WASTEWATER REUSE MANAGEMENT IN THE STATE OF KUWAIT

Saleh Al-Muzaini*

Environmental Sciences Department
Environmental Earth Sciences Management
Kuwait Institute for Scientific Research
Kuwait

INTRODUCTION

The State of Kuwait lies to the northwest of the Arabian Gulf, between latitudes 28° and 30°N and between longitudes 46° and 48°W. To the north and west it shares a border with Iraq, and to the south and southwest it borders Saudi Arabia. Kuwait is a flat, sandy desert broken by shallow depressions and low hills. It occupies a total area of 17 818 km^2 and has a population of about 1.6 million [1].

Kuwait has a desert climate: hot and dry in the summer and cold in the winter. The temperature in the summer ranges between 40 and 48°C, and in winter between 2 and 20°C. The average annual rainfall is 115 mm [1]. It is an arid country that lacks natural resources of freshwater. This hindered the development of the country for many years. With the discovery of oil, the economy of Kuwait became strong enough to undertake considerable development programmes. Primarily, seawater desalination plants were built to meet most of the country's potable water requirements. Subsequently, distilled water from power plants blended with about 8% brackish water has also been used to provide drinking water. About 90% of the buildings are now connected to a freshwater pipe network. Others get their supply by water tankers.

The first desalination plant in Kuwait was built and commissioned in Shuwaikh in 1953 with a capacity of one million gallons of freshwater per day. By early 1984, four giant desalination plants had been established in Shuwaikh, Shuaiba, Doha, and Ras Al-Zour. Their total capacity is about 120 million gallons per day [1, 2].

Besides the desalination plants, Kuwait has two areas with natural underground water, Rawdatain and Umm Al-Aish. Their combined capacity is about 1.5 million gallons per day; this capacity could be increased to 3.5 million gallons per day [2]. Figure 1 presents freshwater production for the period 1954–1991 [2].

Most of the freshwater produced is used for domestic activities and industrial establishments located inside and outside the Shuaiba Industrial Area (SIA). The production and consumption of water have increased, and with their increase the volume of wastewater generated has also become very large. A small fraction of the treated sanitary wastewater is used for irrigation and the rest is discharged to the sea, whereas industrial effluents are all discharged to the sea after treatment. Careful planning for effective utilization of wastewater may help improve agriculture and landscape development in the country.

However, wastewater reuse requires an understanding of environmental risks, and water quality requirements, for the intended use.

*Address for correspondence:
Department Manager
Environmental Sciences Department
KISR, P.O. Box 24885
13109 Safat, Kuwait

DOMESTIC SEWAGE TREATMENT PLANTS

More than 90% of the Kuwaiti population is confined to a large coastal area of Kuwait Bay. This population is provided with three sewerage networks, each serving a separate catchment area and leading to a sewage treatment plant (STP). There are four main municipal wastewater treatment plants: Ardhiya, Jahra, Riqqa, and Failaka. In addition to these plants, there are several small treatment facilities in the SIA [3, 4]. Figure 2 shows the location of the sewage treatment plants and the area served by the sewerage network.

The Ardhiya plant, which was commissioned in the late sixties, is the largest and the oldest STP in Kuwait. Ever since it was started, it has been continuously expanded to serve a greater area. The plant serves the north and eastern part of Kuwait City. It was designed to treat 150 000 m^3/day. The Jahra plant has a design capacity of 70 000 m^3/day. The Riqqa plant was designed to treat 100 000 m^3/day and was put into operation in 1981. It collects sewage from the coastal areas located in the south of Kuwait City. The Failaka treatment plant was designed to serve the Island of Failaka, which is located about 30 km off the coast of Kuwait. Presently the plant is out of operation due to technical problems. Table 1 presents information on the design capacities and average flow reaching the Ardhiya, Jahra, and Riqqa plants [5].

STEPS FOR TREATED EFFLUENT REUSE

The Kuwaiti government has taken steps to support the Ministry of Public Works (MPW) in improving and expanding the sewerage system in order to overcome problems related to the efficiency of the treatment plants. The MPW amended the water pollution law in 1980, adding provisions concerning treated effluent utilization. The MPW took the initiative to educate people about effluent disposal and the level of treatment, and asked them to maintain their installations properly. The MPW also coordinated with the agencies concerning the utilization of sanitary wastewater effluent. Industrialists have been asked to design their own program to manage domestic wastewater within their area of responsibility.

