# Municipal and Industrial Water Management

Jean G. Chatila

## I. INTRODUCTION

Water, like energy, will probably become the most critical natural resource issue facing most parts of the world. By the year 2025, a full 35% of the world population will be living under conditions of water scarcity or stress compared to about 6% in 1990 (Al Radif, 1999). In the Arab world, parts of which were once referred to as the Fertile Crescent, precipitation is low, droughts are frequent, and rivers are few. Under a business-as-usual scenario, countries in the region will experience serious water shortages in coming years, with grave consequences on economic and social development plans. Moreover, many experts warn that disagreements over water have the potential to create political tensions (Darwish, 1994). Thus, water will be a major concern that can catalyze stability and cooperation or inhibit both. The main problem in confronting the water crisis is the lack of the political will to advocate use efficiency, undertake a new discourse, or invest in new research. In an endless attempt to resolve the water deficit, Arab countries are having to rely on non-conventional water resources, namely, desalination and wastewater treatment and reuse, to satisfy increasing demand (Chatila, 2003).

To address water scarcity, governments in the Arab region need to target optimum utilization of available water resources, and possibly augment water supplies through the exploitation of new natural or non-conventional resources. This is accomplished through wastewater reclamation, brackish and seawater desalination, and rainwater harvesting. However, augmenting water supplies will not provide a sustainable answer. Addressing water shortages necessitates the adoption of well-planned policies focused on improving water management, rationalizing water consumption, and protecting water supplies from over-use and pollution. A system of laws and policies is needed, in which governments enforce comprehensive codes and regulations including health standards. This chapter presents a set of proposed regulations and policy recommendations that should be considered.

The high population growth rate in Arab countries exceeds by far the growth rate of developing water resources. Consequently, the annual per capita share of water resources is decreasing at an increasing rate. This chapter tackles the current problem through three-interdependent venues, namely:

1. It provides a brief overview of demand and supply projections in the member countries of the Economic and Social Commission for Western Asia (ESCWA) up to the year 2050. Population estimates are based on data provided by the statistics section of the ESCWA head office in Beirut. Demand projections were performed for per capita consumption in the domestic, agricultural, and industrial sectors, and a total demand for each sector was determined based on the projected population figures and the respective per capita demand. Then, the break-even year between projected demand and expected supply was estimated for each member state.
2. A set of policies and regulations are recommended in order to reduce water shortages in the near future.
3. Establishing a proper water tariff structure is discussed with suggested principles for pricing domestic, agricultural, and industrial water.

## II. WATER DEMAND AND SUPPLY

### *a. Population projection*

The ESCWA region, which consists of 13 member states with a total area of 4 million km$^2$, is divided

TABLE 1 POPULATION SIZE (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1950 TO 2050 (THOUSANDS)

| | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bahrain** | 115.6 | 156.1 | 219.6 | 347.0 | 490.0 | 617.2 | 713.1 | 812.2 | 895.9 | 947.5 | 991.6 |
| **Egypt** | 21834.0 | 27840.0 | 35285.0 | 43749.0 | 56332.8 | 68469.7 | 80063.3 | 90490.7 | 100371.0 | 108369.4 | 114844.2 |
| **Iraq** | 5158.3 | 6847.0 | 9356.0 | 13007.3 | 18078.1 | 23114.9 | 30338.7 | 37664.3 | 43929.1 | 49476.3 | 54915.7 |
| **Jordan** | 916.0 | 1694.0 | 1703.7 | 2165.9 | 3423.3 | 5003.1 | 6279.7 | 7837.9 | 9610.7 | 11607.6 | 13837.9 |
| **Kuwait** | 152.2 | 278.0 | 744.3 | 1374.9 | 2143.0 | 1971.6 | 2419.7 | 2813.4 | 3115.2 | 3347.7 | 3526.9 |
| **Qatar** | 25.0 | 45.0 | 111.3 | 229.2 | 485.4 | 599.1 | 692.2 | 760.6 | 793.3 | 818.0 | 844.1 |
| **Oman** | 456.4 | 558.2 | 722.9 | 1130.0 | 1784.5 | 2541.7 | 3517.5 | 4719.3 | 5996.3 | 7208.5 | 8309.9 |
| **Lebanon** | 1442.7 | 1857.4 | 2469.0 | 2669.2 | 2555.3 | 3281.8 | 3722.9 | 4172.5 | 4605.9 | 4928.5 | 5168.9 |
| **KSA** | 3201.4 | 4074.7 | 5744.8 | 9604.4 | 16045.3 | 21606.7 | 28778.5 | 36424.2 | 42990.7 | 48661.2 | 54461.0 |
| **Syria** | 3495.1 | 4561.0 | 6258.0 | 8704.0 | 12386.0 | 16124.6 | 20464.1 | 24555.1 | 28078.1 | 31624.6 | 34490.1 |
| **UAE** | 69.6 | 90.2 | 222.8 | 1015.2 | 1920.5 | 2441.4 | 2851.2 | 3169.7 | 3375.9 | 3509.3 | 3615.2 |
| **WB & Gaza** | 560.6 | 740.9 | 938.5 | 1207.4 | 1838.8 | 2859.6 | 3244.0 | 4095.7 | 5065.3 | 6153.7 | 7361.7 |
| **Yemen** | 4316.0 | 5247.0 | 6331.6 | 8218.7 | 11589.6 | 18112.1 | 25366.2 | 34189.8 | 43734.1 | 51855.8 | 58801.1 |

geographically and ecologically into two sub-regions, namely, the Mashreq and the Arabian Peninsula. The Mashreq includes Lebanon, Syria, Jordan, Iraq, and Palestine (the West Bank (WB) and the Gaza Strip), in addition to Egypt, while the Arabian Peninsula includes Bahrain, Kuwait, Oman, Qatar, Kingdom of Saudi Arabia (KSA), the United Arab Emirates (UAE), and Yemen. Over 72% of the region has an annual rainfall of less than 100 mm; about 18% receives between 100 and 300 mm annually; less than 10% receives between 300 and 1,300 mm annually (ACSAD, 1997).

In the current study, previous population historic data and censuses, up to 2000, available from different member states were collected from the Statistics Office of ESCWA. Then, population projections, up to year 2050, were performed using statistical methods and regression analysis. These figures were used to estimate the domestic, industrial, and agricultural demand for water. Table 1 shows past and future projected population figures in the ESCWA member states.

The increase in population is above the world average and much above that in the industrialized countries. Table 1 shows that the rate of growth is high and the population is expected to double in the next 25 years, which will certainly have

TABLE 2 DOMESTIC WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

| | Demand (liters/capita/day) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **2000** | **2010** | **2015** | **2020** | **2025** | **2030** | **2040** | **2050** |
| **Bahrain** | 540 | 555 | 585 | 600 | 620 | 642 | 667 | 723 | 789 |
| **Egypt** | 130 | 135 | 145 | 150 | 157 | 164 | 172 | 191 | 213 |
| **Iraq** | 160 | 170 | 190 | 200 | 214 | 228 | 245 | 282 | 326 |
| **Jordan** | 130 | 135 | 145 | 150 | 157 | 164 | 172 | 191 | 213 |
| **Kuwait** | 540 | 555 | 585 | 600 | 620 | 642 | 667 | 723 | 789 |
| **Qatar** | 540 | 555 | 585 | 600 | 620 | 642 | 667 | 723 | 789 |
| **Oman** | 130 | 135 | 145 | 150 | 157 | 164 | 172 | 191 | 213 |
| **Lebanon** | 356 | 370 | 380 | 390 | 396 | 404 | 412 | 428 | 446 |
| **KSA** | 356 | 370 | 380 | 390 | 396 | 404 | 412 | 428 | 446 |
| **Syria** | 130 | 135 | 145 | 150 | 157 | 164 | 172 | 191 | 213 |
| **UAE** | 540 | 555 | 585 | 600 | 620 | 642 | 667 | 723 | 789 |
| **WB & Gaza** | 90 | 95 | 105 | 115 | 125 | 136 | 150 | 182 | 221 |
| **Yemen** | 90 | 95 | 105 | 115 | 125 | 136 | 150 | 182 | 221 |

