Variation of Erbil Municipal Wastewater Characteristics Throughout 26 Years (1994-2020) with Possible Treatments and Reusing: A Review

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Abstract. This research aimed to study characteristics variation of Erbil municipal wastewater (EMWW) during 26 years (1994-2020), appropriate treatment using different methods, and suitability of the treated wastewater (WW) for disposal to the natural environment or using for irrigation purpose. Forty-seven WW quality parameters were studied. A number of EMWW characteristics such as five-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), ammonia nitrogen (NH₃-N), total suspended solids (TSS) were exceeded the WW discharge standards. Consequently, EMWW needs treatment process prior to disposal to the environment. Primary treatment units with lagoons or oxidation ditch or wetland were applied as first scenario for treatment of EMWW; While, using only lagoons or oxidation ditch or wetland directly was the second situation. EMWW normally regarded as weak/low to medium WW type and it is classified as good to injurious irrigation water kind. Commonly, time had not great effect on EMWW characteristics. Life style, climate, sewerage system (combined or separate systems), climate, and areas/zones had effect on the quality of the municipal WWS. Primary units plus wetland led to removal efficiency of 94.75 %, 93.07 %, 89.47 %, 96.72 %, and 57.68 % for BOD₅, COD, NH₃-N, TSS and PO₄, respectively. Treatment of EMWW using both primary units and wetland resulted in achieving effluents agreed with the standards for disposal of WW. Generally, treated EMWW can be used for cooked vegetables and irrigating green areas.

Keywords: Erbil; Lagoon; Oxidation ditch; Wastewater Characteristics; Wetland.

1. Introduction
Municipal wastewater (MWW) denotes to the domestic wastewater (WW) in addition to those discharged from commercial, institutional, and similar services. MWW includes of WW produced by residences, businesses such as restaurants and shopping centres, institutions such as schools, universities, hospitals, prisons, and rest homes, recreational facilities, storm water, infiltration and industries in a definite community (Al-Zboon and Radaideh, 2012). MWW is the most abundant kind of WW that located into the category of low-strength WWS, characterized by low organic strength and high particulate organic matter content (Sikosana et al., 2019).
Sewerage system in Erbil City, Kurdistan Region-Iraq covers both storm water and grey water. Commonly, black water from toiles are treated using cesspools and septic tank with cesspools (in some cases). Therefore, neither full combined and nor full separate sewerage systems are available in Erbil City. In the recently constructed cities and villages in Erbil City and due to the investment laws,
small scale WW treatment plant (WWTP) is compulsory for treatment of the produced WWs and in some areas it uses for irrigating green areas. Erbil MWW (EMWW) sometimes used for irrigation directly and in some cases it reaches to the Greater-Zab River water at Gwer area without treatment (Mustafa and Sabir, 2001; Amin and Aziz, 2005). To date, centralized WWTP is not available in Erbil City. Accordingly, treatment of EMWW is necessary for irrigation and prior disposal to the natural environment or water sources. In this work, two options were presented for treatment of EMWW. In the first option, EMWW is treated using primary treatment units plus aerated lagoons or oxidation ditch or wetland; while in the second scenario, EMWW is treated by lagoons, oxidation ditch or wetland. In literature, primary units, lagoons, oxidation ditch, and wetland were applied widely for treatment of MWWs (Asano and Tchobanoglous, 1987; USEPA, 2000; Teleman et al., 2004; Lian-Feng et al., 2011; Al-Zboon and Radaideh, 2012; Gikas and Tsihrintzis, 2014; Hadisoebroto et al., 2014; Metcalf and Eddy, 2014; INDITEX, 2015; Jasim, 2020).

Although, there are some published works on EMWW characteristics, impact, and treatment (Shekha, 1994; Aziz et al., 1998; Mustafa and Sabir, 2001; GDWR, 2001; Ali, 2002; Aziz, 2004; Amin and Aziz, 2005; Ganjo et al., 2006; Shekha, 2008; Bapeer, 2010; Shekha et al., 2010; Shekha, 2013; Amine and Shekha, 2016; Shekha et al., 2016; Aziz and Ali, 2017; Aziz and Ali, 2018). However, studying EMWW characteristics variation, treatment via different scenarios and reusing of treated water over a period of 26 years have not been published yet. Subsequently, the objectives of the current research were to study: 1) characteristics of EMWW during 26 years (1994-2020), 2) treatment of EMWW using different options, and 3) the suitability of reusing of treated EMWW for irrigation purposes.

