The ability of using treated wastewater for irrigation purposes: middle Euphrates of Iraq as a case study

K R Al-Murshady, A Z Al-Qaisi and Z H Ali
1 Al-Qasim Green University, College of Water Resources Engineering, Babylon, Iraq
2 Al-Furat Al-Awsat Technical University, Al-Mussaib Technical College, Iraq

E-mail: dr.atheermohsin@wrec.uoqasim.edu.iq

Abstract. The sustainability of water resources is the goal of the present research. Samples of wastewater after treatment are collected from the Wastewater Treatment Plants (WWTPS) located in the Middle Euphrates provinces of Iraq (Najaf, Karbala, Diwaniya, and Babylon); as a case study. The physical, chemical, and heavy metals parameters tests of these samples will be carried out throughout the year and during the four seasons (Spring, Summer, Autumn, and Winter). The results showed that the minimum average exceeded the standards for EC, TDS, and TSS concentrations of all seasons are 7.74%, 0.77%, and 52.5%; respectively; while for COD, BOD, SO42-, and NH4 are 43.48%, 172.72%, 44.09%, and 92.02%; respectively. The other concentration of parameters is within standards and give the ability to irrigate potentially eaten fresh vegetables and fruits within two weeks of irrigation, cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, parks and civic roadsides, and sports stadiums, Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage Crops, Industrial crops and Forest Trees. A SWOT analysis is conducted to assess the ability to use this treated wastewater for irrigation purposes as an Environmental Impact Assessment (EIA). It is concluded that the ability to use this treated wastewater for irrigation some kinds of plants on different seasons. Also; it is concluded that some units of WWTPs need to rehabilitate and treat the parameters that out-off standards to be suitable to irrigate other kinds of plants.

1. Introduction
Water is essential for every form of life, for all aspects of socio-economic development, and for the maintenance of healthy ecosystems. While there are sufficient freshwater resources at the global level to enable continued agricultural and industrial development, the long-term sustainable use of water resources is of growing concern. This is particularly the case when considering the intrinsic disparity in water quality and availability across regions [1].

The volume of wastewater generated by domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions, and economic development [2].

Wastewater and agriculture are two sectors when the economic and environmental benefits of joint water management have been demonstrated through case studies around the world. This is particularly important in arid and semi-arid regions where freshwater shortages force farmers to consider all water sources that can be used economically and efficiently to irrigate their crops, ensure their financial stability and promote sustainable development [1].

The largest consumer of water in the Middle East is agriculture which accounts for 66% of demand [3]. Therefore, the water shortage problem cannot be objectively analyzed nor adequately addressed without a thorough consideration of agriculture in the region [4].

Droughts and water scarcity are major issues not only in drylands but also in the world regions where freshwater is abundant. Many regions around the world facing these problems as in the Middle East are facing water stress with water scarcity [2].

Wastewater reuse is an integral part of water demand management, promoting the protection of high-quality fresh water and reducing both environmental pollution and overall supply costs [5].
To manage health and environmental hazards, the world health organization (WHO) provides guidelines for the safe reuse of wastewater in agriculture, including treatment and non-treatment options, which take into the entire chain-from cultivation to consumption water [6].

Wastewater has become one of the valuable resources for irrigation water. Suitable irrigation methods can effectively negative environmental effects. Depending on the irrigation method used, flood irrigation can seriously pollute an entire field. For spray irrigation, wastewater at least meets secondary treatment standards of disinfection to reduce arousal and health risks. Drip irrigation, constantly the most environmentally friendly approach. Underground drip irrigation can mitigate environmental risks and can decrease nitrate leaching rates reached 70% [7].

Salinity, pathogens, Nutrients, Suspended solids, COD, BOD, and heavy metals, are the main parameters considerably important for the quality of the irrigation water.

The use of treated wastewater in agriculture contributes to saving water and expanding agricultural areas to produce various crops and also to reducing costs related to production, importation and use of fertilizers due to the presence of the necessary elements for plants in these waters [8].

There is competition for freshwater between domestic uses and agriculture, while the environment is exposed to pollution by discharging large quantities of untreated wastewater into deserted lands. In these areas, most of the time, farmers have no choice but to use untreated wastewater for agriculture and horticulture. Under these conditions, the safe use of treated wastewater enables nutrients to be recycled for productive purposes, thereby reducing wastewater pouring into rivers and the sea and providing other freshwater resources for more vital uses [9].

Many researchers studied the evaluation and assessment of WWTPs on the Middle Euphrates to study the impact of these impact plants on the environment [10-12].

The lack of study using treated wastewater for irrigation purposes in the literature gives a valuable opportunity. Therefore, the aim of the present research is to study the ability for using the treated wastewater that effluent from WWTPs at Middle Euphrates provinces (Babylon, Karbala, Diwaniya, and Najaf) to irrigate different crops through testing samples of this water and compared the results of a tested physical, chemical, and heavy metals with the available standards related to the irrigation purposes.