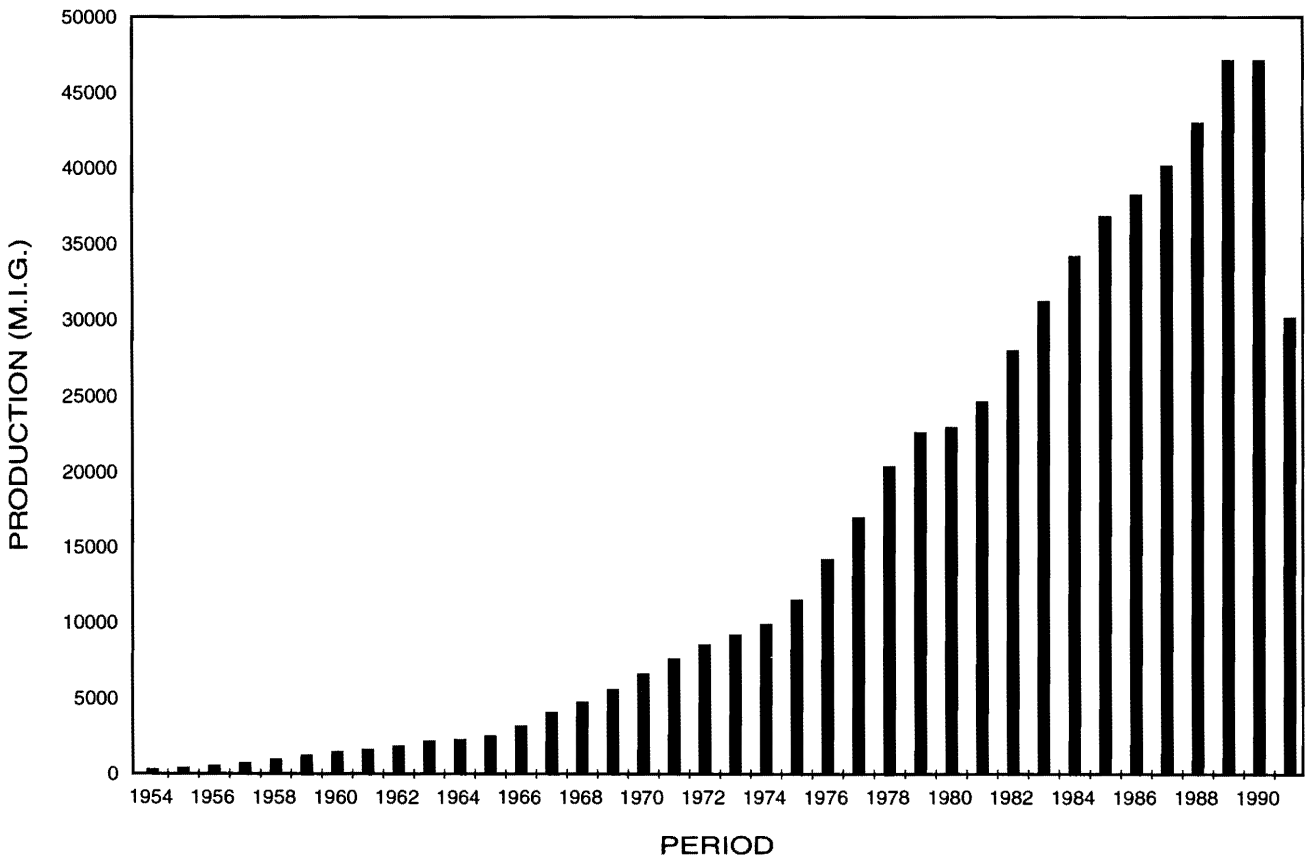

Figure 1. Gross Production of Fresh Water by Ministry of Electricity and Water during 1954–91 (in M.I.G.).

The MPW is taking further steps towards the effective handling of domestic wastewater effluent. Among these steps, building an integrated effluent disposal facility, sewerage system and farming areas are together considered as an appropriate solution of the problem. A sewer survey and rehabilitation program has been implemented by MPW to clean the sewerage system and to generate data on the remedial work required for sewers and manholes.

