Microbial Water Quality Assessment of Wadi Hanifah (Riyadh-Saudi Arabia) For Landscape Irrigation Use: A Case-Study

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Abstract: Fresh water in the Middle East and North Africa region is becoming scarcer. The use of Wadi Hanifah (the valley of Hanfia) water for irrigation of landscape as a sustainable source was investigated in this paper. The microbial quality of running water in Wadi Hanifah was assessed at eight sampling sites. The sampling sites were selected to cover the full length of the wet part of Wadi Hanifa. The results showed that the bioremediation facility which is constructed on the wadi has decreased the levels of fecal and total coliform in the water. The results also indicated that high levels of fecal and total coliform have been observed after the connection between Wadi Hanifa and Batha channel which carries sewage water to the valley. The results of most sampling sites showed high levels of total coliform and fecal coliform during the months of April and May, particularly at the sites in the upstream of the Wadi due to the big rain events which happen during April and May in Riyadh. The results also concluded that Wadi water could be potentially a sustainable water resource for landscape irrigation after simple treatment to reduce fecal and total coliform levels.

Key words: Fecal coliform • Total coliform • Wadi Hanifa • Water quality • Sustainability.

INTRODUCTION

Many countries located in the Middle East region are arid and suffering from water shortage. The water usage for different applications, including drinking, industrial and agricultural activities, may diminish the available water resources and thus finding alternative resources is essential [1]. Treating and reusing the wastewater for non-potable purposes, such as agriculture, could contribute in resolving the problem of water scarcity and wastewater disposal. Using the treated wastewater for agricultural applications becomes common practice worldwide.

The situation of water availability in the MENA region is common to countries located in arid and semi-arid areas. In these areas, water is becoming more scarce forcing planners to consider developing non-conventional water resources including treated wastewater (TWW) reuse [2,3]. The use of treated wastewater gained increased attention since the mid-1940s, especially in arid and semi-arid areas [4] and is continuing to be considered as a reliable source of irrigation water to satisfy increasing agricultural demands. TWW reuse has been implemented in many countries to irrigate different crops and has increasingly been integrated in the planning and development of water resources in many countries such as Jordan and Tunisia [5, 6].

Additionally, using treated wastewater for irrigation is beneficial since it reduces the need for high purification levels and fertilization costs since soil and crops serve as bio-filters and wastewater contain nutrients [7]. The wastewater quality is an important factor for safe irrigation. The concentration and chemical and biological composition of dissolved constituents in water combined with the amount of water used determines its quality to be used in agriculture. Many standards have been set by different institutions to control the quality of the irrigated water [2].

Wadis (valleys) play a major role in assimilation or carrying off the municipal and industrial wastewater and run-off from agricultural land. The municipal and industrial wastewater discharge constitutes the constant polluting source, whereas, the surface run-off is a seasonal phenomenon, largely affected by climate in the basin. Seasonal variations in precipitation, surface run-off, interflow, groundwater flow and pumped in and outflows have a strong effect on wadi discharge and subsequently on the concentration of pollutants in wadi water [8].

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Pathogen loadings derive from non-point source inputs from urban or agricultural activities [9, 10], dry weather flows from storm sewers [11], wet weather loadings from combined or sanitary sewer overflows [12], or discharges from wastewater treatment plants. Climate factors are primary among drivers of source water contamination due to their influence on the transport of contaminants by precipitation-induced runoff. Runoff generated by rainfall is associated with increased levels and variability of fecal contamination in downstream surface water [13, 14].

The treatment processes of wastewater must be sustainable in terms of environmental, economic and social aspects of sustainability. The environmental sustainability is identified by some indicators including greenhouse gases, waste discharge and energy consumption. Economic sustainability involves financial, capital and operating, costs and benefits. The social sustainability is assessed according to the working conditions such as worker stress and work satisfaction. Balkema et al. [15] have studied these sustainability indicators to assess them for evaluation of environmental, economic and social aspects of wastewater treatment processes.

In this study, we are assessing the microbial water quality of WadiHanifa, Riyadh, Saudi Arabia, for the use of its water as sustainable water resource to irrigate landscape to persevere groundwater and desalinized water for other uses.

