

Good Practice Examples on the Utilization of Treated Wastewater for Irrigation Purposes

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Content

- Facts and figures that constitute the driving forces for the development of non-conventional water resources
- The main Water Scarcity Initiatives that constitute the framework of Ww reuse
- The existing situation in regards to water resources available and Ww treatment in various MED countries
- Selected success stories
- Problems and good practices associated with Ww reuse
- Positive and negative effects of Ww reuse
- The context of designing a reuse scheme
- Challenges ahead – The Medaware Project

Water Imbalance

- mainly in the summer months

- *due mainly to the*:
  - relatively and uneven distribution of precipitation
  - high temperatures
  - increased demands for irrigation water
  - impacts of tourism

- Total population, (Med countries) - **427 million** (yr 2000).
  - It was 285 million in 1970, presenting an increase of 142 million, or 50%, in thirty years.

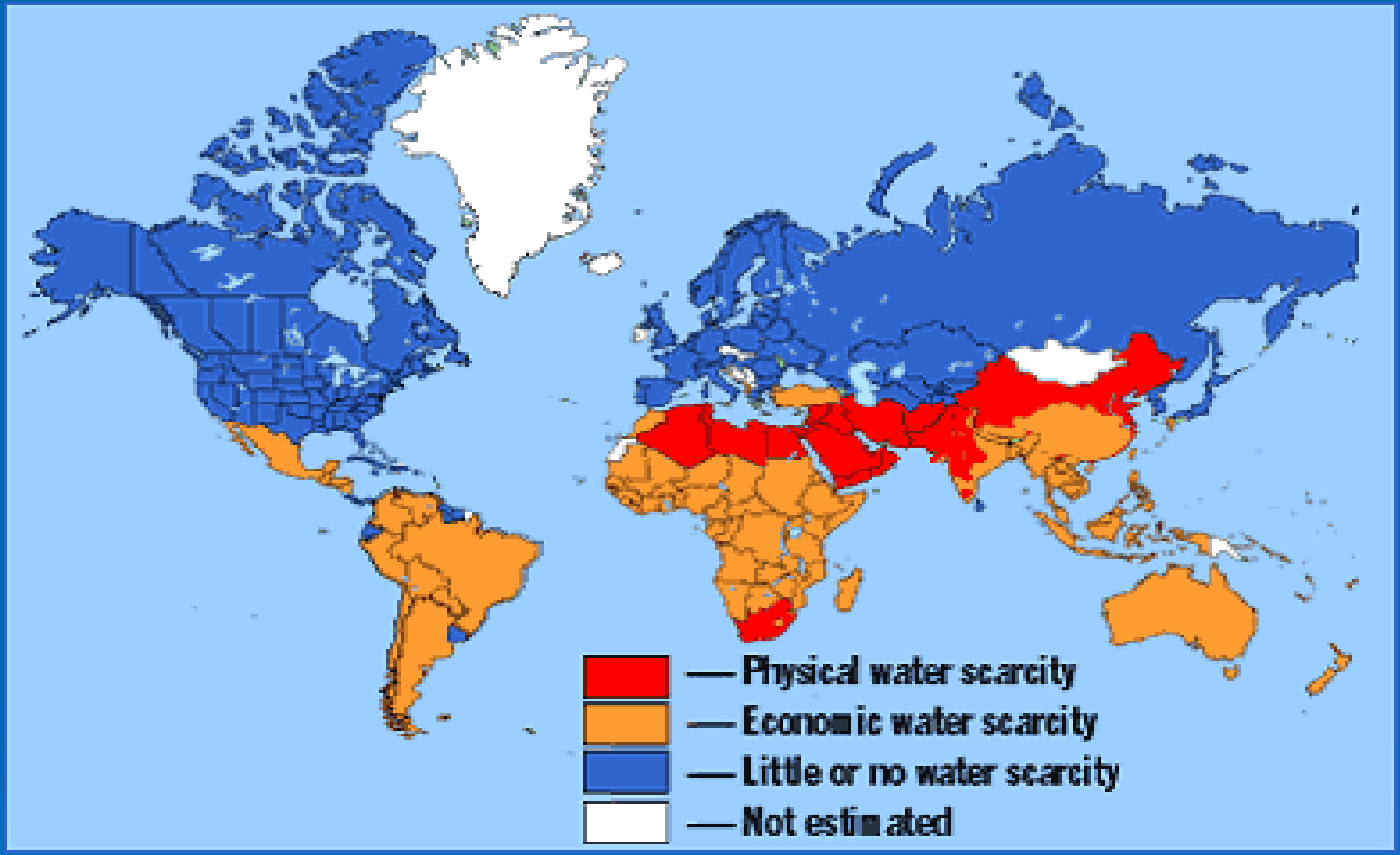
- ….Population at **523.5 million by 2025**, which demonstrates a certain decrease in the population growth rate with a little under 97 million (or 22.5% increase) additional inhabitants in 25 years.

- Presently the average rate of urbanization is at 64.3%, while it is expected to reach 72.4% by 2025.
  - This rise is mostly due to the urban growth in the southern and eastern countries.

- In absolute terms the **urban population** of all Mediterranean countries - 274.5 million in 2000 - will reach 379 million by 2025.

The Population dynamic is the main factor that:

- **influences the most basic needs**
  - determining the consumption of all sorts of resources
  - provoking the most direct environmental pressures

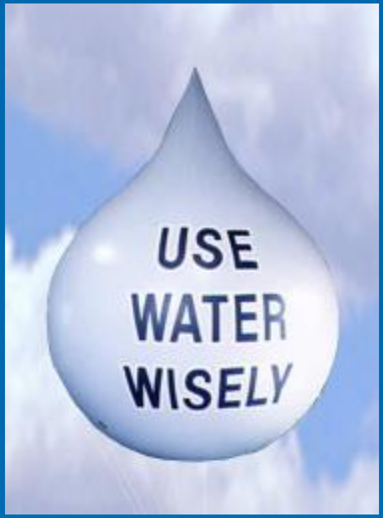


In many situations in various countries wastewater is simply too valuable to waste!