An important project to be carried out by the MPW is the construction of a new STP in Sulaibiya to replace the old Ardhiya plant. The new plant will improve wastewater effluents and reduce odor problems. Also, a major step to be taken by MPW in the future, as recommended by the Kuwait Master Plan, is the construction of deep sewer tunnels enabling nest lifting and pumping stations to be abandoned. This will improve the sewerage system and minimize odor problems [5].

There are several other plans now underway to utilize treated wastewater effluents. Such effluents will be recycled and utilized not only to make up for the shortage of water, but to regain and recharge underground aquifers. Wastewater from sanitary treatment plants is a valuable water resource, which in Kuwait is available for irrigation at a low cost (calculated to be a quarter to a sixth of that for desalinated potable water) [6]. Thus, the future planning for wastewater reuse in Kuwait is focused on the development of the green area by plantation using modern irrigation techniques.

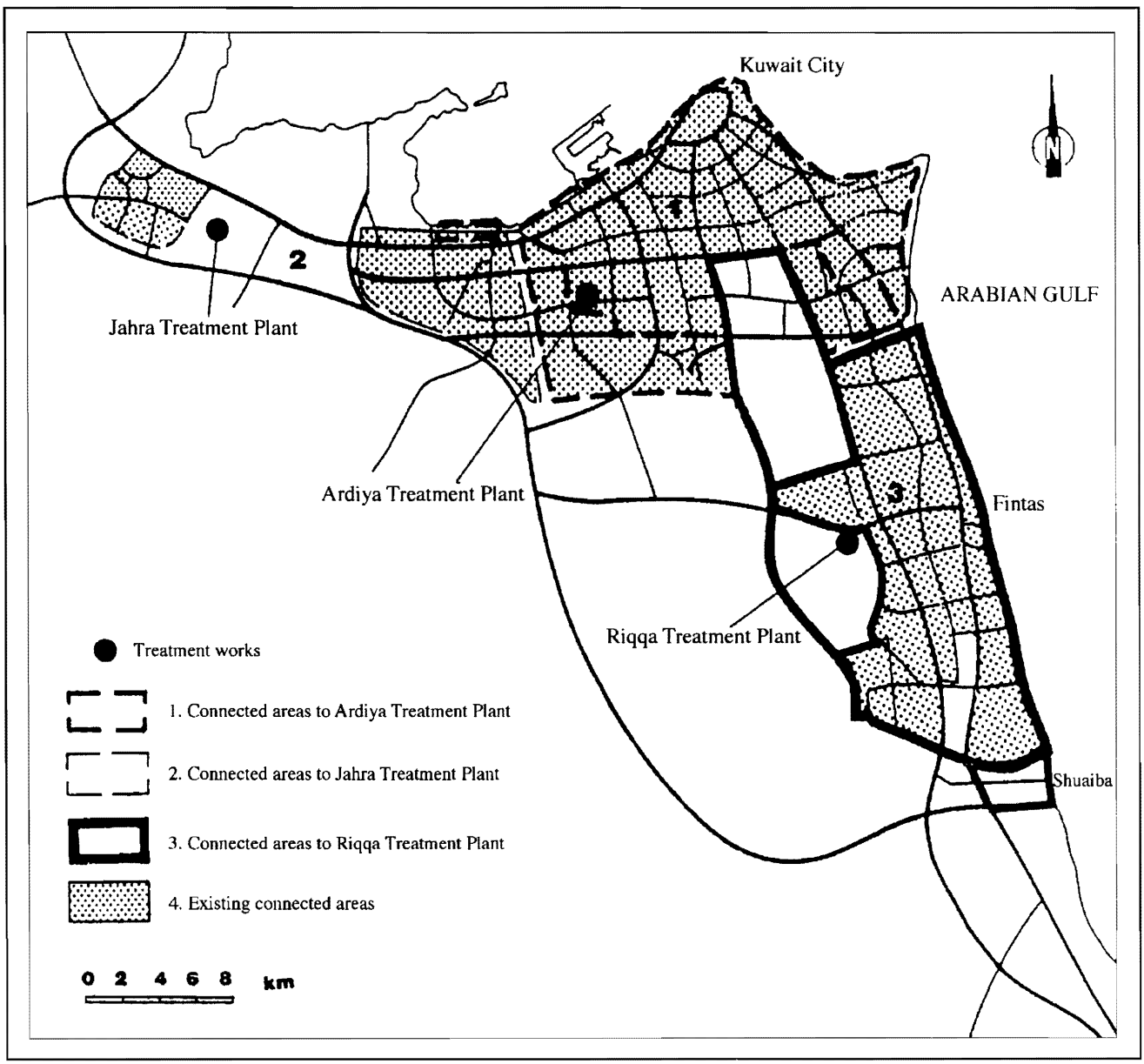

Figure 2. Location of Sewage Treatment Plants.