TABLE 3 INDUSTRIAL WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

| | Demand (liters/capita/day) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
| **Bahrain** | 95 | 100 | 110 | 115 | 119 | 123 | 128 | 139 | 150 |
| **Egypt** | 30 | 35 | 45 | 50 | 55 | 61 | 68 | 84 | 103 |
| **Iraq** | 50 | 75 | 125 | 150 | 184 | 221 | 261 | 355 | 465 |
| **Jordan** | 30 | 35 | 45 | 50 | 55 | 61 | 68 | 84 | 103 |
| **Kuwait** | 15 | 20 | 30 | 40 | 50 | 61 | 75 | 107 | 146 |
| **Qatar** | 95 | 100 | 110 | 115 | 119 | 123 | 128 | 139 | 150 |
| **Oman** | 15 | 20 | 30 | 40 | 50 | 61 | 75 | 107 | 146 |
| **Lebanon** | 55 | 65 | 95 | 115 | 142 | 174 | 211 | 299 | 407 |
| **KSA** | 30 | 35 | 45 | 50 | 55 | 61 | 68 | 84 | 103 |
| **Syria** | 30 | 35 | 45 | 50 | 55 | 61 | 68 | 84 | 103 |
| **UAE** | 95 | 100 | 110 | 115 | 119 | 123 | 128 | 139 | 150 |
| **WB & Gaza** | 5 | 10 | 20 | 25 | 32 | 39 | 47 | 66 | 88 |
| **Yemen** | 15 | 20 | 30 | 40 | 50 | 61 | 75 | 107 | 146 |

a major effect on available water resources. The situation is similar in other Arab countries.

### *b. Demand projection*

The goal of the study is to project domestic, industrial, and agricultural water demand in ESCWA member states up to the year 2050. Total demand is computed for each member state and compared with available supply resources in the state. A breakeven year is determined for each country. Demand projection is based on different water resources studies and tables that are established by the ESCWA secretariat or compiled from different sources and meetings of the expert groups in ESCWA office in Beirut, Lebanon, during the last few years, in addition to personal communication with concerned ministries and water authorities in member states. Although this chapter is concerned with municipal (domestic) and industrial water management, we include water demand projections for the agricultural sector for comparative purposes.

Historic data on the per capita basis for domestic demand and the per capita daily industrial and agricultural equivalent of water was collected from ESCWA sources. Based on current applications, a second-degree function produced a good fit for the data with a very reasonable coefficient

TABLE 4 AGRICULTURAL WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

| | Demand (liters/capita/day) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
| **Bahrain** | 671 | 554 | 772 | 820 | 866 | 919 | 980 | 1128 | 1297 |
| **Egypt** | 2,417 | 2,395 | 2,119 | 2,070 | 2,024 | 1,982 | 1,950 | 1,928 | 1,934 |
| **Iraq** | 6,853 | 1,0728 | 6,087 | 5,886 | 5,725 | 5,617 | 5,553 | 5,410 | 5,253 |
| **Jordan** | 520 | 433 | 330 | 302 | 352 | 259 | 243 | 219 | 200 |
| **Kuwait** | 102 | 139 | 138 | 139 | 140 | 142 | 146 | 158 | 173 |
| **Qatar** | 615 | 876 | 615 | 500 | 513 | 743 | 763 | 814 | 860 |
| **Oman** | 1,766 | 1,632 | 1,139 | 1,014 | 917 | 838 | 776 | 706 | 672 |
| **Lebanon** | 938 | 793 | 1,171 | 1,256 | 1,328 | 1,402 | 1,475 | 1,623 | 1,781 |
| **KSA** | 2,493 | 1,874 | 1,358 | 1,151 | 975 | 826 | 699 | 498 | 353 |
| **Syria** | 1,533 | 2,612 | 2,076 | 2,070 | 2,087 | 2,097 | 2,103 | 2,134 | 2,202 |
| **UAE** | 1,355 | 1,571 | 1,555 | 1,602 | 1,661 | 1,726 | 1,798 | 1,969 | 2,135 |
| **WB & Gaza** | 209 | 208 | 206 | 202 | 197 | 192 | 188 | 184 | 185 |
| **Yemen** | 638 | 463 | 315 | 304 | 269 | 229 | 219 | 190 | 171 |

TABLE 5 ANNUAL DOMESTIC WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M³)

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| **Bahrain** | 97 | 125 | 152 | 167 | 184 | 200 | 218 | 250 | 286 |
| **Egypt** | 2,673 | 3,374 | 4,237 | 4,669 | 5,186 | 5,712 | 6,301 | 7,555 | 8,929 |
| **Iraq** | 1,056 | 1,434 | 2,104 | 2,482 | 2,942 | 3,395 | 3,928 | 5,093 | 6,534 |
| **Jordan** | 162 | 247 | 332 | 386 | 449 | 522 | 603 | 809 | 1,076 |
| **Kuwait** | 422 | 399 | 517 | 573 | 637 | 695 | 758 | 883 | 1,016 |
| **Qatar** | 96 | 121 | 148 | 159 | 172 | 182 | 193 | 216 | 243 |
| **Oman** | 85 | 125 | 186 | 225 | 270 | 321 | 376 | 503 | 646 |
| **Lebanon** | 332 | 443 | 516 | 562 | 603 | 647 | 693 | 770 | 841 |
| **KSA** | 2,085 | 2,918 | 3,992 | 4,641 | 5,265 | 5,855 | 6,465 | 7,602 | 8,866 |
| **Syria** | 588 | 795 | 1,083 | 1,232 | 1,407 | 1,575 | 1,763 | 2,205 | 2,681 |
| **UAE** | 379 | 495 | 609 | 659 | 717 | 767 | 822 | 926 | 1,041 |
| **WB & Gaza** | 60 | 99 | 124 | 154 | 187 | 227 | 277 | 409 | 594 |
| **Yemen** | 381 | 628 | 972 | 1,250 | 1,560 | 1,934 | 2,394 | 3,445 | 4,743 |

of correlation $R^2$ close to unity in most cases. A power or exponential fit may have produced good fit as well but the second-degree polynomial proved to be more successful. The regression equations were solved and the parameters determined. Typical equations of polynomials were established. Demand projections were performed on per capita basis for the years 2010 to 2050 using statistical methods and regression analysis, as shown in Tables 2, 3, and 4.

Projected population data were used along with projected water demand to obtain the total demand on a volumetric basis in million cubic meters (MCM) for the industrial, domestic, and agricultural sectors, as indicated in Tables 5, 6, and 7.

Table 8 shows the total demand in each ESCWA member state for the period 1990 to 2050 on a volumetric basis (MCM).

Domestic water demand represents a small fraction of the total water utilized, particularly when compared to the agricultural sector. Improvement in the standard of living, delivery services, and urban migration resulted in increased domestic demand. The industrial production structure in most of the ESCWA member countries is geared towards consumer goods and petroleum refinement, where most activities are confined close to urban centers. Some industries have specific water quality and quantity requirements, which vary according to the type of industry.