Water Scarcity / Initiatives

- The Mediterranean Water Chapter (Rome in 1992) → new resources of water

- Declaration of the Euro-Mediterranean Ministerial Conference (Turin)
  - integrating water resources management into sustainable development policies
    - participation of the civil society, water users, organizations at local, regional and national level
  - mobilization of non-conventional water resources

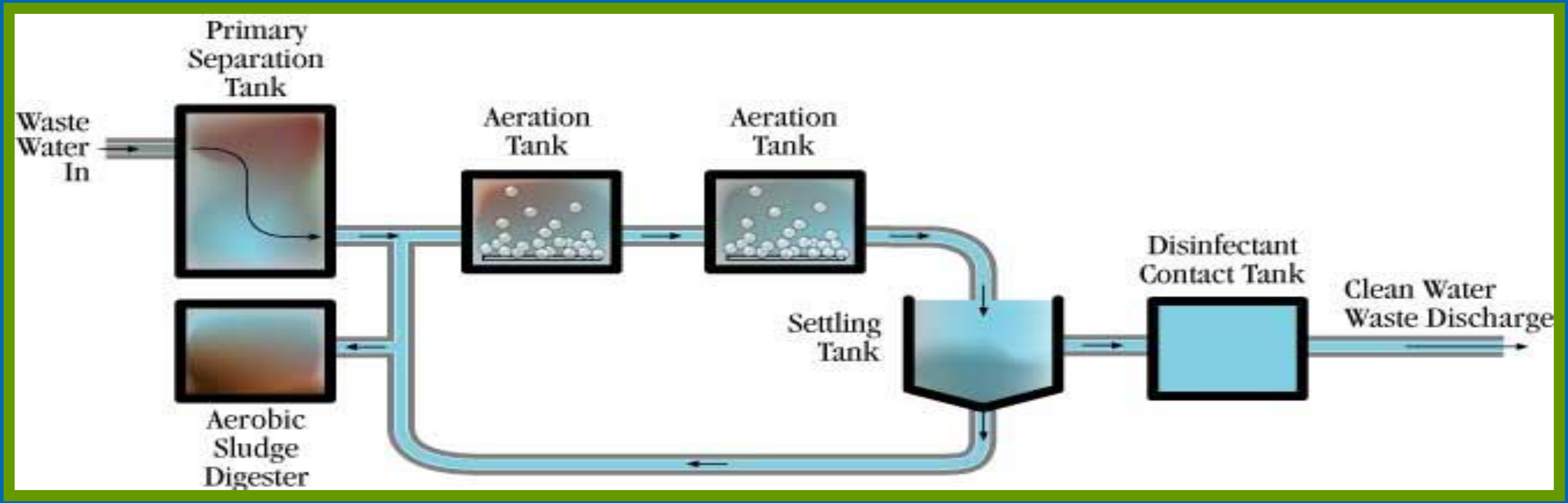


Fresh Water

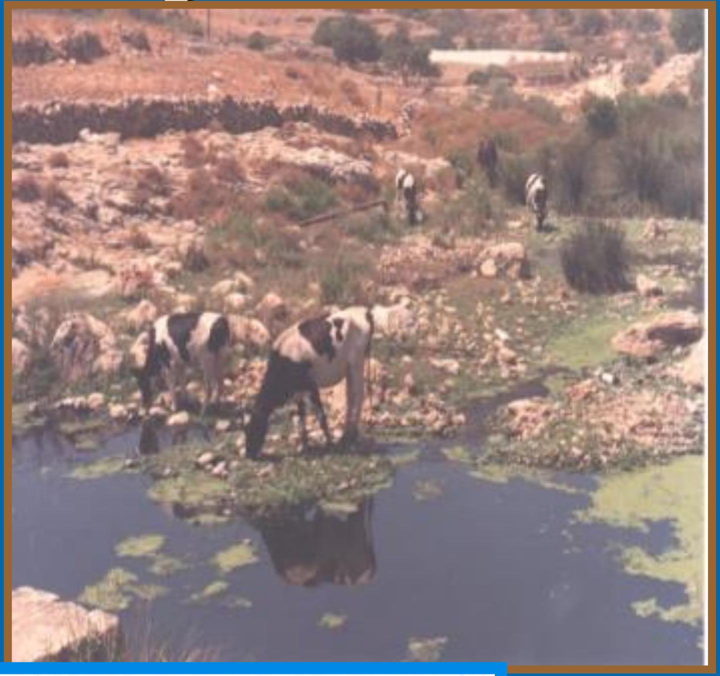
- is limited
- its quality is under constant pressure
- Preserving freshwater quality is important for drinking water supply, food production and recreational water

The Role of Wastewater

- To alleviate water shortages serious consideration must be given to wastewater reclamation and reuse
- Treatment of wastewater provides an effluent of sufficient quality that it should be put to beneficial use and not be wasted


Primary Separation Tank
Waste Water In
Aeration Tank
Aeration Tank
Disinfectant Contact Tank
Clean Water Waste Discharge
Settling Tank
Aerobic Sludge Digester

Cattle drinking from contaminated waters



Grey wastewater stream discharged
through open channels

Wastewater discharge area

Alfalfa crops in Beit Lahaya area

Orchard trees irrigated
with reclaimed wastewater

Rainfall, Water Resources Available and Water Demand

Country	Average Annual Rainfall (mm)	Water resources available (surface, groundwater) MCM/yr	Water demand MCM/yr
Cyprus	465	300	265.9
Jordan	semi desert <200	780	810
	Arid 200-350		
	Semi arid 350 - 500		
	Semi humid > 500		
Lebanon	Coastal Areas: 700 – 800	Surface Water: 2600 Ground Water: 400 – 1000 Average 3300	1400
	Mountain areas: 1200 –2000		
Morocco	NW > 500	30000	11000
	High points in the med region >1500		
	East < 200		
	South <100		
Palestine	Mountain areas 700	295	354
	N and W 400		
	S 200		
Turkey	580-1300 mm	110000	42000

Treated Wastewater Produced and Reused

Country	Treated wastewater produced MCM/yr	Wastewater reused MCM/yr	Treated Wastewater Reused / Treated Wastewater Produced
Cyprus	20	5	0.25
Jordan	73	73	1
Lebanon	6	No data available	No data available
Morocco	40	70 (Not treated)	Not applicable
Palestine	30	5.44	0.18
Turkey	1245	No data available	No data available

Selected Success Stories

Examples

- **U.S.**: municipal water reuse accounted for 1.5% of total freshwater withdrawals in 2000
- **Tunisia**: recycled water accounted for 4.3% of available water resources in 1996 and may reach 11% in 2030 (~ 25% of the treated effluent is being reused)
- **Israel**: it accounted for 15% of available water resources in 2000 and may reach 20% in 2010
- **Kuwait**: 10% of the treated effluent is being reused
- **Cyprus**: 25% of the treated effluent is being reused
- **Palestine**: 18% of the treated effluent is being reused

