A Sustainable Waste Water Management Project: MEDAWARE

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Abstract

The MEDAWARE Project was initiated by the collaboration of 7 Med countries in 2003. The main aim of the project was to develop tools and guidelines for the promotion of the urban wastewater treatment and reuse in the agricultural production in the Mediterranean countries for a sustainable environment and resources. Within this scope METU team undertook an inventory of the urban wastewater treatment plants (WWTP) in Turkey [1]. The gathered information indicated that of the 5-6 billion m^3 wastewater produced yearly in Turkey, around 1.6 billion m^3 receives some degree of treatment and approximately 1 billion m^3 is currently being secondary treated. Of this amount only 123 million m^3, originating mainly from two municipality WWTPs, is being used in direct irrigation of crops. Effluents in both applications do not meet the national and international reuse water standards. Most Mediterranean countries have neither wastewater reuse standards nor criteria. However a regulation-bulletin for reuse, directly adapted from US-EPA, was put into effect as of 1991 in Turkey. The Turkish bulletin, is fairly advanced by the current concepts, however lacks technology based stipulations but in the same time unrealistically stringent in terms of microbiological criteria. A criteria proposed for the MED countries, developed purely on scientific bases and risk assessment calculations in 2000, may be adopted in Turkey for a more realistic and pragmatic approach to reuse treated wastewaters in crop irrigation.

Water Statistics for Turkey

According to State Hydraulic Works (DSI-2001) of Turkey the total annual freshwater potential of Turkey is around 187 billion m^3. Around 30-35 billion m3 is being used for irrigation and 6 billion m^3 as freshwater supply for the urban settlements. Sources of freshwaters used in Turkey is given in Table 1.

Waste Water Statistics and Waste Water Treatment in Turkey

As of 2004, total of 129 urban wastewater treatment plants (WWTP), serving for populations greater than 3 000 pe, exist in 43 cities. According to the 2001 Turkish State Institute of Statistics (SIS) figures, 35% of the total population is being served by urban wastewater treatment plants in Turkey This figure is increasing year by year as it was mere 20% in 1994.

Nine treatment plants employ advanced wastewater treatment; 37 have some form of biological treatment (activated sludge, trickling filter, stabilization pond systems) and 13 utilize only physical treatment. Wastewater treatment statistics are summarized in Figs. 3-5. It has been estimated that annually

	Rural Withdrawal distribution (%) (Total water amount: 164 x 10^6 m^3)	Urban Withdrawal distribution (%) (Total water amount: 6202 x 10^6 m^3)
Spring	24.3	22.1
Lake	0.53	10.3
River	1.54	2.21
Dam	4.90	39.6
Groundw	67.4	24.1
Pond	0.37	1.57
Other	0.96	0.12

Table 1. Water Withdrawal in Turkey (DSI-2001)

