tank up to closest hotel's roof in order to prevent the odor. The MBR will clean the water and be used for the irrigation of the park. The extra recycled water can be distributed to the cafes and restaurants around or to the residences for domestic uses.

Kyrenia has huge parking problem due to lack of parking lots. There are 2 car parks designed on the site. These will serve only for the visitors and limited with maximum 2 hours parking. Lastly, the café on the edge will be renovated and extended with a terrace to the sea.

Another point of the system is; it is suggested to be taken as a module and can be used multiple units of the system under the park which can be connected to the historical buildings along the harbor and recycle the water constantly. Additionally, another idea which can be applied is setting voltaic solar panels on top of these hotels roof. Since Cyprus receives high amount of sun, the solar panels can produce all the electricity needed for the wastewater treatment plants pumping. Even there can be much produced electricity than needed which can be used in the hotels or buildings around it. The further research must be done for the exact outcome.

## E. Summary of Part V

The aim of the design is to enhance the space quality, provide green open space for public with using sustainable technology. The park is the busiest and attractive part of the city located in Turgut Tahsin street. The total area is nearly 4.700 $m^2$ and it is parallel to the harbor. The area is 3 to 6 meters up to sea level. There are many historical buildings especially surrounding the horse shoe shaped harbor where these buildings turn into cafes and bars. Mostly the buildings around the project area have commercial function on the ground floor and residential on the upper floors.

The design concept of the park comes from the organic streets of Kyrenia. Junction points of the streets leads people into the park. With the large trees and high shrubs, during hot summer days the park creates a pleasant stay under the shadow. Generally there are 3 zones, first is the multipurpose area where is hard surface and platform to the military ceremonies or any other events. There is continuous series of wood-concrete benches on the east side of the area where people may sit and watch the events. In the middle part there is a wide meadow for sitting or lying down. In the very center of the middle part is a children playground, it is surrounded with dense vegetation for security reasons and also as space definer. The top end part of the park is hard surface urban plaza with raised bed around palm trees and round benches. Next to the hotel building, the slope of the site has taken into consideration and used as horizontal stairs for nice view to the sea and the plaza.

Since the sustainability is the main goal to achieve, apart from MBR system under the park, there are solar panels designed on top of the high hotel buildings in order to produce the needed electricity for pumping of MBR system.

# 6. PART VI

## 6.1. Global Warming

Global warming or in other words climate change is one of the biggest dangers of our century. Greenhouse gases and fossil fuels keep the heat close to the earth’s surface. With the start of industrialization in 1700s human beings started to emit much more of fossil fuels. As a result of this; global warming, melting of the icebergs, die out of many species and loss of lands are inevitable. Strong impact of climate change will threat on the water resources.

A new analysis, performed by consulting firm Tetra Tech for the Natural Resources Defense Council (NRDC), examined the effects of global warming on water supply and demand in the contiguous United States. The study found that more than 1,100 counties -- one-third of all counties in the lower 48 -- will face higher risks of water shortages by mid-century as the result of global warming. More than 400 of these counties will face extremely high risks of water shortages.

Fig. 6.1: Global Warming Effects on the Icebergs

Source: http://www.dosomething.org/actnow/

Average temperatures have climbed 1.4 degrees Fahrenheit (0.8 degree Celsius) around the world since 1880, much of this in recent decades, according to NASA's Goddard Institute for Space Studies. For further interest about human effected climate change, a movie "*The Inconvenient Truth*" is suggested to watch.

"It is the increase of Earth's average surface temperature due to greenhouse gases, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise escape from Earth." (http://www.dosomething.org/actnow/).

## 6.2. European Union's Role on the island

Cyprus became a member of European Union in 2004. On the other hand Northern Cyprus and the European Union have somewhat strained relations based on the fact the European Union (EU) does not recognize Northern Cyprus (formally, the Turkish Republic of Northern Cyprus) and sees it as a military occupation of one of its member states… Aside from complicating the accession of Turkey to the European Union, it has placed the north in international isolation. It was hoped that the accession of the south in 2004 would provide the catalyst for unification so the two halves could join the EU as one country on 1 May 2004. However, the unification plan was voted down by the population of the Republic of Cyprus (http://en.wikipedia.org/wiki/Northern_Cyprus_and_the_European_Union).