TABLE 6 ANNUAL INDUSTRIAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M³)

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| **Bahrain** | 17 | 23 | 29 | 32 | 35 | 38 | 42 | 48 | 54 |
| **Egypt** | 617 | 875 | 1,315 | 1,556 | 1,817 | 2,125 | 2,491 | 3,323 | 4,318 |
| **Iraq** | 330 | 633 | 1,384 | 1,862 | 2,530 | 3,291 | 4,185 | 6,411 | 9,321 |
| **Jordan** | 37 | 64 | 103 | 129 | 1 57 | 194 | 239 | 356 | 520 |
| **Kuwait** | 12 | 14 | 26 | 38 | 51 | 66 | 85 | 131 | 188 |
| **Qatar** | 17 | 22 | 28 | 30 | 33 | 35 | 37 | 41 | 46 |
| **Oman** | 10 | 19 | 39 | 60 | 86 | 119 | 164 | 282 | 443 |
| **Lebanon** | 51 | 78 | 129 | 166 | 216 | 279 | 355 | 538 | 768 |
| **KSA** | 176 | 276 | 473 | 595 | 731 | 884 | 1,067 | 1,492 | 2,047 |
| **Syria** | 136 | 206 | 336 | 411 | 493 | 586 | 697 | 970 | 1,297 |
| **UAE** | 67 | 89 | 114 | 126 | 138 | 147 | 158 | 178 | 198 |
| **WB & Gaza** | 3 | 10 | 24 | 33 | 48 | 65 | 87 | 148 | 236 |
| **Yemen** | 63 | 132 | 278 | 435 | 624 | 867 | 1,197 | 2,025 | 3,134 |

TABLE 7 ANNUAL AGRICULTURAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M$^3$)

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| **Bahrain** | 120 | 125 | 201 | 228 | 257 | 286 | 320 | 390 | 469 |
| **Egypt** | 49,697 | 59,854 | 61,924 | 64,431 | 66,851 | 69,038 | 71,439 | 76,262 | 81,070 |
| **Iraq** | 45,219 | 55,076 | 67,405 | 73,048 | 78,704 | 83,642 | 89,037 | 97,698 | 105,292 |
| **Jordan** | 650 | 791 | 756 | 778 | 1,007 | 825 | 852 | 928 | 1,010 |
| **Kuwait** | 80 | 100 | 122 | 133 | 144 | 154 | 166 | 193 | 223 |
| **Qatar** | 109 | 192 | 155 | 133 | 142 | 211 | 221 | 243 | 265 |
| **Oman** | 1,150 | 1,514 | 1,462 | 1,524 | 1,580 | 1,639 | 1,698 | 1,858 | 2,038 |
| **Lebanon** | 875 | 950 | 1,591 | 1,810 | 2,022 | 2,246 | 2,480 | 2,920 | 3,360 |
| **KSA** | 14,600 | 14,779 | 14,265 | 13,696 | 12,962 | 11,971 | 10,968 | 8,845 | 7,017 |
| **Syria** | 6,931 | 15,373 | 15,506 | 17,007 | 18,705 | 20,143 | 21,553 | 24,633 | 27,721 |
| **UAE** | 950 | 1,400 | 1,618 | 1,760 | 1,922 | 2,062 | 2,216 | 2,522 | 2,817 |
| **WB & Gaza** | 140 | 217 | 244 | 271 | 295 | 321 | 348 | 413 | 497 |
| **Yemen** | 2,699 | 3,061 | 2,916 | 3,304 | 3,357 | 3,257 | 3,496 | 3,596 | 3,670 |

Agricultural water demand accounts for the majority of water use. Data from ESCWA show that the cultivated area in 1997 was about 20.2 million hectares in which 44.6% were irrigated using surface and groundwater sources, while the rest was rain-fed.

### *c. Supply projection*

The state of development of surface and ground water resources varies from country to country within the ESCWA region, depending on each country's specific context and conditions. Some countries such as Syria, Lebanon, Jordan, Egypt, Iraq, and Palestine have dependable surface water due to the relatively high rainfall. Water sources are in the form of major rivers and springs. The main rivers are the Nile in Egypt, the Euphrates and Tigris in Syria and Iraq, the Orentis in Lebanon and Syria, the Litani in Lebanon, and the Jordan River in Jordan and the West Bank. Furthermore, water supplies are supplemented by groundwater reserves.

On the other hand, countries like KSA, Kuwait, Bahrain, Qatar, UAE, Oman, and Yemen are known to have a severe desert environment, where surface water resources consist of limited quantities. Thus, they have no option but to rely on non-conventional sources, such as desalination and treated wastewater. Aquifers with varying degrees of salinity provide another source for water. They are used to satisfy the domestic and agricultural water requirements. Based on several

TABLE 8 TOTAL ANNUAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M$^3$)

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| **Bahrain** | 234 | 272 | 382 | 427 | 476 | 525 | 580 | 688 | 809 |
| **Egypt** | 52,987 | 64,103 | 67,476 | 70,656 | 73,853 | 76,875 | 80,232 | 87,139 | 94,316 |
| **Iraq** | 46,605 | 57,143 | 70,893 | 77,392 | 84,176 | 90,328 | 97,151 | | 121,147 |
| **Jordan** | 850 | 1,101 | 1,192 | 1,293 | 1,614 | 1,541 | 1,694 | 2,093 | 2,606 |
| **Kuwait** | 514 | 514 | 665 | 744 | 832 | 914 | 1,010 | 1,207 | 1,426 |
| **Qatar** | 221 | 335 | 331 | 322 | 348 | 428 | 451 | 500 | 554 |
| **Oman** | 1,245 | 1,658 | 1,687 | 1,810 | 1,936 | 2,079 | 2,239 | 2,642 | 3,127 |
| **Lebanon** | 1,258 | 1,471 | 2,237 | 2,537 | 2,842 | 3,172 | 3,527 | 4,227 | 4,969 |
| **KSA** | 16,861 | 17,973 | 18,729 | 18,932 | 18,958 | 18,711 | 18,500 | 17,939 | 17,930 |
| **Syria** | 7,654 | 16,373 | 16,926 | 18,650 | 20,605 | 22,304 | 24,012 | 27,807 | 31,699 |
| **UAE** | 1,395 | 1,984 | 2,342 | 2,546 | 2,777 | 2,976 | 3,195 | 3,626 | 4,056 |
| **WB & Gaza** | 204 | 327 | 392 | 458 | 529 | 614 | 712 | 970 | 1,327 |
| **Yemen** | 3,143 | 3,821 | 4,166 | 4,989 | 5,541 | 6,058 | 7,088 | 9,066 | 11,547 |

TABLE 9 **CONVENTIONAL ANNUAL WATER SUPPLY (MILLION $M^3$) IN ESCWA MEMBER STATES***

| | Surface Water | Groundwater Recharge | Groundwater Use | Total Supply |
|---|---|---|---|---|
| **Bahrain** | 0 | 100 | 258 | 358 |
| **Egypt** | 55,500 | 4,100 | 4,850 | 64,450 |
| **Iraq** | 70,370 | 2,000 | 513 | 72,883 |
| **Jordan** | 350 | 277 | 486 | 1,113 |
| **Kuwait** | 0 | 160 | 405 | 565 |
| **Qatar** | 1 | 85 | 185 | 271 |
| **Oman** | 918 | 550 | 1,644 | 3,112 |
| **Lebanon** | 2,500 | 600 | 240 | 3,340 |
| **KSA** | 2,230 | 3,850 | 14,430 | 20,510 |
| **Syria** | 16,375 | 5,100 | 3,500 | 24,975 |
| **UAE** | 185 | 130 | 900 | 1,215 |
| **WB & Gaza** | 30 | 185 | 200 | 415 |
| **Yemen** | 2,250 | 1,400 | 2,200 | 5,850 |

* Water supply data are based on years 1995, 1996, 1997, and 1999

country papers presented during the Expert Group Meetings held at the ESCWA head office in Beirut in 1995, 1996, 1997, and 1999, the following supply figures in Table 9 compile available annual conventional water resources for member states.

The breakeven point for water supply and demand is estimated for each member state, as indicated in Table 10. Some countries will continue to depend on surface water from major rivers, while others will rely on groundwater and desalinated seawater.