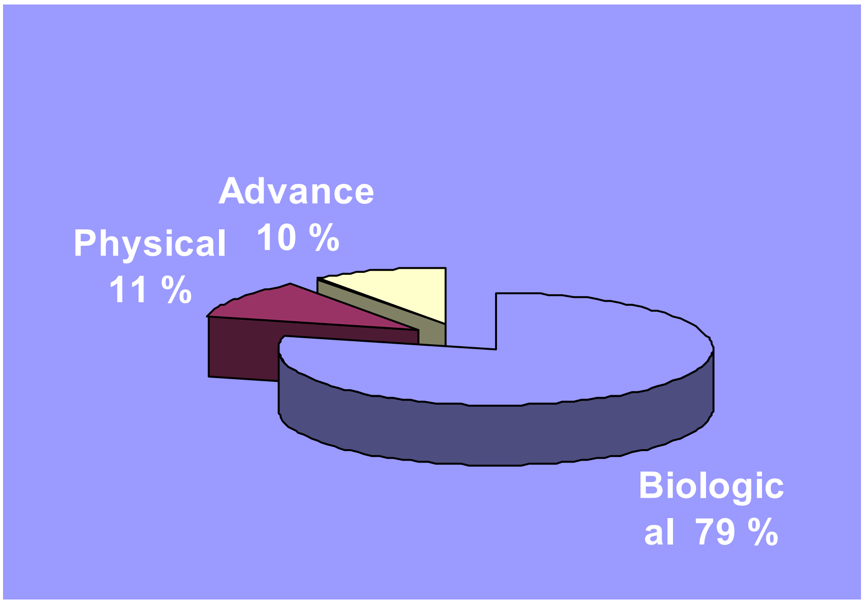

Figure 2. Breakdown of WWTPs in Turkey

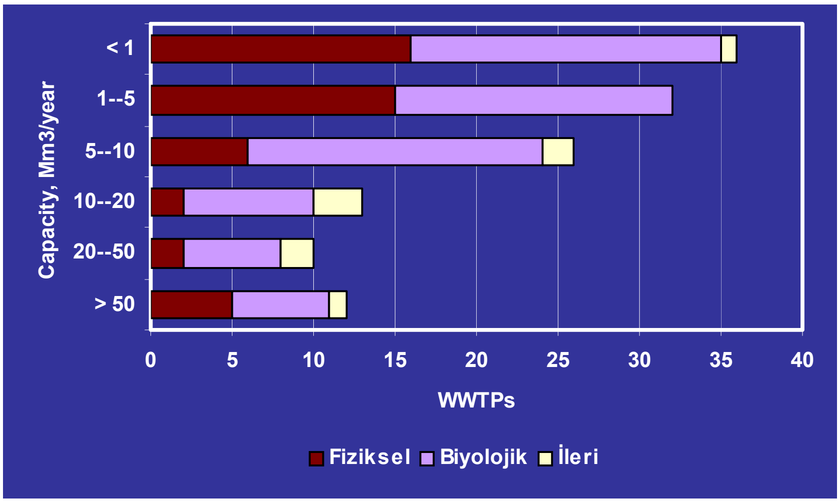

Figure 3. Capacity Distribution of WWTPs

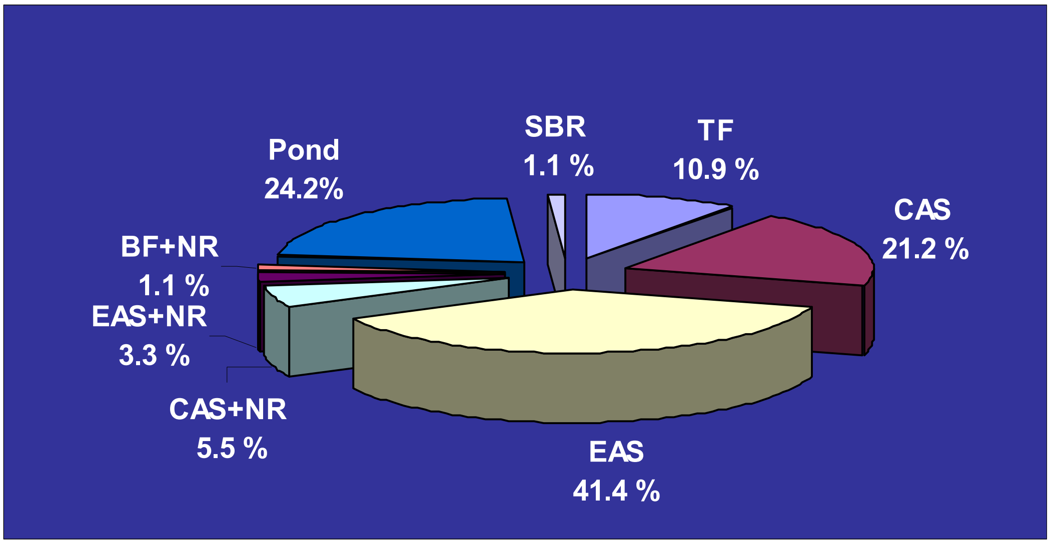

Figure 4. Disitribution of Biological Technologies in Numbers
CAS: Conventional Act. Sludge; EAS: Extended Aeration Act. Slu; TF: Trickling Filter.; BF: Biyological filters.; NR: Nutrient treatment.; SBR:Sequencing Batch reactor