Cyprus

Larnaca Wastewater Treatment Plant

Location: Meneou Area, behind the international airport of Cyprus

Year of the project development: plant in operation since 1995, reuse in 2000

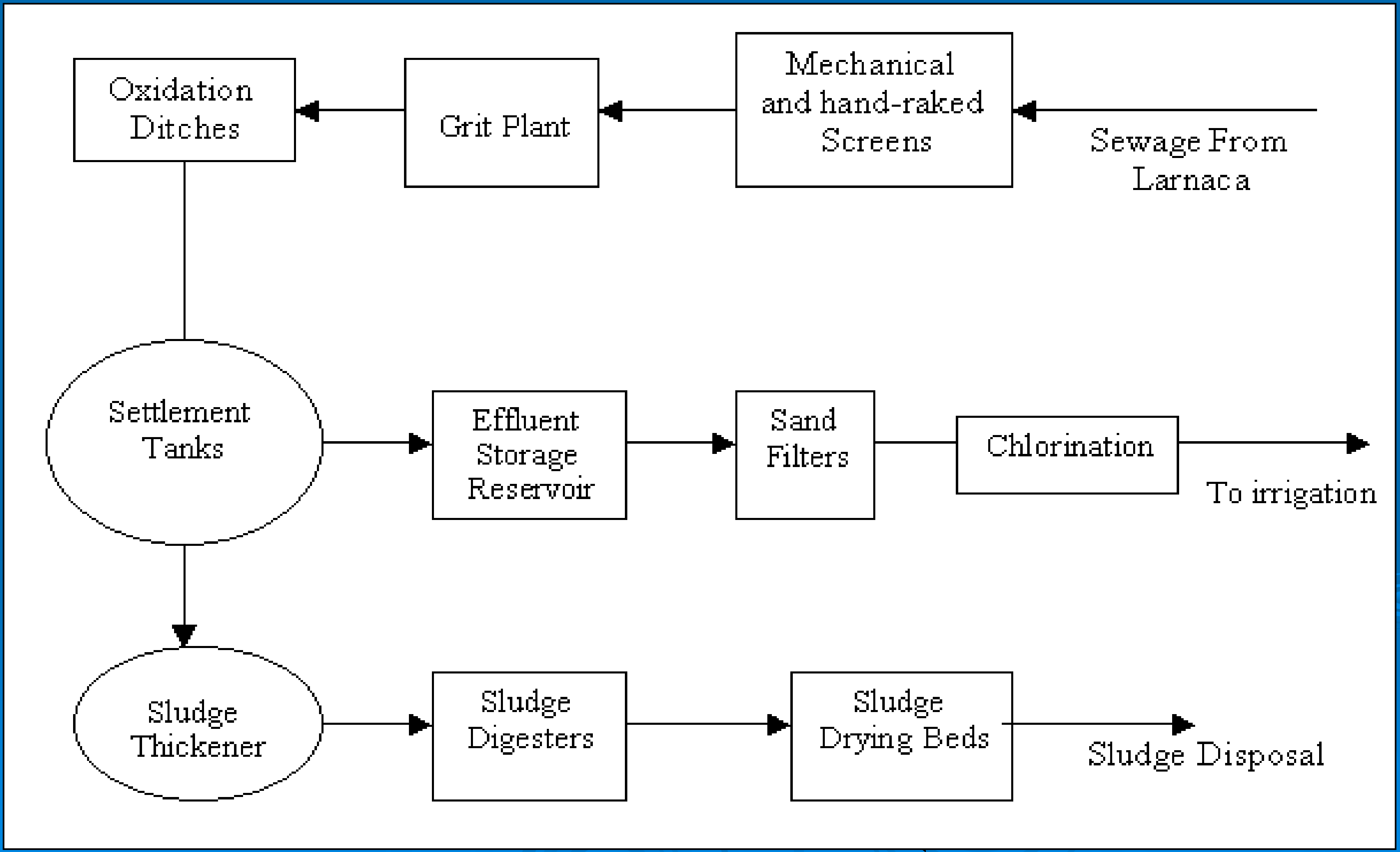
Water origin: domestic wastewater, for 46,340 PE. At the moment the plant serves only 36,000 PE.

Design capacity: 8,500 m^3/d, summer: 5,500 m^3/d, winter: 4,500 m^3/d

Treatment: Bar racks, grit chamber, aeration tanks, secondary settlement tanks, sand filter and chlorination tank.

Cyprus

Larnaca Wastewater Treatment Plant



Cyprus

Larnaca Wastewater Treatment Plant

Sand Filter

Filter Press

Irrigation Pumping Station

Sludge Drying Beds

Effluent Quality		Removal efficiency
Parameter	Value (mg/l)	
BOD_5	2.6	99.37
COD	56	93.10
SS	1.7	99.46
pH	7.5	-
Total N	8.5	90.22
NH_3-N	2.4	96.76
$NO_{3-}N$	6.9	-
N	17.8	-
Conductivity	3.4 (mS/cm)	-
Cl	555	2.97
B	0.8	-
P	0.6	92.04
Cd	<0.01	-
Cu	0.01	-
Ni	0.06	-
Pb	1.87	-
Zn	0.35	-
Cr III	<0.01	-
Total E.Coli/100ml	5	-
Intestinal E.Coli/100ml	0	-
Residual Cl	0.2	-

Cyprus

Water reuse applications

- Since the plant has been in operation, the effluent is being used for irrigation of agricultural land at Dromolaxia Village where corn and alfalfa are cultivated.

- The treated water is also used by the hotels, International Airport and Larnaca Municipality for the irrigation of gardens, parks and fields during the summer season.

  - For that purpose, the effluent is being discharged through pumping stations.

  - An average agricultural area of 150 ha is being regularly irrigated.

Cyprus

Costs:

- The total cost of the project is 30 million CYP (50 million €), out of this, 5.5 million CYP (9.3 million €) is the cost of the tertiary treatment plant with the reuse network and pumping station.

- The cost for the production of tertiary treated water is around 0,3 CYP (0.5 €) per m^3

Cyprus

	Year	Population Equivalent (PE)	%	Capacity of the Treatment Plant (m^3/day)
Larnaca WWTP Evolution.	2012	67,000	100%	17,000

Cyprus

Ayia Napa - Paralimni Wastewater Treatment Plant

Location: Cavo Greco area (between Ayia Napa and Paralimni)

Year of the project development: The plant has been constructed in 2000 and has been operated since August 2002.

Water origin: The treatment plant provides municipal wastewater treatment within the boundaries of the municipalities of Ayia Napa and Paralmni for 75,000 PE.

Design capacity: is 12,000 m^3/d. The plant operates close to its full capacity at 9,600 m^3/d in the summer and decreases in winter months to 4,000 m^3/d.

