4

WSP Usage in the Eastern Mediterranean

4.1 TURKEY

Turkey has an on-going programme of wastewater treatment plant construction for which the Iller Bank has overall responsibility. Thirty-one treatment plants were commissioned between 1985 and 1996, currently treating population equivalents ranging from 11,000 to 310,000; of these, 16 are WSP systems (Table 4.1). Out of the total of 45 new wastewater treatment plants under construction in 1997 27 are WSP systems, and 20 of these are in Southeast Anatolia (Tables 4.2 and 4.3). The wastewater being treated is predominantly of domestic origin.Wastewater reuse for crop irrigation is being practised in Turkey, but its extent varies from region to region.

All the WSP systems constructed so far comprise a primary facultative pond and one or more maturation ponds with, in general, all the ponds being equally dimensioned. The precise design criteria used are not always clear, although the maximum surface BOD loading on the primary facultative pond permitted by the Iller Bank for anywhere in Turkey is 200 kg/ha d. The WSP systems are generally of good physical design and have been well constructed, with vehicle ramps usually incorporated to facilitate desludging. However, many systems are poorly maintained and this is affecting their performance. In some cases the maturation ponds are so overgrown with rooted macrophytes that they are at risk of becoming totally choked. Information on the precise design and performance of WSP systems in Turkey is very sparse. However, future WSP designs will now include anaerobic ponds, and designs for larger cities will incorporate anaerobic ponds followed by a highly loaded activated sludge plant, the effluent from which will then be polished and disinfected in a series of maturation ponds.

The WSP system at Aksaray is one of the largest WSP systems operating: it was commissioned in 1993 and designed for a Phase I population equivalent of 103,575, increasing to a final design population of 360,000 in 2015. The current population of Aksaray is estimated to be around 160,000, but only about 50,000 are sewered. The only significant non-domestic wastewater it receives is from a 200-bed hospital. The pond complex comprises four series in parallel, each with a primary facultative pond followed by two maturation ponds. The overall area is 25 ha and all the ponds are of similar area and dimensions with a length to breadth ratio of approximately 3 to 1. The facultative ponds were originally 2 m deep and the maturation ponds 1.5 m deep. Pretreatment comprises simple screening after which the flow is theoretically split equally between the four

Table 4.1 WSP systems in Turkey completed by 1997

Location	Design horizon	Population equivalent	Capital cost (1997 TL billions[a])
Aksaray	1990	103,575	177
Aksehir	1900	54,176	194
Bucak	2000	42,000	-
Dvrek	2005	37,400	-
Hekimhan	2000	18,040	60
Igdir	2017	83,000	-
Ilgin	1984	25,032	-
Kozan	2006	93,409	181
Manvgat	988	38,498	-
Samsat	2022	15,000	-
Selçuk	2000	30,000	376
Sereflikochisar	1986	25,000	-
Suruç	2014	55,717	-
Surfa	1990	310,000	-
Terme	1995	24,300	238
Yenicaga	2001	11,014	106

[a] January 1997 exchange rate: 1 billion TL = 7,405 ecu.

Source: Iller Bank.

series, two of which are fed by gravity and the other two by pumping. Currently the pumps are not being operated so the entire sewage flow is entering the two gravity-fed series, with approximately 90 percent of the flow passing through one of them. Rooted macrophytes are growing in parts of the final maturation ponds. The final effluent enters a small river from which water is abstracted for crop irrigation directly opposite the effluent discharge.

The WSP system at Sereflikochisar was commissioned in 1987 and designed for a Phase I population equivalent of 25,000. The sewered population in 1997 was estimated to be 58,000, so the system is already overloaded. It comprises two series of five ponds covering a total pond area of 20 ha (Figure 4.1). Although designed as primary facultative ponds, the first ponds in each series appear to be anaerobic; this is probably due to the excessive loading they receive, as evidenced by the sludge banks within them. The system has not been desludged since commissioning.