2. Materials and Methods

2.1 EMWW (Erbil Municipal wastewater)

The main wastewater (WW) channel in Erbil City is located at the left side of Erbil-Mosul Main Road at Tooraq Q., Fig. 1. EMWW at Tooraq Q. commonly consists of WWs produces at residential areas, shops and super markets, restaurants, hotels and motels, car washing places, north industrial area, universities and schools, worship places, governmental and administration buildings, private sector houses and buildings, washings, infiltration, and losses of water supply system. Additionally, storm water is mixed with the MWWs during rainy seasons and it dilute the concentration of pollutants.

![Fig. 1. Erbil Municipal Wastewater Main Channel](image-url)
2.2 Data Collection and Analysis
Data from published works were collected. Forty-seven quality parameters for EMWW were collected, arranged, and compared with WW disposal standards. In the current study, EMWW characteristics data during 26 years (1994-2020) were collected and studied. First and last recognized published data on EMWW were published in 1994 and 2020 (Shekha, 1994; DEI, 2020); therefore, the period between 1994 and 2020 was selected. Data on pH, temperature, electrical conductivity (EC), total salts (T. salts), total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), turbidity, chloride, total acidity (T. acidity), total hardness (T. hardness), five day biochemical oxygen demand (BOD5), chemical oxygen demand (COD), ammonia (NH3-N), nitrite (NO2-N), nitrate (NO3-N), sulphate (SO4), dissolved oxygen (DO), phosphate (PO4), sodium percentage (Na%), sodium adsorption ratio (SAR %), total coliform, sodium (Na), calcium (Ca), magnesium (Mg), cadmium (Cd), copper (Cu), zinc (Zn), lead (Pb), total volatile solids (TVS), total non-volatile solids (TnVS), biodegradability ratio (BOD5/COD), color, manganese (Mn), total organic carbon (TOC), phenols, oil and grease, oxidation-reduction potential (ORP), salinity, total alkalinity (T. alkalinity), Alkalinity %, TVC bacteria, Phytoplankton density, total bacteria count, total bacteria cell, total fungi cells, and discharge for EMWW were collected, arranged and studied.

3. Results and Discussions
3.1 Characteristics of EMWW
Collected data were arranged into three parts (Tables 1 to 3). Additionally, range and WW discharge standards are shown in the tables as well. pH, temperature, chloride, NO3-N, and SO4 found within the allowable limit of disposal of WW. While, TSS, BOD5, COD, NH3-N, NO2-N, color, oil and grease, Mn, PO4, Mg, Cu, Zn, Pb, and phenols were surpassed the WW disposal standards (EPA, 2003; Iraqi Environmental Standards, 2011). Consequently, EMWW requires treatment processes so as to be fit with WW disposal standards and reusing. EMWW observed been as weak/low to medium WW type according to (Henze and Comeau (2008) and Metcalf and Eddy (2014) and this found agreeing with Sikosana et al. (2019). BOD5 values of 6.3 mg/L to 304 mg/L for EMWW are agree with published data by JSWA (2013). Lower COD values were reported in a number of South Korean WWTPs by Choi et al. (2017). Additionally, lower BOD5, COD, TSS, PO4, NO3-N, and NO2-N for two municipal WWTPs in Indonesia were reported (Wijaya and Soedjono, 2018). On the other hand, lower BOD5, COD, NO3-N, NO2-N, and turbidity values for MWW in there WWTPs in Malaysia were reported (Sabeen et al., 2018). Teleman et al. (2004) reported lower values of COD, BOD5, PO4, TSS, and turbidity for MWW in Germany WWTP. EMWW parameters normally agree with the MWW characteristics in developing countries (Sperling, 2007). Life style, season, sewerage system (combined or separate systems), climate, and areas/zones had effect on the quality of the MWW. Fluctuations were noticed in the EMWW quality; Commonly, time had not great effect on EMWW characteristics. Mustafa and Sabir (2001) reported that EMWW discharge was 0.85 m3/s. While, discharge for 2020 calculated as 5.56 m3/s (Metcalf and Eddy, 2014; GDWS, 2020). The discharge increase may be attributed to increase in population, losses in water supply, expansion of Erbil City and sewerage system, and extra storm water. Mixing of storm water and water supply bad using leaded to dilution of EMWW, especially in rainy seasons (Aziz; 2004). Biological problems are available in EMWW; accordingly, treatment and disinfection is necessary for EMWW. Nutrients (organic matter, nitrogen compounds, and phosphate) are present in EMWW, it is useful for agriculture and irrigation purpose. Heavy metals such as Cd, Cu, Zn, and Pb were reported in EMWW and exceeded the WW discharge standard limits, normally effects on the biological treatment processes and needs extra treatments (Aziz et al., 2011).
Table 1. Characteristics of Erbil MWW-Part 1