2. Methodology and data
The methodology of this research is represented by collecting samples of wastewater from a suggested study area of WWTPs and then tested to get raw data that necessary for the analysis and getting the results.

2.1. Case study
The case study could be represented as the study area in which is selected to include WWTPs in the Middle Euphrates provinces; namely; Babylon, Najaf, Karbala, and Diwaniya; as indicated in figure 1. Wastewater treatment can be divided into two main steps: the waterline and the sludge line. The water line is structured into the pre-treatment, primary treatment, secondary treatment (biologic reactor and secondary reactor) and tertiary treatment (sand filtration, UV (ultraviolet) treatment and chlorination) [13]. Generally, all WWTP in these provinces consists of units as shown in figure 2 [14-18].

Usually, the assessment of the impact on the environment by any WWTP is achieved through test samples of wastewater after a treatment process through the season of the year [5]. Therefore, in the present study, several samples of wastewater after treatment had been taken from each WWTP through the four seasons; Spring, Summer, Autumn, and Winter. The tests include the following parameters: The physical properties tests represented by Electrical Conductivity (EC), Total Dissolved Solid (TDS), and Total Suspended Solids (TSS); chemical properties such as pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Chloride (Cl⁻), Phosphate (PO₄³⁻), and Sulfate (SO₄²⁻), Nitrate (NO₃⁻), Nitrite (NO₂⁻), Ammonia (NH₄); some heavy metals such as Lead (Pb), and Cadmium (Cd).
Figure 1. Location of WWTPs in the Middle Euphrates provinces of Iraq (Babylon, Karbala, Najaf, Diwaniya) as a case study.

Figure 2. Flow chart of WWTP in the Middle Euphrates of Iraq (Babylon, Karbala, Najaf, Diwaniya)
1: screens; 2: pump; 3: chamber; 4: storage tank; 5: flume; 6: chamber; 7: aeration tank; 8: distribution chamber; 9: settling tank; 10: collection chamber; 11: flume; 12: chlorination unit; 13: outlet; 14: sludge pump; 15: sludge collection tanks; 16: drying bed.

2.2. Tests
The tests are conducted through sampling treated wastewater from WWTPs and collected in the specific bottles; as three samples per week (i.e. 12 samples per month and 48 samples per season). The total samples are 192 per year in each of WWTP and 768 in all WWTPs of Middle Euphrates through the present study. The methods, materials, and facilities of the tests are conducted directly by the staff of WWTPs laborites; but some tests are conducted indirectly by the staff of the laboratories of the Ministry of Science and Technology due to available materials and facilities on WWTPs laborites.
2.3. Characteristics of Wastewater for irrigation purposes

Reuse of treated wastewater helps to alleviate the pressure on traditional water resources by using part of treated wastewater for irrigation and industry. However, the use of treated wastewater for irrigation is one of the methods which are currently widely used [6]. Irrigation with treated wastewater has potential for both positive and negative environmental impacts [19] and with careful planning and management, the use of treated wastewater in agriculture can be beneficial to the environment.

Untreated water (raw wastewater) causes health, human and animal risks if it is used in agricultural irrigation, and many communicable diseases such as cholera and typhoid appeared, for example in Marrakesh (Morocco), Syria and Yemen [20].

Studies carried out in Iraq have shown that treated sewage water can be used to irrigate fodder crops and some vegetables. In general, in Baghdad, treated effluent directed to the Diyala River from treatment plants goes to Tigris River through additional natural flow purification processes before it is abstracted for irrigation downstream [21].

Several standards and organizations which interesting in reusing wastewater put the limited and required parameters that should be taken into consideration such as WHO, EPA, National Academy of Science, Iraqi standard Specifications, Syrian standard specifications [5, 22]. However; the tests of some of these parameters are not available in the laboratories.

3. Results and discussions

The results of the tested treated wastewater sampled from WWTPs in the Middle Euphrates provinces during the seasons of the 2019 year will be presented in this section. The parameters that affect the ability to use this wastewater for irrigation purposes are compared with standards.

3.1. Physical parameters

The results of the tested physical properties are given in table 1. It is the most important parameter in determining the suitability of water for irrigation use and generally measured as the electrical conductivity (EC) of water or the concentration of total dissolved solids (TDS) [5]. Electrical conductivity (EC) is a good measure of salinity and it is the most significant issue in determining the suitability of water for irrigation. The most important negative effect on the environment caused by irrigation with wastewater is the increase in soil salinity, which can decrease productivity in the long term [19]. However, irrigation water with conductivity in the range of 750–2250 μS/cm is permissible for irrigation and widely used [23, 24].

