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MAXIMIZING THE BENEFITS FROM WATER AND ENVIRONMENTAL SANITATION

Wastewater treatment and reuse costs: A Middle–East Case

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Shortage of water has led many regions of the world to think seriously about reuse of wastewater effluent for non-domestic uses. The cost of water production for reuse is of great interest. The paper presents comparative figures of costs for sewage collection, sewer system, house connection, various levels of treatment and centralized management of wastewater storage and distribution. The State of Kuwait in the Middle-Eastern region is used as the case.

Introduction

The city of Kuwait and its suburb has a modern sewer system collecting sewage for centralized treatment. It is served by three main wastewater treatment plants: Reqqa, Jahra and Sulaibiya (Built, operate and transfer: BOT) having design capacities of about 104,000, 56,000 and 375,000 m^3/d respectively. Newly built (2004) Sulaibiya plant replaced an old plant at Ardiya with added influent flow. Reqqa and Jahra plants provide conventional biological treatment (activated sludge) for secondary treatment and effluent filtration and chemical disinfection for tertiary treatment. Sulaibiya plant provides conventional biological treatment (activated sludge) of secondary level and uses ultra-filtration, reverse osmosis and UV (Ultra-violet ray) disinfection as advanced treatment. The effluents of the plants are transferred to a centralized storage place from where treated effluent is distributed to agricultural farms or other points of use. A small part of effluent water is used for landscaping and land-greening projects. Figure 1 shows the scheme of wastewater treatment, transfer, storage and uses in Kuwait.

Costs

It is difficult to determine absolute cost figures for sewer services, treatment, effluent transfer to central storage, and distribution of treated effluent to sites of reuse due to several factors:

- Variable service areas of treatment plants
- Ages of treatment plants
- Level of treatment provided
- Capacity of treatment plant
- Distances of treatment plants from DMC (Centralized effluent storage facility)
- Variable quality of effluent water from different plants.

In Kuwait, Reqqa and Jahra plants are the parts of the old system of wastewater treatment facilities in Kuwait. These systems are completely separated and function as independent projects. However, the treatment of sewage up to secondary and tertiary levels in these plants is similar and compatible. An estimate based on 1982 figures shows an annual cost of KD 4,401,446 for a combined average flow of 160,000 m^3/d. The estimate included straight 20 years depreciation of mechanical equipment, 40 years depreciation of civil works, 30 years depreciation of sewage lines, 5% annual increase in operation and maintenance costs, the cost of 400 KD for each house connection and 6 persons per house. The population of the State of Kuwait in 1982 was about 1.7 million. The derived cost is equivalent to KD 0.342 per 1000 imgal (4.54m^3) for sewage collection and treatment up to secondary level. The cost for treatment only to secondary level is about KD 0.101/ 1000 imgal (4.54m^3). The remainder of KD 0.241 per 1000 imgal is attributable to sewer network, pump stations and other items related to sewage collection.

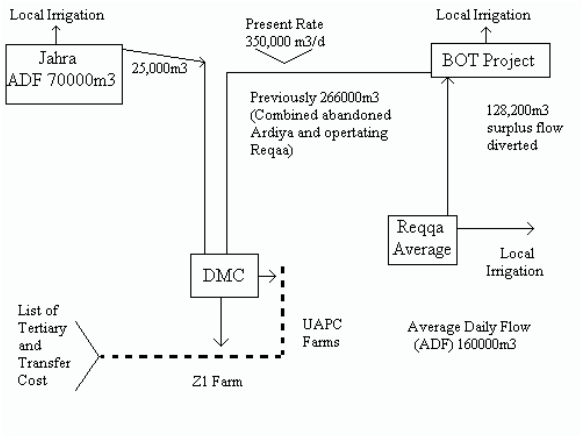


Figure 1. Scheme of treated effluent transfer to DMC (effluent storage center)

The tertiary treatment at Reqqa and Jahra is provided to render secondary effluent to be suitable for the reuse as irrigant. The advanced treatment (beyond tertiary) at BOT is provided to improve the effluent quality further so that the treated effluent can be reused unrestrictedly for irrigation and other purposes. It is noted however, that treated wastewater at present is mainly used for irrigation purposes. The added costs for rendering effluent for reuse through tertiary treatment (beyond secondary), advanced treatment (beyond tertiary) and transfer of treated effluent to central storage place are important elements in the State's program of augmenting national water resources through reuse of treated effluent.