Cypriots who were born after 1974 (I. Peace Action of Turkey on the island) cannot become a Cyprus citizen and cannot travel anywhere outside Turkey. Plus they do not hold EU passports which gives them the opportunity to study or live in EU countries. However they can have the right to get a Turkish passport but for the citizenship of Turkey they should deal with papers and go over a process. In a referendum plan offering peace and unity, presented by seventh Secretary-General of the United Nations Kofi Annan in 2005, it was hoped that North Cyprus would join in Union together with the South. The plan was invalidated by the veto of South Cyprus.

All these privileges given to South Cyprus excluded North Cyprus from the benefits of the Union. Despite this all the country applies sustainable solutions in all cases with the help of Turkey. Hopefully there will be a peaceful solution between both parts of the country in the near future.

## 6.3. Solutions for Effective Water Usage

There are many ways to save the water with very simple precautions. First of all we should understand that water is not a non ending spring. We should educate our children from a very early age about the importance of water. When we understand the sensitivity of topic they will understand too.

1. Conscious use of water
2. Desalination
3. Bringing water from Turkey with pipeline
4. Joint programs with South Cyprus
5. Revitalization of existing dams and wells
6. Application of waste water management
7. Sustainable Design

Further precautions,

By public:

-filtering garden taps

-shortening bath time

-washing cars at the car wash not at home

-going to public beaches or pools instead of constructing their own

-collecting rain water with a shallow pit in their gardens for irrigation use

-putting 1 liter water bottle in the flush box in order to reduce flushing amount

-peeing in the bath during shower (if its needed)

By government:

-monitoring of groundwater usage (illegal water trafficking)

-forming a drought management structure in government

-teaching about water as mandatory curriculum in primary schools

-Strict laws on water usage / construction of individual pools

Here is an example of a solution which can be applied. So that clean water will not be wasted and saved for drinking or cooking. They are called “eco bath” and becoming popular nowadays.

Fig. 6.2: Sustainable Solutions in order to Save Water


Source: http://the-nicest-pictures.blogspot.de/2013_05_01_archive.html
Source: http://www.generalhydroponics.com/blog/wp-content/uploads/2011/08/water-garden.jpg

## F. Summary of Part VI

Global warming is without a doubt big danger of our era. By melting of icebergs, high emitting of fossil fuels, in very near future water resources will be threatened and many countries will face with the water problems. Immediate precautions must be taken and sustainable solutions must be applied around the world.

European Union has very dominant effect on Cyprus. Since South Cyprus became a member in 2004, the role of the EU became more important. Unfortunately the Turkish side of Cyprus could not participate in the Union due to veto of South Cyprus following a referendum proposed by Kofi Annan in 2004. Since that time EU supports the South Cyprus in many fields especially sustainability projects. By this help SC achieved many desalination plants also some small-medium scale water treatment plants. In the North part, Turkey is the main financial supporter.

Although carrying water with balloons from Turkey was not a sustainable solution, nowadays North Cyprus is preparing to opening of the biggest project of the century, bringing water from Turkey to the island with underground pipes will solve/help the islands water problem for following 50 years. The aim of this study is to think about further generations and find a stable solution to the problem.

However, apart from constructing dams or plants there are many other solutions which may be very effective in long term. This little solutions start with being conscious about the water consumption. Digging a shallow hole or having an extra water tank open at top in the garden to collect rain water for garden irrigation, shortage of shower time, washing cars and carpets at the gas stations, putting filter on the taps or using beaches or common pools instead of constructing separate pool are some serious solutions of water scarcity.

# 7. PART VII

## 7.1. Conclusion

The water is without a doubt the biggest threat for Cyprus. The island still experiences some water shortages in dry hot summer days due to low amount of rainfall. The problem is not only the lack of rain but also wrong consumption of clean water. People see water as a not ending spring. Careless farmers or even companies dig a pit underground in order to withdraw ground water, this illegal water evasion results of having salty sea water involved into clean ground water. This leads to unhealthy agricultural products with low quality. This chain goes till the farmers to use chemicals in their products.

Apart from this another point is the harm that hotels and/or recreational places give to the marine habitat. Unfortunately due to lack of control and deterrent fines, the hotels especially the ones located near to the sea discharge wastewater directly into the sea, the worse is the pipes end not very far from the beach. According to a private laboratory analysis, the Escheria coli bacteria level approved to be very high in the sea water where these hotels accused to discharge wastewater. No matter how or who, the result is dead caretta carettas and other marine species under protection list. The color of the sea is changed and it is already unhealthy to swim in some specific points.

There are many different levels of solutions. Most of the refinement techniques are explained in this study. By this way the government can encourage also support institutions to apply sustainable solutions. However there are some easy but important precautions that everyone can take. The country will have very serious problems in following decades and we should start acting now.

