Essential Treatment Processes for Industrial Wastewaters and Reusing for Irrigation

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ABSTRACT

The aims of this work were to characterization of industrial wastewaters such as dairy and steel manufacturing wastewaters, possible treatment processes, and reusing the treated wastewater for irrigation purpose was discussed. Fresh wastewater samples were collected from Yörüksüt Dairy Factory and Erbil Steel Company and analyzed for 21 water quality parameters. Chemical oxygen demand (COD), color, total suspended solids (TSS) etc. were exceeded the standards for disposal of wastewater. Thus, treatment processes are essential prior disposal of wastewater to the environment or using for irrigation purpose. Based on the characteristics of the wastewaters, the treatment processes such as primary, secondary and tertiary were discussed. In addition, the quality of raw wastewater samples and proposed treated industrial wastewaters were compared with the guidelines for the irrigation purpose.

Key words: Industrial wastewater; treatment; dairy wastewater; irrigation; reuse.

1. INTRODUCTION

Water scarcity is an increasingly severe global problem which may be mitigated by re-using wastewaters after suitable treatment methods (Skouteris et al., 2012). In abundant dry or semi-dry regions water become rare resources and administrators are forced to find effective and economical ways to increase water sources. On the other hand, a rapid growth of population increased food requirements; these lead to reuse water for different purposes and to increase agricultural productivity (Pescod, 1992). The industrial discharge carries various types of contaminants to the river, lake, and groundwater. The quality of freshwater is very important as it is highly consumed by the human for drinking, bathing, irrigation and etc. The presence of contaminants from industrial contaminant within the water may reduce the yield of crops and the growth of the plant and it will harmful to the aquatic living organism too (Ho et al., 2012). Industrial wastewater can be recycled and used for irrigation purpose, if passes through sufficient treatment processes. New treatment technologies can help us to remove almost all pollutants from wastewater and recycle it again and it would be utilized for different uses or to back into the environment (Iannelli and Giraldi, 2011). Industrial wastewater comes from industrial processing operation such as food processing including (dairy, canning, and sugar), material processing (steel and iron, oil, and coal coke and gas), chemical processing (paper and pulp, rubber, and tanning), miscellaneous industries include (atomic power and radioactive waste) (Punmia, et al., 2011).

Irrigated land with reclaimed water may decrease purification levels and fertilization costs because both soil and crops work as bio-filter, and wastewater contains nutrients which works as the enrichment of the land (Haruvy, 1997). In many countries, treated industrial wastewater is an important source for irrigation, but they have a national policy and should set with standards for reclaim wastewater for irrigation (Pescod, 1992). In Erbil City-Iraq which is located in a semi-arid region, a huge volume of industrial wastewater disposed to surface water without sufficient treatment, and leave a significant impression on the environment. On the other hand, many lands are not irrigated because of lack of water. Even groundwater cannot be use due to unavailable irrigation well (Gardi, 2014). In addition, drilling of wells are limited due to regulations of Ministry of Agriculture and Water Resources. Consequently, reusing of treated wastewaters leads to watering large areas. A dairy factory in Erbil city locates far from the center of the city close to a semi-arid rural in irrigation land. Because of lack of any treatment plant in that factory everyday large volume of wastewater thrown to the surrounded land without any treatment and this wastewater mix with Erbil municipal wastewater, which has an effect on public health and cause poor quality of surface water. Consequently, untreated wastewater has an odor and it disturbs people. This water can be treated by fixing treatment plant close to the factory to treat wastewater by three processes such as physical, biological, and chemical processes and can reuse the formed wastewater for irrigating the area around this company, and this lead to fill the empty lands and increase food products. Regarding Erbil Steel Company (ESC), a primary wastewater treatment plant is available in the factory that treats the wastewater and reuses for cooling machines and steel by circulation and for irrigate the landscape in the factory; after appropriate treatment and according to standards it can be used for irrigating. For the current work, the wastewater data from two factories in Erbil (Yörüksüt Dairy factory and Erbil steel company) were collected and tested for 21 water quality parameter, then the results were compared with water quality standards that can be used for irrigation purposes. The objective of this study was to characterization of produced wastewater from Dairy Factory and Steel Factory in Erbil City and to present potential treatment processes for the fresh industrial wastewaters and reusing for irrigation purpose.