### *d. Discussion*

The high population growth rate in the West Asia region exceeds by far the rate of developing water resources. Consequently, the annual per capita share of water resources is decreasing at an increasing rate. This study shows that developing water resources on a business-as-usual basis will leave the region with serious water shortages, particularly in the Arabian Peninsula where the annual water deficit could increase to as much as 67% of demand by 2015. It is clear that current water resources cannot satisfy future demand much past 2005 without alternative sources and policies. Water deficits can be reduced, though not eliminated, especially if emphasis is placed on cutting the wasteful use of water in agriculture, which accounts for the majority of water use in the region, and by shifting current policies away from heavy emphasis on food self-sufficiency. Supplies of renewable water in the region are fully used or already overexploited, whereas demand will continue to rise rapidly. Currently water deficit is partially made up for by desalination and by over-exploitation of groundwater, which is resulting in fast depletion of aquifer reserves, deteriorating water quality, and higher salinity in the soil. Furthermore, existing wastewater treatment facilities may create health hazards due to the disposal of untreated wastewater. In general, the water sector suffers from weak institutions, inadequate technical capabilities, and unsatisfactory coordination among concerned authorities. There is an urgent need to review policies regarding the development and rational use of water resources throughout the region. The development of additional water resources in the region will require well planned, detailed, and integrated studies of the potential for surface, groundwater, and non-conventional water resources to meet rising demand, and cooperation between member states in these studies. Water policy formulation is very data intensive. Reliable data are the basis for sound planning and implementation of these policies.

Several options exist to address the imbalance of water demand and supply. The business-as-usual option assumes that no further development of water resources is anticipated, and emphasis is placed on prioritizing the usage of water for domestic purposes and then industrial and agricultural purposes. In general, the tendency of countries is to exploit easily accessible water resources first. Remaining sources will surely require heavy investment, laborious investigation, and intensive research programs. Moreover, disputes may arise regarding shared water resources if proper conflict resolution measures are not adopted. A second option would be to emphasize supply augmentation by investing in non-conventional resources to satisfy the needs of water users. This option is not easy to fulfill at a reasonable cost. It should be noted, though, that consistent improvements in technology and operation have somewhat reduced capital and operating costs of non-conventional sources.

An optimal solution would be to adopt policy remedies that can achieve a gradual and rational decrease in consumption patterns by adopting high efficiency irrigation practices, imposing tariffs on water use, and improving wastewater management. Therefore, extensive investigation, development, and reform programs are essential to develop the additional water resources needed, minimize water losses, and effect the optimum rationalization of water use.

## III. POLICY AND INSTITUTIONAL REFORMS

Water scarcity could result from the lack of supplies and/or the abuse and overuse of available water resources. Pollution by industry, urban wastewater, and agricultural run-off reduces the fitness of fresh water sources. A steady decline in groundwater levels has been documented due to over-pumping of aquifers. Inappropriate irrigation practices contribute to increased soil salinization and erosion, and result in higher sediment loads in watercourses. Industrial wastewater discharged into surface water or mixed with municipal wastewater raises serious concerns about environmental problems and diseases. Uncontrolled wastewater irrigation practices may cause major detrimental effects to public health.

Proper management of municipal and industrial water resources requires policies, standards, norms, and regulations in order to ensure water availability, avoid contamination, and protect public health. The role of government should shift from a provider to that of a regulator and planner. For example, government water institutions should plan for necessary water investments, commission studies, and arrange for project implementation within an overall national strategic water master plan. Such a plan needs to explain how available water resources will be developed and utilized by the different sectors and should spell out operation and maintenance (O&M) requirements, means of cost recovery, a list of rehabilitation projects, efficiency programs, and the administrative architecture needed to achieve the goals of the master plan.

Water departments should have the primary task of issuing water and health standards, regulating water use, rationalizing domestic, industrial, and irrigation water use, limiting illicit connections, encouraging participation of the private sector, laying down the standards of service, consulting users first, involving the participation of rural communities in O&M activities, and introducing adapted technologies and equipment.

Although not formally and fully documented, most, if not all, Arab countries have a number of technical and operational policies for managing municipal and industrial water use. These include policies pertaining to the levels of service provision to the customer, water quality delivered, system and customer metering, preferred standards, and current practices for materials and construction. A standard practice document should be prepared in each country. This document should provide guidelines to engineers and other interested parties to achieve satisfactory design for the transmission and distribution systems as well as for operational standards in the water supply sector adhering to the requirements set by the water authorities.
As a result of current shortcomings, the following policy reforms are suggested:

### *a. Environmental protection*

Protection, enhancement, and restoration of water quality, and abatement of water pollution should be the focus of operations by the water authorities. It is important to support efforts to improve and expand clean sanitation and the treatment of wastewater. Water authorities are expected to apply efficiency pricing to encourage water conservation. They should also employ the 'polluter-pays' principle through the imposition of pollution charges to reduce pollution from industrial waste, mining runoff, and wastewater discharges. A balanced strategy involving economic incentives, effective legislation, and regulatory standards and guidelines for levels of pollution control should be used to reduce effluents at the source, particularly if toxic substances are present. For pollution originating from agricultural activities, initiatives to minimize soil erosion and restore and protect surface and subsurface waters degraded by agricultural pollutants should be supported.

Strategies and cost-effective mechanisms for ecologically sustainable management, protection, and restoration of recharge areas and water-dependent ecosystems, such as wetlands, floodplain areas, and coastal zones should be administered. Based on the increasing importance of groundwater, it is critical to establish linkages between ground and surface water in managing river basins and establish programs and policies, including land use policies that restore and protect the quality of groundwater and groundwater recharge areas.

Reducing water pollution in urban areas requires coordinated policies and steps to lower municipal and industrial discharges of wastewater. To reduce the cost of waste treatment, authorities should give incentives to both industries and municipalities to reduce their waste loads. Municipal sewer and sewage treatment surcharges can be applied to water supply fees, preferably on the basis of volume. The industrial use of municipal sewerage systems should be based on clearly established standards for pretreatment and on user charges based on the volume and pollution load of industrial effluents. Best practice guidelines for minimum levels of pollution in both municipal and industrial sources should be developed and enforced. Establishing the appropriate standards requires careful analysis of the costs and benefits, given the very large price tag associated with cleanup operations, monitoring of compliance, and enforcement. Using innovative systems, water conservation, demand management, separation of toxic pollutants, and reuse for irrigation water can reduce the cost of sewage treatment.

### b. Community and private sector participation

A new set of laws or policies should be established to encourage private sector participation. In addition, community participation can enhance enforcement. With better information and legal support, such participation could provide a cost-effective way to identify enforcement problems. The key is the public disclosure of information on the discharge of industrial and municipal pollution. Disclosure improves compliance by supplementing the limited monitoring resources of public agencies in cooperation with affected communities. It strengthens enforcement efforts by focusing the attention of public officials on health and environmental problems associated with noncompliance. Wasteful use of water should be eliminated, and mining activities that seriously damage water resources should be regulated and controlled. For water investments and projects, environmental considerations should be given importance to protect natural ecosystems and direct development to less sensitive or already altered watersheds.

TABLE 10 **BREAKEVEN YEAR FOR AVAILABLE SUPPLY AND DEMAND IN ESCWA MEMBER STATES**

| | Breakeven year based on actual* supply | Breakeven year based on effective** supply |
|---|---|---|
| **Bahrain** | 1995 | 2009 |
| **Egypt** | 2000 | 2001 |
| **Iraq** | 2007 | 2011 |
| **Jordan** | 1990 | 2003 |
| **Kuwait** | already | 2001 |
| **Qatar** | already | 1997 |
| **Oman** | safe | ample supply |
| **Lebanon** | 2018 | 2027 |
| **KSA** | 1995 | 2010 |
| **Syria** | 2017 | 2035 |
| **UAE** | bad | major deficit |
| **West Bank & Gaza** | 1999 | 2005 |
| **Yemen** | 2010 | 2020 |

* Actual supply refers to conventional water supplies only.
** Effective supply refers to conventional and non-conventional water supplies

### c. Wastewater effluent criteria

Water authorities should establish general guidelines for the quality of wastewater discharged to streams and other water bodies. These controls should be designed to prevent pollution and the spread of disease resulting from the careless discharge of wastes. The distinction between environmental and human risks for different water uses has led to the formulation of standards, expressed in maximum receiving capacity of water for specific categories of pollutants most frequently discharged into the marine environment.