The treated wastewater could be used for irrigation at Najaf province in the spring and Autumn seasons; because the concentration of EC parameter in the treated wastewater is within standards; while the other provinces; it is out of the standards as shown in figure 3. The water with very high salinity is not suitable for irrigation except for crops with high salt tolerance; such as Field crops (Barley, Wheat, Rice, Broad Bean, Corn, Cotton, and Cowpea, Safflower, Flax, and Groundnut), Vegetable crops (Beet, Broccoli, Cabbage, and Cantaloupe), Forage crops (Alfalfa, Barley hay, Bermudagrass, Orchardgrass, and Tall fescue), and Fruit crops (Almond, Apple Pear, Pomegranate, and Grape); where the soils need continuous drainage and great care [25].

The treated wastewater could be used for irrigation at Najaf province in the spring and Autumn seasons; because the concentration of EC parameter in the treated wastewater is within standards; while the other provinces; it is out of the standards as shown in figure 3. The water with very high salinity is not suitable for irrigation except for crops with high salt tolerance; such as Field crops (Barley, Wheat, Rice, Broad Bean, Corn, Cotton, and Cowpea, Safflower, Flax, and Groundnut), Vegetable crops (Beet, Broccoli, Cabbage, and Cantaloupe), Forage crops (Alfalfa, Barley hay, Bermudagrass, Orchardgrass, and Tall fescue), and Fruit crops (Almond, Apple Pear, Pomegranate, and Grape); where the soils need continuous drainage and great care [25].
Table 1. Physical parameters of the treated wastewater from the WWTPs of Middle Euphrates provinces.

| Province | Tests | Standards for Irrigation Purposes |
|----------|-------|-----------------------------------|
|          |       | 2000 | 2000 | 45 | EPA 1992, FAO 2000 Standards [22] |
|          |       | 750–2250 | μS/cm | 2500 | 40 | Iraq fact, Issue 4260 [23] |
|          |       | 2250 | 2500 | 60 | Iraqi Specifications from WWTPs [24] |

| Seasons | E.C. | TDS | TSS | Notes |
|---------|------|-----|-----|-------|
| Babylon |      |     |     |       |
| Spring  | 3750 | 2583 | 61  | Closed to all standards except E.C. |
| Summer  | 3750 | 2625 | 76  | Un-closed to all standards |
| Autumn  | 3400 | 2430 | 41  | Closed to all standards except E.C. |
| Winter  | 3411 | 2439 | 188 | Closed to all standards except E.C. and TSS. |
| Karbala |      |     |     |       |
| Spring  | 3230 | 2424 | 93  | Closed to all standards except E.C. and TSS. |
| Summer  | 3425 | 2628 | 112 | Un-closed to all standards |
| Autumn  | 2867 | 2393 | 84  | Closed to all standards except E.C. and TSS. |
| Winter  | 3145 | 2467 | 121 | Closed to all standards except E.C. and TSS. |
| Diwaniya|      |     |     |       |
| Spring  | 3628 | 1701 | 131 | Closed to all standards except E.C. and TSS. |
| Summer  | 3740 | 1572 | 56  | Closed to all standards except E.C. |
| Autumn  | 3134 | 1487 | 128 | Closed to all standards except E.C. and TSS. |
| Winter  | 3483 | 1713 | 217 | Closed to all standards except E.C. and TSS. |
| Najaf   |      |     |     |       |
| Spring  | 2052 | 2031 | 94  | Closed to all standards except TSS. |
| Summer  | 2740 | 2138 | 73  | Closed to all standards except E.C. and TSS. |
| Autumn  | 2258 | 2019 | 66  | Closed to all standards. |
| Winter  | 2638 | 2257 | 150 | Closed to all standards except E.C. and TSS. |

Figure 3. The concentration of EC on treated wastewater from WWTPs of Middle Euphrates.

The concentration of TDS permissible limit of the treated wastewater is found in a different season of the WWTPs. These indications lead to the ability for using this water to irrigate crops at all seasons except Babylon on spring and summer seasons and Karbala on summer season; as shown in figure 4. This water is suitable to irrigate cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains according to EPA1992 and FAO2000 standards; where the limit ranged as (1500-2000) mg/l [22] at Diwaniya province at all seasons and at Najaf province on Autumn season. On other hand, it is suitable to irrigate cooked vegetables, parks and civic roadsides,
sports stadiums; Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial Crops and Forest trees; according to the Syrian Standards specification No.2752, 2008; where the limit is 1500mg/l [22].

As was referred to in Table 1, the permissible concentration of TSS on treated wastewater from WWTPs is ranged as (40–60) mg/l [Iraq fact 2012, Iraqi Standards from WWTPs [23, 24]. Therefore, the treated wastewater has the ability for irrigation crops at the Middle Euphrates in the Spring and Autumn seasons at Babylon province, Spring, Autumn and Winter seasons at Karbala province, and all seasons at both Diwaniya and Najaf provinces; as shown in Figure 5. On other hand, according to the Syrian Standards specification No.2752, 2008; this treated water is suitable to irrigate cooked vegetables, parks and civic roadsides, and sports stadiums; where the limit is 50 mg/l; and Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial crops and Forest trees; where the limit is 150mg/l [22].