| References                  | Parameters                  |
|-----------------------------|-----------------------------|
| **pH**                      | **Temp. (°C)**              |
| **EC (μs/cm)**               | **T. Salts (mg/L)**         |
| **TS (mg/L)**                | **TSS (mg/L)**              |
| **TDS (mg/L)**               | **Turbidity (NTU)**         |
| **Chloride (mg/L)**          | **T. Acidity (mg/L)**       |
| **T. Hardness (mg/L)**       |                             |
| Shekha (1994)                | 6.8-8.4                     |
|                             | 10-23                       |
|                             | 430-946                     |
|                             | 441-972                     |
|                             | 6-128                       |
|                             | 30-101                      |
|                             | 0.18-5.62                   |
|                             | 207-432                     |
| **Aziz et al. (1998)**      | 6.75-7.6                    |
|                             | 531-574.9                   |
|                             | 340                         |
|                             | 4.97                        |
|                             | 20.4                        |
| **Mustafa and Sabir (2001)**| 7.4-8.85                    |
|                             | 13.5-18                     |
|                             | 284-873                     |
|                             | 13.5                        |
|                             | 43                          |
| **GDIWR (2001)**            |                             |
|                             | 6.5-8.06                    |
|                             | 296-756                     |
|                             | 20-225                      |
|                             | 0.4-1.62                    |
|                             | 120-292                     |
| **Ali (2002)**              |                             |
|                             | 6.82-8.2                    |
|                             | 491-835                     |
|                             | 314.2                       |
|                             | 0.41                        |
|                             | 1000                        |
|                             | 7.1-53.2                    |
| **Aziz (2004); Amin and Aziz (2005)** | 6.1- |
|                             | 1400-2300                   |
|                             | 996-1800                    |
| **Ganjo et al. (2006)**     | 6.1-6.6                     |
|                             | 149-165                     |
| **Shekha (2008)**           | 6.5-7.82                    |
|                             | 496-831                     |
| **Bapeer (2010)**           |                             |
|                             | 40-60                       |
| **Shekha et al. (2010)**    |                             |
|                             | 434.6                       |
|                             | 80.1                        |
|                             | 354.5                       |
| **Shekha (2013); Amine and Shekha (2016)** | 6.99- |
|                             | 486.1                       |
|                             | 236.8                       |
|                             | 0.86                        |
|                             | 2.68                        |
| **Shekha et al. (2016)**    |                             |
|                             | 7.0-7.5                     |
|                             | 455-825                     |
| **Aziz and Ali (2017)**     |                             |
|                             | 16.2-25.1                   |
|                             | 273-577                     |
|                             | 300-900                     |
|                             | 200-400                     |
|                             | 100-500                     |
|                             | 18.3                        |
|                             | 44.2                        |
|                             | 28-33.9                     |
|                             | 8                            |
| **Aziz and Ali (2018)**     |                             |
|                             | 6.78                        |
|                             | 582.6                       |
|                             | 372.9                       |
|                             | 10000                       |
|                             | 1800                        |
|                             | 820                         |
|                             | 19.7                        |
|                             | 30.5                        |
|                             | 40                          |
|                             | 194                         |
Table 2. Characteristics of Erbil MWW-Part 2