## TANNOURA IRRIGATES ITS GARDENS WITH GREYWATER

**Have you ever heard of a village where a public phone booth was installed before running water reached the houses? It is the true story of a Lebanese village,Tannoura.**

Children are running back and forth with empty gallons in hands, while mothers are stacking gallons filled with water in the wheel-barrow. The crowd is waiting for Zahia and her daughters to finish filling their last gallon from the Tannoura's small spring. "All this trouble with those gallons for so little water that I can only use to clean floors", says Zahia.

Tannoura not only suffers from water shortage, but it also seems suffering from all water related problems at once. The residents have to buy water by the truckloads costing around $10 per load of 2000 liters, which is quite expensive for families living on an average of $450 per month, and needing an average of 4 loads per month.

However, not everyone can afford that, so those who can't are obliged to adopt water saving behaviours. As a matter of fact, most households reuse their water 2 to 3 times before discharging it in the cess-pit. For instance, clothes washing water is collected to be used for floor sweeping, then to be used for toilet flushing.

If there was a global Water Demand Management competition, for sure Tannoura would have won the first prize.

The village of Tannoura is equipped with a water pipe network and two water reservoirs, which were first implemented in late 1960s and then replaced after 20 years. But people never received water at home, because their network was never connected to the Shamsine water source network, which supplies potable water to Rashaya Caza. "Today these reservoirs and networks are corroded because they were never filled with water", said the 'mokhtar' (local mayor) of Tannoura, Mr. Moufid Abou Zor. The new houses, constituting 40% of the total, are not connected to the old water network of the village.

For over 20 years now, the Municipality of Tannoura, with the cooperation of various influential people in the area, have tried to solve the water issue of the village. However, no projects have been comprehensively implemented and no promise has been fulfilled yet, including the two water supply projects that were implemented during 2007/2008.

However, the year 2006 brought hope to the villagers when the Middle East Center for the Transfer of Appropriate Technology (MECTAT) initiated a Greywater Treatment and Reuse Project in Tannoura, funded by IDRC-International Development Research Center of Canada. The project aimed at reusing treated greywater, which is the wastewater resulting from kitchen sinks, washing machines and showers, as an available resource that has not been utilized so far and which has the potential of making irrigation water available in backyard gardens.

Thirty five houses in Tannoura benefited from this project. Each house was equipped with a 3 or 4-barrel treatment kit, in which anaerobic treatment of the greywater takes place, and then it is pumped into a drip irrigation network, installed in the garden. "Thanks to the greywater project, I can finally make use of my arid backyard, and grow vegetables and fruits for my children by using the greywater that we generate, at no cost and without any effort", said Amal Serhal, a resident of Tannoura.

The project was not only restricted to scientific research. Women empowerment was also undertaken through several training activities.

The success of the greywater project in Tannoura and in 9 neighboring towns would encourage the government to adopt similar greywater projects, simple to implement and with tangible results to be felt at the household and community level.

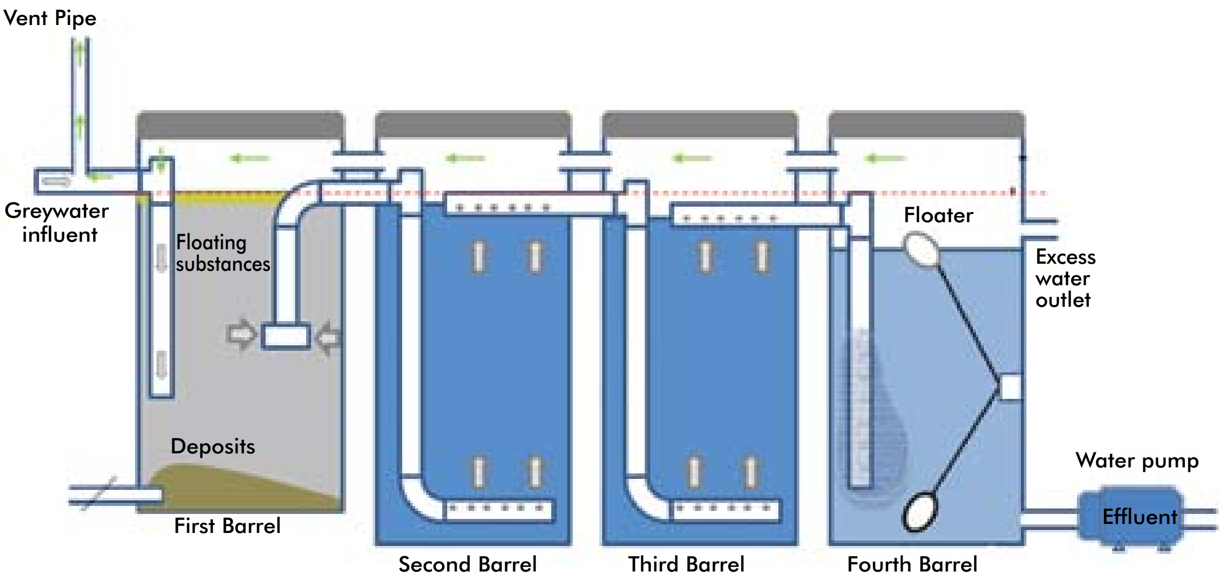
Tannoura is not an exception in the Middle East, as thousands of towns suffer from the water scarcity problems, where environmental conditions, worsened by political negligence, are making water shortage one of the main issues of the 21st century.

*Nadine Haddad and Lea Kai, Al-Bia Wal-Tanmia (Environment & Development) magazine*

## DESCRIPTION OF THE GREYWATER TECHNOLOGY

Four plastic (PE) barrels, lined up and interconnected with PVC pipes, constitute the greywater treatment kit. The first barrel acts as a primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease, floats. Once solids and floating material are trapped, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel, and then into the fourth. In the two middle barrels anaerobic bacteria work on breaking down the organic material found in the greywater. The last barrel acts as a storage tank for treated greywater and as soon as it is filled, a floating device switches on the water pump which then delivers the treated water, through the drip irrigation network, to 20-30 trees.

Laboratory results indicate that irrigation with treated greywater is safe and that there are no environmental and health impacts related to it.




*The system is airtight and watertight. Grey arrows indicate the flow direction of GW in the 4 barrels and the green arrows indicate the flow direction of gases that are produced during the digestion process, which are vented through a pipe above the roof level of the house. No odor is detected at the site.*

Industrial discharges should always be considered for treatment. As a further guarantee that the discharge will not exceed the receiving capacity of the marine environment, some basic effluent standards may be applied. Effluent standards are expressed in a statistical form to allow their control by the corresponding authority.

### *d. Wastewater reuse*

Wastewater treatment is increasingly being utilized as a water source. However, treated wastewater is reused mainly for irrigating fodder crops, gardens, highway landscapes, and parks (Zubari, 1997). The remainder is dumped at disposal areas where it infiltrates shallow aquifers or is discharged into the sea. Reclaimed wastewater can have a larger role as a non-conventional water source provided that proper irrigation practices are applied. In water reclamation, the level of treatment depends on the ultimate use of treated wastewater, whether for irrigation or recharge. It is important to deal specifically with monitoring environmental changes that result from the reuse of wastewater for agricultural practices, and establish technically feasible and cost-effective wastewater reclamation methods for tertiary treatment.

### *e. Quality of delivered water*

Water quality should meet or exceed World Health Organization (WHO) guidelines for drinking water quality (WHO, 1993). Systematic and random sampling programs should be set up by local water authorities to monitor the variations in water quality throughout the distribution system from the source to consumer's taps. The frequency of sampling should be sufficient to obtain statistically meaningful information and cover systematically all discrete zones within the supply zone. The concerned water authority should perform continuous w ter quality monitoring at all sites, where water is taken directly from a surface source for immediate treatment, and where a risk assessment indicates a significant risk of producing water after treatment that may not comply with WHO guidelines with risk consequences to public health.

### *f. Leakage management monitoring*

Leakage in the water distribution network is a particularly significant source of water loss. Water samples should be taken from permanent sampling points installed at key locations within the distribution on the trunk mains. Pressures should be monitored periodically within the distribution system and on trunk mains. Data from the continuous monitoring of flows, pressures, and water quality parameters, should be assembled to create a database of long-term performance.