**MATERIAL AND METHODS**

**Study Area of WadiHanifa:** On the Najd plateau of central Saudi Arabia, WadiHanifa runs southeast for around 120 kilometers (75 mi) before losing itself on the fringes of the Rub' al-Khali, or Empty Quarter. Fed by more than 40 tributaries, this great watercourse has a catchment area covering much of the eastern Najd, more than 4500 square kilometers (1740 sq mi), across what was historically known as al-Yamamah (Fig. 1). The meandering valley (Wadi in Arabic) is dry for nearly all of the year but remains fertile, thanks to aquifers close to the surface. It has attracted human settlement for millennia.

Approximately 450,000 cubic meters of water (dry weather flow) continually flows out of Riyadh (the capital city of Saudi Arabia) each day into the WadiHanifa from various side wadis and channels. The main sources of flow into the Wadi are as follows; The North Diversion Channel (33,000 m³/day), WadiGudwannah (6000 m³/day), Wadi Umm Qassar (9,000 m³/day), West Ship (19,300 m³/day), Namar (9000 m³/day), Sultanah (4500 m³/day), Alshafa (4500 m³/day) and Batha Channel, “Manfouha STP outfall” (370,000 m³/day average and 450,000 m³/day peak) [17, 18]. These flows are expected to increase two-fold by the year 2021. At the moment this water can be reused for irrigation, agriculture but cannot be used for potable water uses, because of water quality concerns. In attempt to treat the Wadi water, a bioremediation facility was built mid-way in the Wadi length as shown in

![Fig. 1:WadiHanifa Location (Modified from [16]).](image)
Fig. 1. The water quality of water after the bioremediation facility showed signs of change in the level of many parameters, however, the Wadi receives water from Al-Batha Channel which carries water from the Manfoha wastewater treatment plant and the water quality of the Wadi deteriorate after that.

Riyadh currently consumes 1.3 million cubic meters of water and this is expected to rise to 3 million cubic meters by the year 2021. Because of the continual draw-down of the water table to cope with the city’s ever increasing population, Riyadh has had to find alternative sources of water. Now most of the city’s (desalinated) water supply is piped in from the coast 350 km away, a very expensive and unsustainable option [17].

Monitored Parameters and Analytical Methods: In order to represent the water quality of the Wadi system accounting for stream and inputs from drains that have impact on downstream water quality, the monitoring and sampling plan was designed to cover a wide range of determinants at specific sites. Under the water-quality monitoring plan of Wadi Hanfia, samples were collected each month at three points across the Wadi width at eight sites. Collecting, preservation and transportation of the water samples to the laboratory were as per standard methods [19].

The eight sites were selected to cover the full length of the wet part of Wadi Hanfia as shown in Fig. 2. Their names are SW3C (site 1), SW12A (site 2), SW12C (site 3), SW14 (site 4), SW20 (site 5), SW8G (site 6), SW10B (site 7) and SW16 (site 8). The sites 1 and 2 are chosen before the bioremediation facility, while sites 3, 4 and 5 are before the connection between batha channel, which carries water from Manfoha wastewater treatment plant to the Wadi and sites 6, 7 and 8 are located after batha channel.

Water temperature was measured on site using mercury thermometer. All other parameters were determined in laboratory following the standard protocols [19]. The samples were analyzed for pH, Total Coliform (CFU/100 ml), Fecal Coliform (CFU/100 ml) and temperature (°C). The basic statistics of the data set on Wadi water quality is summarized in Table 1.
Table 1: The basic statistics of the data set on Wadi water quality

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Stations</th>
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<tbody>
<tr>
<td></td>
<td>SW3C</td>
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<tr>
<td>Temp (°C)</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>pH</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Total Coliform (CFU/100 ml)</td>
<td>Mean</td>
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<tr>
<td></td>
<td>Std. Dev.</td>
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<tr>
<td>Fecal Coliform (CFU/100 ml)</td>
<td>Mean</td>
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<tr>
<td></td>
<td>Std. Dev.</td>
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</table>

RESULTS AND DISCUSSION

Water Quality: The maximum and minimum of the total coliform for SW3, which located in the start of the wet part of the wadi, during the 12 months of sampling period, are 48700 and 5300 cfu/100 ml, respectively. Also, the average total coliform colonies in SW3 are 23441.7 with standard deviation of 11678.9. Correspondingly, the maximum and minimum fecal coliform in SW3 water sample are 37600 and 1900 cfu/100 ml, respectively and the average and standard deviation of SW3 are 13591.6 and 9818.3, respectively (Fig. 3a). Table 1 shows the average, standard deviation, maximum and minimum values for the sampling sites.