The single series of two ponds at Ilgin was designed for a population of 25,000 and currently serves a population of 15,000 (Figure 4.2). Due to infiltration little effluent is discharged from the second pond, and consequently effluent from the first pond is used for the irrigation of sugar beet. A similarly designed single two-pond series at Selçuk was commissioned in 1990 and serves a population which varies from 25,000 in winter to 50,000 in the summer tourist season. It was designed for a Phase I population equivalent of 30,000, increasing to 60,000 in 2020, and covers an area of 31 ha. The floating macrophyte *Eichhornia crassipes* (water hyacinth) has been placed on the ponds and now covers 50 percent of the surface of the primary facultative pond. The final effluent discharges into a medium-sized river and is not directly used for

Table 4.2 WSP systems under construction in Turkey from 1997 (except South Anatolia)

Location	Design horizon	Population equivalent	Flow (l/s)	Capital cost (1997 TL billions[a])
Bor	2025	89,490	245	366
Ercis	2021	137,000	350	258
Gerede	2023	42,500	50	139
Kadinhani	2030	52,000	163	156
Karaman	2024	312,600	1,015	321
Muradiye	2025	36,000	250	107
Söke	2020	126,000	510	176

[a] January 1997 exchange rate: 1 billion TL = 7,405 ecu.

Source: Iller Bank.

Table 4.3 WSP systems under construction in Southeast Anatolia in 1997

Location	Population equivalent (year 2030)	Capital (1997 TL billions[a])
Kurtalan	86,600	11
Midyat	133,277	11
Nusaybin	222,000	18
Sason	32,100	7
Silvan	243,350	16
Besiri	31,500	8
Cizre	250,000	17
Cermik	64,000	12
Derik	45,000	9
Erganii	154,000	17
Gözpinar	20,000	6
Hani	50,000	7
Kozluk	105,000	12
Kulp	40,000	9

[a] January 1997 exchange rate: 1 billion TL = 7,405 ecu.

Source: Iller Bank.

Figure 4.1 Primary facultative ponds at Sereflikochisar - that on the right has been emptied and desludged. The central channel is a flow by-pass facility

irrigation, although the pond system is surrounded by fields of cotton which is an important crop in the area.

4.2 CYPRUS

The city of Nicosia has two wastewater treatment plants: a small aerated lagoon system at Lakacamia and the Mia Milea plant north of the "green line" which is larger and comprises aerated lagoons followed by conventional WSP. This system, which treats a mixture of domestic and industrial wastewater and serves communities on both sides of the "green line", comprises four series of ponds in parallel, each composed of an aerated lagoon (15,570 m^3, 2.5 m deep), a facultative pond (31,500 m^2, 1.5 m deep) and a maturation pond (15,100 m^2, 1.5 m deep). The system currently treats an estimated flow of 10,600 m^3/d with a

Figure 4.2 Primary facultative pond at Ilgin

BOD_5 load of 7,040 kg/d. It is thus seriously overloaded since its design BOD load was 2,523 kg. This has been caused by expansions in the city's sewerage system which have occurred without a corresponding expansion of the treatment plant. The final effluent, which is discharged into the Pedicos River, has an unfiltered BOD and suspended solids concentrations routinely in excess of 100 mg/l and 150 mg/l, respectively, which is well in excess of the effluent standards of < 20 mg BOD/l and < 30 mg SS/l. The system in its overloaded state has at times since 1991 generated unacceptable levels of odour which blows back over residential areas of the city. Consideration is currently being given to upgrading the system to treat a flow of 20,000 m^3/d and a BOD load of 11,300 kg/d.

The wastewaters from the central slaughterhouse and rendering plant at Kophinou are currently treated by a WSP system which comprises two anaerobic ponds in parallel (each with a volume of 9,550 m^2, 4 m deep; desludging is required frequently) (Figure 4.3), followed by a single facultative pond. Pretreatment comprises pumping the effluent through a rotosieve to remove coarse solids such as animal hair and meat scraps. The combined influent BOD of the slaughterhouse and rendering plant wastewater is approximately 2050 mg/l, and the average daily flow is 344 m^3/d (the plant does not operate everyday and the number and type of animals slaughtered varies). The plant achieves a BOD removal of 95 percent despite the fact that the facultative pond is undersized and the plant is at times overloaded. The system has occasionally suffered odour problems due to excessive sulphide generation in the anaerobic ponds, which has been traced to a high sulphate concentration (1050 mg/l) in the water from one of the boreholes used at the slaughterhouse.