INDUSTRIAL EFFLUENTS

The majority of industrial activities are located in the SIA, which is located about 50 km south of Kuwait City. The total area of the SIA (both its eastern and western sectors) is about 22.98 million m^2. It has the authority to set all the regulations and standards necessary to protect the environment from pollution. Previous studies conducted by the Shuaiba Area Authority (SAA) showed that wastes generated and discharged to the SAA marine area contained high pollutant concentrations. Therefore, it is considered unacceptable to discharge industrial wastewater into the Riqqa domestic STP, because the plant's effluent is used for agricultural purposes.

The SAA has decided to treat wastewaters within its area. The collection and treatment of combined industrial effluents at a central treatment plant within the SIA is technically feasible and is considered to be the most cost-effective solution. Such treatment is to be conducted to satisfy the effluent quality criteria as shown in Table 2 and will ultimately improve inshore water quality. Therefore, the SAA is taking steps not only towards reducing existing environmental problems but also towards developing a new strategy for utilizing sanitary and industrial wastewaters.

As conceptualized, a central STP will be established to improve the quality of the combined wastewater to a standard which is adequate for landscape irrigation. Depending on the STP's efficiency, the treated wastewater may be used for such other purposes as: (1) irrigating of food and non-food crops; (2) creating recreational areas; (3) recycling for further use by industry; and (4) recharging brackish groundwater aquifers [6–8].

Sanitary wastewater production in the SIA is projected to reach about 5060 m^3/day, and the current sanitary wastewater flow is about 3000 m^3/day. Industrial wastewater represents over 90% of the current total wastewater flow in the SIA, which is estimated to be 31 000 m^3/day. With the addition of a new petrochemical complex and other planned expansion project, the total industrial and sanitary wastewater producted will be around 55 670 m^3/day. The various sources of wastewater and their projected average flows are summarized in Table 3 [3].

WATER AVAILABILITY

Water is Kuwait's most limited and strategically important resource. Treated wastewater, which represents 70–80% of the potable water used, constitutes an enormous resource in Kuwait where natural water resources are insufficient. At this time, approximately 320000 m^3/day of wastewater is produced (Table 1). This quantity will increase with population growth and further industrial development, and can be expected to double early in the next century [9–11].

Table 1. Treatment Process and Sewage Flow Forecasts for Kuwait's Treatment Plants.

	Plant		
	Ardhiya	Jahra	Reqqa
Treatment Process	Two-stage aeration activated sludge; anaerobic digestion; sand drying beds; tertiary treatment with pre-and post-chlorination	Extended aeration activated sludge; sand drying beds; tertiary treatment with pre-and post-chlorination	Extended aeration activated sludge; sand drying beds; tertiary treatment with pre- and post-chlorination
Date Commissioned	1971	1981	1981
Present Design Capacity (m^3/d)	150000	70000	100000
Catchment Population (millions)			
1990	1.16	0.19	0.36
2020	1.19	0.39	0.88
Sewage Inflow (m^3/d)			
1990	192000	32000	58000
2020	225000	73000	166000

Source: Ghobrial, 1986. Sewage inflow rates are predicated based on expected increases in catchment population and in overall per capita sewage contribution (from 165 to 190 l/d).

Kuwait is currently using less than 10% of its treated wastewater in agriculture [12]. An area of 9 million m^2 has been chosen in the Sulaibiya district for an agricultural irrigation project. The focal point of the effluent reuse system is referred to as the Data Monitoring Center (DMC). This is the place where all treated domestic wastewater is discharged into two 170 000 m^3 reservoirs. From the DMC, the treated wastewater is transferred to several farms. Each farm contains storage reservoirs and on-site pumping systems to supply the irrigation network. The farms produce a variety of agricultural products including animal fodder (an average of 3000 tons/month), and vegetables such as spinach, potatoes, onions, and eggplants which are not eaten raw, as a precaution [13, 14].