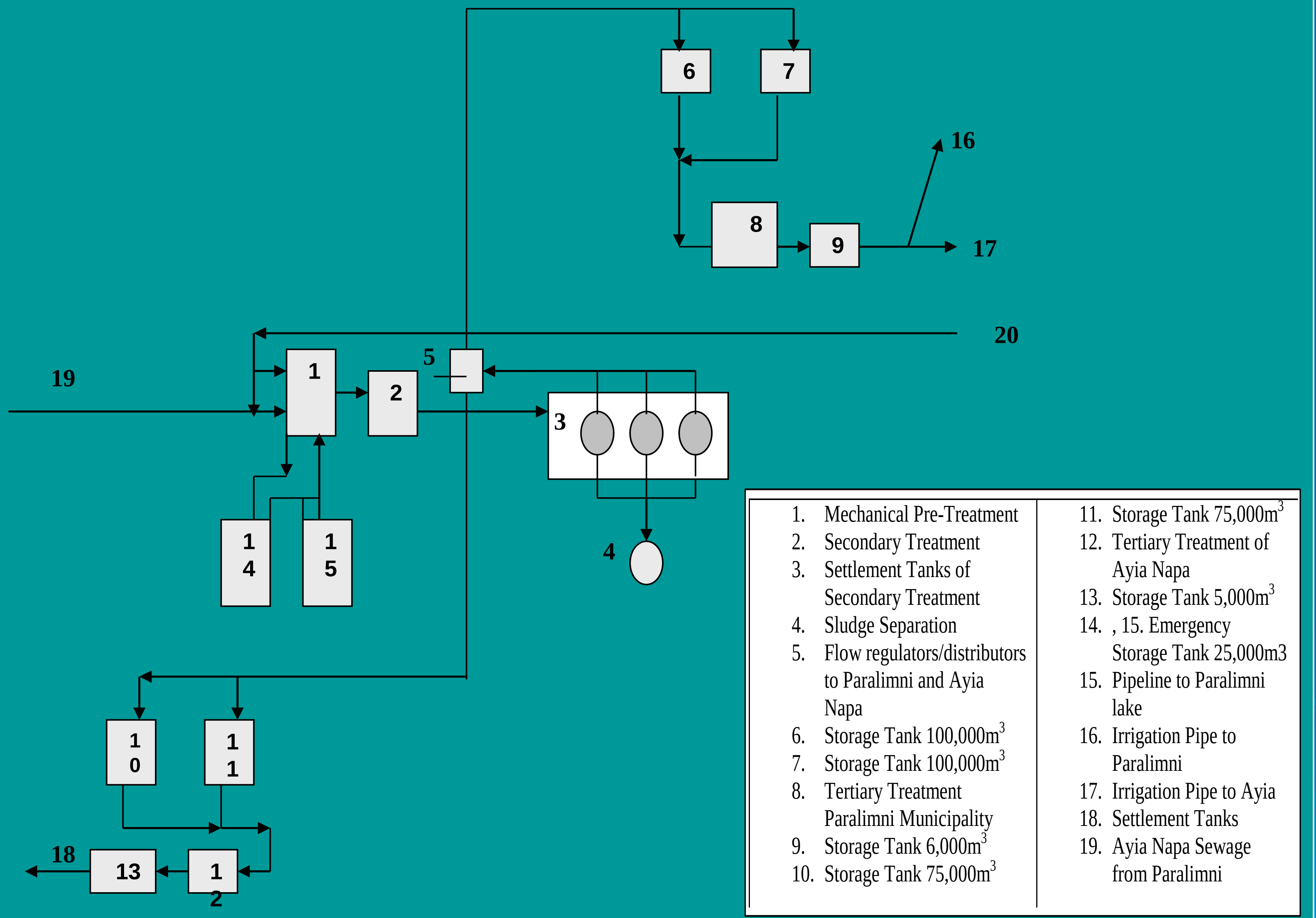
Since the start-up of its operation, 100% of treated wastewater is being used as irrigation water in summer.

Treatment Process

- The system consists of Primary Treatment (coarse and fine screen), Secondary Treatment (activated sludge) and Tertiary Treatment (Sand Filter and Chlorination).

- There is also a sludge treatment unit, that consists of a sludge thickening tank and belt filter press.

- The mechanical pre-treatment and the secondary treatment takes place in a common system for the two municipalities, while there are 2 storage tanks and 2 tertiary treatment plants one for each municipality.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1. Mechanical Pre-Treatment
2. Secondary Treatment
3. Settlement Tanks of Secondary Treatment
4. Sludge Separation
5. Flow regulators/distributors to Paralimni and Ayia Napa
6. Storage Tank 100,000m^3
7. Storage Tank 100,000m^3
8. Tertiary Treatment Paralimni Municipality
9. Storage Tank 6,000m^3
10. Storage Tank 75,000m^3
11. Storage Tank 75,000m^3
12. Tertiary Treatment of Ayia Napa
13. Storage Tank 5,000m^3
14. , 15. Emergency Storage Tank 25,000m3
15. Pipeline to Paralimni lake
16. Irrigation Pipe to Paralimni
17. Irrigation Pipe to Ayia
18. Settlement Tanks
19. Ayia Napa Sewage from Paralimni

Pretreatment

Settlement Tank

Aeration Tank

Storage Tank (Secondary treated water)

Effluent Quality (Summer)		Removal efficiency	Effluent Quality (Winter)		Removal efficiency
Parameter	Value (mg/l)		Parameter	Value (mg/l)	
COD	52.5	92.50	COD	48.9	86.23
BOD	1.48	99.62	BOD	1.14	99.43
SS	2.65	98.93	SS	1.95	98.89
Total N	15.1	75.45	Total N	23.8	40.50
NH_4^+	0.95	97.29	NH_4^+	0.31	99.03
NO_2^-	52.3	-	NO_2^-	84.1	-
NO_3^-	52.3	-	NO_3^-	84.1	-
Total P	6.65	34.16	Total P	6.12	29.66
PH	6.8	-	pH	6.7	-
T	28.9	-	T	16	-
Alkalinity	1.67	72.17	Alkalinity	1.7	73.85
Conductivity	1.8	10.00	Conductivity	2.2	15.38
Free Cl	0.81	-	Free Cl	2.94	-
Total Cl	1.72	-	Total Cl	3.94	-
Total E.Coli	0	-	Total E.Coli	0	-
Intestinal E.Coli	7	-	Intestinal E.Coli	5	-
Intestine Worms	0	-	Intestine Worms	0	-