It is clear that irrigation using saline water can add a salt concentration to the soils and a problem may be occurring due to the increase in concentration that is harmful to the crop or landscape. Therefore, it is necessary to control the salinity when using treated wastewater for irrigation.

3.2. Chemical parameters

The concentrations of chemical parameters in treated WWTPs of Middle Euphrates provinces are different in all seasons and in the provinces themselves as given in table 2. In fact, this is due to the
different control of the laborers themselves on the treatment process of each WWTP that shown in figure 2; previously; and the variety of climate conditions in each plant especially the temperature. Generally; the concentrations of pH on the treated water from all WWTPs in Middle Euphrates provinces and on all seasons are within standards as shown in figure 6. If pH is less than 7, the solution contains more H+ than OH- and is acidic; if pH is greater than 7, the solution is basic [26]. Thus, the treated wastewater is alkaline in nature and suitable for irrigation because macronutrients are more likely available in soil having high pH value and micronutrients are redundant in the acidic environment [27]; especially of potentially eaten fresh vegetables and fruits within two weeks of irrigation and cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, where the values of pH range as (6-9) [22].

The concentrations of COD and BOD in treated WWTPs of Middle Euphrates are within standards for both Babylon and Najaf provinces in all seasons; while of Karbala province, the concentration of BOD is within standards in all seasons; but the concentration of COD is out of standards in both spring and summer seasons. In Diwaniya, BOD is out of standards in all seasons; while COD is within standards on Autumn season only; as shown in figures 7 and 8.

**Table 2.** Chemical parameters of the treated wastewater from the WWTPs of Middle Euphrates provinces.

| Province | Tests          | Seasons | Standards for Irrigation Purposes |
|----------|----------------|---------|-----------------------------------|
|          | pH | COD | BOD | Cl | SO\[^2\]- | PO\[^2\]- | NO\[^3\]- | NO\[^2\]-N | NH\[^3\] | Notes                                                                 |
| Babylon  |    |     |     |    |         |         |         |           |         |                                                                 |
| Spring   | 7.9 | 14 | 22.76 | 433.2 | 894.5 | 2.08 | 35.1 | 0.35 | 19.33 | Closed to all standards except Cl and SO\[^2\]-.                   |
| Summer   | 7.41 | 84 | 20.23 | 419.1 | 794.8 | 1.91 | 8.91 | 0.41 | 14.83 | Closed to all standards except Cl and SO\[^2\]-.                   |
| Autumn   | 7.4 | 7 | 22.47 | 345.2 | 872.5 | 1.33 | 28.2 | 0.40 | 23.50 | Closed to all standards except SO\[^2\]-.                           |
| Winter   | 7.15 | 13.7 | 34.13 | 453.6 | 873.3 | 2.82 | 8.83 | 0.37 | 19.15 | Closed to all standards except Cl and SO\[^2\]-.                   |
| Karbala  |    |     |     |    |         |         |         |           |         |                                                                 |
| Spring   | 7.45 | 207 | 12.5 | 337 | 1138 | 2 | 75 | 0.55 | 7.5 | Closed to all standards except COD, SO\[^2\]- and NO\[^3\]-N.       |
| Summer   | 7.4 | 217 | 22 | 312.5 | 814.75 | 5 | 28.75 | 1.025 | 8.67 | Closed to all standards except COD, SO\[^2\]- and NO\[^3\]-N.       |
| Autumn   | 7.4 | 62.34 | 22.25 | 315 | 1383 | 5 | 32.83 | 0.525 | 7.96 | Closed to all standards except SO\[^2\]-.                           |
| Winter   | 7.4 | 87.58 | 5 | 399 | 1299 | 2 | 60 | 0.4 | 11.2 | Closed to all standards except Cl, SO\[^2\]- and NO\[^3\]-N.       |
| Diwaniya |    |     |     |    |         |         |         |           |         |                                                                 |
| Spring   | 8 | 215 | 103.32 | 351 | 636.33 | 4.26 | 34.63 | 0.006 | 26.64 | Closed to all standards except COD, BOD and SO\[^2\]-.               |
| Summer   | 7.76 | 194.5 | 75.33 | 319.65 | 1145.5 | 2.46 | 18.25 | 0.0315 | 23.78 | Closed to all standards except COD, BOD and SO\[^2\]-.               |
| Autumn   | 7.1 | 86 | 74.21 | 309 | 527 | 2.17 | 12.25 | 0 | 24.17 | Closed to all standards except BOD.                                 |
| Winter   | 8 | 253 | 183.5 | 364 | 573 | 2.56 | 18.65 | 0.005 | 31.63 | Closed to all standards except COD, BOD, Cl and SO\[^2\]-.           |
| Najaf    |    |     |     |    |         |         |         |           |         |                                                                 |
| Spring   | 7.82 | 34.75 | 17 | 458.75 | 1025 | 16.25 | 36.25 | 0.57 | 8.65 | Closed to all standards except Cl and SO\[^2\]-.                   |
| Summer   | 7.9 | 43.16 | 16.08 | 331 | 846.75 | 21.75 | 37 | 0.57 | 7.25 | Closed to all standards except SO\[^2\]-.                           |
| Autumn   | 7.66 | 70 | 17.5 | 333.33 | 976.66 | 2.83 | 50 | 0.58 | 4.83 | Closed to all standards except Cl and SO\[^2\]-.                   |
| Winter   | 7.7 | 29 | 15 | 478 | 926 | 4 | 35 | 0.6 | 7.2 | Closed to all standards except Cl and SO\[^2\]-.                   |
On other hand, the concentrations of BOD give the ability for using these treated wastewaters to irrigate potentially eaten fresh vegetables and fruits within two weeks of irrigation in Karbala province at spring and winter seasons and in Najaf province at Winter season only; where a limit is 15 mg/l [22]; while it is suitable to irrigate cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains in Najaf province in all seasons; but in Babylon province in Sumer season only, and in Karbala province in both Spring and Winter seasons. While for COD; the treated wastewater has the ability to irrigate potentially eaten fresh vegetables and fruits within two
weeks of irrigation at Babylon and Najaf in all seasons, Karbala at Autumn and winter seasons, and Diwaniya at summer; where a limit is 150 mg/l [22]; while it is suitable to irrigate cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains at all provinces and in all season except in Spring and Summer at Karbala; and in Spring and Winter at Diwaniya provinces; where the limit is up to 200 mg/l [22].