| References | Parameters | BOD₅ (mg/L) | COD (mg/L) | NH₃-N (mg/L) | NO₂-N (mg/L) | NO₃-N (mg/L) | SO₄ (mg/L) | DO (mg/L) | PO₄ (μg/L) | Na (%) | SAR (%) | Total coliform cell/100 ml X 10⁶ |
|------------|------------|-------------|------------|--------------|--------------|--------------|------------|------------|------------|--------|---------|------------------------------|
| Shekha (1994) | 145 | 0.04 - 0.49 | 0.00 - 0.08 | 0.01 - 10.4 | 0.0015 - 0.113 | 15.17 - 16.4 | 0.81 - 0.97 | 0.34 - 42.5 |
| Aziz et al. (1998) | 30.6-304 | 0.00 - 0.10 | 0.00 - 1.02 | 0.0016 - 0.0382 | 14 - 0.02 | 2 | 0.4 - 1.15 | 0.018 - 0.1004 | 4-180 |
| Mustafa and Sabir (2001) | 80-105 | | | | | | | 3.3 - 4 |
| Ali (2002) | 17.5-219 | 0.01 - 0.13 | 0.00 - 1.02 | | | | | | |
| Aziz (2004); Amin and Aziz (2005) | 13-110 | 20-188 | 7.6-22 | | | | | 6.1 - 38.0 | 0.19 - 1.96 |
| Ganjo et al. (2006) | | | | | | | | 69.8 - 73 | 14-16 | 200-380 |
| Shekha (2008) | 9.3-208 | 130-901 | 0.00 - 0.19 | 0.02 - 0.61 | 0.00 - 4.44 | 0.00 - 3.8 | 0.419 - 1.167 | 5.7-18 |
| Hama Saeed et al. (2010) | 110-170 | 132-195 | | | | | 0.0 | 160 |
| Parameter | Value | Range | Standards | References |
|-----------|-------|-------|-----------|------------|
| Na (mg/L) | 30.6-32.1 | 0.38-2.3 | 0.38-62 | Ganjo et al. (2006) |
|           | 0.38-2.3 | 0.38-62 | 0.38-62 | Shekha (2013), Amine and Shekha (2016) |
|           | 62 | 30.6-32.1 | 0.38-62 | DEI (2020) |
| Ca (mg/L) | 5.4-6.4 | 1.8-4.8 | 1.8-85 | Ganjo et al. (2006) |
|           | 1.8-4.8 | 1.8-85 | 1.8-85 | Shekha (2013), Amine and Shekha (2016) |
|           | 85 | 5.4-6.4 | 1.8-85 | DEI (2020) |
| Mg (mg/L) | 2.8-3.4 | 0.1-0.42 | 0.1-30.8 | 0.5* | Ganjo et al. (2006), Shekha (2013), Amine and Shekha (2016) |
|           | 0.1-0.42 | 0.1-30.8 | 0.1-30.8 | 0.5* | DEI (2020) |
|           | 30.8 | 2.8-3.4 | 0.1-30.8 | 0.5* | DEI (2020) |
| Cd (mg/L) | 0.46-73 | 0.46-73 | 0.01* | Shekha (2013), Amine and Shekha (2016) |
| Cu (mg/L) | 0-18.69 | 0-18.69 | 0.2* | Shekha (2013), Amine and Shekha (2016) |
| Zn (mg/L) | 0-76.92 | 0-76.92 | 0.2* | Shekha (2013), Amine and Shekha (2016) |
| Pb (mg/L) | 0-61.76 | 0-61.76 | 0.1* | Shekha (2013), Amine and Shekha (2016) |

*: Iraqi Environmental Standard (2011)  
**: Environmental Protection Regulations (EPA) (2003).

**NH₄-N (mg/L)**

Table 3. Characteristics of Erbil MWW-Part 3
3.2 Treatment of EMWW

As mentioned earlier, some EMWW parameters such as BOD5, COD, TSS etc. were exceeded the effluent standards. Therefore, EMWW requires treatment. COD values for EMWW were ranged between 12.2 mg/L to 901 mg/L, Table 2; Sikosana et al. (2019) reported that aerobic processes are most suitable for MWWs with COD values of less than 1000 mg/L. Biodegradability ratio for EMWW was close to and higher than 50%; this mean that biological processes are efficient (Aziz and Ali, 2017; 2018). Presence of toxic materials such as Cd, Cu, Zn, and Pb effects on the biological treatment processes. Consequently, further physical/chemical treatment technologies are required to remove/minimize the effect of toxic matters (Aziz et al., 2011; Metcalf and Eddy, 2014). For treatment of EMWW, two scenarios were proposed: 1) treatment using primary treatment units plus aerated lagoon or oxidation ditch or wetland methods, and 2) Using only aerated lagoon or oxidation