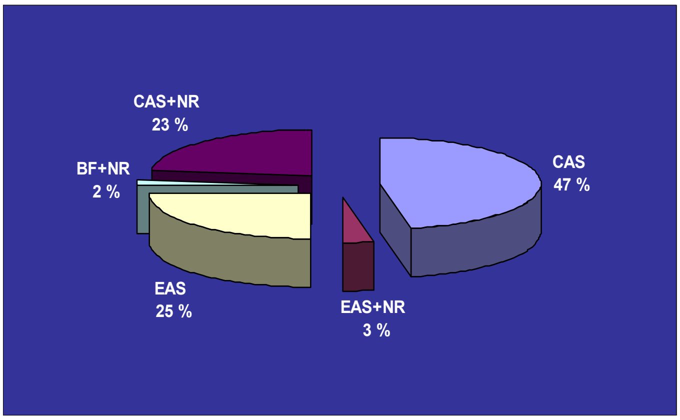

Figure 5. Distribution of Biological Technologies on the bases of Flow of Wastewater Treated

total of 1.6 billion m^3 of domestic wastewater receive some form of treatment, of which 1 billion m^3 receive secondary treatment. This figure is important in that secondary treated wastewaters may be reused in agriculture upon additional treatment When treated effluent quantities are considered, 13.7% of the urban wastewaters are being treated at advanced level for organics and nutrient removal

The 73.5% and 12.8% of wastewaters are treated by biological and physical treatment methods, respectively. Data from 56 treatment plants indicated that 64 % of these discharge their effluents into streams and rivers. Approximately 21 % of the plants practice marine disposal (into Black Sea or Mediterranean) and remainder discharge into drainage and irrigation canals, lakes, reservoirs and on land. [1]

Wastewater Reuse

In terms of sustainable environment, reuse of treated wastewaters in agriculture is poorly practiced in Turkey. The wastewater reuse is accomplished through “direct” and “indirect” irrigation. “Direct” is to mean the reuse of effluents directly in agriculture for irrigation, whereas “indirect” indicates reuse through a receiving body. Among the studied WWTPs; Eskisehir WWTP (24,820,000 m^3/year) and Gaziantep WWTP (73,000,000 m^3/year) effluents are directly being used in irrigation of farm land of 50,000 and 80,000 hectares, respectively. In the two reuse practices effluents do not conform with the recognized reuse standards in the world. As a result the highest gastrointestinal disease rate is observed in Gaziantep province of Turkey as shown in Fig. 6. Although some of the WWTP administrations claimed no reuse for disposal, evidently their discharges are being indirectly used in irrigation as shown in Table 2. There is also indication that at regions where improper reuse being practiced for agricultural irrigation the incidence rates of gastrointestinal diseases are the highest in the country. For example, as can be seen from Fig. 8 that South Eastern Region (GAP) of Turkey appears as the most problematic having cities with incident risk values above that average for Turkey (0.093%) [1].

