Residential Wastewaters Treatment System in Kuwait

Esra Aleisa  
Industrial and Management Systems Engineering Department  
Kuwait University, Kuwait  
e.aleisa@ku.edu.kw

Khawla A. Al-Shayji  
Department of Chemical Engineering  
Kuwait University, Kuwait  
K.alshayj@ku.edu.kw

Rawa Al-Jarallah  
Department of Civil Engineering  
Kuwait University, Kuwait  
rawa1@yahoo.com

Abstract—This paper provides a literature review and description on current practices to treat domestic wastewaters in Kuwait. Emphases are directed towards the Al-Sulaibiya Wastewater Treatment Plant as it recycles around 64% of residential wastes alone using advanced Reverse Osmosis (RO) technology. The survey highlights the effluent water types, treated quantities, cost, tariff, and biological and chemical analysis of the end product.

Keywords—Wastewater treatment; Tertiary effluent; Reverse Osmosis (RO); Desalination.

I. INTRODUCTION

Due to the rapid growth in population, rapid increase in urban development and life style, the state of Kuwait is facing a challenge in meeting the demand for the ever increasing drinking water requirements. Authorities aimed to treat and reuse domestic wastewaters to: elevate the strain on depleting scarce ground water wells, provide a cheaper alternative than desalinated water, reduce the environmental adverse impact of desalination plants, and eliminate the dumping of wastewaters to coastal areas or terrestrial landfills. This paper provides a literature survey on water resources in Kuwait and current practices to treat domestic wastewaters. It emphasizes the use of Reverse Osmosis (RO) technology, the use of treated tertiary and RO effluent, applied terrify, and the countries future plans to a better utilization.

II. WATER RESOURCES IN KUWAIT

Kuwait has an arid climate, featuring very hot summers with temperatures ranging from 38-46 degrees Celsius on average during the summer season, while exceeding 50 degrees Celsius in July. Kuwait anticipates few rains during winter. According to Al-Humoud and Al-Ghusain[1], Kuwait receives about 100 mm (3.94 in) of rain annually. Rain precipitation is highly variable from year to year (40-240 mm).

Fresh groundwater was discovered in limited quantities in both the Rawdatain and Umm Al Aish. Pumping operations commenced in 1962, while the estimated reservoir of both fields is around 40,000 million gallons. Kuwait has also brackish groundwater (1200-7000 ppm). The brackish water is used for various purposes such as, irrigation, livestock watering and construction works and to be blended with distilled water [1].

III. DESALINATION

Kuwait started producing its own fresh water through desalination in 1951 [2]. Since then, desalination became the major source of fresh water of countries on the Arabian Gulf. Desalination however is an expensive practice [3], one tenth of Kuwait oils production was consumed by the cogeneration power desalination plants (CPDP) in 2003 [4]. The desalination process is not environmentally friendly and it also contributes to the wastewater discharges that affect coastal water quality. The effluent from desalination plants is a multi-component waste, with multiple effects on water, sediment and marine organisms. This is generally due to the highly saline brine and high temperature cooling seawater that are mixed and then discharged into the sea, which may be increased in temperature, contain residual chemicals from the pretreatment process such as the residual chlorine, antiscalant and antifoaming agents, and heavy metals from corrosion. In addition, burning fuel for desalination produces CO₂, NOₓ, SO₂, and other harmful pollutants to the environment [4]. Air emissions from sea water desalination plant are found to release SO₂, CO, NO₂ and greenhouse gases GHG such as CO2 and VOCs is also found at [2]. Acidic rain is observed in areas near to desalination plants.

IV. WASTEWATER PLANTS

In response to the severe environmental influence of dumping wastewaters into landfills or into the sea, and due to scarcity of water in the Kuwait region, Kuwait established wastewater treatment plants around the country in late 1950's. By 1984, all secondary treatment wastewater plants were upgraded to tertiary. Originally, there were three wastewater treatment plants in Kuwait Ardiya, Riqqa and Al Jahra. Together receiving a total of 200,000 m³/d. The main source of wastewater arriving at the plants is municipal wastewater, which is a combination of the water and carried wastes removed from residential, institutional, and commercial establishments together with infiltration water, surface water, and storm water [5].

At the Ardiya station, the COD removal efficiency was 78% which was considered unacceptable. This might have
been attributed to the technology used or due to overloading the system [6]. As a result, Al-Ardiya wastewater treatment plant was transformed to a pumping station and a pre-treatment plant to remove coarse particles and degreasing. Al Ardiya plant also contained two circular buffer tanks to balance effluent variation to regulate the out flow. The station is also equipped with a scrubber system to treat air extracted and reduce emitted odors [7].