### *g. Demand management*

Demand Management comprises three interrelated policies to reduce leakage and excessive system pressure in relation to the designed level of service and control of flow in service connections.

- **Leakage policy:** Concerned staff should define a target level of leakage for a given supply zone as a whole and set a program to achieve the target. Once district meters are introduced, a detailed assessment of the variation of leakage within each supply zone will be possible. This will highlight any rapid or gradual rise in leakage levels.
- **Pressure reduction:** In some instances when designing both network extensions and district metering, the water authorities should emphasize identifying opportunities for full time pressure reduction where it can be demonstrated to be economic. Consideration should also be given to schemes offering part time pressure reductions either over part of a day or over a season.
- **Consumption control:** the water authorities should reinstate realistic water charges when an acceptable level of service has been achieved. Currently, tariffs are based on flat rates. Water authorities should aim at metering of individual consumers, which is a long-term objective, as one possible method of assessing charges.

## IV. WATER TARIFFS

Water authorities should define water tariffs that users have to pay for service provision. In fact, these tariffs should in principle cover the total costs to provide good quality water in adequate quantities. However, in reality domestic water tariffs are mostly not enough to cover the salaries of employees and the costs of maintenance. Domestic water is sold at a nominal daily flow where rates are lower for smaller towns and increase proportionally. In addition, it is recognized that not all subscribers pay their dues, and water authorities are unable to fully control and limit illegal connections. As for irrigation practices, water is generally priced at a flat rate or at rates that are associated with the area that the users are allowed to invest in. This section describes different aspects of water tariff structure and presents concepts and recommendations for a new water tariff system. It is worth mentioning that economic considerations are becoming important in preparing the framework for decisions regarding future water supply. It is well accepted that major hikes in the marginal cost of water supply could be expected in the future, as fresh water may be imported or produced through seawater desalination. Thus, current low water tariffs will be difficult to maintain, and consumers should be prepared for a substantial increase in the real cost of water supply.

### *a. Tariff factors*

Several factors may affect water tariffs setting and should be taken into consideration. In the domestic sector pricing should account for factors such as the type of service, subsistence level of consumption, and the purpose for which the water is used. In the agricultural sector, prices should reflect the intensity of water use per crop, the number of water applications, and the size of the irrigated area. In the industrial sector, pricing should take into consideration differences among industries in terms of intensity of use, type of water source, quality of supplied water, quantity of effluent streams, and the type and quality of effluents.

### *b. Tariff criteria*

Criteria for establishing water rate configurations are based on elements of local acceptability, economic efficiency, cost recovery, and equity. User acceptability, represented by the ability to pay, is an important parameter. Care should be taken to meet the basic needs of the poor or those who cannot afford new water rates. Economic efficiency focuses on achieving water services at minimum cost, which may be reached when the price of water is equal to the marginal cost. Cost recovery indicates that the rate reflects the true cost of water, where system repairs and expansion costs are adequately covered. Equity is based on sharing the costs of the water delivery system among customers in a fair manner. Consideration must be given to the existence of large industrial or agricultural water users where water authorities may be compelled to maintain larger delivery systems to accommodate their requirements. It is feared that small users may end up compensating for water use charges of a few larger users. Meters, if available, for large industrial, commercial, and institutional consumers should be monitored periodically and compared with the billing records. Efficient rate structuring should include mechanisms for recovering the true cost of water services, without resulting in under-pricing, overpricing, or subsidizing some consumers at the expense of others.

### *c. Water pricing strategies*

Socioeconomic and political considerations call for a gradual move towards the implementation of a pricing policy that equates the marginal and opportunity costs for water. Prior to the formulation and implementation of pricing schemes, there is a need to evaluate water sources, characteristics of water demand, and socioeconomic conditions. Special consideration must be given to the nature of water resources, which exhibit spatial and temporal variability. If present domestic consumption patterns continue unaltered, governments in the Arab region are required to allocate financial resources towards the construction of hydraulic structures, distribution systems, and support facilities with capacities to accommodate increased demand. A large number of wastewater treatment plants will also be required to handle the resulting higher wastewater volume load. This huge investment may result in considerable economic strain, especially with limited financial resources and constrained budgets. However, proper logistics for integrated supply-demand management and planning, along with just allocation of shared water sources through equitable agreements, will contribute significantly to alleviating water deficits. In this instance, it is important to implement demand management programs, including the application of proper economic criteria that emphasize appropriate pricing schemes to reduce the imbalance between

## SULAIBIYA WASTEWATER TREATMENT AND RECLAMATION PLANT-KUWAIT

**Ibrahim Al-Ghusain**

The Sulaibiya Wastewater Treatment and Reclamation Plant in Kuwait is the largest facility of its kind worldwide to use reverse osmosis (RO) for domestic wastewater treatment and reclamation. The plant is also the first infrastructure project of its size in the Middle East to be executed under a 'Build, Operate, and Transfer' (BOT) scheme. This is in line with the government of Kuwait's plan to target the effective participation of the private sector in water infrastructure projects. A joint venture between Al Kharafi Group of Kuwait and GE Ionics has been established in 2001 to undertake the 30-year concession contract for the Sulaibiya Wastewater Treatment and Reclamation Plant with the Government of Kuwait.

The plant is initially designed to treat up to 425,000 cubic meter of raw domestic wastewater per day. The capacity would eventually reach up to 600,000 cubic meters per day during the 30-year concession period. The Plant treats around 60 per cent of Kuwait's total domestic wastewater. The specifications of reclaimed water produced from the Sulaibiya plant exceed World Health Organization (WHO) standards for potable water. The engineering, procurement, and construction (EPC) value of the project is US$500 million, while the total income to the contractor is estimated at US$1.8 billion. Over the period of its concession, the project is expected to save the Government of Kuwait in excess of US$12 billion, representing the price differential between what the contractor sells the reclaimed water for versus what the government would otherwise pay for it. The government will buy all reclaimed water produced by the plant.

The use of reclaimed water is limited to agricultural and industrial applications and possibly in a variety of other usages such as gardening, car washing, and the cleaning of buildings. Potentially, reclaimed water could be re-charged in an underground aquifer to become a strategic water asset.

### Plant Facilities

The Sulaibiya plant includes the following facilities:

- Preliminary Treatment and Pumping Station at Ardiya;
- Transfer Pipelines from Ardiya to Sulaibiya;
- Biological Treatment in Sulaibiya; and
- Reclamation Plant at Sulaibiya.

Preliminary treatment of the wastewater starts with screening, sand, and grease removal upon its arrival at Ardiya inlet works. The wastewater is then directed to two buffer tanks. Each tank is 67 meters in diameter and 7 meters deep. These tanks regulate the flows arriving to Ardiya before being pumped to Sulaibiya.

The Pumping Station at Ardiya contains 8 pumps, 2 of which are on standby, to transfer the wastewater through three pressure pipelines, extending over 25 kilometers from Ardiya to Sulaibiya. In order to safeguard the environment at the Ardiya inlet works, in view of its proximity to residential areas, all facilities in the site are enclosed. In addition, all facilities at the site are furnished with state-of-the-art odor control treatment system.

The biological treatment system, consisting of 9 biological treatment trains, forms the heart of the Sulaibiya plant. Each train consists of an Aeration tank (147 meters long, 28 meters wide, and 8 meters deep) and a circular secondary clarifier (56 meters in diameter and 8 meters deep). The

demand and supply, and promote effective efficiency measures.

This strategy is based on the perception that water is a marketable commodity, whose value is set by the law of demand and supply. The attachment of economic value to water would promote conservation, efficiency, and encourage privatization in the development, treatment, and distribution of water resources. Also, it can be considered as a criterion to improve water allocation and to set the administrative price level for water. The association of water directly with its production costs should be considered in the context of the social conditions within the country. The poor must be recognized as having an equal claim to potable water, as everybody else, at an equitable price. Under certain circumstances, subsidies may be used to provide for minimum water requirements. The public must be informed of the importance of pricing policies as a means of water resource management, and its preservation for future generations. The formulation and implementation of appropriate water pricing policy can contribute significantly towards the sustainable management of water resources.

secondary treated water from the biological treatment system is then directed to the reclamation plant.