Effluent Quality (Summer)		Removal efficiency	Effluent Quality (Winter)		Removal efficiency
Parameter	Value (mg/l)		Parameter	Value (mg/l)	
COD	55	92.14	COD	50.6	85.75
BOD	1.6	99.59	BOD	1.4	99.30
SS	3.1	98.74	SS	2.18	98.75
Total N	15.1	75.45	Total N	23.8	40.50
NH_4^+	0.84	97.60	NH_4^+	0.40	98.75
NO_2^-	0.09	-	NO_2^-	0.02	-
NO_3^-	58	-	NO_3^-	97.1	-
Total P	6.81	32.57	Total P	7.57	12.99
PH	6.71	-	PH	6.62	-
T	29	-	T	16	-
Alkalinity	1.65	72.50	Alkalinity	1.74	73.23
Conductivity	1.81	9.50	Conductivity	2.23	14.23
Free Cl	1.11	-	Free Cl	3.9	-
Total Cl	2.13	-	Total Cl	5.12	-
Total E.Coli	0	-	Total E.Coli	0	-
Intestinal E.Coli	7	-	Intestinal E.Coli	5	-
Intestine Worms	0	-	Intestine Worms	0	-

Cyprus

Water reuse applications

- Since the plant has been in operation, the effluent is being used for irrigation of agricultural land in Paralimni where potatoes are mostly cultivated.

- The treated water is also used by the hotels and the Municipalities for the irrigation of gardens and parks during the summer season.

  - For that purpose, the effluent is being discharged through pumping stations.

  - An average agricultural area of 100 ha is being regularly irrigated.

Cyprus

Costs:

- The total cost of the plant is 8,5 million CYP (14.4 million €), out of this 3,5 million CYP (5.9 million €), is the cost of the tertiary treatment plant with the reuse network and pumping station.

- The cost for the production of tertiary treated water is around 0,3 CYP (0.5 €) per m^3 (20 cents for secondary treatment and 10 cents for tertiary treatment).

- The Sewerage Board of Paralimni and Ayia Napa sell this water at the price of 15 cents CYP/m^3 for the hotels and 6 cents CYP/m^3 for agriculture (0.25 and 0.10 €/m^3 respectively).

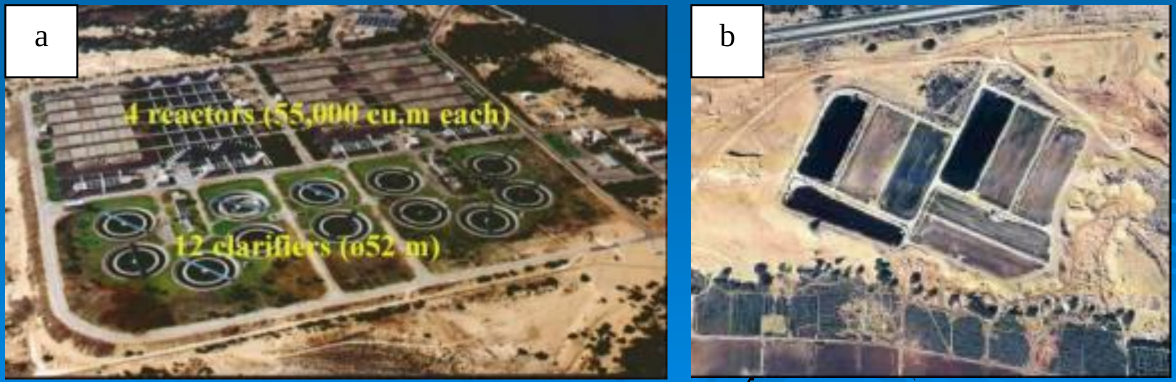
Cyprus

Ayia Napa-Paralimni Plant Evolution.

Year	Population Equivalent (PE)	%	Capacity of the Treatment Plant (m^3/day)
2003	50,000 (A) 25,000 (B)	70% (A) 65% (B)	12,000
2006	70,000 (A) 27,000 (B)	100 (A) 80% (B)	15,500
2012	70,000 (A) 31,000 (B)	100% (A) 100% (B)	20,000

