Characteristics and potential treatment technologies for different kinds of wastewaters

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1. INTRODUCTION

Commonly, the quality of wastewater is characterized by physical, chemical and biological analysis. The concentration of wastewaters depends on the source of the wastewater, function and the activity of particular industries. Wastewaters produced from houses, businesses, schools and public buildings have different characteristics compared to industrial wastewaters. Industrial wastewaters (for instance produced wastewaters from tannery industry, food processing industries, steel factory, dairy factory etc.) contain high amount of organic, inorganic constituents and heavy metals(Aziz and Ali, 2016. On the other hand, municipal landfill leachate (MLL) contains high concentrations of organic and inorganic materials, colour, ammonia-nitrogen, phenols etc. (Aziz et al., 2010; Aziz and Maulood, 2015). Industrial wastewaters and MLL regard as strength wastewaters (Aziz et al., 2010; Metcalf and Eddy, 2014). Typical characteristics of some industrial wastewaters are shown in Table 1.
Selection of appropriate treatment techniques for wastewater is related to its characteristics and the purpose for the treatment process (Aziz and Ali, 2016). Bustillo-Lecompte and Mehrvar, (2015) concluded that slaughterhouse wastewater (SWW) are commonly pre-treated by screening, settling, blood collection, and fat separation, followed by physicochemical treatment, including dissolved air flotation, coagulation/flocculation and/or secondary biological treatment. Tannery wastewater (TWW) contain high amount of pollutants with alkaline range; physical-chemical processes are most suitable for this kind of wastewater. Normally, municipal wastewater (MWW) from Erbil City-Iraq regards as weak waste water with biodegradability ratio of more than 50 (Amin and Aziz, 2005). Practically, primary with secondary treatment processes are useful for MWW and later it can be used for irrigation. Additionally, wetlands, sequencing batch reactor, oxidation ditch etc. are applicable for treatment of MWW and reusing for irrigation purpose (Surampalli et al., 1997; Aziz, 2011). According to the study done by Bashir et al. (2012), the electro-oxidation treatment for stabilized municipal landfill leachate (MLL) can result in removing of a considerable amount of non-biodegradable matters (COD), color and ammonia-nitrogen. The electro-oxidation is a powerful technology, mainly for low BOD$_5$/COD or high toxic landfill leachate which is hard to be treated biologically). In literature, different treatment methods such as coagulation-flocculation, dissolved air flotation, SBR, ion exchange, adsorption, filtration etc. were applied for treatment of MLL (Bahsir, 2010, Aziz 2011; Mojiri et al., 2014).In contrast, dairy wastewater (DWW) which characterized by high organic matter content and recommended by many researchers to be treated biologically (Dawood et al., 2011; Deshannavar et al., 2012; Lateef et al., 2013; Shahriari and Shokouhi, 2015). Ali (2017) conducted numerous laboratory experiments for treatment of DWW using activated carbon added to trickling filters; natural rock, disposed plastic caps, and useless PVC pipes with different sizes and depths were used as trickling filter media (Ali, 2017).

As known that the effluents of the industries contain huge amounts of both inorganic and organic chemicals and their byproducts (Bougherira et al., 2014). Nowadays, most of industries in Erbil City are in small scale sector and are there is not appropriate and scientific treatment plants and discharge industrial effluents through unlined channels and streams to the environment which causing huge contamination of air, water and soil (environmental pollution). The present study was focused on the characterization of various kinds of wastewaters in Erbil City-Iraq. Produced wastewaters from SWW, TWW, MWW, MLL, and DWW were collected and analyzed for 15 wastewater quality parameters. On the other hand, discussion of wastewater treatment processes and identifying appropriate treatment technology for each type of the collected wastewaters and reusing for irrigation purpose was another goal of current work.
Table 1: The average characteristics of four industrial wastewaters (Hammer and Hammer Jr, 2014; Cristian, 2010)

