The Use of Treated Waste Water for Irrigation Purposes in the Administrative District of Kerbala, Iraq

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Abstract. The aim of this study was to assess the feasibility of reusing urban treated wastewater for agricultural irrigation in the administrative district of Kerbala in Iraq. Water scarcity in this region has a negative effect on agriculture, especially irrigated agriculture, and the resulting reduction of arable land in the region is predicted to lead to problems with food production. One of the few guaranteed alternative sources of water under the current conditions is treated municipal wastewater. The study thus made a quantitative and qualitative analysis of existing water sources for the city of Kerbala for the period 2014 to 2019, as well as examining water consumption by the population during that period. The period-wide water shortage for irrigation of agricultural land was also determined, and a comprehensive assessment of the possibility of using treated wastewater from the treatment facilities of the town of Kerbala for irrigation purposes was thus developed.

Keywords: water shortage, treated wastewater, water consumption, irrigated agriculture

1. Introduction

Population growth and urbanisation in the city of Kerbala have occurred at the expense of agricultural land while increasing demand for food products. Additionally, the increases in population of up to 200 million people in Turkey and Syria, which are above Iraq, have contributed to these countries building dams on the Euphrates River. The Al-Hussainiyah River, which is the main source of water supply in the administrative district of Kerbala, takes its waters from Euphrates River, and as a result of the construction of these dams, its water intake has been reduced by half, minimising availability for irrigation.

The use of treated wastewater is a promising approach to solving the problem of water scarcity for irrigation of arable land in the city of Kerbala, and the reuse of treated wastewater for agriculture continues to be of great importance generally, especially in developing countries [1]. Innovations and promising technologies in the field of wastewater treatment that can lead to large-scale reuse or recycling of these waters in various sectors of the economy are thus of great benefit[2].
Wastewater has been used in agriculture for decades in countries such as India, the United States, Australia, Spain, and South Africa [3]. Under the conditions of increased freshwater scarcity experience by many Arabian countries such as Saudi-Arabia [4] [5] and Kuwait [6], the irrigation of land such as seen in the Simferopol and Krasnogvardeisky districts [7] [8] and Jordan [9] [10] by the reuse of is now receiving greater attention and increased recognition. Political decisions are also involved in reducing water losses, improving water resource management, and reducing the needs of the population. Many countries have already passed laws on the conservation and rational use of drinking resources; however, few of these reforms have produced tangible results [11].

2. Object of the study
The object of this study was the preservation of the areas of irrigated agriculture by identifying alternative sources of water supply for irrigation purposes, most specifically the use of treated wastewater to address water scarcity in the city of Kerbela.

3. Research methods
The current study was based on data from the Directorate of Water Resources in Kerbala province from 2014 to 2019. Analytical research methods were used to determine the volume flow of the Al-Hussainiyah River, water consumption by the population during per year, and the resulting water scarcity levels with regard to the irrigation of land during the growing season. Alternative sources of water replenishment were explored with regard to use of treated wastewater from the city for the irrigation of surrounding lands, and a predicted calculation of the increase in the amount of irrigated water available over the course of a phased introduction of treatment facilities to city districts was made.

4. Research results
The main source of water supply for the city is the Al-Hussainiyah River, which has five branches (Al-Wanad, Al-Kamalia, Abu-Zarah, Al-Rushdia, and Al-Hnidia). The private sector of the city also uses several underground sources of water from wells, though these are not taken into account in this work. Table 1 presents data for the last six years of monthly water volumes for the Al-Hussainiyah River.

**Table 1.** Water volume in the Al-Hussainiyah River for the period 2014 to 2019 [12].

| Months | 2014     | 2015     | 2016     | 2017     | 2018     | 2019     | Average Volume (m³) |
|--------|----------|----------|----------|----------|----------|----------|---------------------|
| Jan    | 26784000 | 13392000 | 37765440 | 40443840 | 32408640 | 44193600 | 32497920            |
| Feb    | 27578880 | 14587776 | 31069440 | 40443840 | 29730240 | 22498560 | 27651456            |
| Mar    | 34979904 | 15106176 | 21159360 | 40443840 | 37765440 | 31069440 | 30087360            |
| Apr    | 41212800 | 32400000 | 31069440 | 40443840 | 38033280 | 31069440 | 35704800            |
| May    | 47139840 | 53139456 | 48746880 | 29998080 | 41783040 | 39104640 | 43318656            |
| Jun    | 39265344 | 50086080 | 48479040 | 51157440 | 40443840 | 48479040 | 46318464            |
| Jul    | 53568000 | 53568000 | 57585600 | 49550400 | 38033280 | 54103680 | 51068160            |
| Aug    | 53568000 | 37149408 | 58389120 | 48479040 | 35087040 | 55442880 | 48019248            |
Numerous studies have included calculating water consumption for the Al-Hussainiyah project; this study, relied on the Economic Feasibility Study of Al-Hussainiyah Irrigation Project in Kerbala Province, however, as this also acted as a design study for the project. Table 2 shows the consumption of water by the population and for agricultural purposes.