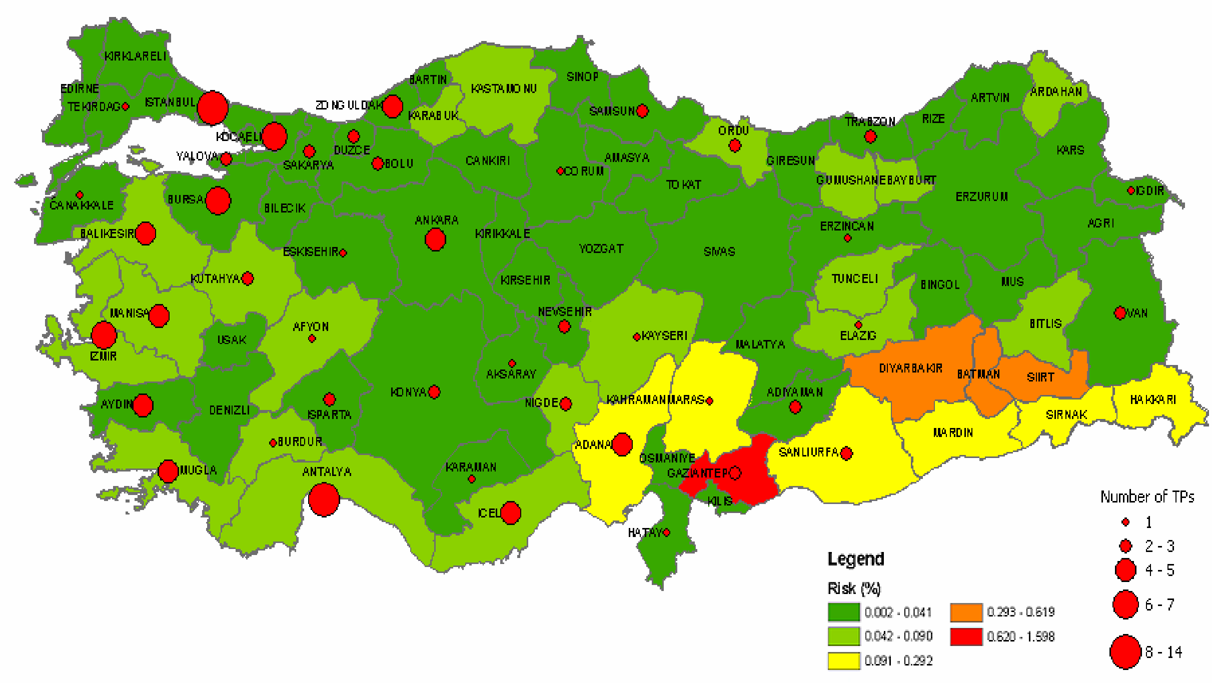

Figure 6. Combined chart showing locations of WWTPs and % risk of water-borne diseases occurrences in Turkey

Province	Place	Name of plant	m3/a	Receiving environ.	Irrigation status
Aksaray (Primary	**Merkez**	**Aksaray Municipality WWTP**	**9 125 000**	**Karasu Stream**	**INDIRECT ***
Ankara	**-**	**ASKI, Ankara Municipal. WWTP**	**192 695 545**	**Ankara Creek**	**INDIRECT ***
Eskisehir ** #	**-**	**ESKI, Municipality WWTP**	**24 820 000**	**Porsuk River**	**INDIRECT ***
Gaziante p ** #	**-**	**GASKI , Municipality WWTP**	**73 000 000**	**S. Creek**	**DIRECT**
Igdır (aer. Stabilizat	**Merkez**	**Igdır Municipality WWTP**	**551 880**	**Aras River**	**DIRECT**
Kayseri	**-**	**Kayseri Municipality**	**32 850 000**	**Karasu**	**INDIRECT ***
Adana	**Kozan**	**Kozan Municipality**	**2 780 000**	**Kozan**	**INDIRECT ***
Adana	**Yumurta**	**Yumurtalık Municipality**	**48 000**	**Ayas Creek**	**INDIRECT ***
Konya	**Ilgin**	**Ilgın Municipality WWTP**	**2 838 240**	**Bulasan**	**INDIRECT ***
Nevsehir	**Urgup**	**Urgüp Municipality**		**Damsa**	**INDIRECT ***
İzmir #	**Merkez**	**IZSU Municipality WWTP**	**182 500 000**	**Izmir Bay**	?