| Constituent          | Unit | Milk Processing | Meat Packing | Synthetic Textile | Chlorophenolic Manufacture |
|----------------------|------|-----------------|--------------|-------------------|---------------------------|
| BOD5                 | mg/L | 1000            | 1400         | 1500              | 4300                      |
| COD                  | mg/L | 1900            | 2100         | 3300              | 5400                      |
| Total solids         | mg/L | 1600            | 3300         | 8000              | 53000                     |
| TSS                  | mg/L | 300             | 1000         | 2000              | 1200                      |
| Nitrogen             | mg/L | 50              | 150          | 30                | 0                         |
| Phosphorus           | mg/L | 12              | 16           | 0                 | 0                         |
| pH                   | mg/L | 7               | 7            | 5                 | 7                         |
| Temperature          | mg/L | 29              | 28           | -                 | 17                        |
| Grease               | mg/L | -               | 500          | -                 | -                         |
| Chloride             | mg/L | 616             | 382.6        | -                 | 27000                     |
| Phenols              | mg/L | -               | -            | -                 | 140                       |

2. MATERIALS AND METHODS

2.1. Description of the sites

In this work, the produced wastewaters from five different sites in Erbil City-Iraq were collected. The formed wastewaters at all locations are discharged directly to the natural environment without any prior necessary treatment processes.

2.1.1. SWW (Slaughterhouse wastewater)

The SWW generated from slaughterhouse in Erbil City-Iraq, Fig.1. Erbil Slaughterhouse located in the right side of Erbil-Makhmoor main road and approximately 20 km far from Erbil City Centre. The formed wastewater at Erbil Slaughterhouse is composed of blood of animals from slaughtering and cleaning, washing waters, black water from toilets or urinals and storm water during rainfall periods. Number of slaughtered big size animals such as cow varied from 700 to 800; while for goat and sheep are ranged between 6500 and 9300. Because of increase in population, growth of economy, and the current situation in the area, the number of slaughtered animals will increase. A small wastewater treatment plant was built in the slaughterhouse campus. But, during the sample collection period the treatment plant was out of service and the wastewater was discharged directly to the surrounded environment without any treatment.
2.1.2. TWW (Tannery wastewater)

Tannery factory for cleaning and preparing animal leathers is located in the right side of Erbil-Makhmoor main road. It approximately 12 km far from Erbil City Centre, Fig. 2. It lies in 36° 10’ 18”N and 43° 54’ 26” E. Preparation of leathers needs numerous processes. In some steps, chemicals used to remove hair and preparation of the leather. Of course, adding chemicals effect on the quality of the wastewater. Currently, TWW collected in the concrete tanks beside of the factory. Later, the collected wastewater
transported by tankers and disposed at Erbil landfill site without treatment.

![Tannery Factory](image)

**Fig.2.** Tannery wastewater in Erbil City

### 2.1.3. MWW (Municipal wastewater)

MWWs from Erbil City merge near Turaq Quarter and situated on the left side of Erbil-Mosul main road and approximately 8 km far from Erbil City Centre, Fig. 3. Turaq Quarter lies on 36° 10’ 15” N and 43° 56’ 12” E. In 2001, the amount of wastewater for Erbil City at Toraq site was ranged from 0.85 m³/s to 1.7 m³/s (Mustafa and Sabir, 2001). Nowadays, the flow rate (Q) of wastewater exceeds 2 m³/s. The wastewater at specified location is composed of: 1) domestic sewage, which originates from kitchens and bathrooms of dwellings, public buildings as well as street wash water, 2) industrial wastewater from Northern and Southern industrial areas, and 3) storm water during rainfall periods (Amin and Aziz, 2005). Sometimes, municipal wastewater in Erbil City used illegally by farmers for irrigation some types of plants. In winter, the wastewater mixed with Greater-Zab River which is one of the tributaries of Tigris River.

### 2.1.4. MLL (Municipal landfill leachate)

Erbil Landfill Site (ELS) is situated on the left side of the Erbil–Mosul main road (near Kani-Qrzhala Sub-district) in Erbil-Iraq and is approximately 15 km from Erbil City center, Fig. 4. The geographical coordinates are 36°10’23”N and 43°35’32”E. The landfill, which established in 2001, has a total site area of 37 ha. Most of the landfill area has already been used. The site receives more than 3000 tons of MSW daily (based on data obtained from the ELS administration staff). Disposed MSW is mixed without appropriate separation of components. Thus far, studies on the MSW characteristics in Erbil City are limited. A small fraction of recyclable materials, such as plastic, glass, and metals, are separated by scavengers on-site. Because of absence of engineering landfill design and a gas collection system, the fresh MLL is directly disposed to the natural environment and forms gas emission to the atmosphere.
Fig. 3. Municipal wastewater in Erbil City