The concentrations of Cl parameter in the wastewater after treatment in the plants of Middle Euphrates provinces are within the standard in some seasons and out off in others. This concentration is within Iraq fact, Issue 4260 standards at Babylon province in Autumn season only; and out of EPA 1992 and FAO 2000 standards in all seasons; but it is within Iraqi Specifications from WWTPs. In Karbala and Diwaniya provinces, the concentration of Cl parameter is within Iraqi standards at Spring, Summer, and Autumn seasons for all seasons; and at all seasons for Iraqi Specifications from WWTPs; but it is out of EPA 1992 and FAO2000 standards in all seasons. On other hand, this concentration is within Iraq fact, Issue 4260 standards at Summer and Autumn seasons, out of Iraqi Specifications from WWTP standards at Spring and Winter seasons; but it is out of EPA 1992 and FAO2000 standards in all seasons also as shown in figure 9. It is worth mentioning that these concentrations of Cl permit to use of the treated wastewater from these provinces to irrigate cooked vegetables, parks, civic roadsides, sports stadiums, Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial crops and Forest trees; where the maximum permissible limits are 350mg/l; according to the Syrian Standards Specification No.2752, 2008 [22].

![Figure 9](image_url)

**Figure 9.** The concentration of Cl on treated wastewater from WWTPs of Middle Euphrates.

Sulfate (SO\(_4^{2-}\)) plays an important parameter for irrigation crops because it is a source of salts in the water when it is excessed the standards [25]. However, the concentration of SO\(_4^{2-}\) in the treated wastewater from the WWTPs in the Middle Euphrates is out of standard as given in table 2. This concentration is giving the ability to use this water for irrigation at Diwaniya province in the Autumn season only as shown in figure 10. On other hand, this water is not suitable to irrigate potentially eaten fresh vegetables and fruits within two weeks of irrigation and cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, where the values of SO\(_4^{2-}\) is 400mg/l [22]. These concentrations of SO\(_4^{2-}\) don’t permit to use of the treated wastewater from these provinces to irrigate cooked vegetables, parks, civic roadsides, sports stadiums, Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial Crops and Forest trees; where the maximum permissible limits are ranged as (350-500) mg/l; according to the Syrian Standards Specification No.2752, 2008 [22].
Figure 10. The concentration of \( \text{SO}_4^{2-} \) on treated wastewater from WWTPs of Middle Euphrates.

The concentration of Phosphate (\( \text{PO}_4^{2-} \)) is within standards; as shown in figure 11, and gives an indication of the ability for using irrigation crops at Middle Euphrates in all seasons and suitable to irrigate potentially eaten fresh vegetables and fruits within two weeks of irrigation and cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, where the values of \( \text{PO}_4^{2-} \) is 30mg/l [22]. On other hand, this concentration permits to use of this treated wastewater to irrigate cooked vegetables, parks and civic road sides, sports stadiums; where the maximum permissible limits are 3mg/l; while it is permissible for using to irrigate Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage Crops, Industrial crops and Forest trees; where the maximum permissible limits are 20mg/l according to Syrian standards No.2752, 2008[22].