Table 2. Reuse of Treated Wastewaters in Central, Eastern, SouthEastern, Western Blacksea and Mediterranean Regions in Turkey

Figure 7. The Photograph of the VRM Type MBR Plant in METU Campus, Ankara

Recently a membrane treatment plant, MBR, shown in Fig. 7, has been commissioned in METU campus in Ankara, where effluents are sterile and free from organics and are suitable for unrestricted irrigation. Currently MBR treated effluents are being used for lawn irrigation in the campus. The MBR plants in the world are growing in number and are due to be technology standards for treatment and reuse of wastewaters.

Cost of Treatment and Reuse

Cost of secondary wastewater treatment in Turkey has been studied within the MEDAWARE project. Treatment costs of domestic effluents in different processes is summarized in Table 3. As can be seen from this figure, in terms of initial investment, conventional activated sludge and denitrifying oxidation ditch are the least costly. Whereas denitrifying activated sludge and extended aeration modifications are comparable with each other, provided that 266.2 € is excluded from the comparison. This figure belongs to recently constructed plant in Fethiye which does not exactly represent the true figure of construction for such a plant. The most costly is the MBR process. However MBR process is a form of tertiary treatment and may not directly be compared with the others.

In terms of operational costs more or less the same ranking is applicable. It should be noted that secondary treatment, with or without nutrient treatment, produces effluents unfit for unrestricted irrigation from microbiological point of view. Whereas MBR plants produce effluents which are suitable for unrestricted irrigation.

Treatment Technology	Initial Cost (€/capita)	Unit Operational Cost (€/m^3)
Conventional activated sludge	13.76 – 46.67	0.0146 – 0.0903
Denitrifying activated sludge	32.30 – 266.2	0.0473 – 0.0553
Extended Aeration act. sludge	29.00 – 49.85	0.0320 – 0.1260
Denitrifying oxidation ditch	12.72 – 83.47	0.0528 – 0.1534
Vacuum membrane reactor MBR *	250 - 330	0.13 € electricity 0.45 € elctrcity +

* based on METU MBR plant experience

Table 3. Comparison of treatment costs for domestic effluents

Wastewater Reuse Standards

Most Mediterranean countries have neither wastewater reuse standards nor criteria. However the 'Technical Aspects Bulletin' (Official Gazette dated 7.1.1991, no. 20748), linked to the Turkish Water Pollution Control Regulation has been issued in 1991 to stipulate irrigation water standards for reuse of waters in agriculture [2]. The Turkish bulletin, is fairly advanced by the current concepts, however lacks technology based stipulations and is unrealistically stringent in terms of microbiological criteria, as seen in Table 4. Considering the economics of reuse in agricultural irrigations the current standard needs to be updated in the light of the current scientific evidence. The microbiological quality standards in the world are seen to differ significantly between countries. The Title 22, adopted by the green belt states of the USA, represents the strictest and technology based standard. While the WHO standard, represents somewhat the pragmatic approach. Where <1000 FC/100 ml is purely adopted from swimming water standards and <2 NTU is based on the assumption that with a turbidity at or below 2 NTU the likelihood of getting helminthic eggs through reused water in irrigation will be tolerably low. The newest standards are those adopted by Australia, Tasmania, Japan which are allegedly based upon the recent scientific evidence and the 100-200 FC or E. Coli /100 ml is adopted for freshwaters. The Israeli reuse standard adopted from Title 22 is presented in Table 5 [4]. Attainable reuse water standards should clearly take into account the local conditions while reasonably safeguarding the population. An attempt to establish a unified guideline for the Mediterranean countries, based upon risk assessment, using epidemiological data and model studies, has been established as proposed by Blumenthal *et. al*. (2000) [3] and tabulated in Table

6. Three microbiological quality criteria are proposed in the guideline, namely, nematode eggs, FC or *E. coli* and suspended solids (SS), along with the technology requirements. In cases where there is evidence that microbiological criteria are met SS criteria may be overlooked. This has important implication in that the low cost lagoon technology, which is extremely suitable for the MED countries, may produce effluents which can meet the microbiological standards but produce turbid effluents. Comparing with the Turkish standard the main difference is that Turkish standard does not specify a minimum technology requirement for different water classes nor does it consider helminth eggs, in the reuse water.