Currently, Kuwait has four wastewater treatment plants in operation; these are listed in Table I.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Al Riqqa</th>
<th>Al Jahra</th>
<th>Um Al-Hayman</th>
<th>Sulaibiya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructed</td>
<td>1982</td>
<td>1982</td>
<td>2001</td>
<td>2002</td>
</tr>
<tr>
<td>Initial Capacity</td>
<td>85,000</td>
<td>65,000</td>
<td>27,000</td>
<td>425,000</td>
</tr>
<tr>
<td>Expanded Capacity m³/d</td>
<td>180,000</td>
<td>-</td>
<td>-</td>
<td>600,000</td>
</tr>
<tr>
<td>Current Inflow m³/d</td>
<td>170,000</td>
<td>100,000</td>
<td>16,000</td>
<td>450,000</td>
</tr>
<tr>
<td>Tertiary treated water m³/d</td>
<td>166,000</td>
<td>98,000</td>
<td>15,680</td>
<td>-</td>
</tr>
<tr>
<td>RO water treated m³/d</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>320,000</td>
</tr>
</tbody>
</table>

**A. Treatment of wastewaters that are not connected to the national sewage network**

As part of the national movement to protect the environment, the local environmental authority had planned to create a sewage pit to replace an existing wastewater dump site. This dumpsite was an unlined landfill that accepted wastewater arriving in tank trucks that transport sewage water from remote areas that were not connected to the main MPW network by then [8]. The construction of such pit was of particular importance as it planed pump daily accumulated waste to be treated to tertiary effluent quality at Umm Al Hayman (Waste Water Treatment Plant) WWTP. Umm Al Hayman was connected to that pit because it was the only plant that is working below the designed capacity and is thus capable of accepting those waters [9]. Over two hundred water tank truck loads that accumulate to over 6000 m³/day of wastewaters was saved and recycled by accomplishing this project. This pit is temporary until remote areas from which the admitted tank trucks were arriving are connected to the main (Ministry of Public Works) MPW sewage network.

**V. AL SULAIBIYA WASTEWATER TREATMENT AND RECLAMATION PLANT**

Commenced in 2005, Al-Sulaibiya wastewater treatment and reclamation plant is the largest facility that uses Reverse Osmosis (RO) and Ultrafiltration (UF) membrane water purification facility. The facility was constructed with an initial capacity of 425,000 m³/d to treat domestic wastewaters to potable quality for non-potable use. Just after few years in operation, the facility is accepting around 500,000 m³/d, which means that the plant is recycling around 64% of the entire sewage of the country alone. Future plans are directed towards expanding the capacity to 600,000 m³/day.

Al-Sulaibiya WWTP receives wastewaters through a 25km-long main feeder pipeline that conveys a pre-treated flow from the Ardiya pumping station. As discussed earlier, the Ardiya station does receiving, initial screening, degreasing, odor removal and flow regulation. A satellite image for the Sulaibiya waste treatment and reclamation plant is shown in Fig 1.

**Figure 1.** A satellite image for the Sulaibiya waste treatment and reclamation plant.

**A. Biological Treatment at Al-Sulaibiya WWTP**

Preliminary treated effluent from Ardiya pumping station first arrives to the inlet structure at the Sulaibiya WWTP. The inlet structure mixes the inflow of wastewaters with backwash of the ultrafiltration. Also, the inlet structure distributes the resultant flow to the nine aeration tanks where the core of the biological treatment takes place. Oxygen diffusers at the bottom of the aeration tanks pump oxygen to start the aerobic activity that stimulates the biological treatment. The nine aeration tanks are around eight meters deep and constitute a total volume of 208,900 m³[7]. The mixed liquor then flows to 67 diameter and eight meters deep secondary clarifiers. In the secondary clarifiers, the sludge precipitates at the bottom of the tank while secondary effluent floats to the top. The effluent then enters the reclamation plant, which is the second purification unit of the plant. It is discussed in the next section.

A part of the precipitating sludge is returned as an active biomass to the aeration tanks while the access is transferred to the sludge gravity belt thickener to reduce the moisture content from the sludge. Then, the sludge is transferred to the orbit digesters to reactivate the bacteria in the sludge and
naturalize it. The resultant sludge is then sent to the drying beds, where its stays up to 6 months depending on the season. Finally, the compost is periodically turned for a week and stored. This type of compost is typically used to improve soil properties and as manure for planting animal feed.