Table 2. Volume of monthly water consumption for population and agricultural purposes [13].

| Months | Volume (m³ * 10⁶) |
|--------|-------------------|
| Jan    | 19.86             |
| Feb    | 29.39             |
| Mar    | 55.84             |
| Apr    | 83.35             |
| May    | 102.23            |
| Jun    | 113.9             |
| Jul    | 114               |
| Aug    | 94                |
| Sept   | 63.74             |
| Oct    | 46.87             |
| Nov    | 27.81             |
| Dec    | 17.6              |

A comparison between the consumption of water by the population for household needs, industry and agriculture and the actual water supply in the river is presented in graph 1.
Figure 1. Comparison between consumption of water and the average volume of the Al-Hussainiyah river.

It can be seen from Figure 1 that the water supply is adequate for only three months of the year; starting in February, there is a shortage in water supply for many months. A particularly acute shortage of water is observed during the period where irrigation of arable land is required, from April to August. Water deficits occur when water demand exceeds supply, and the relevant water deficit was calculated according to the following equation:

$$\text{Water deficit} = \frac{\text{water demand} - \text{water supply}}{\text{water demand}} \times 100\% \quad (1)$$

so that

Water deficit in Apr. = \((83350000-35704800)/(83350000)\)*100\% = 57.16\%

The highest water deficits were thus 57.16\% in April, 57.63\% in May, 59.34\% in June, 54.76\% in July, and 48.88\% in August.

To address this problem, options for the use of groundwater were considered. However, the level of occurrence of artesian waters at a depth of less than 500 meters and the remoteness of such sources from the location of irrigated lands did not allow such an approach to be applied due to its uneconomic nature.

An assessment was then made of the actual amount of wastewater generated and the commissioning of treatment facilities.

In Kerbala, there has previously been one old sewage treatment plant located in the Shabanat district, about 2 km from the city centre. The design capacity of the station is 100,000 m$^3$ per day. In February 2020, the next wastewater treatment plant, with a design capacity of 400,000 m$^3$ per day, was put into operation; this is located about 5 km from the city centre. Figure 2 shows the location of the existing and planned new wastewater treatment plants and the city's sewerage network.
As seen in Figure 2, currently only one-third of the city of Kerbala has a sewage network. The rest of the city is planned to receive sewerage in the future, an urgent need based on an annual population growth of 1,500,000 people and about 20,000,000 tourists visiting each year. The table below show the amount of wastewater generated from the part of the city with sewerage, some of which passes through the treatment plants; the rest is discharged without treatment into water bodies. Wastewater entering the treatment plant is presented in Table 3, while untreated wastewater is shown in Table 4.

**Figure 2.** Location of sewerage stations and networks in the city of Kerbala [14].

| Months | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Average Volume (m³) |
|--------|------|------|------|------|------|------|---------------------|
| Jan    | 2034524 | 1535840 | 2516620 | 3031390 | 3385670 | 2744480 | 2541421 |
| Feb    | **1426452** | 1535260 | 2442960 | 2993585 | 3338670 | 2415870 | 2358800 |
| Mar    | 1691976 | 1779440 | 2756740 | 3768910 | 3219470 | 3092290 | 2718138 |
| Apr    | 1545320 | 1566580 | 2706860 | 3510670 | 3305450 | 2978050 | 2602155 |
Table 4. Wastewater volume expelled without treatment into water bodies for the period 2014 to 2019 [14].

| Months | Wastewater volume without treatment in cubic meters | Average Volume (m³) |
|--------|------------------------------------------------------|---------------------|
|        | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  |         |
| Jan    | 848109 | 1083795 | 2151340 | 3167332 | 4501202 | 4853970 | 2767625 |
| Feb    | 907920 | 1201232 | 2179690 | 2647295 | 4578845 | 4068248 | 2597205 |
| Mar    | 1109765 | 1362573 | 2513437 | 3631647 | 4535190 | 4384907 | 2922920 |
| Apr    | 1140970 | 1549650 | 1158725 | 4697712 | 4707350 | 4860435 | 3019140 |
| May    | 1016505 | 1104257 | 1833925 | 3935765 | 4752195 | 4791197 | 17433844 |
| Jun    | 572915 | 1445240 | 1987280 | 4310350 | 4728035 | 4962372 | 3001032 |
| Jul    | 1058200 | 1915865 | 2162672 | 3349525 | 4411585 | 5499250 | 3066183 |
| Aug    | 1220300 | 2188722 | 2188080 | 5190914 | 4167713 | 4517403 | 3245522 |
As shown in Table 4, there has been an annual increase in wastewater discharge without treatment, creating uncontrolled environmental pollution. These official statistics also take into account only the flow of sewage from the part of the city with a sewerage network, which represents only one-third of the total area. On completion of the laying of sewerage networks throughout the city and the cleaning all generated wastewater, these indicators will thus increase manifold.