Last but not least, the most important thing is not to just build hundreds of desalination or treatment plants but to educate our kids, the next generations, be an example for them about conscious consumption of water and raise them as useful, considering and smart individuals for society.

## 7.2. REFERENCES


Elkiran G., *Integrated Water Resources Planning and Management of TRNC*, Dogu Akdeniz University Science Institution, Doctorate Thesis, 2006. 98pp.

ASP, *Agricultural Structure and Production,* Ministry of Agriculture and Forestry, Department of Agriculture TRNC, 1996-2003.

Al Baz I., Otterpohl R., Wendland C., *Efficient Management of Wastewater,* Springer-Verlag Berlin- Heidelberg, 2008.

MEDA Water, SOGESID., *Local Water Supply, Sanitation and Sewage, Country Report Cyprus*., November 2005.

Duraiappah, 1998, *Seminar on the Role of Ecosystems as Water Suppliers* Geneva, 13-14 December 2004.

Sampat 2000, *Seminar on the Role of Ecosystems as Water Suppliers* Geneva, 13-14 December 2004.

Anderson K., Sheffield S. CFT Term Report, *Water Reuse*, September 2006.

Omorphos C., Georgiou A., Skordis P. (Water Development Department) *Water Management in Cyprus: Challenges and Opportunities*, Natioanal Report, 2006.

*Water*, Wikipedia, http://en.wikipedia.org/wiki/Water, page last modified on 30 January 2014.

World Health Organization (WHO). (2008). *Safer Water, Better Health: Costs, benefits, and sustainability of interventions to protect and promote health*; Updated Table 1: WSH deaths by region, 2004.

Kevin Y., Cost Analysis of Membrane Bioreactors to Reverse Osmosis Filters, 2010.

*Cyprus*, Wikipedia, https://en.wikipedia.org/wiki/Cyprus, page last modified on 1 February 2014.

Ensuring the Survival of Endangered Plants in the Mediterranean, http://www.medislandplant.eu/ ,Copyright ©2012

Zachariadis T., *Residential Water Scarcity in Cyprus: Impact of Climate Change and Policy Options.* 2010.

WWF, Cyprus Mediterranean Forests, http://worldwildlife.org/ecoregions/pa1206, © 2014 World Wildlife Fund.

Makhzoumi & Pungetti, *Cyprus Landscape*, http://users.uoa.gr/~kgeorghi/files/20_cyprus_landscape.pdf, 1999.

*Turtles and Conservation in Cyprus,* http://www.aboutcyprus.org.cy/en/turtles-and-conservation-in-cyprus, Copyright © 2012

Cypriot Biologists Nature Research and Protection Association 2005-13.

Kotsila P., *The socio-environmental history of water development and management in the Republic of Cyprus*, September 2010.

Cyprus Environmental Problems Dossier: Salination of Water Resources, http://www.cyprusaction.org/humanrights/environment/waterresources/.

Tanji and Kielen, *Analyzing the trade offs of wastewater re use in Agriculture: An Analytical framework*. November 2002.

*Tourism in Cyprus*, Wikipedia, http://en.wikipedia.org/wiki/Tourism_in_Cyprus, page last modified on 22 November 2013.

Tourism statistics for the period January-August 2003: North Cyprus Ministry of Economy and Tourism.

Enzler S.M. *History of Water Treatment,* Copyright © 1998-2014.

www.water.worldbank.org, © 2014 The World Bank Group.

*Wastewater Treatment Methods and Disposal*, http://water.me.vccs.edu/courses/ENV149/methods.htm.

*Wastewater Chemical Process*, http://www.thomasnet.com/articles/chemicals/wastewater-chemical-treatment, Copyright© 2014 Thomas Publishing Company.

Wilderer and Schreff, 2000; *Crites and Tchobanoglous*, 1998.

Hartmann, 1999; Wilderer and Schreff, 2000; Burian et al, 2000.

Hophmayer-Tokich S., *Wastewater Management Strategy: centralized v. decentralized technologies for small communities,* http://www.utwente.nl/mb/cstm/reports/downloads/wastewater_management_strategy.pdf

Bakir, 2001; UNEP/GPA, 2000; Jackson, 1996.

*Stabilization Pond*, Wikipedia, http://en.wikipedia.org/wiki/Stabilization_pond, page last modified on 19 March 2013.

Kiavisi K., *The Potential for Constructed Wetlands for WWT and Reuse in developing Countries*, 5 June 2000.