Fig. 3: Total Coliform, fecal Coliform and water temperature for sites before the bioremediation facility.
The maximum and minimum of the total coliform for SW12A, which located just before the bioremediation facility, during the 12 months of sampling period, are 49900 and 13000 cfu/100 ml, respectively. Furthermore, the average total coliform colonies in SW3 are 26475 with standard deviation of 10918.7. Similarly, the maximum and minimum fecal coliform in SW12A water sample are 42900 and 4700 cfu/100 ml, respectively as shown in Figure 3b and the average and standard deviation of SW3 are 16691.6 and 9942.6, respectively.

SW12C, which located just after the bioremediation facility, during the 12 months of sampling period, has maximum and minimum total coliform of 37300 and 6100 cfu/100 ml, respectively. Furthermore, the average total coliform colony in SW12C is 18566.7 with standard deviation of 8681.9. Likewise, the maximum and minimum fecal coliform in SW12C water sample are 20700 and 700 cfu/100 ml, respectively as shown in Figure 4a and the average and standard deviation of SW3 are 9041.6 and 6391.1, respectively.

The maximum and minimum of the total coliform for SW14 during the 12 months sampling period are 37300 and 6100 cfu/100 ml, respectively. Also, the average total coliform colonies in SW14 are 12100 with standard deviation equals to 8207.42. Consistently, the maximum and minimum fecal coliform in SW14 water sample are 15800 and 400 cfu/100 ml, respectively and the average and standard deviation of SW3 are 4941.6 and 3839.1, respectively (Fig. 4b).

SW20, which located just before the connection between batha channel and WadiHanifa, during the sampling period has maximum and minimum total coliform of 69300 and 5900 cfu/100 ml, respectively. Furthermore, the average total coliform colonies in SW20 are 12100 with standard deviation of 17490. Likewise, the maximum and minimum fecal coliform in SW20 water sample are 29200 and 700 cfu/100 ml, respectively as shown in Figure 4c and the average and standard deviation of SW20 are 6933.3 and 7858.7, respectively.

It is noted from the results of SW12C, SW14 and SW20 that the total and fecal coliform densities are lowered drastically. The fecal coliform density for the three sampling sites have dropped below the standard set by ministry of water and electricity for the restricted irrigation, which is 1000 cfu/100 ml.

The maximum and minimum of the total coliform for SW8G, which located just after the connection between batha channel and WadiHanifa, during the 12 months sampling period are 71000 and 24100 cfu/100 ml, respectively. Moreover, the average total coliform colony in SW8G is 46575 with standard deviation of 14585. Similarly, the maximum and minimum fecal coliform in SW8G water sample are 42500 and 8400 cfu/100 ml, respectively as shown in Fig. 5a and the average and standard deviation of SW8G are 26258.3 and 11207.3, respectively.

The results of sampling site SW8G showed increase in total and fecal coliform densities compared to the results of sites SW12C, Sw14 and SW20 because SW8G is located after the connection between batha channel and WadiHanifa, the channel carries treated municipal wastewater from Manfoha wastewater treatment plant to WadiHanifa (Fig. 6).

The maximum and minimum of the total coliform for SW10B during the 12 months sampling period are 49100 and 23100 cfu/100 ml, respectively. Also, the average total coliform colony in SW10B is 35525 with standard deviation equals to 9591.1. Consistently, the maximum and minimum fecal coliform in SW10B water sample are 28400 and 10500 cfu/100 ml, respectively and the average and standard deviation of SW3 are 20816.6 and 6570.9, respectively (Fig. 5b).

SW16, which located at the end of WadiHanifa, during the 12 months sampling period has maximum and minimum total coliform of 48100 and 4700 cfu/100 ml, respectively. Furthermore, the average total coliform colonies in SW16 are 16125 with standard deviation of 11762.7. Likewise, the maximum and minimum fecal coliform in SW16 water sample are 18200 and 400 cfu/100 ml, respectively as shown in Figure 4a and the average and standard deviation of SW3 are 6800 and 5726, respectively.
Fig. 4: Total Coliform, fecal Coliform and water temperature for sites before the connection between batha channel and wadiHanifa.
Fig. 5: Total Coliform, fecal Coliform and water temperature for sites after the batha channel.
The results of most of the sampling sites showed high level of total coliform and fecal coliform during the months of April and May, particularly in the sites in the upstream of the Wadi due to the big rain events which happen during April and May in Riyadh.