Both Nitrite (\( \text{NO}_2^- \)) and Nitrate (\( \text{NO}_3^- \)) are important nutrients for plants, but they are toxic to fish and humans at high concentrations [26]. The concentration of \( \text{NO}_3^- \) in the treated wastewater of Middle Euphrates gives the ability to use in irrigation of potentially eaten fresh vegetables and fruits within two weeks of irrigation and cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains for all seasons; except at Karbala province in Spring and Winter Seasons; where the standards are 50mg/l [22] as shown in figure12. Moreover; this concentration of \( \text{NO}_3^- \) gives the ability to use this treated wastewater to irrigate cooked vegetables, parks and civic road sides, sports stadiums; where the maximum permissible limits are 20mg/l; while it is also permissible for using to irrigate Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage Crops, Industrial crops and Forest trees; where the maximum permissible limits are 25mg/l; according to the Syrian Standards Specification No.2752, 2008 [22].

Figure11. The concentration of \( \text{PO}_4^{2-} \) on treated wastewater from WWTPs of Middle Euphrates.
The concentration of NO$_2$‒N is closer to the standards which should be zero value as given in table 2; and the treated wastewater from the WWTPs of the Middle Euphrates has the ability for using as irrigation water for crops, especially at Diwaniya province; where the concentration of NO$_2$‒N is closer to (0 mg/l) at all seasons; while at Karbala province, this concentration is somewhat far from zero value at Summer season; as shown in Figure13.

Ammonia (NH$_3$) toxicity increases with pH and temperature [26], and should not exceed 10mg/l at best; according to Iraqi standards of WWTPs [24]; as denoted in table 2. However, in the present study; the concentration of NH$_3$ at Karbala province is within standards in all season except Winter season and at Najaf province in all season; while the other provinces (i.e. Babylon and Diwaniya) is out of standards; as shown in figure 14. On other hand, according to the Syrian Standards Specification No.2752, 2008 [22], these concentrations of NH$_3$ don’t permit to use of the treated wastewater from these provinces to irrigate cooked vegetables, parks and civic roadsides, sports stadiums; where the maximum permissible limits are 3mg/l; while it is also not permissible for using to irrigate Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial crops and Forest trees; where the maximum permissible limits is 5mg/l; but it is suitable to irrigate cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, where the limit is up to 10mg/l [22].
Figure 14. The concentration of NH$_3$ on treated wastewater from WWTPs of Middle Euphrates.

3.3. Heavy metals

Heavy metals are not specifically defined, but they are generally elements that possess physical properties such as transition metals, some metalloids, lanthanides, actinides, their density is more than 59 cm$^3$, as they are called toxic metals [28]. However, in the present study, both Cadmium and Lead are within the EPA,1999, FAO,2000, Syrian standard specification No.2752, 2008, National Academy of Sciences, 1973, US Academy of Sciences,1972 standards [22, 24]; as given in table 3.

Table 3. Heavy metals (Pb and Cd) results of treated wastewater from WWTPs of Middle Euphrates.

| Province | Tests | Standards for Irrigation Purposes | Pb mg/l | Cd mg/l | Note |
|----------|-------|----------------------------------|---------|---------|------|
| Babylon  | Spring| 0.075 0.05 EPA 1992, FAO 2000 Standards[22] | 3.8 0.04 | | Closed to all standards at all seasons; especially at Winter and except EPA 1992 and FAO 2000 Standards. |
| Babylon  | Summer| 2.9 0.045 | | | |
| Babylon  | Autumn| 3.27 0.04 | | | |
| Babylon  | Winter| 2.83 0.04 | | | |
| Karbala  | Spring| 3.0 0.03 | | | Closed to all standards at all seasons; especially at Autumn and except EPA 1992 and FAO 2000 Standards. |
| Karbala  | Summer| 2.98 0.039 | | | |
| Karbala  | Autumn| 2.94 0.04 | | | |
| Karbala  | Winter| 3.16 0.04 | | | |
| Diwaniya | Spring| 2.98 0.04 | | | Closed to all standards at all seasons; especially at Winter and except EPA 1992 and FAO 2000 Standards. |
| Diwaniya | Summer| 3.05 0.04 | | | |
| Diwaniya | Autumn| 3.03 0.04 | | | |
| Diwaniya | Winter| 3.0 0.04 | | | |
| Najaf    | Spring| 3.10 0.041 | | | Closed to all standards at all seasons; especially at Winter and except EPA 1992 and FAO 2000 Standards. |
| Najaf    | Summer| 3.04 0.038 | | | |
| Najaf    | Autumn| 3.04 0.039 | | | |
| Najaf    | Winter| 2.81 0.040 | | | |
This treated wastewater is suitable to irrigate some corps such as Legumes, Bean, Beetroot, and Turnip [22] in all seasons of treatments, especially in winter at Babylon, Diwaniya, and Najaf; while in Autumn at Karbala; as shown in Figures 15 and 16. It's worth noting that Cd is toxic to legumes, beets and turnip in low concentrations maybe reach to (0.1mg/l) of food crops; where low limits are recommended due to the possibility of accumulation in plants and soil in concentrations that may harm humans. On other hand; Pb can inhibit cell growth in high concentrations.