The settled sludge in clarifiers is thickened in gravity belt thickeners before it is transferred to 8 aerobic digesters (58 meters long, 24 meters wide, and 7 meters deep). Upon digestion, the sludge is pumped to sludge drying beds. After drying the sludge is stored for 6 months in order for it to be considered safe as a natural fertilizer.

Secondary treated water is sent to 5 rotating disc filters before being fed to 5 trains of ultra-filtration (UF) units containing 8,704 membrane modules. The filtered water then flows to the 3-stage reverse-osmosis (RO) plant for reclamation. There are 6 RO trains. Each train contains 7 skids and the total number of membrane modules in these skids is 20,832. The RO membranes secure the complete removal of suspended solids and microbes. Reclaimed water then flows to the permeate basin. From this basin, reclaimed water is pumped to the network of the Ministry of Public Works at Sulaibiya. Most treatment and reclamation processes in plant facilities are fully automated using process control systems.

*Dr. Ibrahim Al-Ghusain is General Manager, UDC (Kharafi National) Kuwait.*

The proposed water tariff revision, if implemented, would mean additional revenue would accrue. It is important to hike the water tariff to cover the costs of increased power charges, pay scales and wages of O&M staff, repairs of pumping machinery, distribution system, and the cost of material and labor. The water authorities are under the obligation to increase revenues and meet O&M costs. In addition, fines and penalties must be imposed when water misuse occurs.

For urban water supply, the pricing strategy should replace the current flat fees with tariff schemes consisting of two parts: a fixed charge and a variable charge. The fixed charge gives the service provider a reliable stream of revenue to cover overhead expenses, and the variable charge provides consumers with incentives to use water more efficiently. However, the fixed fee should be large enough to maintain a continuous cash flow to the water authorities even if the users are not using their water. The feasibility of tariffs by consumed volume depends on the practicality of using meters. It is important to use increasing block rates for high consumption, and possibly decreasing block rates for very high

consumption. This diminishes the impact of the pricing structure on consumption patterns. The same rate structure should apply to industries. It is important to investigate the feasibility of applying a special tax on water supplied to industrial enterprises to partly finance drinking water supply projects in villages and semi-urban centers.

For irrigation water, pricing should set charges on the basis of average use rather than the marginal cost of supply. Water authorities should calculate charges by dividing the average cost of service by area irrigated, often adjusting the results by season, type of crop, or technology used. Charges may not be adjusted by region even though regional variations in water availability may be responsible for differential water and technology costs.

### d. Recommended tariffs

Water supply authorities should have the power to set and adjust water rates. Volumetric pricing and metering should be adopted, uniform tariffs removed, and low prices abolished. In addition, there is a need to significantly increase water charges to all users. It is crucial to implement water-pricing schemes to achieve short- and long-term policy goals, recover costs, encourage water conservation, protect the environment, and provide performance related incentives for water suppliers to reduce the costs of water supply and for consumers to use water more efficiently. The following are proposed water tariffs for the main water users in Arab Countries:

#### 1. Domestic and wastewater tariffs

Municipal and wastewater tariff structures should operate by means of an increasing block rate, where charged prices increase with increasing consumption. In this type of structure, the income per capita is taken into account in setting the unit cost. The tariff should cover the costs of water from its source, exploration and source development, water treatment, transport, and storage, wastewater treatment, wastewater reuse, water disposal, and associated environmental effects such as reduction in fossil-water stocks. These costs, however, can be summarized into three main categories: (i) capital costs, (ii) operational costs, and (iii) costs associated with the deprivation or enrichment of resources. In short, if the efficiency of water delivery and use are increased, losses in the delivery system are reduced, and illegal connections are terminated, the water revenues can cover the cost of delivery. However, this requires effective monitoring and control processes to be enforced by water authorities.

#### 2. Irrigation water tariff

The irrigation water tariff imposed on farmers may be operated by means of fixed rating systems or increasing rates. It is more feasible to shift to the increasing rate system since it is an effective mechanism that allows for proper management of water demand, reflects the extent of water shortage, and provides effective water saving incentives.

### 3. Industrial water tariff

The industrial sector should adopt the same increasing rate tariff structure as that suggested for the domestic sector, whether industries obtain their water supplies from water authorities or from private wells. In many cases, large and medium size industries, some universities, army units, and governmental organizations have their own groundwater wells. Accordingly, they do not pay for the water they consume. In this instance, they are free to extract as much water as they desire without any control or monitoring. They only pay the costs that are associated with the capital and operation charges of their own equipment. This policy does not promote water preservation or efficiency, and usually leads to wasteful use and the depletion of groundwater resources, which have been observed due to the lack of control on utilization and the excessive use of dilution of wastewater effluents to meet the required guidelines of disposal in the wadis or in other environmental sinks.

## V. CONCLUSION AND RECOMMENDATIONS

To meet future water challenges and avert water shortages, water policies and strategies must emphasize an integrated approach to achieve simultaneous management of demand and supply, including economic criteria for water allocation and efficiency. There is a need to evaluate the merits of attaching an economic value to water. As a result, water could be treated as a scarce economic resource and protected accordingly.

Arab countries should adopt water strategies that stress the need to improve municipal and industrial water resources management with particular emphasis on the sustainability of present and future uses. Consequently, water strategies should revolve around the following dimensions: resource development and management, legislation and institutional reforms, management of shared water resources, public awareness, performance, health standards, private sector participation, public-private partnerships, community involvement, financing, pollution protection, quality monitoring, preventing the depletion of resources, and research and development.

### a. Demand and supply

In general, conventional water sources are not sufficient to meet demand for fresh water in the ESCWA region, where rapid industrialization and higher standards of living are expected to drive water shortages. Currently, renewable water resources in the region are fully exploited. Water deficits can be addressed by adopting rational use, higher efficiency, wastewater reuse, conservation, and desalination. The latter will play a greater role in augmenting traditional water supplies. Some countries will continue to depend on surface water from major rivers, while others will rely on groundwater. Therefore, the prospects for water availability are uncertain, requiring new strategic investments by Arab countries in reallocation among competing sectors and increased water use efficiency. These demand management measures can then be succeeded by investments in non-conventional sources to develop additional water supplies. In addition, the reliability of water sources will be of increasing importance in the future, necessitating systematic contingency planning to ensure adequate and effective response to droughts, floods, and other climatic changes and to minimize their adverse effects. Implementation of these policies is the key to deal with water deficit problems. Failure to address the imbalance between demand and supply may result in further deterioration in water quality and quantity.

### b. Policy reforms

The adoption of a comprehensive framework for analyzing policies would help guide decisions about managing water resources where significant problems exist, or are emerging, concerning the scarcity of water, the efficiency of service, the allocation of water, or environmental damage. The complexity of the analysis would vary according to capacity and circumstances, but relatively simple frameworks can often clarify priority issues. This analysis should account for all social, environmental, and economic objectives,

## WATER RECYCLING IN TUNISIA

Sanitary wastewater infrastructure in Tunisia has recently been widely developed and expanded. Large-scale projects were completed, notably the wastewater treatment system in "Sidi Hussein al Sigoumi" area. where the building of a huge wastewater treatment plant, with a capacity of 60,000 $m^3$/d, is under way, along with the construction of 40 km network. Moreover, the rehabilitation of the Greater Tunis Treatment System, comprising 132 km of ducts, is projected to be completed in 2010. Tunisia has 106 treatment plants that treated 238.5 million cubic meters (MCM) in 2009.

This sector also covers industrial areas and concentrates on widening the scope of industrial wastewater treatment. The first treatment plant in the southern suburbs of the capital was established in "Bin Aroos" area, and industries are encouraged to install primary filtration facilities with government financial aid through the mechanisms provided by the Pollution Prevention Fund.