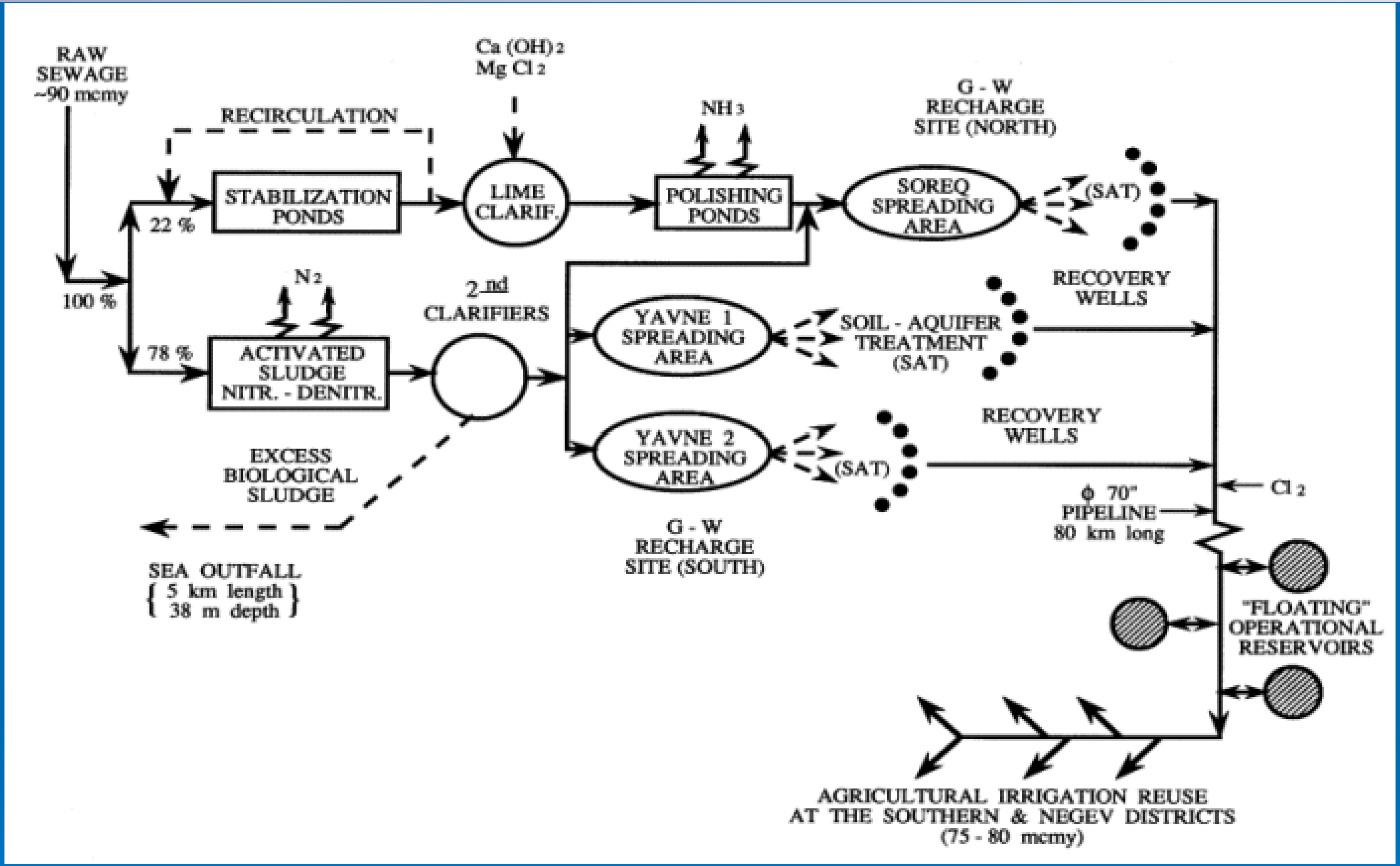
Israel- Dan Region Project

- **Year of the project development:** 1994
- **Water origin:** Wastewater of Tel Aviv Metropolitan Region
- **Design capacity:** 120 MCM/yr.



The Dan Region Wastewater Treatment Plant (a) and soil aquifer treatment (SAT basins) (b).

Israel- Dan Region Project



Effluents of biological treatment including nutrient removal are recharged into the groundwater aquifer by means of spreading sand basins for additional polishing and long-term storage. High quality reclaimed water is eventually pumped out and used for unrestricted irrigation.

Israel- Dan Region Project

- ***Reclaimed water quality*:**

FC	: 1/100 ml
TC	: 1/100 ml
BOD	: < 0.5 mg/l
COD	: 7 mg/L
TSS	: 1 mg/l
TN	: 0.4 mg/l
TP	: 0.08 mg/l

Israel- Dan Region Project

Water reuse applications:

In 1993, 87 MCM of wastewater was treated, of which 75 MCM was recharged and about 100 MCM (together with groundwater) was supplied for agricultural irrigation in Negev.

Total area affected by irrigation:

An average agricultural area of 16,000 ha.

Types of products cultivated in irrigated areas:

Field-crops (cotton, cereals, sunflower, etc.), fruit plantations and vegetables, flowers aimed for export.

Costs: 0,45 US$/$m^3$.

Israel- Dan Region Project

Problems

Some of the physico-chemical processes, such as sorption and ion-exchange may become over-saturated with time, resulting in the breakthrough of certain substances.

The open reservoirs require monitoring for algae growth and decline in water quality due to natural fowl (birds) as well as wind and dust-borne microorganisms.

The possibility of physically covering the reservoirs with floating covers or geodesic domes is currently being studied.

Spain- Almeria

- **Location:** Almería, South of Spain.
- **Year of the project development:** 1997
- **Water origin:** domestic wastewater
- **Design capacity:** 32,000 m^3/day (11.7 MCM/yr).

Spain- Almeria

- **Treatment process:** Activated sludge, high speed filtration, ozonation.

- ***Reclaimed water quality*:**

COD:	20-120 mg/l
BOD_5:	35 mg/l
TSS:	< 30 mg/l
TC:	< 100 /100 ml
Helmith eggs:	0

Spain- Almeria

Irrigation of vegetables and fruit (e.g. tomatoes, citrus), 3000 ha

The final cost of reclamation water is 0.65 €/m^3.

The main problem is to gain support from farmers and the regulators.

Jordan: JUST and Wadi Hassan Pilot Projects, Irbid

<u>Year of the project development:</u> The treatment plants have been in operation since 2003.

<u>Volume (or flow) of water affected:</u>
From Wadi Hassan WWTP = 365,250 m^3/y, 1000 m^3/day.
From JUST = 219,150 m^3/y, 600 m^3/day.

<u>Water treatment before reuse (technologies/process applied):</u>
Wadi Hassan WWTP = Extended Aeration.
(JUST) WWTP = Rotating biological contactors (RBC)

Water reuse applications:
Reclaimed water is used in irrigating fodder and fruit crops, 9,500 ha

Parameter	Wadi Hassan WWTP	JUST WWTP
BOD	9 mg/l	5 mg/l
COD	64 mg/l	93 mg/l
TSS	23 mg/l	4 mg/l
NH_4	0.97 mg/l as N	< 0.09 mg/l as N
E-Coli	7,000 MPN/100 ml	-
Total Coliform	>=160,000 MPN/100 ml	< 2 MPN/100 ml
pH	-	6.6

Irrigation method

- Drip irrigation system using in colour-coded purple pipes.
- In addition, PA (Consultation Agency) and JUST engineers introduced a new spraying system. With that system larger drops of water are produced to ensure no aerosol effect and spray does not travel beyond the boundaries of the site.
- This is the first time such a pioneering technology has been used in the Jordan.

Jordan

- Wadi Mousa Pilot Project (near Petra City, South of Jordan)

- Aqaba Pilot Project (Aqaba City, South of Jordan)

Other

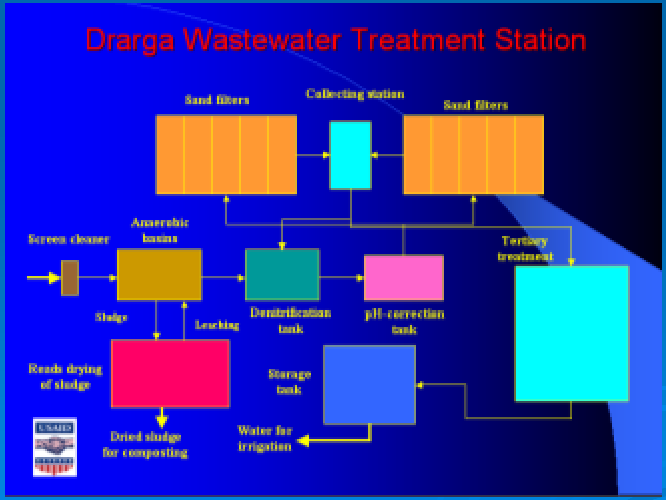
- Empuriabrava reuse system (Northern Costa Brava, Girona, Spain)