It is noted from the results mentioned above that the standard deviation of all the data is very high, which implicate that the rain events and climatic condition of the region affect greatly the fecal and total coliform concentrations in the Wadi water. Variability in coliform density tends to be positively related to precipitation (Cha et al., 2010),therefore increases in total annual precipitation will likely elevate contamination levels.

Several standards for the reuse of wastewater for agricultural and landscape irrigation, both restricted and unrestricted, have been issued in Saudi Arabia. Initially, the Ministry of Agriculture and Water (MAW) issued several draft and tentative standards [20, 21], all of which were strict and prevented agricultural use of the treated effluent [22]. In 2003, the Ministry of Municipal and Rural Affairs (MMRA) issued new standards [23], which were replaced in 2006 by the latest standards [24], set by the Ministry of Water and Electricity (MWE) [25].

In general, samples exceed the drinking water standards. They also exceed European Union (EU) guideline microbiological standards for bathing water (500 total coliforms/100ml and 100 faecal coliforms/100ml) and also for EU maximum limits (10,000 total coliforms/100ml and 2000 faecal coliforms/100ml). Also, According to MWE (2006), the fecal coliform water quality standard for restricted irrigation is 1000 cfu/100 ml.

### Statistical Analyses

#### Total Coliform:

The t-test result for total coliform shows no significant difference between readings from stations SW12A and Sw12C. This shows that the bioremediation facility does not have a significant effect on the total Coliform amount.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>SE Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW12A</td>
<td>12</td>
<td>26475</td>
<td>10919</td>
<td>3152</td>
</tr>
<tr>
<td>SW12C</td>
<td>12</td>
<td>18567</td>
<td>8682</td>
<td>2506</td>
</tr>
</tbody>
</table>

\[
\text{Difference} = \mu (\text{SW12A}) - \mu (\text{SW12C})
\]

Estimate for difference: 7908
95% CI for difference: (-492, 16308)

T-Test of difference = 0 (vs ≠): T-Value = 1.96 P-Value = 0.064 DF = 20

However, the bioremediation facility shows seasonal changes that can be noticed in the box plot (Fig. 7). Using correlation analysis, it is concluded that the facility also breaks the correlation between readings after and before its location, but its efficiency is not enough to cause a significant change in the total coliform. The box plot shows that the readings after the station spanned a higher range of values that proves seasonal working efficiency.

The t-test result for total coliform shows significant difference between readings from stations SW20 and Sw8G. The sewage water from Batha channel, which carries water from Manfoha wastewater treatment plant, has a significant effect on the total coliform as shown in the t-test results given below. The box plot (Fig. 8) shows a remarkable change in the total coliform values both in mean and span.
Fig. 7: Boxplot for total coliform for stations SW12A and SW 12C.

Fig. 8: Boxplot for total coliform for stations SW20 and SW8G.

Fecal Coliform:
The t-test shows that the bioremediation facility affects significantly the concentration of fecal coliform as there is a significant difference between readings from SW12A and SW12C. The difference is clear also in the box plot diagram (Figure 9).

Fig. 9: Boxplot for fecal coliform for stations SW12A and SW 12C.

Fig. 10: Boxplot for fecal coliform for stations SW20 and SW8G.

The t-test shows that the bioremediation facility affects significantly the concentration of fecal coliform as there is a significant difference between readings from SW20 and SW8G. The sewage water from Batha channel has a significant effect on the fecal coliform as shown in the t-test results given below. The box plot (Figure 10) shows a remarkable change in the total coliform values both in mean value and span.

CONCLUSIONS

The results showed that the bioremediation facility which constructed on the wadi has decreased the levels of fecal and total coliform in the water. The results also indicated that high levels of fecal and total coliform have
been observed after the connection between Wadi Hanifa and Batha channel. The results of most of the sampling sites showed high level of total coliform and fecal coliform during the months of April and May, particularly in the sites in the upstream of the Wadidue to the big rain events which happen during April and May in Riyadh. The results also concluded that Wadi water could be potentially a sustainable water resource for landscape irrigation after simple treatment of water to remove fecal and total coliform from water. It is noticed from the results mentioned above that the standard deviation of all the data is very high, which implicate that the rain events and climatic condition of the region affect greatly the fecal and total coliform concentrations in the Wadi water.

REFERENCES