MWW sampling location

a) Satellite image

b) Municipal wastewater
Fig. 4. Landfill leachate at ELS
2.1.5. Dairy WW (Dairy wastewater)

DWW produced by a dairy factory (Yoruksut dairy factory YDF) which is one of the Turkish Dairy Factory in Erbil City established since 2010 near Gwer Sub-District. The factory is about 13 km far from the City center and is located at 36° 9' 45" N to 43° 51' 57" E and 371 meter above sea level (Fig.5). It produces approximately 40-50 tons of yoghurt and buttermilk per day (www.yoruksut.com.tr).

![Location of the Dairy factory (YDF)](image)

![Erbil-Mosul Main Road](image)

a) Satellite image of YDF

![Produced wastewater](image)

b) Produced wastewater

**Fig.5.** Produced wastewater from YDF
2.2. Sampling and Analysis

Physico-chemical analyses of wastewaters from the considered regions were conducted in the Sanitary and Environmental Engineering laboratory, College of Engineering, Salahaddin University-Erbil, Erbil, Iraq. The samples were collected in plastic containers and immediately transported to the laboratory. They were stored in the refrigerator at 4 °C prior to experimental use to prevent biological activities and changes in their characteristics (APHA, 2005). The fresh collected samples were characterized in terms of temperature, pH, turbidity (FTU), electrical conductivity (µmhos/cm), total salts (mg/L), total acidity (mg/L), total alkalinity (mg/L), total hardness (mg/L), chloride (mg/L), five day biochemical oxygen demand (BOD$_5$) (mg/L), total solids (mg/L), TSS (mg/L), and TDS (mg/L). Measuring of parameter were followed the Standard Method for the Examination of Water and Wastewater (APHA, 2005). Experiments, such as BOD$_5$, chloride, total hardness, total acidity, and total alkalinity, were determined by titration methods (chemical method). The other experiments, such as pH, EC, turbidity, and TSS were conducted using instruments in the Sanitary and Environmental Laboratory. pH was measured using a pH meter type HI 8424/HANNA. A turbidity meter type Lp 2000/HANNA was used to measure the turbidity in the samples. EC in the samples was measured using Wissenschaftlich-Teshnischewerkstatten (WTW-LF42). Electrical balance, evaporating dish, filter paper, and oven were also used to measure total and suspended solids in the collected water samples.

3. RESULTS AND DISCUSSIONS

3.1. Characteristics of wastewater samples

The results of physico-chemical analyzes of the collected wastewaters are presented in Table 2. From the results, it can be noted that some of the measured parameters of wastewaters do not meet the standards (Iraqi and EPA effluent standards). There is a variation in the results which showing variations in the degree of pollution from one site to another.

Temperature is a main factor in biological activity rate for microorganism inside the wastewater. Referring to the standards of the EPA (2003) and Iraqi disposal standards (2011), the measured temperature parameter for all types of the wastewaters were below the allowable limits. The temperature variation from one site to another and from one sample to another is due to weather conditions and time of sampling but regional ecosystem may also be involved (Messrouk et al., 2014). pH is one of the most important parameter which has effect on the biological activity within the wastewater. The highest value of pH was recorded for TWW of 10.2 and considered as strong alkaline. This is due to the chemicals and overdose cleaners which were used to remove hair and predation of the leather. A neutral pH of 7.5 and 7.28 was recorded for the SWW and MLL, respectively. A slightly acidic pH of 6.78 for MWW was recorded. An acidic in pH value for MWW is might due to the degradation of organic matter within the wastewater.

BOD$_5$ for all wastewater samples were higher than the allowable limits. The highest BOD$_5$ was recorded for the SWW of 400 mg/L. High BOD$_5$ value for SWW could be explained by the abundance of organic matter (rumen debris) and the concentration of blood in the effluent (Messrouk et al., 2014). The lowest value of BOD$_5$ was obtained for MWW of 44 mg/L according to the literature (Amin and Aziz, 2005). Erbil MWW was classified as moderate to weak wastewater according to its BOD$_5$ values. In contrast, the BOD$_5$ for MLL and TWW were 273 and 320 mg/L, respectively. Leachate characterization changes with the climatic regions in addition to the
landfill operational practices. Organic substances (BOD$_5$ and COD) and ammonia-nitrogen are two main chemical features of environmental concern in landfill leachate (Bashir et al., 2012).