Vymazal J., Kröpfelova L., *WWT in Constructed Wetlands with Horizontal Sub-Surface*, 2008.

Yadov M. and Dharmendra, *A Critical Review on Performance of Wastewater Reuse Systems*, Volume 4, Number 3 (2014), pp. 233-238.

Gitiri Kamau C., *Constructed Wetlands: Potential For Their Use In Treatment Of Grey Water In Kenya*, http://www2.gtz.de/Dokumente/oe44/ecosan/en-constructed-wetlands-potential-for-use-2009.pdf , March 2009.

Jan &Lenka *WWT in CW with FWS*, 2008.

*Types of Constructed Wetlands for Wastewater Treatment*, http://link.springer.com/chapter/10.1007/978-1-4020-8580-2_4, Volume 14, 2008, pp 121-202, 2008.

*Constructed Wetland*, Wikipedia, http://en.wikipedia.org/wiki/Constructed_wetland, page last modified on 21 January 2014.

*Wastewater Gardens*, http://www.wastewatergardens.com/1en_overview.html

Yeo K., *Cost Analysis of Membrane Bioreactors to Reverse Osmosis Filters*, Spring 2010.

Ovivo MBR System, http://www.treatmentequipment.com/files/mbr/mbr_brochure.pdf, Copyright 2011.

*Membrane Bioreactor*, Wikipedia, http://en.wikipedia.org/wiki/Membrane_bioreactor, page last modified on 10 November 2013.

Sutton M. P., MBR for Industrial WWT: *Applicability and Selection of Optimal System Configuration*, http://www.environmental-expert.com/Files/5306/articles/11542/259.pdf, Copyright 2006.

*Cyprus to Introduce Desalination Plants*, http://www.cyprusresalesdirect.com/news/news_08aug07/.

*Agriculture in Cyprus*, Wikipedia, http://en.wikipedia.org/wiki/Agriculture_in_Cyprus, page last modified on 2 July 2013.

Fatta D., *Wastewater Reuse: Problems and Challenges in Cyprus, Turkey, Jordan and Morocco*, European Water11/12: 63-69, 2005.

*Nicosia Bi-Communal  Wastewater Treatment Plant, Cyprus*, http://www.water-technology.net/projects/nicosiawastewatertre/, Copyright 2012.

*Parks*, Topos 55, pp16, 17. 2006.

*11 Facts About Recycling*, http://www.dosomething.org/actnow/.

*Northern Cyprus and the European Union*, Wikipedia, http://en.wikipedia.org/wiki/Northern_Cyprus_and_the_European_Union, page last modified on 7 January 2014.

"The Economist Intelligence Unit's quality-of-life index" (PDF). Economist Intelligence Unit. 2005. Retrieved 2 August 2011.

Agriculture Product Pictures, page 34:
http://www.starch.dk/isi/starch/img/barley.JPG,
http://www.organicgardening.com/sites/default/files/images/tomato-tips-380-1.jpg
http://www.pyroenergen.com/articles09/images/molokhiya2.jpg
http://ipinionsyndicate.com/wp-content/uploads/2013/02/chickpeas.jpg
http://tiszaivandor.com/wp-content/uploads2011/06/almond.jpg
http://www.prlog.org/10661275-lemon-detox-diet-recipe-maple-syrup-cayenne-pepper.jpg

References Design Poster 01 Plant Photos

Euphorbia_dendroides : http://upload.wikimedia.org/wikipedia/commons/9/9f/Alc%C3%BAdia_-_Cami_de_Manresa_-_Euphorbia_dendroides_03_ies.jpg

Prununs dulcis: http://m0.i.pbase.com/g3/99/524399/2/55740270.DSC02726.jpg

Quercus ilex: http://www.biolib.cz/IMG/GAL/BIG/65023.jpg

Iris foetidissima: http://upload.wikimedia.org/wikipedia/commons/5/52/Iris_foetidissima-flower-5.jpg

Olea europea: http://upload.wikimedia.org/wikipedia/commons/7/73/Olea_europaea_group.jpg

Begonia x benariensis: http://www.benary.com/article-images/begonia-x-benariensis-big-rose-with-bronze-leaf-c4130-38.jpg

Acacia cyanophylla: http://traglor.cu.edu.tr/objects/objectFile/10_4_2008_22_18_27_acacia_cyanophylla.jpg

Nerium oleander: http://www.photomazza.com/IMG/jpg_Nerium_oleander_c_Giuseppe_Mazza.jpg

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