![Figure 15. The concentration of Pb on treated wastewater of Middle Euphrates.](image)

![Figure 16. The concentration of Cd on treated wastewater of Middle Euphrates.](image)

3.4. **SWOT analysis**

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats; and so, a SWOT Analysis is a technique for assessing these four aspects in many fields of human activities [29]. According to the aforementioned results of the present study, a SWOT analysis is adapted to assess the ability to use the treated wastewater from WWTPs of the middle Euphrates provinces for irrigation purposes as given in Table 4.
**Table 4. SWOT analysis of the treated wastewater from WWTPs of Middle Euphrates.**

| Strengths | Weakness |
|-----------|----------|
| 1 Preserving water reserves, as using it in agriculture or any other uses instead of potable water leads to the provision of this water and the expansion of agricultural areas to produce a variety of crops. | 1 There are health risks when exposed to insufficiently treated wastewater due to the presence of different types of viruses, bacteria and others, in addition to high concentrations of chemicals that are not removed in the different treatment stages, which may cause damage to plants. |
| 2 Reducing costs related to the production, importation and use of fertilizers due to the presence of essential elements for plants in these waters. | 2 If it is used to feed groundwater and is not treated properly, it can contaminate that water and it may cause clogging of the irrigation networks when it is used. |
| 3 It recharges the groundwater, avoiding the degradation and salinization of freshwater resources. | 3 The tertiary treated water cannot be stored. |
| 4 Provides an easily accessible source of water for the economic, industrial and agricultural sectors, and promotes economic development and food production. | 4 The entry of chemicals into sensitive ecosystems (plants, soil, water). |

| Opportunities | Threats |
|---------------|---------|
| 1 The role of sanitation in sustainable development and promotion and development of water resource management through the reuse of treated water. | 1 The general public opinion is that recycled water is not accepted for irrigation, being “waste water”. |
| 2 Set a budget for applied research for wastewater treatment and reuse in agriculture. | 2 The reuse of treated wastewater may cause livestock diseases if irrigation is mismanaged. |
| 3 Providing advanced modern purification for wastewater treatment (to suit its use in unrestricted agriculture), desalination of salt water and other unconventional water, and provision of devices for conducting various tests. | 3 Not to conduct awareness campaigns and warn consumers to ensure public safety, as well as warn workers in the field to apply public health rules. |

4. Conclusions

It is concluded from the present study the following:

1- It has been observed that the Autumn season is the best between all seasons and for all provinces of the Middle Euphrates in treating wastewater and using it for irrigation purposes.

2- The crops that suitable to be irrigated by the treated wastewater from the WWTPs of Middle Euphrates provinces are cooked vegetables and fruits if not done water it within two weeks of harvesting it; such as Fodder, Crops, Grains, parks and civic roadsides, sports stadiums; Fruit trees, Sides of external roads, Green landscapes, Cereals and Forage crops, Industrial Crops and Forest Trees.

3- The treated wastewater from the WWTPs of Middle Euphrates provinces is suitable for irrigation crops with high salt tolerance; such as Field crops (Barley, Wheat, Rice, Broad Bean, Corn, Cotton, and Cowpea, Safflower, Flax, and Groundnut), Vegetable crops (Beet, Broccoli, Cabbage, and Cantaloupe), Forage crops (Alfalfa, Barley hay, Bermudagrass, Orchardgrass, and Tall fescue), and Fruit crops (Almond, Apple Pear, Pomegranate, and Grape); where the soils need continuous drainage and great care.
4- The concentrations of EC, TTS, TDS, COD, BOD, NH3, Pb, and Cd of the treated wastewater are more closed with standards at WWTP of Najaf province than others at all seasons; while the concentrations of pH, Cl, and PO4-2 of the treated wastewater are more closed with standards at WWTP of Karbala province than others at all seasons. The concentration of NO3-N of the treated wastewater is more closed to standards at WWTP of Babylon province than others at all seasons. Instead of that, NO2-N at WWTP of Diwaniya province at all seasons. While it is found that the concentration of SO4-2 is within standards at WWTP of Diwaniya province during the Autumn season only.

5- The minimum average exceeded the standards for EC, TDS, and TSS concentrations of all seasons are 7.74%, 0.77%, and 52.5%; respectively; while for COD, BOD, SO4-2, and NH4 are 43.48%, 172.72%, 44.09%, and 92.02%; respectively

6- A SWOT analysis refers to Strengths as preserving water reserves, reducing costs, recharging groundwater, and promotes economic development and food production; Weakness as health risks, contamination of groundwater and may cause clogging of the irrigation networks, tertiary treated water cannot be stored, and entry of chemicals into sensitive ecosystems (plants, soil, water); Opportunities as sustainable development of water resource management, support a budget for applied research for wastewater treatment and reuse in agriculture, and providing advanced modern purification for wastewater treatment; Threats as general public opinion, livestock diseases, and not to conduct awareness to apply public health rules.