Figure 1 shows BOT project in place of Ardiya plant which has been abandoned since the new plant started operation in August 2004. Flow-weighted average costs (1982) for tertiary treatment of secondary effluent and the cost of effluent transfer from plants to central storage were estimated to be 0.0748/1000 imgal (4.54m^3) and KD. 0.03667/1000 imgal (4.54m^3) respectively. It is noted that the estimates for tertiary treatment and effluent transfer to DMC (Data Monitoring Center – Central effluent storage place) were based on the operating stage of Jahra and Reqqa plants with implied depreciation conditions as applied previously to the estimates of those of sewage collection and treatment costs up to secondary level.

The BOT plant was commissioned in August 2004. Flows diverted from Ardiya plant to inflow line of the BOT project. An initial estimate of capital cost of BOT project appeared to be about KD. 130, 000, 000 (Personal contact MPW). The project is expected to charge effluent-users about KD 0.181/m^3. Assuming users' direct cost representing the capital, operation and service charges, a rough estimate of total cost of wastewater treatment at BOT project is about KD. 0.822/1000 imgal (4.54m^3). The estimate of 1982 treatment cost indicated that the total treatment cost up to tertiary level at Jahra and Reqqa is nearly KD. 0.176/1000 imgal (4.54m^3). Consumer price index in Kuwait increased approximately 48 units during the period of 1982-2003 with the base index of 100 in 1980 (MP. 2003). Compensating for price increase, the "1982 cost" for wastewater treatment up to tertiary level is adjusted to obtain its would-be cost at 2003. The adjusted cost up to tertiary treatment in year 2003 is thus expected to be about KD 0.261/1000 imgal (4.54 m^3). Subtracting the unit cost up to tertiary level from the unit cost of BOT project, the difference is about KD 0.561 per 1000 imgal (4.54 m^3). The cost difference may be attributed to advanced treatment by ultra-filtration and RO processes. It is noted that the estimate is a simple approximation in absence of actual figures and consideration of money value (interest). As the BOT plant is almost complete, the actual cost figures should be available soon to verify the estimate.

Table 1 is a summary of unit costs adopted from various sources (MEW, 2002, 2003; MP, 2002, 2003; MPW, 1995; DMC Database (MPW)) and derived estimates of figures on unit costs for providing various levels of wastewater treatment and water sources in Kuwait.

Table 1. Estimated Cost of Wastewater Treatment & Water Supply (1KD = About 3.3 US$)

Item	Approximate Cost in Kuwaiti Dinar/m^3	Base year
Sewage network +treatment up to secondary level	0.075	1982
Treatment only up to secondary level	0.022	1982
Sewage collection, House connection &pumping stations only	0.053	1982
Tertiary treatment only	0.017	1982
Transfer & storage cost to DMC only	0.008	1982
Approximate BOT treatment cost	0.181	2003
Charge for BOT effluent use (Approximate)	0.181	2003
Advanced treatment (ultra-filtration + RO)	0.124	2003
Desalinated pure water (Approximate)	0.617	2003
Charge to public for desalinated water	0.194	2003
Tanker water supply	0.066	2003