Effluent reuse is not generally practised in Cyprus, although the Water Department of the Ministry of Agriculture has set up an impressive reuse demonstration project outside Nicosia: effluent from a maturation pond is used to irrigate plots of maize, cotton, safflower and jojoba, with freshwater controls (Figure 4.4); crop yields from the wastewater-irrigated plots are higher than those from the freshwater control plots (Section 12.3).

Figure 4.3 Anaerobic pond at Kophinou treating slaughterhouse wastewater

Figure 4.4 Wastewater reuse demonstration project outside Nicosia. The plots on the left are irrigated with effluent from the maturation pond (shown lower left); those on the right are freshwater controls

4.3 ISRAEL*

WSP have been regarded as the wastewater treatment technology of first choice in Israel, given the need for the use of treated wastewater for irrigation. Early WSP, built in the 1950s, comprised two alternately used anaerobic ponds in parallel (1-2 days retention time), followed by a "minimal" facultative pond with a retention time of only 5-7 days (compared with the then more usual 20-30 days) (Shuval, 1951). The principal considerations in determining these unconventional WSP design criteria were:

(1) to achieve sufficient removal of solids to allow for efficient pumping of effluents and to prevent major clogging of sprinkler irrigation systems;
(2) to assure sufficiently aerobic conditions in the facultative ponds *at least under summer conditions* to prevent serious odour nuisance to housing in the vicinity of the ponds and the irrigated fields;
(3) to be low in cost and land use, and simple to construct, so as to encourage wastewater recycling and reuse as a water resource conservation policy in a country that would face serious water shortages in the future, and as an effective strategy to minimize environmental pollution in a country with little or no permanent watercourses to receive and dilute wastewater effluents;
(4) despite the recognised low level of removal of faecal indicator organisms and pathogens in such simple short-detention-period WSP, a reasonable degree of health protection could be assured by strict limitation of the crops grown to exclude vegetables and salad crops eaten uncooked; and
(5) to motivate farmers and water planners to promote wastewater recycling and reuse with a low-cost, easy-to-implement technology as a first stage, which could later be upgraded.

* This section is based on a briefing paper prepared for this Manual by Professor H. I. Shuval of the Hebrew University of Jerusalem.

These initial WSP design criteria were recognised as being only for an interim period of study and evaluation. They could be modified later and brought up to more conventional design criteria if health considerations warranted it and as the economic situation improved.

A national wastewater reuse and recycling policy was incorporated in the Israel National Water Plan of 1956, and wastewater was specifically mentioned as a water resource in the Israeli Water Law of the same year. In 1965 the Ministry of Health issued regulations that permitted the reuse of WSP effluents for the irrigation of crops other than vegetables and salad crops eaten raw.

Between 1952 and 1975 some 200, mainly small, WSP systems were built generally following the above interim design criteria and mostly for the irrigation of industrial crops, especially cotton. During this time domestic water consumption was relatively low, 80-100 litres per person per day, and as a result wastewaters were very strong, with a BOD of 400-600 mg/l. Accordingly the volumetric loadings on the 1-2 day anaerobic pond were as high as 500 g BOD/m^3 day (or even higher), and the surface loadings on the facultative ponds were as much as 1,000 kg BOD/ha day (cf. Section 6.3 and 6.4). Odour nuisance was, as a result, quite intense, particularly during the colder winter months. Odour was controlled by reducing these high loadings (see Shelef, 1975), and Zohar (1986) recommended the following more appropriate design equation for facultative ponds, which was adopted for use in Mediterranean Europe (Mara and Pearson, 1987) (see Section 6.4):

$$\lambda_s = 10T \qquad (4.1)$$

where λ_s = the surface BOD loading, kg/ha day
T = mean temperature of the coolest month, °C

By 1994 domestic water consumption had risen to a mean of 250 litres per person per day, and thus the wastewater BOD reduced to around 300 mg/l (Etan, 1995). Reducing the loadings on WSP meant increasing WSP land area requirements, so few Israeli pond systems comprised sufficient maturation ponds to allow the effluent to be used for unrestricted irrigation. As a result, restricted irrigation has been the norm in Israel (Figure 4.5).