| Parameter                  | Value                      | Reference                  |
|----------------------------|----------------------------|----------------------------|
| TVS (mg/L)                 | 206.8                      | 100-300                    | Shekha et al. (2010) |
| TnVS (mg/L)                | 227.9                      | 100-600                    |
| BODs/COD                   | 0.487-0.830                | 0.487-0.830                | Aziz and Ali (2017) |
| Color (Pt.Co,)             | 186-379                    | 186-379                    | Nil*                 |
| Mn (mg/L)                  | 1.3-4.6                    | 1.3-4.6                    | 0.2*                 |
| TOC (mg/L)                 | 19-180                     | 19-180                     |
| Phenols (mg/L)             | 0.044-0.102                | 0.044-0.102                | 0.01-0.05*           |
| Oil & grease (mg/L)        | 0.04-1.05                  | 0.04-1.05                  | Nil*, 10 **          |
| ORP (Mv)                   | -107.4 (-33.2)             | -107.4 (-33.2)             |
| Salinity                   | 0.26-057                   | 0.26-057                   |
| T. Alkalinity (mg/L)       | 260-340                    | 157.3-326                  | Mustafa and Sabir (2001) |
|                           | 157.3-236                  | 206                        | Aziz and Ali (2017) |
|                           | 301                        | 8.93-40.15                 | Aziz and Ali (2018) |
|                           |                            | 17.67-19.11                | DEI (2020)           |
| Alkalinity (%)             | 8.93-40.15                 | 8.93-40.15                 | Shekha (1994)        |
|                           |                            | 17.67-19.11                | Aziz (2004), Amin and Aziz (2005) |
| TVC Bacteria (Cfu/mL)      | 110*10^5 - 176*10^5        | 110*10^5 - 176*10^5        | Aziz and Ali (2017) |
| Phytoplankton density      | 21787.5                    | 21787.5                    | Shkekha et al. (2010) |
| Total Bacteria Count (X10^8)| 0.002-0.74                | 0.002-0.74                 | Shekha (2008)        |
|                           | 0.047-77                   | 0.047-193                  | Shekha (1994)        |
|                           | 0.87-193                   |                             | Aziz et al. (1998)   |
| Total fungi cells/L X 10^4| 0.049-107.5                | 0.035-240                  | Shekha (1994)        |
|                           | 0.035-240                  |                             | Aziz et al. (1998)   |
| Discharge (m^3/s)          | 0.85-1.7                   | 0.85-5.56                  | Mustafa and Sabir (2001) |
|                           | 1.23-2.61                  |                             | GDIWR (2001)         |
|                           | 1.696-3.582                |                             | DEI (2013)           |
|                           | 5.56                       |                             | GDWS (2020)          |

*: Iraqi Environmental Standard (2011)
**: Environmental protection regulations (EPA) (2003).
ditch or wetland. For both scenarios, data for parameters BOD₅, COD, NH₃-N, TSS, and PO₄ reported in Tables 1 and 2 were used.

3.2.1 First Scenario
Normal WWTP consists of primary, secondary/biological, advanced treatment units. Primary treatment units involve screens and comminution, grit removal, flow equalization, primary sedimentation tank units (Metcalf and Eddy, 2014; Jasim 2020). Removal efficiencies for some pollutants such as BOD₅, COD, NH₃-N, TSS, and PO₄ in the primary treatment units are shown in Table 4 (Asano and Tchobanoglous, 1987; Teleman et al., 2004; Metcalf and Eddy, 2014). Effluent of primary unit become influent for the further treatment processes such as aerated lagoons, oxidation ditch and wetland. Removal efficiencies for BOD₅, COD, NH₃-N, TSS, and PO₄ using aerated lagoons, oxidation ditch and wetland are illustrated in Table 5. It can be noticed from the results shown in Table 5 that commonly wetland was efficient, when compared with the other methods. Treatment of EMWW using both primary units and wetland resulted in the effluent parameters of WW disposal to satisfy with the standards of EPA (2003) and Iraqi Environmental Standard (2011).