7- Conducting biological tests on treated wastewater to study its effect on the farmers who perform the irrigation process and the people close to the area.

8- Conducting new treatments on wastewater for the purpose of using it to irrigate other types of plants.

References
[1] FAO2017 Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany (Rome, Italia).
[2] Ungureanu N, Vladut V, Dinca M, and Zabava B-S 2017 7th Int. Conf. on Thermal Equipment, Renewable Energy and Rural Development (TE-RE-RD) (Drobeta Turnu Severin, Romania).
[3] FAO 2009 Irrigation in the Middle East Region in Figures- AQUASTAT Survey-2008 FAO Water Reports (Rome, Italy) pp233-49.
[4] Sadik A K and Barghouti S 1994 The water problems of the Arab world: Management of scarce water resources ed In P. Rogers and P. Lydon (Massachusetts, USA: Harvard University Press) pp 4-37.
[5] Shakir E, Zahraw Z, and Al-Obaidy A-H 2017 Egyptian Journal of Petroleum 26 (1) 95-102.
[6] DHWA 2002, Draft Guidelines for the Reuse of Greywater in Western Australia (Department of Health, Perth, Australia) p37.
[7] IWMI 2006 Water Policy Briefing: Recycling Realities: Managing health risks to make wastewater an asset Global water partnership GWP (GWP Advisory Center at IWMI) 17.
[8] Milad R A, Benzaghta M A, and Amaref M A 2019 J. Misurata University for Agricultural Sciences 1 196-208 (In Arabic).
[9] WHO1989 Guidelines for the Safe Use of Wastewater in Agriculture (WHO, Geneva).
[10] Alanbarni M A, Alazzawi H Q, Al-Ansari N A, and Knutsson S 2015 J. Civil Engineering and Architecture 9 749-55.
[11] Alanbarni M A, Al-Ansari N A, Altaee S A, and Knutsson S 2014 J. Earth Sciences and Geotechnical Engineering 4 55-68.
[12] Taha R A 2017 J. Babylon University, Engineering Science 25 892-909 (In Arabic).
[13] Amores M J, Meneses M, and Pasqualino J, Antón A, and Castells F 2013 J. Cleaner Production 43 84-92.
[14] Alanbarni M A, Alazzawi H Q, Al-Ansari N A, and Knutsson S 2015 J. of Civil Engineering and Architecture 9 749-55.
[15] Altaee S A-k and Alanbari M A 2015 J. Engineering Sciences Babylon University 2 1-9.
[16] Palmer S J 2004 Karbala wastewater treatment plant, process description Project No. 24910-602 1 (Bechtel International Systems, Inc.) (In Arabic).
[17] Salem D, Mohammad Q K, Hassan M H, Radhi A, and Ali F A 2020 Kufa J. of Chemistry Sciences 1 1-7 (In Arabic).
[18] Babylon Census Directorate 2013 Records Un-puplished data (Babylon Governorate, Iraq).
[19] WHO 2005 A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region (World Health Organization, Regional Office for the Eastern Mediterranean Regional, California Environmental Health Association).
[20] Baddor A R 2006 Sudan Engineering Society J. 52 69-74.
[21] Aziz A M, and Aws A 2012 Waste Water Production Treatment and use in Iraq Country report (Ministry of Water Resources, Republic of Iraq.).
[22] Al-Zaabi M M, Jizdan O, Majr A, Haboob M N, Darweesh H, Haqoon M. 2014 The use of treated wastewater in agricultural crops (General Authority for Scientific Agricultural Research, Ministry of Agriculture and Agrarian Reform, Syrian Arab Republic) (In Arabic).
[23] Iraqi Facts 2012 Wastewater Treatment Standards Used for Irrigation 3 (4260) Table 1.
[24] Iraqi specifications 2019 WWTPs Records Un-published data (Middle Euphrates Provinces, Iraq).
[25] Fipps G 2003 Irrigation Water Quality Standards and Salinity Management Strategies The Texas A&M System (College Station, Texas) B-1667 4-03.
[26] Rao P V 2002 Textbook of Environmental Engineering Prentice-Hall of India, Private Limited, (New Delhi).
[27] Poyen F B, Kundu P K, and Ghosh A K 2018 J. Inst. Eng. India Ser. A, (the Institution of Engineers), India.
[28] Duffus J H 2002 Heavy Metals—A Meaningless Term? Technical Report (Pure Appl. Chem., International Union of Pure and Applied Chemistry IUPAC) 74 (5):793–807.
[29] Akhobadze G N, 2018 IOP Conf. Series: Materials Science and Engineering IOP Publishing 451 1-5.

Acknowledgment
The authors are grateful for the assistance from WWTPs at Middle Euphrates for giving the information about the wastewater treatment issues. Moreover, the authors are grateful to the staff of the Ministry of Science and Technology Laboratory for facilitating the necessary laboratory tests.