63 MCM, i.e. almost 27% of the 238.5 MCM treated in 2009, were reused, and the area irrigated by reclaimed water amounted to 10,000 hectares. The volume of reused water is projected to rise in 2014 to above 50% of the total volume discharged by treatment plants.

It is expected that a formidable project shall be launched soon for transporting volumes of reclaimed water from the north to the central regions, where large areas will be used for cultivating fodder crops and fruit trees, in addition to the construction of barriers to control creeping sand and desertification, and the production of grains that can be used for biofuels. The project shall be funded within the framework of the Clean Development Mechanism (CDM).

Under the plan for the treatment of sanitary wastewater in Tunisian villages, the Tunisia International Center for Environmental Technologies was commissioned to explore appropriate, simple and economical techniques for the treatment of water used in rural areas. The Center, in collaboration with the Ministry of Scientific Research and the National Sanitation Utility, has completed a model plant for the treatment of wastewater generated in the north-eastern region, based on the fact that the climate, soil and flora of that region are characterized by special features that form a natural tool for water purification, instead of traditional electromechanical equipment used in treatment plants.

The Center established a pilot model plant for Juqar village in Zaghwan district which applies the technique of treating used water through aquatic plants, with a capacity of 1$m^3$/h. The plant serves nearly 800 inhabitants, and its reclaimed water is used for irrigation. The prevailing trend now is to build similar rural plants compatible with various climates in north-west, central and south Tunisia, and to spread such plants ubiquitously across the country.

It should be pointed out, in this respect, that the National Program for the Conservation of Irrigation Water, launched in 1995, took on all the financial and technical support needed for the provision of water-efficient equipment for 345,000 ha of arable land.

*Suleiman Bin Yusuf, Al-Bia Wal-Tanmia (Environment & Development) magazine* and evaluate the status of water resources as far as the level and composition of projected demand. Special attention should be given to the views of all stakeholders. From a general understanding of the different water laws, standards, and policies in water management and wastewater treatment process and criteria, one can suggest the following:

- Relieve expected water stresses by necessary water efficiency measures and integrate groundwater recharge into a comprehensive water basin management;
- Obtain water quality data and other information to establish integrated databank using standardized international methods and integrate training as a part of the whole process;
- Treat wastewater properly prior to disposal to avoid contamination, integrate reuse, and issue legal and environmental regulations in planning projects;
- Adopt an integrated watershed management approach for elaborating policies and strategies of water resources development, management, conservation, and select the appropriate technology to fit the socioeconomic capabilities and tradition;
- Apply geographic information systems (GIS) as important tools for planning water resources projects and emphasize hydro-meteorological conditions when applying modern techniques;
- Establish a coordination mechanism between concerned ministries and government agencies to avoid fragmentation between authorities and agencies;
- Develop impact-monitoring indicators to measure the progress in meeting objectives;
- Improve cost recovery and modernize municipal management and finance systems;
- Adopt sustainable water use approach for elaborating policies and strategies of water resources development, management, and conservation, in which the following issues are stressed:

a. **Typical water use:** trends in water use are related to key socio-economic indicators. Often, seasonal and peak use offer potential for cost effective capital savings. But, system losses remain high in many regions.
b. **Technical initiatives:** apply simple, yet effective, water saving technologies along with pilot programs and campaigns for public education. Also promote leakage reduction technologies, where repair and rehabilitation technologies offer cost-effective solutions.
c. **Financial initiatives:** cost of service assessment is crucial to the water authorities for efficient operations. Rate setting is needed to promote sustainable systems and enhance increased billings and collections as well as inventory control. In addition, reduced litigation and penalties are effective as well as debt analysis and restructuring.
d. **Operations & maintenance initiatives:** include privatization and outsourcing, competitiveness and performance, operational audits and evaluations, restructuring & organizational design, incentive pay schemes, and training & development.
e. **Supplemental sources:** include recycled wastewater, water harvesting, rainwater catchment systems, captured flood runoff, brackish water, submarine springs, crop substitution, and desalination.

The objectives of water policies should be to achieve the following improvements:

For Industry: Apply extensive water efficiency measures to substantially reduce the quantity of water used per unit output. Prevent source pollution or reduce the volume of wastewater generated through process changes. Ensure waste is treated to meet strict regulatory standards prior to disposal.

For Municipal Water Supply and Sanitation: Implement more efficient and accessible delivery of water services and sewage collection, treatment, and disposal, with an ultimate goal to provide complete coverage. Also, extend existing supplies through water efficiency and reuse and other sustainable methods with greater involvement of the private sector, NGOs, and user groups and try to attain cost recovery to ensure financial viability while applying graduated fees to assist the poor.

For Irrigation: Include modernized irrigation practices with greater attention to cost recovery, drainage and salinity control, measures to reduce pollution, improvements in O&M of existing systems, and investments.

For the Environment and Poverty Alleviation: rigorous attention should be given to minimize resettlement, maintain biodiversity, and protect ecosystems in designing and implementing water projects. Conserved water and energy supplies can be used instead of developing new supplies to extend service to the poor and maintain ecosystems. Low-cost and environmentally sound methods should be pursued.

### c. Tariff structures

Water authorities should assess rational water tariffs to achieve full cost recovery in a gradual manner. To cater for socioeconomic conditions, tariffs reflecting the effective water supply cost cannot be doubled or tripled overnight. There is a need to establish affordable water tariffs based on the income of different segments of society. Special attention must be given to meet the most basic needs of the poor in order to avoid hardship. The design of water tariffs must be based on factual social, economic, and technical data. The application of tariffs should be accompanied with a public educational campaign to convince people to accept the "consumer pays" principle. Any adequate and feasible valuation policy of water should be linked to the presence of management departments having significant prerogatives and technical and financial means.

There is no denying that implementing water-pricing reforms is very difficult. Subscribers may resist paying for water and may even resort to applying political pressure to reverse any policy reforms. Technical and managerial capacity may be inadequate to assess and enforce new water pricing schemes. In this instance, governments in the Arab region may consider using non-price measures to encourage consumers to use water more efficiently, including transferring management responsibilities to user groups and/or promoting the development of water rights and water markets. It is believed that potential benefits might arise by transferring management responsibility to users, where user groups collect water charges and maintain the physical facilities. Indeed this approach has become the favored approach for improving the financial sustainability of water systems.

A changing water paradigm is occurring in which environmental, financial, and social constraints are redefining the value of water, which includes not only the cost of production and treatment but should also include the overall impact on the quality of life, health and safety, and economic effects on society and industry. Therefore, societies in the Arab region are called upon to contribute to the reduction of water consumption and to educate children of the practical and ethical value of water efficiency and conservation for future generations and environmental protection. The involvement of the public at large and non-governmental organizations (NGOs) in water affairs should not be viewed as a choice but as a requirement for effective management and for safeguarding affordable drinking water supply.

## REFERENCES

Al Radif, A. (1999). "Integrated water resources management (IWRM): An approach to face the challenges of the next century and to avert future crises." *Desalination*, 124, 1999: 145–153.

ACSAD (1997). "Water Resources and their Utilization in the Arab World." 2nd Water Resources Seminar, March 8-10, Kuwait. Arabic Centre for the Studies of Arid Zones and Drylands, Damascus.

Chatila, J.G. (2003). "Laws, policy measures, standards and regulations in the water sector in Lebanon: a review and perspective." *Water Policy*, 5, 2, 2003: 165-177.

Darwish, A. (1994). "Water Wars: The Next Major Conflict in the Middle East." Lecture at the Geneva Conference on Environment and Quality of Life.

WHO (1993). *Guidelines for Drinking Water Quality.* World Health Organization, Rome.

Zubari, W. K. (1997). "Towards the Establishment of a Total Water Cycle Management and Re-use Program in the GCC Countries." 7th Regional Meeting of Arab IHP Committees, 8-12 September, Rabat, Morocco.