Table 2. Water Quality and Effluent Discharge Criteria [3].

Pollutant	Discharge to Sea	Landscape Irrigation	Low-Grade Industrial Water	Irrigation and Low-Grade Industrial Water
COD	200	150	150	150
TSS	30	15	15	15
TDS	-	4500	4500	4500
TKN	20	20	40	20
Total Oxidized N	100	-	-	-
NH_3N	10	10	10	10
Total N	125	40	125	40
Oil	10	5	5	5
H_2S	0.5	0.1	0.1	0.1
CN	1.0	0.1	0.1	0.1
Phenol	1.0	Nil	0.5	0.5
Detergents	1.0	-	-	1.0
Inorganic Phosphate	0.5	-	-	-
Cr (total)	0.3	0.3	0.3	0.3
As	0.1	0.1	-	0.1
Cd	0.07	0.01	-	0.01
Cu	0.1	0.2	-	0.2
Fe	1.0	5.0	-	5.0
Hg	0.001	-	-	0.001
Pb	0.1	5.0	-	5.0
Mn	0.2	0.2	-	0.2
Ni	0.01	0.2	-	0.2
Al	-	5.0	-	5.0
Co	-	0.05	-	0.05
Be	-	0.1	-	0.1
Li	-	2.5	-	2.5
V	-	0.1	-	0.1
Zn	-	2.0	-	2.0
Fe	-	1.0	-	1.0
pH	5.5–9.0	-	-	6.5–9.0
Temperature (°C)	20–45	-	-	Max 45
Total Coliform (per 100 ml)	2000	100	-	100

All values are given in mg/l, except where indicated.

Agricultural development in Kuwait is expanding and depends mainly on groundwater resources [15]. In recent years, extensive greenhouse agriculture has increased the demand for desalinated water. The total average consumption of desalinated water in irrigation is about 0.5 million m^3/year [15]. In the coming years, the demand for water is expected to increase according to the expansion of the use of agricultural greenhouses.

COST AND FINANCING

The scarcity of water is a fundamental constraint to future economic development. The current situation in Kuwait requires reorienting development by improving management plans, increasing efficiency, and reducing waste [16]. Kuwait's government has already financed both sewage and industrial wastewater treatment plants for reuse. Treated wastewater constitutes a valuable resource in Kuwait, and is available for irrigation at a low cost, estimated to be about US $0.103 cents/gall. Therefore, treating wastewater for reuse may be more economical than treating it for discharge. Present studies show that 50 million gallons, or approximately US $51 195 worth, of treated water is dumped daily into the sea. This money can be collected daily by selling the treated water to farmers [11]. It is an enormous source of wealth if the MPW is able to collect it as revenue. As water quality standards becomes more stringent, treatment costs will increase, making wastewater management uneconomical unless it is linked with efficient reuse programs [17].

HEALTH ASPECTS

Treated wastewater may contain biological and chemical contaminants that may present health risks. The chemical constituents of concern are toxic heavy metals, pesticides, and organic contaminants that may cause adverse long-term health effects [18]. Quality criteria for treated wastewater has been set by the Kuwaiti government to ensure its safe utilization [6]. The Department of Health Services has established regulations for reusing treated wastewater [19]. The Public Health Laboratory has been responsible for monitoring the quality of wastewater used for irrigation as well as the quality of farm products before marketing. Based on monitoring wastewater and farm products quality, no adverse environmental or public health effects are expected [20].

EFFLUENT REUSE MANAGEMENT PROGRAM

The total volume of wastewater (sanitary and industrial) produced in Kuwait is estimated to be 320 000 m^3/day. Wastewater generated in the SIA is discharged into the sea after partial or no treatment. Thirty four percent of the treated sanitary wastewater is currently being used to irrigate non-food crops, while the rest is discharged into the sea.

Table 3. Various Sources of Wastewater and Their Projected Flows in the SIA [3].