B. Reclamation Treatment at Al-Sulaibiya WWTP

The First step in the reclamation plant is the 60 µm Disc filters. The backwash of the disk filters is returned back to the beginning of the biological treatment plant to be mixed with raw sewage at the inlet structure. The effluent enters the ultrafiltration section that consists of 8,700 UF membranes; each membrane consists of 10,000 tubes through which the water filtered through a transpiration process. The collected product proceeds to the Reverse Osmosis section. The RO section contains 21,000 membranes that are divided into three consecutive steps. The rejection of the first step continues to the second, and the rejection of the second proceeds to the third RO step. It is estimated that 15% of the inflow is rejected at the final RO step. This constitutes the brine, which is dumped into the sea.

Also, until the expansion at Al Sulaibiya takes place, any raw sewage accepted above the capacity of 425,000 is treated to a secondary level and is dumped into the sea. The end product is fresh water of potable quality. The properties of the produced water are described later sections.

C. Effluent Quality from Wastewater Treatment Plants

Both effluents from tertiary and RO treatment plants meet the Ministry of Electricity and Water (MEW) standards for irrigation. Table II. Note that the total dissolved solids (TDS) indicator of RO is between 20-30 ppm and will never exceed 100 ppm. The TDS of typical bottled drinking water ranges between 100-150 ppm, while that of distilled water is 3-5 ppm.

VI. UTILIZATION OF TREATED EFFLUENT

The RO WWTP at Sulaibiya was originally built at its location (Sulaibiya fields) due to the abundance of brackish water wells in that area. The original idea was to inject brackish water wells with the RO potable water effluent and then distribute the products to households across the country. Due to political reasons, the planned has changed and effluent is now pumped to irrigation purposes.

A. The Use of Treated Wastewaters for Irrigation

Many agricultural practices indicate the value of using treated wastewaters for irrigation purposes. For instances, treated wastewaters have been used for centuries in countries like Mexico, Vietnam, China and Saudi Arabia. In Pakistan and Greece studies confirmed that treated wastewaters have increased the yield of the produce [10].

In Kuwait, among the first attempt to utilize tertiary treated wastewaters was through the United Company for Agricultural Produce, which supplies 70% of consumed cattle feed in Kuwait; and the Kuwait Public Authority for Agriculture Affairs and Fish Resources (PAAF), which used it for city landscaping [11].

In general, treated wastewater effluent is currently used in the following sectors:

- Tertiary effluent:
  - Landscaping for highways, main roads and public parks[12]
  - Irrigation for animal feed
  - Commercial golf courses, private parks and malls

- RO effluent:
  - Irrigation of crops in Wafra and Abdaly

### Table II. Effluent Chemical and Biological Composition from Tertiary and RO WWTP in Kuwait (Al Khily, 2009)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Tertiary irrigation water</th>
<th>R.O Drinking water (MEW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td>–</td>
<td>6.5-7.5</td>
<td>6.5 – 8</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µs/cm</td>
<td>1100-2200</td>
<td>1500</td>
</tr>
<tr>
<td>T.S.S. mg/L</td>
<td>&lt; 10</td>
<td>15</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>V.S.S. mg/L</td>
<td>&lt; 7</td>
<td>15</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>C.O.D. mg/L</td>
<td>&lt; 40</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>B.O.D 5 mg/L</td>
<td>&lt; 10</td>
<td>20</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Grease &amp; Oil mg/L</td>
<td>NIL</td>
<td>5</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>T.D.S. mg/L</td>
<td>800-1500</td>
<td>&lt; 100</td>
<td>400</td>
</tr>
<tr>
<td>Chloride mg/L</td>
<td>200-400</td>
<td>12</td>
<td>103</td>
</tr>
<tr>
<td>Ammonia mg/L</td>
<td>1-5</td>
<td>15</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Nitrate mg/L</td>
<td>0.1-1.5</td>
<td>&lt; 1</td>
<td>–</td>
</tr>
</tbody>
</table>

B. Tertiary Effluent

Recently, tertiary treated water is also pumped to Sahara Golf course, Marina Mall, Sabah Al Salem gardens, Kuwait International Airport, Kuwait Airways headquarters, Aumaria and Rabia farms and landscapes along Kuwait highways. Most of the tertiary water used in these projects comes from Al-Riqqa and Al Jahra WWTP. More details about exact quantities pumped are found at [13].