Table 2: Characteristics of different types of wastewaters

| Analysis       | Unit   | Type of wastewater | SWW  | TWW  | MWW  | MLL  | DWW* | Standards          |
|----------------|--------|--------------------|------|------|------|------|------|-------------------|
| Temperature    | °C     |                    | 22.6 | 18.86| 21.86| 12.58| 21.53| <35*, 40**        |
| pH             |        |                    | 7.5  | 10.2 | 6.78 | 7.28 | 7.09 | 6-9.5            |
| Turbidity      | FTU    |                    | 174  | 289  | 19.77| 9.87 | 504  |                   |
| EC             | µs/cm  |                    | 1793.5 | 12500 | 582.6 | 800 | 800  |                   |
| Total salts    | mg/L   |                    | 1147.8 | 8000  | 372.9 | 512  | 512  |                   |
| Total acidity  | mg/L   |                    | 4000  | 0    | 40   | 60   | 60   |                   |
| Total alkalinity| mg/L   |                    | 3300  | 4660 | 206  | 34.68| 260  |                   |
| Total hardness | mg/L   |                    | 2000  | 2600 | 194  | 480  | 620  |                   |
| Chloride       | mg/L   |                    | 800   | 6938 | 30.5 | 209.9| 70   | 750 **            |
| BOD$_5$        | mg/L   |                    | 400   | 320  | 44   | 273  | 650  | <40*              |
| COD            | mg/L   |                    | 600   | 1207 | -    | -    | 951  | <100              |
| BOD$_5$/COD    |        |                    | 0.67  | 0.26 | -    | -    | 0.68 |                   |
| Total solids   | mg/L   |                    | 2000  | 13200| 10000| 1200 | 1200 |                   |
| TSS            | mg/L   |                    | 1200  | 2000 | 1800 | 600  | 600  | 60’, 35”          |
| TDS            | mg/L   |                    | 800   | 11200| 8200 | 600  | 600  |                   |

* Iraqi Environmental Standards, Contract No.: W3QR-50-M074, Rev. No.: 03 Oct 2011

** (EPA) Environment Protection Agency (EPA), Standards for effluent discharge, Regulations, 2003.

+ From Ali, 2017

High value of chemical oxygen demand (COD) was recorded for TWW and DWW, namely 1207 mg/L and 951 mg/L, respectively. These values are reflecting the oxidation of these wastewaters which rich in organic matters. According to the results of investigators a COD value of 1700 mg/L obtained for stabilized MLL (Aziz et al., 2010). On the other hand, the value of COD for DWW was 951 mg/L and exceed the standard limits. Effluents from dairy industry characterized by high concentration of organic compounds (high BOD$_5$ and COD) (Swati et al., 2012, Ali 2017).

The results of BOD$_5$ and COD for dairy and slaughterhouse wastewaters were lower than the results obtained by Cristian (2010). Thus, the characteristics of these effluents can be vary dramatically, depending on the type of product being processed, the production program of system and the methods of operation used (Dawood et al., 2011).

Total suspended solids (TSS) is another important quality parameter in characterization of wastewater. For all types of wastewaters, the value of TSS were high and varied depends on the components of wastewater. The highest TSS value was recorded for tannery wastewater of 2000 mg/L. high level of TSS in TWW could be attributed with their accumulation during the processing of finished leather (Islam et al., 2014). Presence of TSS impurities cause high turbidity in the tannery wastewater stream which was 289 FTU. For slaughterhouse and
municipal wastewaters the value of TSS were also high and exceed the standard limits and namely 1200 and 1800 mg/L respectively.