The Dan Region Wastewater Reclamation Project

This well-known project for the collection and treatment of wastewater in the Tel Aviv region, comprises 120 ha of recirculated facultative (see Shelef and Kanarek, 1995) and maturation ponds, followed by infiltration and percolation through sand dunes into the aquifer (Figure 4.6). After a retention time of over a year in the aquifer, the highly treated coliform-free wastewater is abstracted via 29 recovery wells and used for unrestricted irrigation in the Negev desert in the south of Israel. The year 2000 design population and wastewater flow are 1.7 millions and 200 million m^3/year, respectively.

While the original design in the mid-1950s was based on WSP (Amramy *et al.*, 1962), the huge increase in population in Greater Tel Aviv meant that the local demand for land precluded further use of WSP, and an activated sludge plant has been built in parallel with the original WSP (Kanarek, 1994).

Figure 4.5 Irrigation of winter wheat with WSP effluent in the Negev desert

Wastewater treatment and storage reservoirs

WSTR (see Section 11) were developed in Israel to allow the whole year's wastewater production to be used for irrigation, and to prevent surface water and groundwater pollution due to effluent discharge to the environment during the non-irrigation season. Currently around 100 WSTR are in operation in Israel. Many of these are single WSTR (see Section 11.1), and a few are operated as sequential batch-fed systems (Section 11.2). The latter can achieve faecal coliform removals of 99.999 percent, and so these effluents can be safely used for unrestricted irrigation (Section 12.1).

The future

Israel is currently utilizing essentially all its renewable surface and groundwater resources of some 1,600 million m^3/year. With an urban demand for domestic and industrial purposes of around 600 million m^3/year, the only way to meet the increasingly urban water demand has been to reduce the quantity of freshwater allocated to the agricultural sector, replacing it with treated wastewater. Israel is

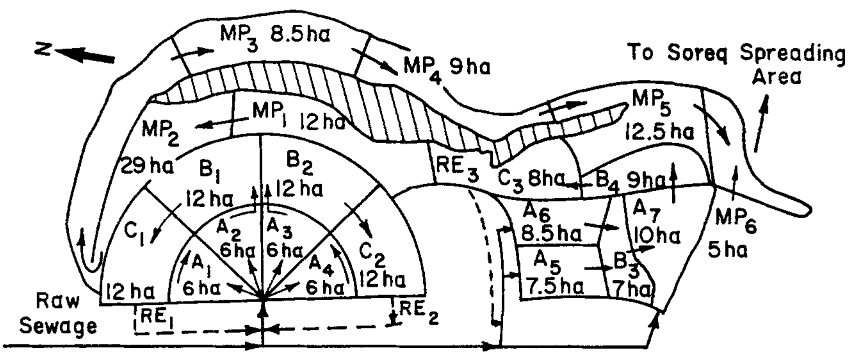

Figure 4.6 Layout of the Dan Region WSP, Tel Aviv. A, primary pond; B, secondary pond; C, tertiary pond; RE, recirculation of effluent. The Soreq spreading area is where the effluent percolates down to the aquifer

now reusing some two-thirds of its wastewater in agriculture, and by 2000 this will increase to around three-quarters. Treated wastewater is now the only sustainable new source of water for the agricultural sector.

WSP have played a major role in wastewater treatment and reuse in Israel. However, this is becoming less feasible due to an increasing population density and the high cost of land now required for residential areas. This has led in recent years, to the construction of electromechanical wastewater treatment plants to reduce land take; many of these are followed by WSTR to conserve wastewater for use in the irrigation season.

4.4 JORDAN

Jordan has 16 major wastewater treatment plants. Six are WSP and ten are conventional electromechanical plants. Over 85 percent of the total wastewater generated in Jordan is treated in WSP. This is clearly sensible given that over 95 percent of the country is desert, so land availability for WSP is not a significant problem.

Five of the WSP systems serve relatively small communities of up to 50,000 population. The other WSP system, at Al Samra, near Amman, is the largest in the Region: it serves Amman and the neighbouring industrial city of Zarqa. The total population served by the Al Samra WSP is around 1.4 million.