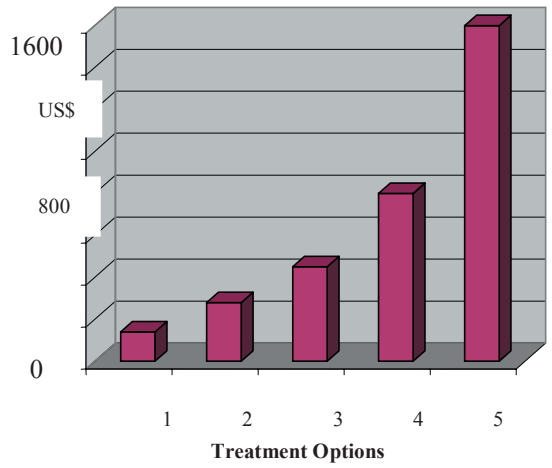
Source: MEW, 2002, 2003; MP, 2002, 2003; MPW, 1995; DMC Database (MPW)

Discussion

In years 2000-2003, total amount of 41.56x10^6 m^3/yr of effluent was supplied from DMC for irrigation uses. The amount was about 23% of estimated potential wastewater in the country. Out of 41.52x10^6 m^3/yr of the managed effluent reuse, about 36.7 x 10^6 m^3/yr (87% of total use) is directly collected and distributed through DMC facility at Sulaibiya. The remainder was distributed by separate system of pumps from Reqqa plant to coastal villages for local uses for landscaping.

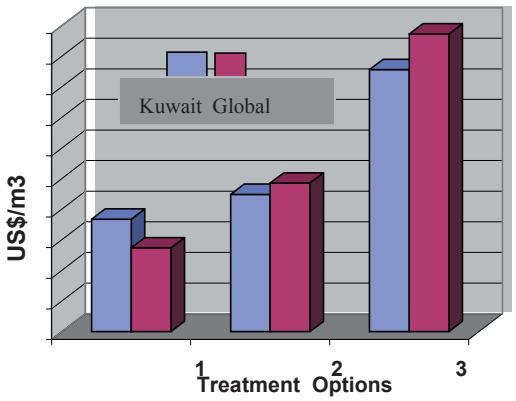
Average effluent quality from conventional systems (Jahra and Riqqa plants) appears to be adequate for restricted irrigation use according to WHO and USEPA guidelines (WHO, 1989; USEPA, 1992). The effluent quality from the new treatment plant using RO processes appears to be excellent with respect to conventional pollution parameters.

The cost estimates shown in Table 1 are approximate. However, they reflect the differentials in the cost of treating wastewater to various levels. Particularly the use of RO system for the refinement of tertiary effluent is new in its



Note: 1=Pour flush latrine, 2=Septic tank system, 3=Wastewater treatment to secondary level, 4=Sewage and wastewater treatment to tertiary level, 5=Sewage collection + advanced micro-filtration and RO treatment beyond tertiary

Figure 2. Pay-at-a-time cost per person for wastewater treatment



Note: 1=Sewage collection + wastewater treatment to secondary level, 2=Sewage collection + wastewater treatment to tertiary level, 3=Sewage collection + advanced micro-filtration and RO treatment beyond tertiary

Figure 3. Centralized sewage collection and treatment costs in Kuwait and global perspective

(Source: UN, 2004 and Durham, 2002)

application. The estimated cost for advanced treatment is KD 0.124/m^3.

Figure 2 depicts relative costs of various options of wastewater treatment in a global perspective. The figures are derived utilizing pay-at-a-time cost figures given in a recent UN publication (UN, 2004). A 30 years service life has been assumed. Pour flush latrine and septic system are assumed to be renewed at every 15 years. In option five (Figure 2), advanced treatment of micro-filtration and RO has been added to tertiary level treatment system.

A cost of 0.375 €/m^3 (micro-filtration + RO) which is approximately equivalent to 0.488 $/$m^3$ (Durham and Mierzejewski, 2002) has been added with tertiary level cost of $800/person (UN, 2004). Wastewater generation per person is assumed to be 150 l/d over 30 years. No amortization on money value is applied.

A direct comparison of costs in Kuwait with UN estimates has limited value as all Kuwait costs are with out any consideration of any amortization. However, the relative increase in costs with the higher levels of treatment shows expected similarity (Figure 3). The lower costs in Kuwait are mainly due to non-amortized values in figures.