Quality Criteria	Irrigation Water Class				
	Class I (very good)	Class II (good)	Class III (usable)	Class IV (usable with caution)	Class V detrimental unusable)
Boron, mg/l	0–0.5	0.5–1.12	1.12–2	>2	
Irrigation Water Class	C1S1	C1S2. C2S2. C2S1	C1S3.C2S3. C3S3.C3S2. C3S1	C1S4.C2S4. C3S4.C4S4. C4S3.C4S2. C4S1	
NO3- or NH4+, mg/l	0–5	5–10	10–30	30–50	>50
Fecal Coliforms, /100ml	0–2	2–20	20–100	100–1000	>1000
BOD5, mg/l	0–25	25–50	50–100	100–200	>200
Suspended Solids, mg/l	20	30	45	60	>100
pH	6.6–8.5	6.5–8.5	6.5–8.5	6.5–9	<6 or >9
Temperature	30	30	35	40	>40

Table 4. Summary of some of the most crucial parameters for reuse in Technical Aspects Bulletin. [2]

Parameters	Group of crops/main crops			
	A Cotton, sugar beet, cereals, dry fodder seeds, forest irrigation, etc.	B Green fodder, olives, peanuts, citrus, bananas, almonds, nuts, etc.	C Deciduous fruits[b] conserved vegetables, cooked and peeled vegetables, green belts, football fields and golf courses	D Unrestricted crops, including vegetables eaten uncooked (raw), parks and lawns
Effluent quality				
BOD_5 total (mg/l)	60[a]	45[a]	35	15
BOD_5 dissolved (mg/l)	–	–	20	10
Suspended solids (mg/l)	50[a]	40[a]	30	15
Dissolved oxygen (mg/l)	0.5	0.5	0.5	0.5
Coliforms counts (/100 ml)	–	–	250	12 (80%) 2.2 (50%)
Resid. avail. chlorine (mg/l)	–		0.15	0.5
Mandatory treatment				
Sand filtration or equivalent	–		–	required
Chlorination (minimum contact time, min)	–		60	120
Distances				
From residential areas (m)	300	250	–	–
From paved road (m)	30	25	–	–

[a]Different standards will be set for stabilization ponds with retention time of at least 15 days.[b]Irrigation must stop 2 weeks before fruit picking; no fruit should be picked from the ground.

Table 5. Israeli Wastewater Reuse Standard [4]

Water category	**Quality criteria**			**Wastewater treatment expected to meet the criteria**
	Microbiological		**Physical-chemical**	
	Intestinal nematode(a) (no. eggs per liter)	**FC or *E. coli*(b) (cfu/100 mL)**	**SS (c) (mg/L)**	
Category I				
a) Residential reuse b) Urban reuse c) Landscape and recreational impoundments (contact is allowed)	**$\leq 0.1^{(h)}$**	**$\leq 200^{(d)}$**	**≤ 10**	**Secondary treatment + filtration + disinfection**
Category II				
a) Irrigation of vegetables b) Landscape impoundments (contact is not allowed)	**$\leq 0.1^{(h)}$**	**$\leq 1000^{(d)}$**	**≤ 20 $\leq 150^{(f)}$**	**Secondary treatment or equivalent (g) – filtration + disinfection or**
c) Industrial reuse (except for food industry).	**-**			**Secondary treatment or equivalent (g) + either storage or well-designed series of maturation ponds or infiltration percolation**
Category III				
Irrigation of cereals and oleaginous seeds, fiber, & seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated)(e), plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.	**≤ 1**	**None required**	**≤ 35 $\leq 150^{(f)}$**	**Secondary treatment or equivalent (g) + a few days storage or Oxidation pond systems**

Table 6. Guidelines developed for MED countries for wastewater reuse in irrigation by Blumenthal et.al. (2000)[3]

Cost of Irrigation versus Product Costs

From Table 3 it can be seen that cost of secondary treating of 1 m^3 of wastewater is variable between 5-15 € cents. Extra cost of coagulation/flocculation and filtration is 5 € cents /m^3 (Israeli data, personal communication) on top of secondary treatment. In case ultra filtration is to be practiced this is additional 15 € cents (Israeli data). Therefore total cost of treatment for irrigation quality of reuse wastewater is 10 – 30 € cents/m3. In MBR technology, our experience is that the energy cost is around 13 € cents/m^3 and 45 € cents/m3 when membrane depreciation is considered.