2. MATERIALS AND METHODS

2.1 Description of Sites

A- Yörüksüt Dairy Factory (YDF)

YDF is one of the dairy factories established in Erbil City since 2013. The factory is far from the Erbil City center about 13 km. It is located at 36° 9' 46" N to 43° 51' 57" E and 357 meters above sea level, Fig.1. It produces approximately 40 to 50 tons of yogurt and buttermilk per day.

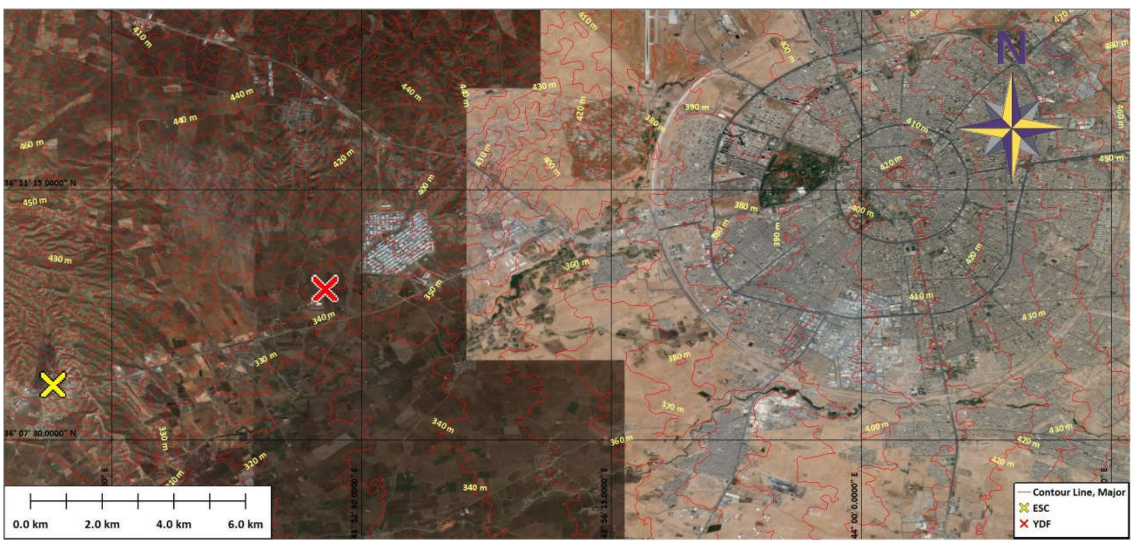

Figure 1. Satellite image of YDF and ESC

B- Erbil Steel Company (ESC)

ESC is one of the most important heavy industry in Kurdistan region, located at 36° 8' 20" N to 43° 47' 52" E and 21.6 km far from Erbil Cite center on the left side of Erbil-Guwer main road, Fig.1. ESC has started integrated steel production in December 2007 and producing over 600 tons of steel daily from the melting of scrap iron at its integrated steel factory and rolling mill.