After completing all sewage network works in the city of Karbala, 500,000 cubic metres per day or 15,000,000 cubic metres per month of treated wastewater will thus be produced, based on the design capacity of the stations. Figure 3 illustrates the consumption of water for the needs of the population and agricultural purposes versus Water supply + Treated wastewater after the completion of all proposed sewage network works in the city of Kerbala.

![Water discharge in the Al-Hussainiyah river, Water consumption for agriculture and population, Water discharge+Treated wastewater](image)

**Figure 3.** Comparison of consumption of water vs. Water supply + Treated wastewater after completion of all sewage network works in the city of Kerbala.

Figure 3 shows a decrease in water deficit ratios where treated wastewater is utilised. Using Equation 1, the maximum water deficits are thus 39.17217% in April, 42.95% in May, 46.18% in June, 41.62% in July, and 32.94% in August, suggesting that deficit rates are reduced by 17.99% in April, 14.67% in May, 13.17% in June, 13.15% in July, and 15.94% in August for an average reduction of **15%**.
The main aspects of using treated waste are quality, suitability, and safety in sanitary and epidemiological terms. Further research was thus required of the quality indicators of such water in use in order to prevent damage to soils during irrigation. The quality of the treated wastewater was assessed on the basis of laboratory data obtained from the Kerbala Sewage Directorate for the period January to December 2019. All agrotechnical and sanitary requirements for wastewater must be met for the figures above to apply.

Water quality was assessed according to the following indicators: Biochemical Oxygen Demand BOD, Suspended Solids, Chemical Oxygen Demand COD, chlorides, nitrates and pH. There are two types of irrigation water quality standards in Iraq, and both are presented in Table 5.

**Table 5. Standards of treated wastewater for agricultural (restricted and unrestricted) irrigation in Iraq [15].**

| Concentration (mg/l) | restricted | Unrestricted |
|----------------------|------------|--------------|
| BOD                  | 40         | 10           |
| T.S.S                | 40         | 10           |
| COD                  | 100        | 40           |
| Cl                   | 600        | 400          |
| NO3                  | 50         | 50           |
| PH                   | 4-8        | 4-8          |

The results obtained from the Kerbala wastewater treatment plant are shown in Table 6; these results were compared with Iraqi standards for agricultural wastewater use.

**Table 6. Quality of wastewater at the wastewater treatment plant in the city of Kerbala [14].**
### 5. Conclusions

1. On using treated wastewater in the city of Kerbala, the water deficit will be reduced by an average of 15% of total water consumption. After the sewerage of the entire city, the amount of treated wastewater should increase on average by 2 to 2.5 times (30 to 35%), which will approximately solve the problem of irrigated agriculture.

2. Treated wastewater can be used for agricultural purposes to irrigate only certain crops (restricted irrigation), such as fodder crops and flax, in accordance with Iraqi water quality standards for the irrigation of agricultural land.

3. In order to prevent land degradation in the process of irrigation of lands with treated waste waters, further study of the state of soils and improvements in the quality of water purification are necessary. Agronomic, technical and environmental criteria should be considered throughout to ensure comprehensive assessment of the quality of irrigation water.

| Concentration Months | Standard Irrigation water | 40*-10** | 40*-10** | 100*-40** | 600*-400** | 50*-50** | 4-8*-4-8** |
|-----------------------|---------------------------|----------|----------|-----------|------------|---------|-----------|
| BOD (mg / l)          | T.S.S (mg / l)            | COD (mg / l) | Cl (mg / l) | NO3 (mg / l) | PH        |
| Jan                   | 18                        | 41        | 90       | 124       | 5         | 8.7      |
| Feb                   | 10                        | 16        | 20       | 155       | 13        | 8.3      |
| Mar                   | 7                         | 32        | 20       | 150       | 40        | 8.7      |
| Apr                   | 8                         | 30        | 20       | 130       | 45        | 4.7      |
| May                   | 30                        | 33        | 70       | 246       | 38        | 6.3      |
| Jun                   | 10                        | 34        | 40       | 131       | 42.27     | 7.4      |
| Jul                   | 11                        | 14        | 40       | 112       | 38        | 7.3      |
| Aug                   | 30                        | 31        | 60       | 82        | 50        | 7.1      |
| Sept                  | 15                        | 25        | 20       | 99        | 5         | 7        |
| Oct                   | 16                        | 22        | 25       | 125       | 20        | 7.1      |
| Nov                   | 9                         | 23        | 25       | 160       | 40        | 7.3      |
| Dec                   | 3                         | 35        | 50       | 250       | 50        | 7.2      |

* Wastewater standards for agricultural (restricted) irrigation in Iraq.

** Iraqi Agricultural (Unrestricted) Irrigation Wastewater Standards.
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