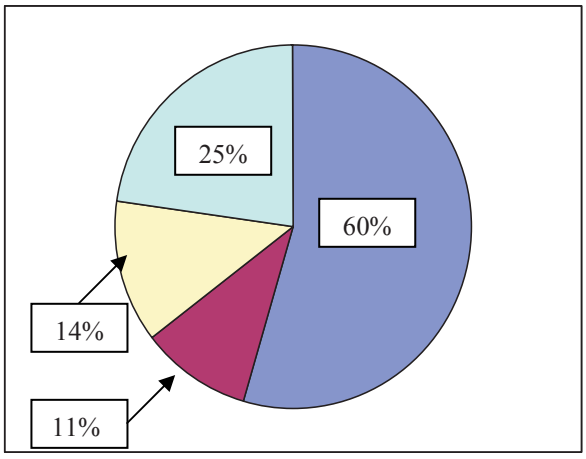
Karen (2002) presented a scheme of relative costs (adopted from Smith and Eiler (1970)) of conventional wastewater treatment system components when total system components are built simultaneously (Figure 4). The scheme is reported to have reasonable estimates applicable around the world. It is noted that Kuwait treatment systems components were constructed at different time-frames. However, the main sewage collection system was constructed in 1982 with gradual minor extensions from time to time (Table 1). Therefore, the main network cost reflects the economy of 1982 in Kuwait. Progressive addition and modification of the treatment systems reduced the cost fraction of the collection system in the total cost of the sewage collection and treatment. Figure 5 shows the trend of cost fraction of sewage collection as higher levels of treatment are added. The cost figures of previous years were adjusted with price index changes in Kuwait to bring the costs to 2003 value. The fraction reduced significantly as the higher levels of treatments were added in progression.

Conclusion

Countries suffering from shortages of water are seriously looking for available options for augmenting water supply from non-conventional sources. Treated wastewater use for non-domestic purposes is a reality in these countries. For the purpose, very often wastewater treatment beyond conventional sanitation requirement is necessary. The users have to pay for the added treatment.

The cost of added treatment is significantly less than drinking water production especially when it is derived through seawater desalination. This is particularly true for middle-eastern countries such as Kuwait.

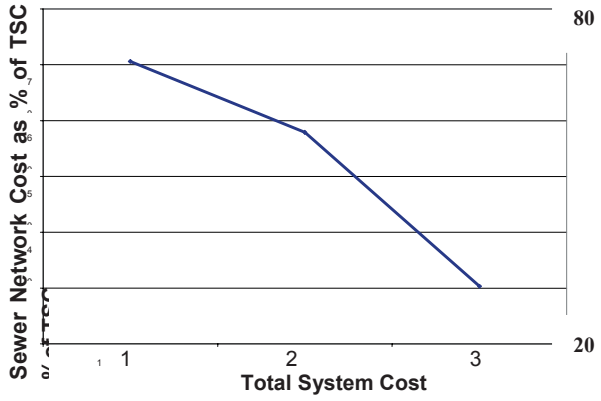
Usually secondary and tertiary effluents are acceptable for restricted use for irrigation and landscaping purposes. The cost of producing such water is about KD 0.112 – 0.136 /m^3 (US$ 0.37-0.45/m^3) in Kuwait.



Note: 60% = Sewers
25% = Treatment plant
14% = Operation + Maintenance
11% = Overhead

Figure 4. Relative costs of conventional wastewater System (Adopted from Karen, 2002)

For unrestricted use of treated wastewater, advanced treatment beyond tertiary may be necessary. One of such treatment scheme applied in Kuwait involves ultra-filtration, reverse osmosis and disinfection to refine tertiary effluent. The unit cost appears to be KD 0.181/m^3 (US$ 0.6/m^3) in Kuwait.



Note: 1=Sewer network + secondary level treatment, 2=Sewer network + secondary + tertiary treatment, 3=Sewer network + secondary + tertiary +advanced (ultra-filtration + RO + UV) treatment

Figure 5. Sewer network cost as % of total system cost (TSC)

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