2.2 Sampling Collection and Analysis

Wastewater samples from YDF and from ESC, including samples for cooling (furnal, steel forms, and steel bar), were collected on March 26th 2017 at 9:30am and 11am respectively. The samples were stored in plastic bottles and immediately transported to the laboratory and stored in refrigerator at 4 °C to prevent any biological action in the wastewater samples until the time of testing. Sampling, storage and transporting were according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The samples were tested for 21 water quality parameters such as pH (Mv), pH, oxidation-reduction potential (ORP) (mv), dissolved oxygen (DO) (%), DO (mg/L), Electrical conductivity (EC) (µ mhoss/cm), EC (µ mhoss/cm[a]), Ω. Cm, total dissolved solids (TDS) (mg/l), Pressure (P) (PSU), P (mm Hg), Temperature (T) (°C), σt, Nitrite (NO_2) (mg/L), chemical oxygen demand (COD) (mg/L), Color (Pt.Co), Ammonia (NH_3-N) (mg/L), Nitrate (NO_3) (mg/L), total Acidity (mg/L), total Alkalinity (mg/L) and Chloride (Cl) (mg/L). All experiments were conducted in the Sanitary and Environmental Engineering Laboratory, Civil Engineering Department, College of Engineering, Salahaddin University-Erbil, Erbil, Iraq. In addition, all tests were performed according to APHA (2005). Tests of pH (mv), pH, ORP (mv), DO (%), DO (mg/L), EC (µ mhoss/cm) EC (µ mhoss/cma), Ω. Cm, TDS (mg/l), P (PSU), P (mm Hg), T (°C) and σt were measured by HANNA Multiparameter measurement (HI9829-00202). Total acidity, total alkalinity, and chloride were measured by titration methods (APHA, 2005). COD, color, NH3-N, NO3, and NO_2 were determined by spectrophotometer (DR/3900 HACH).

3. RESULTS AND DISCUSSIONS

3.1 Characteristics of Industrial Wastewater

The earliest step to discover the solution for treating industrial wastewater and reuse it for irrigation is characteristic of industrial wastewater. Recognizing physical, chemical, and biological characteristics of industrial wastewater is very valuable to design, working, management of accumulation, and disposal of wastewater. The knowledge of the source of industrial wastewater and natural of industrial wastewater is very sustainable, to know the contents of industrial wastewater and their risk. The physical characteristic of industrial wastewater includes solids (total suspended solids and total dissolved solids), color, odor, and temperature. On the other hand, the chemical properties include inorganic chemicals, organic chemicals, and volatile organic carbons. Inorganic chemicals involve NH_3-N, nitrogen, NO_2, NO_3, phosphorus, pH, chloride, sulfate, and alkalinity. Nitrogen and phosphorus are useful for plant growth. Organic chemicals include BOD, COD, and total organic carbon. Biological characteristics include a group of microorganisms discover in wastewater such as bacteria, fungi, protozoa, microscopic plants, and viruses. Bacteria and protozoa are useful for the biological treatment, while fungi, protozoa, and viruses are unacceptable by the public (Lin, 2007; Alturkmani, 2013; Ranade & Bhandari, 2014).

Tab.1 shows typical range of concentration values for industrial wastewater. It can be noticed from Tab.1 that biodegradability ratio (i.e. BOD/COD) for yeast industry, fruits and vegetable canning, textile industry, and beverage industry were greater than 0.5; this means that biological treatment processes are efficient. Commonly, all types of industrial wastewaters contained a high concentration of BOD, COD, TSS, and TDS. Different values of pH are available, due to adding chemicals in the various processes (Aziz and Ali, 2018). Treatments are essential because all TSS values are higher than the standards for disposal of wastewater (i.e. 30 mg/L). For the collected wastewater samples, the results of YDF and ESC are shown in Tab.2. In YDF, they use milk and yeast for their production, which contains high concentration of calcium. On the other hand, in ESC they work with steel, so their wastewater contains high amount of iron and heavy metal. The Dairy product contains a high organic matter, acidic and alkaline cleaning agent, while, wastewater from steel factory contains heavy metals.

The other sources of industrial wastewater contain different pollutants such as slaughterhouse wastewater contains a high amount of total solids, nitrogen, and BOD_5, tannery wastewater contain alkaline, BOD_5, COD, SS, and sodium

(Aziz and Ali, 2018). All water samples remain within the alkaline range (i.e. pH>7). Values for TDS, total alkalinity and Color commonly were high. COD values generally are high; therefore, treatment processes for the produced wastewaters are required prior disposal to the natural environment or reusing. DO values are less than 2 mg/L; it regarded as anaerobic condition and threatens for aquatic life.

Table 1. Characteristics of different types of industrial wastewaters (Kreetachat, 2015).