| Parameters | Removal Efficiency (%) ** | Influent concentration (mg/L) | Average effluent concentration (mg/L) |
|------------|---------------------------|-------------------------------|--------------------------------------|
| BOD₅       | 25-50 (37.5*)             | 6.3-304 (155.15*)             | 96.97                                |
| COD        | 19.29-36.36 (27.82*)      | 12.2-901 (456.6*)             | 329.57                               |
| NH₃-N      | 26.4                      | 0.004-11.4 (5.7*)             | 4.19                                 |
| TSS        | 50-70 (60*)               | 40-1800 (920*)                | 368                                  |
| PO₄        | 15                        | 0.0015-6.97 (3.45*)           | 2.93                                 |

* Average Value  
** Sources: Asano and Tchobanoglous (1987); Teleman et al., (2004); Metcalf and Eddy (2014)

| Parameters | Treatment Methods | Effluent Standard |
|------------|-------------------|-------------------|
| Avg. influent BOD (mg/L) | Aerated lagoon 96.97 | 40 mg/L * |
| BOD removal (%) | Oxidation ditch 70-95 (82.5*) | 90.8-92.3 (91.6*) |
| Effluent BOD (mg/L) | Wetland 9.21 | 8.15 |
| Avg. influent COD (mg/L) | 329.57 | 329.57 | 100 mg/L * |
### Table 6. Performance of aerated lagoons, oxidation ditch and wetland methods

| Parameters               | Treatment Methods                  | Effluent Standard |
|-------------------------|------------------------------------|-------------------|
| Avg. inlet BOD (mg/L)   | Aerated lagoon: 6.3-304 (155.15*)  | 40 mg/L *         |
|                         | Oxidation ditch: 6.3-304 (155.15*) |                   |
|                         | Wetland: 6.3-304 (155.15*)         |                   |
| Effluent BOD (mg/L)     | 27.15                              | 14.74             |
|                         | 13.03                              |                   |

* Average Value
** Removal efficiency for NH$_3$-N.
|                  | Average influent COD (mg/L) | COD removal (%) | Effluent COD (mg/L) | Average influent NH₃-N (mg/L) | NH₃-N removal (%) | Effluent NH₃-N (mg/L) | Average influent TSS (mg/L) | TSS removal (%) | Effluent TSS (mg/L) | Average inlet PO₄ (mg/L) | PO₄ Removal (%) | Effluent PO₄ (mg/L) | *References* |
|-----------------|-----------------------------|-----------------|---------------------|--------------------------------|-------------------|----------------------|-----------------------------|-----------------|----------------------|--------------------------|-----------------|-------------------|------------------|
|                 |                             |                 |                     |                                |                   |                      |                             |                 |                      |                           |                 |                   | INDITEX (2015)    |
|                 | 12.2-901 (456.6*)           | 62.5            | 171.22              | 0.004 -11.4 (5.7*)              | 90-94 (92°)       | 0.57                 | 40-1800 (920*)              | 60.3            | 365.24               | 0.0015-6.97 (3.45*)  | 15-50 (37.5*)    | 2.16              | USEPA (2000); Hadisoebroto et al. (2014) |
|                 | 12.2-901 (456.6*)           | 61.5            | 175.79              | 0.004 -11.4 (5.7*)              | 90-94 (92°)       | 0.46                 |                             |                 |                      | 0.0015-6.97 (3.45*)  | 80              | 0.69              | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
|                 | 12.2-901 (456.6*)           | 89-91.7 (90.4°) | 43.83               | 0.004 -11.4 (5.7*)              |                   |                      |                             |                 |                      |                           |                 |                   | Gikas and Tsihrintzis (2014) |
| Avg influent COD (mg/L) | 12.2-901 (456.6*)           | 12.2-901 (456.6*) | 12.2-901 (456.6*) | Avg influent COD (mg/L) | 12.2-901 (456.6*) | 12.2-901 (456.6*) | Avg influent COD (mg/L) | 12.2-901 (456.6*) | 12.2-901 (456.6*) | Avg influent COD (mg/L) | 12.2-901 (456.6*) | 12.2-901 (456.6*) | Avg influent COD (mg/L) |
| COD removal (%) | 62.5                        | 61.5            | 100 mg/L            | NH₃-N removal (%)               |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | USEPA (2000); Hadisoebroto et al. (2014) |
| Effluent COD (mg/L) | 171.22                      | 175.79          |                     | NH₃-N removal (%)               |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Avg influent NH₃-N (mg/L) | 0.004 -11.4 (5.7*)           | 90-94 (92°)     | 1 mg/L **           | NH₃-N removal (%)               |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | USEPA (2000); Hadisoebroto et al. (2014) |
| NH₃-N removal (%) | ≈ 90                        | 90-94 (92°)     |                     | NH₃-N removal (%)               |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Effluent NH₃-N (mg/L) | 0.57                        | 0.46            |                     | NH₃-N removal (%)               |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Avg influent TSS (mg/L) | 40-1800 (920*)              | 40-1800 (920*)  | 35 mg/L **          | Avg influent TSS (mg/L)         | 40-1800 (920*)    | 40-1800 (920*)          | Avg influent TSS (mg/L)     | 40-1800 (920*)    | 40-1800 (920*)          | Avg influent TSS (mg/L) | 40-1800 (920*)    | 40-1800 (920*)          | Avg influent TSS (mg/L)     |
| TSS removal (%) | 60.3                        | 69-97 (83°)     |                     | TSS removal (%)                 |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Effluent TSS (mg/L) | 365.24                      | 156.4           |                     | TSS removal (%)                 |                    |                      | TSS removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Avg inlet PO₄ (mg/L) | 0.0015-6.97 (3.45*)         | 0.0015-6.97 (3.45*) | 3 mg/L*          | Avg inlet PO₄ (mg/L)            | 0.0015-6.97 (3.45*) | 0.0015-6.97 (3.45*) | Avg inlet PO₄ (mg/L)        |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| PO₄ Removal (%) | 15-50 (37.5*)               | 80              |                     | PO₄ Removal (%)                 |                    |                      | PO₄ Removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |
| Effluent PO₄ (mg/L) | 2.16                        | 0.69            |                     | PO₄ Removal (%)                 |                    |                      | PO₄ Removal (%)             |                  |                      | PO₄ Removal (%)        |                  |                   | Hadisoebroto et al. (2014); Lian-Feng et al. (2011) |