Source of Wastewater	Flow (m^3/day)
Ahmadhi Refinery and LPG Plant	8360
Mina Abdulla Refinery	6910
Shuaiba Refinery	8400
PIC Fertilizer and Polypropylene Companies	4940
Petrochemical Expansion	15 000
Future Refinery Complex	7000
Industrial Wastewater Flow (Design)	43 610
Industrial Wastewater Flow (Ultimate)	50 610
SIA Sanitary (Eastern and Western Sectors)	5060
Combined Total Wastewater Flw (Ulimate)	55 670

LPG = Liquified Petroleum Gas
PIC = Petrochemical Industrial Complex
SIA = Shuaiba Industrial Area

Instead of throwing this amount of tertiary-treated wastewater into the sea, an area of 31 million m^2 has been chosen in Sulaibiya for an agricultural project. It was planned that this project will be used for growing lucerne and other fodder plants. The other major projects utilizing effluent are afforestation projects adjacent to the Al-Safar Highway, Sixth Ring Highway, and Al-Fintas Center [2]. Figure 3 presents the distribution of treated wastewater and the reuse system in Kuwait. Effluent reuse management is an important issue for the government of Kuwait. The program is going to expand green areas in Kuwait by effectively utilizing the valuable water resource that is treated wastewater.

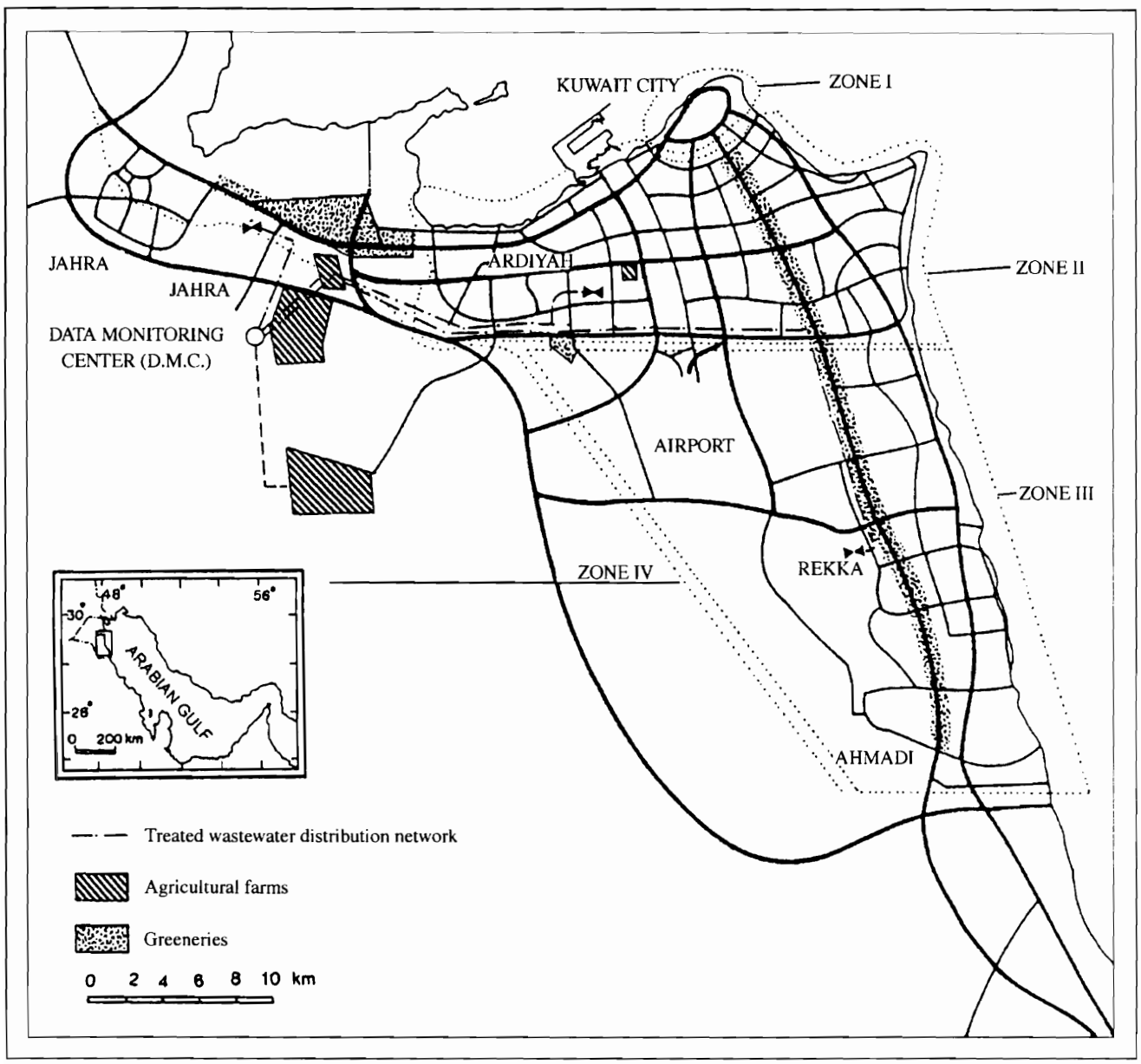

Figure 3. Treated Wastewater Distribution and Reuse.

REFERENCES

[1] Ministry of Information, *Kuwait: Facts and Figures,* 1984, p. 110.

[2] Ministry of Electricity and Water, *Annual Report for Water,* 1989, 1992.

[3] Shuaiba Area Authority, *Shuaiba Industrial Wastewater Treatment Facilities,* 1990.

[4] S. Al-Muzaini, O. Samhan, and M.F. Hamoda, "Sewage-Related Impact on Kuwait's Marine Environment — A Case Study", *Wat. Sci. Tech.,* **23** (1991), pp. 181–189.

[5] Ministry of Public Works, *The Kuwait Sanitary Scheme,* 1993, pp. 25–36.

[6] N. Al-Awadhi, K. Puskas, and S. Al-Muzaini, "The Use of Treated Wastewater for Greenery Development in the State of Kuwait", *The Joint Saudi–Japanese Workshop,* 1994.

[7] J.P. Cowan and P.R. Johnson, *Reuse of Effluent for Agriculture in the Middle East: Reuse of Sewage Effluent.* London: Thomas Telford Ltd, 1984, pp.107–121.