Type of wastewater	pH	TSS (mg/l)	BOD (mg/l)	COD (mg/l)	BOD/COD	TDS (mg/l)
Dairy Industry	4	12150	4000	21100	0.19	19000
Yeast Industry	5.3	540	2100	3400	0.62	35000
Fruits & Vegetable Canning	5.5	2200	800	1400	0.57	1270
Textile Industry	6.5	1800	840	1500	0.56	17000
Pulp & Paper Industry	8	1640	360	2300	0.16	1980
Beverage Industry	9	760	620	1150	0.54	1290
Tannery Industry	10	2600	2370	4950	0.48	8500

Table 2. Characteristics of YDF and ESC wastewaters

No.	Tests	Dairy wastewater	Cooling Furnal Coils	Cooling Forms	Cooling Steel Bars
1	pH (mv)	-140.7	-184.6	-224.7	-164.7
2	pH	8.8	9.59	10.32	9.22
3	ORP (mv)	-76.4	-73.4	-92.5	-79.6
4	DO (%)	0.1	0.1	0.1	0.1
5	DO (mg/L)	0.01	0.01	0.01	0.01
6	EC (µ mhoss/cm)	659	3201	13.79	1834
7	EC (µ mhoss/cm^a)	453	2192	9072	1270
8	Ω. Cm	1515	313	73	546
9	TDS (mg/l)	330	1600	6887	916
10	P (PSU)	0.32	1.68	7.95	0.94
11	P (mm Hg)	>20.4	720.5	720.5	720.5
12	T (°C)	8.75	8.41	7.09	8.87
13	σt	0.1	1.2	6.2	0.5
14	NO_2 mg/L	81	1	18	10
15	COD mg/L	329	180	534	84
16	Color Pt.co	922	67	491	240
17	NH_3-N mg/L	6	0	0.31	0
18	NO_3 mg/L	23.8	4	3	1.4
19	Total Acidity mg/L	40	32	0	16
20	Total Alkalinity mg/L	244	240	676	156
21	Chloride (Cl) mg/L	27.99	699.78	2499.23	299.907

3.2 Industrial Wastewater Treatment Processes

Raw industrial wastewater subjected to physical, chemical, and biological processes, to take off solids, organic matter, and nutrients. Different levels of treatment are used such as preliminary and primary, secondary, and tertiary or advanced industrial wastewater treatment (Metcalf and Eddy, 2014). In some places, the disinfection is done to remove pathogens and that will be the last steps of treatment (Pescod, 1992). Tab. 3 shows the wastewater treatment levels according to EPA(Austin, 2013).

Table 3. Wastewater Treatment Levels (EPA, 2010).

Treatment Level	Process	Indicators	Standard
Primary	Sedimentation	Particle size	<30mg/L
Secondary	Filtration, Biological Chemical	BOD	<30mg/L
		TSS	<30mg/L
		Fecal Coliform bacteria	100cfu/100 ml. (primary contact)
		Fecal Coliform bacteria	200cfu/100 ml. (secondary contact)
		E-coli bacteria	126cfu/100mL
Tertiary	Biological, Chemical	Ammonia	Based on receiving water
		Nitrate	Based on receiving water
		Phosphorus	Based on receiving water
		Pharmaceuticals	Based on receiving water

The purpose of the preliminary treatment process is to take off the large solids and large materials in raw wastewater (Pescod, 1992). While primary treatment process includes the break-up of settleable organic and inorganic solid from wastewater and this can be done by pouring the raw wastewater into a tank and let the solid matters to float at the surface of the tank. The solids then skimmed by large scrappers and pushed to the center of the tank. In the primary treatment process, 25 to 50 % of BOD_5, 50 to 70 % of SS, and 55 to 65 % of grease is removed. In addition, few of organic nitrogen, organic phosphorus, and abundant metals are removed but colloidal and dissolved elements are not removed. In many modern countries, primary treatment is the only treatment process that required for industrial wastewater to use for irrigation. Treated level of primary process is acceptable for irrigating crops that are not used by humans (Pescod, 1992; Braatz & Kandiah, 1996). The primary treatment process is also called physical treatment.