- Santa Cruz, Tenerife (Spain)
- Tallahassee reuse system (Florida)
- The Monterey Wastewater Reclamation Study for Agriculture (California)
- Wastewater reuse in Boca Roca (Southern of Florida, USA)
- Wastewater Irrigation in Guanajuato City (Mexico)
- La Soukra irrigation area (Tunisia)
- Mont Saint Michel (France)
- Clermont Ferrand (France)
- Wastewater reuse in Dariyah (Riyadh City, Saudi Arabia)
- Wastewater reuse in Kuwait City (Kuwait)

Morocco

- Ben Slimane reuse system (South of Rabat, Morocco)
- Ville de Drargua Wastewater Treatment Plans (Morocco)



Palestine

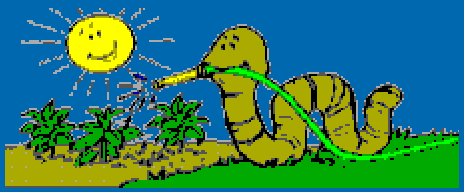
- Wastewater reuse in Al-Bireh (Palestine)
- Beit Lahayaarea

Agricultural Reuse of Urban Wastewater

- Water reuse has recorded indisputable progress in recent years in the Med countries
- Examples show the considerable benefits of wastewater reuse
  - **Financial** (savings in very costly heavy infrastructures)
  - **Socioeconomic** (Ww reuse processes if well managed $\Rightarrow$ agriculture incomes to improve and give access to water for the least well-off)
  - **Environmental** (reducing pressure on, and even restoring ecosystems and resources)

Problems associated with WW reuse

- The real cost of the projects are usually considerably higher than that estimated previously. This is in large part a result of insufficient planning before design and construction of water reclamation projects



- Presence of pathogens in water, chemical contaminants or heavy metals because of insufficient treatment
- The method used to apply the treated wastewater:

Method	Risks	Costs
Sprinkler	Cover the vegetables even for trees. Generate aerosols.	Controllable water consumption. Low labour cost. Low technological cost.
Dripping	Minimal.	Low water consumption. Low labour cost. High technological cost.
Flooding	Large area covered.	Large water consumption. Low labour costs.

Good practises

- Reclaimed wastewater must only be reused for the applications for which permit was issued
- When reclaimed water quality does not meet the fixed standards, reuse must cease
- Sprinkler irrigation should not take place in strong winds
- Quality monitoring and process controls should be supported
- Routine inspections of reclaimed water facilities, including facilities located on the property of end users
- Compliance with all applicable requirements for water reclamation, storage, transmission, distribution, and reuse, of reclaimed water

The positive effects of wastewater irrigation

- It conserves water
- It reduces pollution of rivers, canals and other surface water resources
- It conserves nutrients, reducing the need for artificial fertilizer
- It increases crop yields
- It provides a reliable water supply to farmers

The potential negative effects of wastewater irrigation

- Health risks for irrigators and communities with prolonged contact with untreated wastewater and consumers of vegetables irrigated with wastewater
- Contamination of groundwater (nitrates)
- Build-up of chemical pollutants in the soil (heavy metals)
- Creation of habitats for disease vectors
- Excessive growth of algae and vegetation in canals carrying wastewater (eutrophication)

Problems associated with WW reuse

- **<u>Social acceptance</u> (farmers, retailers and consumers): This is the most sensitive area of this topic. Farmers are not going to reuse water, if their product cannot be sold. Consumers will not buy products where reuse water was used unless it is proven to be safe**

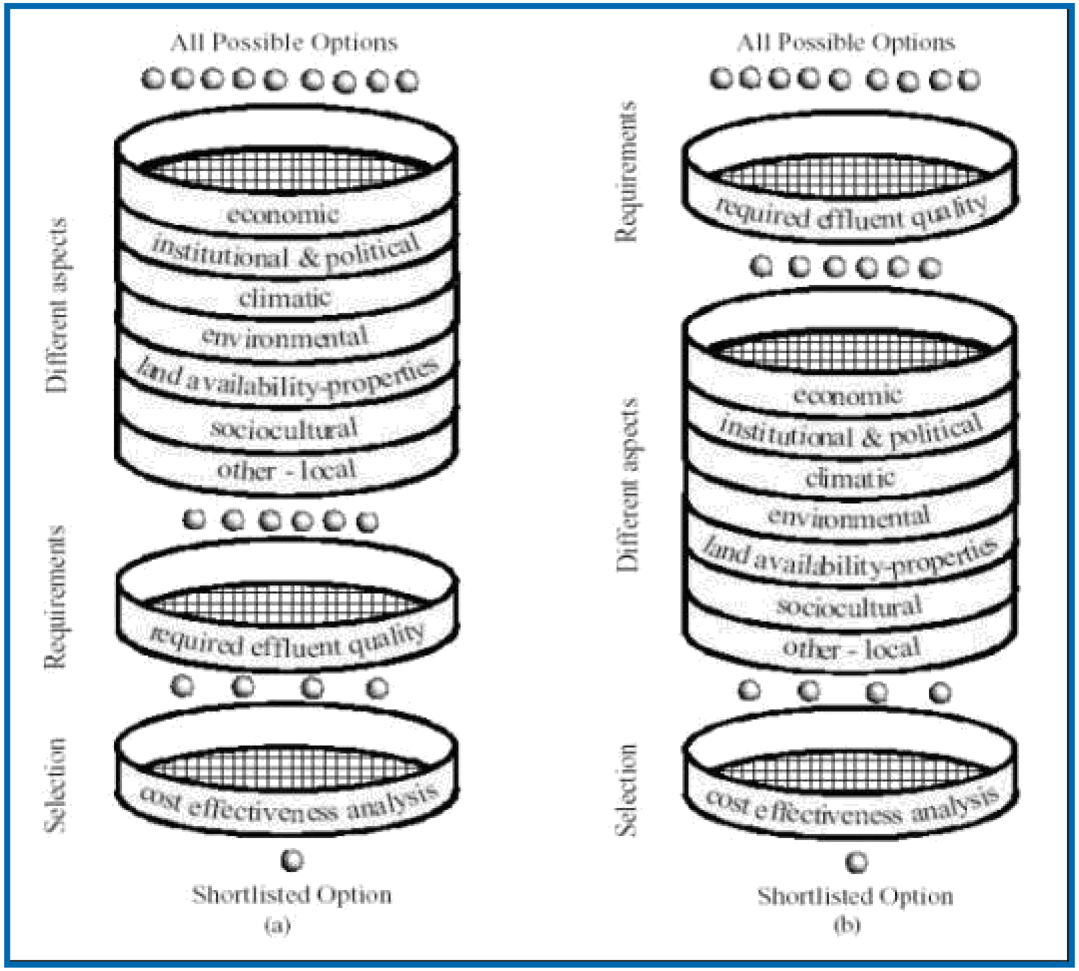
<u>Social issues</u> play a significant role in water reuse initiatives and should be adequately addressed. With adequate political will accompanied by awareness programmes these cultural, religious and social objections can be overcome.