3.2. Potential wastewater treatment methods

The BOD$_5$/COD referred to biodegradability ratio in the effluent wastewater discharges. It is essential to evaluate and obtain the biodegradability ratio for different kinds of raw wastewaters before selection of appropriate treatment technique, because it is generally considered the cut-off point between biodegradable and non-biodegradable waste (Messrouk et al., 2014). If BOD/ COD is greater than 0.6 then the waste is fairly biodegradable, and can be effectively treated biologically. If biodegradability ratio is between 0.3 and 0.6, then seeding of organic matter is required to treat the wastewater biologically because the biological process is slow. While, if BOD/COD less than 0.3, biodegradation will not proceed, thus it cannot be treated biologically due to the majority existence of toxic and no-biodegradable materials (Abdalla and Hammam, 2014). The result of this study indicated that the biodegradability ratio for SWW was 0.67. This is because the composition of slaughterhouse wastewater contains fats, proteins and fibers, as well as the presence of organics, nutrients, pathogenic and non-pathogenic microorganisms (Bustillo-Lecompte et al., 2016). While the biodegradability ratio for DWW was 0.68; this due to composition of yogurt, butter etc. Therefore, biological treatment include aerobic and anaerobic techniques as a successful technique were frequently used by the researches to treat slaughterhouse effluents (Mrya et al., 2015; Bustillo-Lecompte et al., 2016).

Obtained BOD/COD of greater than 50% means that biological treatment processes are efficient. Suspended and attached growth biological treatment processes are applicable (Aziz, 2011; Mojiri et al., 2014; Aziz and Ali, 2016; Ali, 2017). For MLL, the BOD,COD average ratios were 0.096, 0.124 and 0.205 have been published by previous researcher for various leachate wastewater sites. The low BOD$_5$/COD ratio for leachate wastewater indicates that the leachate is stable and difficult to be degraded biologically. Therefore, physico-chemical treatment techniques are particularly recommended for treatment of stabilized leachate. Sequencing batch reactor (SBR) which is a type of biological treatment process and powdered activated carbon were applied for treatment of mature MLL and oil refinery wastewater (Aziz, 2011; Fakhery, 2016).

In addition, the use of coagulation-flocculation treatment technology for removing pollutants in SWW in which the chemicals such as alum, lime, ferric chloride, ferric sulphate and so on were added to the wastewater where the floc is conditioned. Among these coagulants, lime obtained a removal efficiency up to 38.9, 36.1, and 41.9% for BOD, COD and TSS, respectively (Bustillo-Lecompte and Mehrvar, 2015). Furthermore, the application of combined biological and advanced oxidation processes (AOP) is recommended for on-site slaughterhouse wastewater treatment by the researcher Bustillo-Lecompte et al. (2016).

3.3. Reusing of treated wastewater for irrigation purpose

Due to draught, dropping of ground water levels in Erbil City and using drinkable water for irrigation purpose; it is recommended to use treated wastewater for irrigation. Depending on obtained EC and total salts values, fresh TWW is not suitable for irrigation; While MWW has good quality for irrigation (Aziz and Amin, 2005). Depending on chloride values, all kinds of raw wastewaters (SWW, TWW, MWW, MLL, and DWW) cannot be reused for irrigation purpose.
Based on the described treatment methods in the previous section, application of biological treatment process (for example SBR) for treatment of SWW, MWW, and DWW are useful for achieving appropriate irrigation water quality (Surampalli et al., 1997; Azimi et al., 2005, Amin and Aziz). Adding activated carbon to SBR and trickling filters improve the quality of treated wastewater and more suitable for irrigation (Aziz, 2011, Mojiri et al., 2014; Fakhery, 2016; Ali, 2017). Treatment of MLL and TWW by using physical-chemical (coagulation-flocculation, ion exchange etc.), and adsorption added SBR and traditional returned activated sludge will result in acceptable quality of treated wastewater (Aghamohammadi et al., 2007; Ghafari et al., 2009; Bashir 2010, Aziz, 2011).

4. CONCLUSIONS

Fresh wastewater samples (SWW, TWW, MWW, MLL, and DWW) were collected and analyzed for 15 water quality parameters. TWW and MLL had low biodegradability ratio and high amount of total salts. While SWW, MWW, and DWW had high BOD/COD ratio with low amount of contaminants. Physical-chemical treatment techniques are more suitable for TWW and MLL. Biological treatment processes with adsorption are effective for treatment of SWW, MWW, and DWW and the effluent can be used for irrigation purposes.

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