Secondary treatment is required when the industrial wastewater contains a large amount of biodegradable substances. If the BOD/COD ratio in industrial wastewater is greater than 0.6, it can be treated biologically. While, when this ration goes below 0.3, the biological treatment is not required. In between, from 0.3 to 0.6, acclimatization is required before biological treatment (Aziz, 2011; Punmia, et al., 2011). The remaining water from primary treatment is effluent and pumped to the secondary treatment process. Secondary treatment or biological treatment is the process to remove the organic and suspended solids. The biological process can be done by aerobic or anaerobic. Aerobic treatment is done by the attendance of oxygen by aerobic microorganisms such as bacteria which metabolize the organic matter in wastewater. Then the microorganisms should separate from treated wastewater and thus can be done by using a secondary sedimentation tank. Biological treatment can be done by aerobic stage, and hardly by anoxic or anaerobic. In the combination of secondary and primary sedimentation 85% of BOD_5 and SS are removed with some heavy metals (Pescod, 1992; Iannelli & Giraldi, 2011). Based on results of Tab.1, biological treatment processes commonly are effective. While, for the dairy industry, pulp and paper industry biological treatment methods are inefficient and physical-chemical methods are recommended (Aziz, 2011). On the other hand, using rock, plastic materials, disposed PVC pipes etc. as trickling filter media offered good removal efficiencies for the removal of pollutants (Aziz, 2011; Metaclf & Eddy, 2014, Ali, 2017).

The advanced treatment process has tendency to remove > 99 % of contaminants from wastewater (Ranade and Bhandari, 2014). Tertiary wastewater treatment is not required at every wastewater treatment plant, and if it is requiring, it will be different from plant to another and it depends on the type of pollutants. Contaminate include organic matter and suspended solids, nutrient (phosphorus and nitrogen), pathogens, heavy metals, and toxic materials which remains and cannot clean up in the secondary treatment process. The aim of tertiary treatment is to increase the quality of industrial wastewater to a level to be qualifying to reuse it for irrigation. Advanced treatment processes are a mixture of chemical and physical treatment that called physical-chemical treatment. This treatment process needs more money compared with primary and secondary treatment method (Bengtson & Malburg, 2011; Ghangrekar, 2012, Metcalf & Eddy, 2014).

The disinfection process is the final process of wastewater treatment. Disinfection is a chemical treatment process which is used to eliminate or reduce the pathogens. The object of disinfection is to protect public health by reducing pathogens such as microbes, viruses, and protozoa in industrial wastewater. Disinfection can be done chemically by chlorine, ozone, ultraviolet radiation, chlorine dioxide, and bromine. Chlorine is the safest and trustworthy disinfection agents and has good properties (Samer, 2015).

For the collected samples in the present work, biological treatment processes are recommended for BOD/COD > 0.5. While, if biodegradability ratios are too low, physical-chemical methods are suggested. In some cases, biological combined with physical-chemical processes (Aziz, 2011).

3.3 Reusing of wastewater for Irrigation

The quality of raw industrial wastewaters is different and it depends on the source of wastewater, for example the quality of water from dairy, steel, slaughterhouse, tannery, yeast, and paper factory are not the same. Different treatment processes are required depends on the contaminants of wastewater and should be treated to a level to qualify for the different type of irrigation restricted or unrestricted (i.e. forest, greenbelt, wheat, fruits, vegetables, etc.) (Mecalf & Eddy, 2014; Aziz et al., 2017; Aziz and Ali, 2018). Three main arguments should be considered for irrigation by treated wastewater, which cares about public health for farmers and users, the prevention of atmosphere degradation, and eliminates the antagonistic that has an effect on the production of crops. Many organizations for using treated wastewater for irrigation focused on, the concentration of indicator organisms, biodegradable organic matter, suspended solids, turbidity, and residual chlorine that has an effect on public health (Paranychianakis, et al., 2011). Salinity, nutrients, hydrogen ion concentration, and trace elements are also should be considered in treated wastewater. Many organizations have standards for irrigation by treated wastewater such as Food and Agriculture Organization (FAO), and U.S. Environmental Protection Agency (USEPA) (Jeong, et al., 2016). Based on NO_3 and NH_3 values for the collected samples, the concentrations regard as normal to high concentrations.