Conversely assuming that single crop of corn or wheat requires 500 mm of water, and that 2 tons of corn or wheat produced per hectare, and selling price of one ton of corn or wheat is 267 US $ then:
(267 $ * 2 tons) / 5000 m3 / ton = 0.107 $ or 10.7 $ cents/m^3
is the revenue gained per m^3 of water used. Clearly cost of treating domestic effluents to the irrigation water quality far exceeds the revenue to be made from each m^3 of water in irrigation. However lagoon technology, which is being abandoned in the world owing to its turbid effluents, produces treated effluents almost at no cost. This technology may be revived should an easy-to-use biochemical monitoring technique be developed for identifying and enumerating protozoa and helminthes in the effluents.

Conclusion

The following conclusions may be drawn:

- Water scarcity is already a serious problem in MED countries. Those MED countries, including Turkey, which are at present considered reasonably water sufficient may quickly become water deficient in the near future with their high rates of population growth, increased industrial throughput, increased pollution of water resources. Groundwater table has already seriously dropped in some of the regions due to excessive abstraction of water.
- Pumping water for irrigation from distances may often become prohibitive in cost. Reuse of already pumped wastewaters in irrigation may be a solution for sustainable development and for sustainable environment, provided that cost of tertiary treatment is substantially reduced for the farmers.
- At present it is ethically conceived that cost of secondary treatment be borne by the polluters, eg. citizens. However secondary treatment is by no means complete and discharged effluents contain 6-7 logs of coliform organisms. This ethical logic was developed by the water rich Northern countries who do not need to reuse effluents for crop irrigation. The idea was also adopted by the MED countries without due consideration. In the light of sustainability it is mandatory that tertiary treatment be also financed by the consumer and that treated wastewaters be pristine in quality and be available to the farmers at minimal costs. Only by this way sustainable growth and environment may be attained in the MED countries.
- The stringent reuse standards practiced in MED countries may somewhat be relaxed in the light of the present scientific evidence. This will bring back the use of cost effective lagoon technologies in which turbid effluents may be used in irrigation almost at no cost.

The technology may be revived if an easy-to-use biochemical monitoring technique be developed for identifying and enumerating protozoa and helminthes in the effluents.

- Reuse of wastewaters in agricultural irrigation should initially provide extra 1 billion m^3 of water per year in Turkey. This may approach to 6 billion m^3 in years to come.
- At present 35% of the total population in Turkey is being served by urban wastewater treatment plants. Remaining 65 % of population is located in small settlements, villages and towns, who mainly indulge in agriculture. Therefore it is clear that great numbers of small scale, cost effective decentralized treatment plants, whose effluents are suitable for irrigation, will be necessary for sustainable growth and environment.

References

[1] http://www.uest.gr/medaware/progress.htm

[2] WPCR Technical Bulletin, 1991. Turkish Water Pollution Control Regulation Technical Bulletin Dated January 7, 1991, Reference Number 20748.

[3] Blumenthal, U. J., Mara, D. D., Peasey, A., Ruiz-Palacios, G. and Scott, R., 2000. Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines. Bulletin of the WHO Vol.78 (9), pp.1104-1116.

[4] Angelakis A.N., Marecos Do Monte M. H. F., Bontoux L., and Asano T., 1999. "Review Paper, The status of wastewater reuse in the Mediterranean Basin: Need for guidelines", Wat. Res. Vol. 33, (10), pp. 2201-2217.