[8] Environmental Sciences Department, "Feasibility Study of Sanitary Waste Treatment System for the Enlarged Shuaiba Industrial Area", *KISR Report No. 1265,* Kuwait Institute for Scientific Research, 1984.

[9] M.F. Hamoda, "Impact of Socio-Economic Development on Residential Water Demand", *Water Resources Development,* **1(1)** (1983), pp. 77–84.

[10] J. Crook, "Water Reuse in California", *Journal of AWWA,* **77** (1985), p. 61.

[11] Ministry of Public Health, *Strategy of Wastewater Reuse in Kuwait,* Kuwait Government, 1993, p.1.

[12] World Bank, *Middle East and North Africa Environmental Strategy: Towards Sustainable Development.* Washington D.C.: The World Bank, 1989, p. 3.

[13] A. Shacker and E. Kobaylinski, "Regulations Impact Water Reuse Acceptance", *Water, Environment and Technology,* **6(11)** (1994), p. 23.

[14] A. Al-Shatti, "Towards the Use of Industrial Wastewater for Irrigation in Kuwait", *Kuwait Symposium on Management and Technology of Water Resources in Arid Zones, Kuwait,* October 5–7, 1987, pp. 1–2.

[15] Ministry of Public Works, *The Kuwait Sanitary Scheme.* Kuwait: Sanitary Engineering Department, Ministry of Public Works, 1994, pp. 36–37.

[16] Ministry of Public Works, *Irrigation and Data Monitoring Center.* Kuwait: Department of Public Works, 1993, pp. 6–11.

[17] G.F. Leitner, *Preliminary Estimates of Water Resources in Kuwait (Report).* Kuwait: Kuwait Institute for Scientific Research, 1994, p. 1.

[18] G.F. Leitner and D. Kater, *Preliminary Estimates of Water Resources for Meeting Greenery Needs.* Kuwait: Kuwait Institute for Scientific Research, 1994.

[19] Water Resources Division, *The Fourth Strategic Program.* Kuwait: Kuwait Institute for Scientific Research, 1994, p. 4.

[20] F.M. Ghobrial, Lionel, B. Patel, and A. Awad, *Assessment of Raw Sewage and Treated Effluent Characteristics in Kuwait (Report No. 2468).* Kuwait: Kuwait Institute for Scientific Research, 1987.

Paper Received 22 July 1996; Revised 13 May 1997; Accepted 11 June 1997.