Designing a WWTR Scheme

- A number of parameters should be considered when choosing the appropriate technology:
  - economic
  - institutional and political
  - climatic
  - environmental
  - land availability /properties
  - sociocultural
  - and other local ones

- Once these factors have been taken into account <u>the most cost-effective system should be selected</u>, unless the population being served is willing to pay more

Considerations when "screening" alternative processes for (a) developing and (b) developed countries



Costs

- Wastewater reclamation system costs are a function of facility capacity, end-use option and treatment process configuration

- Costs can be identified estimating:

  - facility construction costs
  - equipment purchases and
  - operation and maintenance fees

- Site development and electrical cost are assumed as 10 and 15 percent of the total facility costs respectively

Costs

- Reclamation system's annual cost is comprised of treatment and distribution facility personnel salaries, operating fees (recurring power and chemical cost) and maintenance cost (equipment repairs and replacements)
- Personnel requirements are a function of facility size and complexity
- Maintenance cost (spare parts, replacements) are estimated generally as a percentage of equipment first cost (e.g. 5 %)
- For pipelines and storage tanks, maintenance costs are projected as two percent of capital costs

The main problems that have to be dealt with are:

- The non-regulated use of treated water in agriculture
- The non-existing reuse criteria related to hygiene, public health and quality control
- The non-existing reuse criteria related to irrigation techniques, degree of wastewater treatment, and choice of areas and types of crops to be irrigated
- The lack of efficient control and monitoring of urban wastewater treatment plants
- The lack of trained personnel both in the competent authorities and the treatment plants
- The low level of awareness of the farmers and the public at large

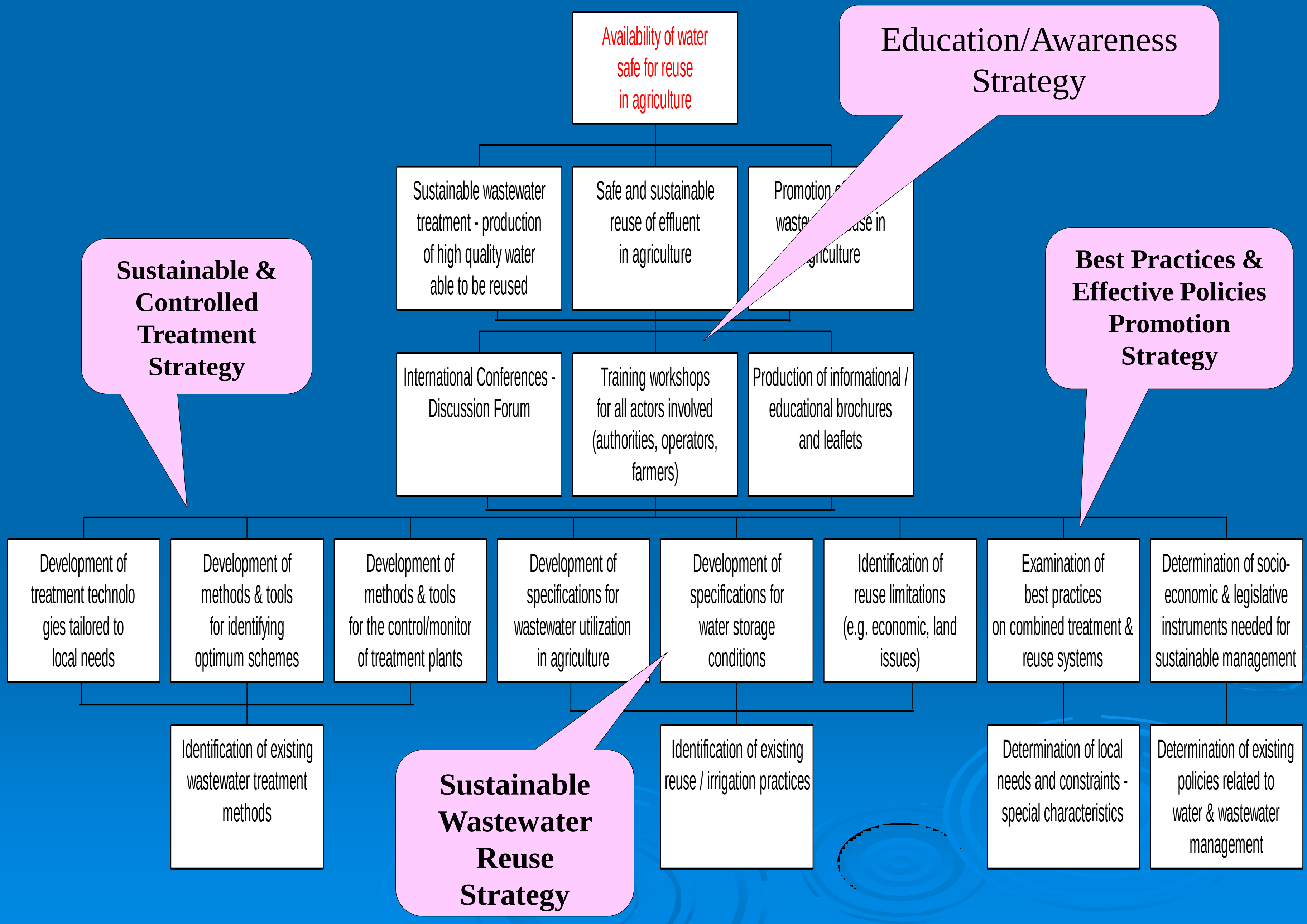
The MEDAWARE Project

- MEDA
- EUROPEAN COMMISSION
  - EURO-MEDITERRANEAN PARTNERSHIP

- Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries

- Greece (National Technical University of Athens and Prospect Systems)
- Cyprus (Agriculture Research Institute)
- Jordan (Jordan University of Sciences and Technology)
- Lebanon (American University of Beirut)
- Morocco (Chouaib Doukkali University)
- Palestinian Authority (Ministry of Environmental Affairs)
- Turkey (Istanbul Technical University and Middle East Technical University)
- Spain (CARTIF Technology Center)

Strategy Analysis Tree



Conclusions

The highest priority in the wastewater management sector has to be given to setting up an effective wastewater management system which will include:

- Maximization of collection of wastewater
- Upgrading the existing wastewater collection systems
- Rehabilitation or upgrading of existing wastewater treatment plants or the construction of new treatment plants
- Establishment of proper standards for influent and effluent wastewater quality
- Education of the farmers

... Thank you