Tab.4 shows the guideline for the quality of water for irrigation that has been done by the University of California Committee of Consultant's Water Quality Guidelines (Pedrero et al., 2010). Results of YDF and ESC wastewater samples revealed that the amount of NO_3 which is equal to 23.8 is in a normal range For YDF, while it is in a low range in ESC. The amount of TDS in the dairy product is 330 mg/l, according to the guideline in Tab. 4 this value is less than 450 mg/l that means no TDS content. In ESC, the value of TDS is 1600 mg/l and 916 mg/l for cooling furnal and cooling steel bars respectively, which they are in a normal range for using for irrigation, while wastewater for cooling form the TDS content is 6887 which is high and severe in range. A normal range of pH for irrigation water from 6.5 to 8.4 as shown in Tab.4, but pH in dairy and steel company in Erbil were higher than this value. These levels can control by treatment of their wastewater to a level that can be suitable for irrigation. Furthermore, the values of chloride for YDF is 27.99 mg/l which is less than 140 mg/l. While for ESC wastewater, higher chloride values of 299.907 mg/l for cooling steel bars, 699.78 mg/l for cooling furnal, and 2499.23 mg/l for cooling steel forms where reported. According to these results, it can be said that the untreated wastewater cannot be used for irrigation directly without treatment. So, industrial wastewater should be treated in different processes before using for irrigation. Furthermore, using treated industrial wastewater for irrigation with different contaminates has the risk-on environment and public health, due to pathogenic microorganisms, heavy metals, chemical organic content. Farmers, crop handlers, consumers, and people that live close to the irrigated land are at risk with exposure. Pathogenic microorganisms involve viruses, bacteria, and protozoan cause disease to the public such as typhoid, diarrhea, vomiting, and malabsorption. Disinfection can reduce the amount of pathogens but this process needs more money and not essential for every agricultural use.

Table 4. Guidelines for irrigation water quality

Potential Irrigation Problem	Units	Degree on restriction on use		
		None	Moderate	Sever
Salinity				
ECw	dS/m	≤0.7	0.7-3	3.0
TDS	mg/l	450	450-2000	2000
Permeability (effects of infiltration rate of water into the soil. Evaluate using ECw and SAR together				
	SAR=0-3	ECw≥0.7	ECw 0.7-0.2	ECw≤0.2
	SAR=3-6	ECw≥1.2	ECw 1.2-0.3	ECw≥0.3
	SAR=6-12	ECw≥1.9	ECw 1.9-0.5	ECw≥0.5
	SAR=12-20	ECw≥2.9	ECw 2.9-1.3	ECw≥1.3
	SAR=20-40	ECw≥5.0	ECw 5.0-2.9	ECw≥2.9
Specific ion toxicity				
Sodium (NA)				
Surface irrigation	mg/l	≤3	3-9	≥9
Sprinkler irrigation	mg/l	≤70	>70	
Surface irrigation	mg/l	≤140	140-350	≥350
Sprinkler irrigation	mg/l	≤100	>100	
Surface-sprinkler irrigating	mg/l	≤0.7	0.7-3	≥3
Miscellaneous effects				
Nitrogen	mg/l	≤5	5-30	≥30
(Total N)				
Bicarbonate	mg/l	≤90	90-500	≥500
(overhead sprinkling only)				
Residual chlorine	mg/l	≤1	1-5	≥5
pH		Normal range 6.5-8.4		

4. CONCLUSIONS

In the current work, untreated wastewater samples from YDF and ESC were collected and analyzed for 21 water quality parameters. Some parameters such as COD, color, TSS etc. were surpassed the standards for disposal of wastewater. Results revealed that commonly fresh industrial wastewater from YDF and ESC cannot be used for irrigation. Biological and/or physical-chemical treatment processes are recommended for the treatment of industrial wastewater so as to be suitable for irrigation purpose.

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