After screening and grit removal, wastewater from the city of Amman flows 39 km by gravity in a 1.2 m diameter steel pipeline to the Al Samra WSP via an inverted siphon (considered to be one of the largest in the world: the wastewater enters the pipeline at an elevation of 680 m; the lowest point of the siphon is at 460 m, and the elevation of the inlet works at the WSP site 580 m). The wastewater is strong, with a BOD of around 700 mg/l, due to the relatively low water consumption (due to water scarcity) of 80 litres per person per day. The total wastewater flow treated in the Al Samra WSP is currently 150,000 m^3/day (average for 1996), equivalent to 80 percent of all wastewater generated in Jordan.

The Al Samra WSP (Figure 4.7) became operational in May 1985 and cost US$ 50 million (64 million ecu). The total pond area is some 200 ha, within a 1100 ha site. There are three series of ten ponds, and each series nominally comprises two anaerobic ponds (each 3.2 ha, 5.1 m deep), four facultative ponds (each 7.25 ha, 2.25 - 1.6 m deep) and four maturation ponds (each 6.25 ha, 1.2 m deep). To improve operational flexibility for desludging the anaerobic ponds, two additional equally sized anaerobic ponds in series were constructed, in parallel with the existing anaerobic ponds, in 1996. At the same time the inlet works were covered to reduce odour emission and a chemical scrubber unit installed to remove hydrogen sulphide from the incoming raw wastewater (although to date this has not been used).

The WSP were designed for a wastewater flow of 68,000 m^3/day, so they are currently overloaded hydraulically by a factor of 2.2. Nonetheless their performance is remarkably good: BOD removal, for example, was 73-85 percent during 1990-95 (an activated sludge plant overloaded to the same extent as the Al Samra WSP would not perform nearly so well). When the WSP were not overloaded (1985-1989), BOD removal was 85 percent, and the geometric mean faecal coliform count in the final effluent was 1240 per 100 ml and no nematode eggs were present.

Figure 4.7 Partial view of the Al Samra WSP, Amman. In the foreground are some of the olive trees, the harvest from which pays towards the O&M costs of the pond system

Due to the high organic and hydraulic loading on the Al Samra WSP, most of the facultative and maturation ponds are anoxic, with normal algal concentrations only occurring in the final two maturation ponds. In particular the load on the first facultative pond is excessively high, of the order of 900 kg BOD/ha day (the mean temperature of the coolest month is 10°C, so this loading is 9 times greater than the normal design loading of 100 kg/ha day for this temperature – see Table 6.3), and it would have been better to have the four facultative ponds in each series in parallel, rather than in series.

Around 1.5 million trees were planted around the Al Samra WSP in 1985. These are irrigated with 2-3 percent of the final effluent, and 5-15 labourers are employed to plant and maintain the trees. Some 60,000 olive trees are leased to a local farmer and this currently provides an income of US$ 12,000 (11,000 ecu) per annum, which pays for a significant proportion of the operation and maintenance costs of the Al Samra WSP (and it is expected that this will increase to cover more than all the O&M costs when all the olive trees mature).

Nearly 85 percent of wastewater in Jordan is reused for crop irrigation, equivalent to around 12 percent of all irrigation water used. All of the Al Samra WSP effluent is reused for irrigation. It is not normally chlorinated, although there is provision for chlorination. It flows 42 km, via the Wadi Dhuleil and the Zarqa River and enters the King Talal Reservoir (capacity: 78×10^6 m^3). The Al Samra effluent, together with effluents from the wastewater treatment works at Jarash and Abu Nuseir, contributes 20-40 percent of the inflow to the reservoir, the balance coming from the Zarqa River, into Wadi Rumeimin. Water from the King Talal Reservoir is released through a distribution network for unrestricted irrigation in the Jordan Valley (the east bank of the Jordan River). An area of around 10,000 ha is irrigated, either solely or partially, with water from the King Talal Reservoir.

The Al Samra WSP have been extensively studied. Further information is given in Al-Salem and Lumbers (1987) and Saqqar and Pescod (1991, 1995*a*, *b*, 1996). Further details of the reuse of the Al Samra effluent are given by Saqqar (1996) and Shatanawi and Fayyad (1996).