* Average Value  
** Removal efficiency for NH₃-N.

3.3 Reusing

In the current study and based on the pH, EC, TDS, and SAR results, degree on restriction on use for EMWW is slight to moderate (WHO, 2006; Aziz et al., 2019). According to EC, T. salts, and Na% values, EMWW is good to injurious type (Amin and Aziz, 2005). In other classification and regarding to T. salts, Cl, SAR, and alkalinity % figures, EMWW is considered as intermediate for certain crops (Amin and Aziz, 2005). Researchers reported that WW in Erbil City was not safe for all kinds of irrigation and they reported that EMWW is suitable for irrigating green areas and for cooked vegetables (Amin and Aziz, 2005). Authors stated that WW in Erbil cannot be used for irrigation directly (Aziz et al., 2019). The achieved results are agreeing with the published data (Aziz and Amin, 2005; Aziz et al., 2019). Of course, treatment of EMWW using various systems decreases contaminants such as organic matter, suspended solids, nitrogen compounds etc. in the EMWW (INDITEX, 2015; USEPA, 2000; Hadisoebroto et al., 2014; Gikas and Tsihrintzis, 2014). As a result, treatment of WW enhancing the quality of EMWW for the irrigation purpose. Disinfection is necessary to overcome biological problems. Based on oil and grease, PO₄, Mg, and Ca values for EMWW, reclaimed EMWW can be used for irrigation (WHO, 2005). Regarding to BOD₅ and TSS
values of treaded EMWW, it can be used for irrigation of ornamental fruit trees and fodder crops (WHO, 2006). According to the values of BOD$_5$, COD, TSS, DO, pH, turbidity, and NO$_3$-N for treated EMWW, it can be used for cooked vegetables, parking areas, playgrounds and side of roads inside cities (WHO, 2006).

4. Conclusions
EMWW generally considered as weak/low to medium WW type, it needs treatment prior to disposal to the natural environment, and it is classified as good to injurious type irrigation water. Although, time did not have a big effect on EMWW characteristics; life style, season, combined or separate sewerage system, climate condition, and areas/zones had effected the quality of the MWWs. Treatment of EMWW using both primary units and wetland led to removal efficiency of 94.75 %, 93.07 %, 89.47 %, 96.72 %, and 57.68 % for BOD$_5$, COD, NH$_3$-N, TSS and PO$_4$, respectively which, resulted the disposed effluents characteristics to be within WW standards. Hence, treated EMWW can be used for cooked vegetables and watering green areas.

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