Effluent at Um Al Hayman WWTP is not well utilized. The tertiary effluent is dumped into the desert and is left to dry. Perhaps two reasons could explain this postponed utilization: First, Um AL-Hayman WWTP is currently the smallest plant processing around 16,000 m$^3$/day and more emphasis was directed towards larger facilities such as Sulaibiya (currently treating 500,000 m$^3$/day). Secondly, future plans include expanding this facility and water reuse plans are postponed until a comprehensive plan is established. However, we still believe that tertiary water at Um AL-Hayman could still be better utilized.

C. RO Effluent

Unlike tertiary effluent RO is pumped to farms of edible produce. These are mainly located in Abdaly and Wafra in Kuwait.
the northern and southern part of the country respectively. On a daily basis, 100,000 m$^3$ are pumped to Abdaly and Wafra each, while the remaining of the above 400,000 m$^3$/day treated by RO is dumped to the sea. The reason behind dumping this valuable resource into the sea that the Data Monitoring Center (DMC) that is constructed to pump RO effluent was not ready to receive the total amount of treated effluent. This is again due to the shift in the original strategic plan that aimed to injecting RO effluent to brackish water well instead of being used for irrigation. During winter season the demand for the RO effluent for planting produce is reduced. Excess RO effluent is pumped to an artificial lake called Um Al rimam.

**D. Sludge**

Currently, sludge produced at some of the WWTPs is used to remediate and improve soil properties. Future MPW projects is inclined toward working with international consultants to study the feasibility of generating electricity from the sludge produced from waste water treatment [14].

**VII. COST OF TREATING WASTEWATER**

Because wastewater treatment can be generally considered as a non-thermal process, it is significantly more cost efficient that desalination. For desalination, while 1000 imperial gallons (4,545 m$^3$) of water costs the MEW KD 2.7 to produce. The customer is charged KD 0.8 for it [1]. On the other hand, it costs KD 0.55 and KD 0.85 to produce 1000 imperial gallons if tertiary and RO treated water respectively. The selling price per 1000 imperial gallons of tertiary treated water is KD 0.12 and KD 0.183 for RO treated water [13, 15]. Not only it is much cheaper to produce, it is also much cheaper to be subsidized to the customers. That is the government loses KD 1.9 for each 1000 imperial gallons of desalinated waters compared to losing only KD 0.43 for subsidizing tertiary water.

**VIII. FUTURE WASTEWATER PLANTS**

The Sanitary sector is in a constant process of improving the wastewater piping system throughout the country [15]. For instance, Al-Riqee is intended to open commence by the end of this month April 2010. A new pumping station in Al-Riqee is intended to replace 29 old pumping stations which will save on operational expenses and uses a technology that is more environmentally friendly. The station will have a centralized control system and an advanced odor control. The Al-Riqee pumping station is designed to have a daily pumping capacity of 780,000 m$^3$. Regarding WWTP [16]:

- The existing plant capacity Jahra will be replaced with a new WWTP at Kabd. When completed in 2012, the Kabd plant will treat about 345,000 m$^3$/day.
- The Jahra WWTP will be decommissioned and converted into a pumping station.
- Al Riqqa capacity will be replaced by expanding the capacity of Um Al Hayman to around 300,000 expandable to 500,000 m$^3$/day.
- The Riqqa planed will be decommissioned as well and converted into a data monitoring center.
- The Sulaibiya WWTP is planned to be expanded to 600,000 m$^3$/day.

**IX. CONCLUSIONS**

Four wastewater treatment plants are in constant operation to achieve the country strategic goal of zero wastewater dumping and full utilization of treated effluent. Tertiary treated effluent from Al-Jahra and Al-Riqqa WWTP are mainly utilized for landscaping of public parks, recreational areas and irrigation of plants along highways and main roads. However, effluent from Um Al Hyman is not well utilized and dumped into the desert to dry out naturally. Perhaps, less emphasis was directed to that plant as it accepts and treats the smallest amount of wastewaters and because near future plans include expanding the capacity of its production. On the other hand, effluent generated from Al-Sulaibiya WWTP uses RO technology, where treated water is biologically and chemically meet quality standards of potable water for non-potable use. Around half of the product of the RO facility is transported to crop farms, while the remaining is dumped to the sea. This is because the data monitoring system responsible for pumping and distributing the treated water was originally designed to inject the produced waters into nearby brackish water wells. Therefore, it was not ready to handle pumping the daily treated effluent to far distances it irrigate crops at the Abdaly and Wafra farms. Research need to be developed towards creating an emergency plan that is dynamic and efficient to handle urgent situations for any malfunctions or any unforeseen events.

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