The Effect of Blackwater Disposal on Municipal Wastewater and Soil Properties with Potential Solutions: Erbil as a Case Study, Kurdistan Region, Iraq

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GRAPHICAL ABSTRACT

Table. Physical and chemical characteristics of BW, MWW and BWMWW

No.	Parameters	Units	BW	MWW	BWMWW
1	Temperature	°C	21.10	21.39	22.08
2	Turbidity	FTU	439.83	26.37	33.89
3	TS	mg/L	1200	500	500
4	TSS	mg/L	600	200	400
5	TDS	mg/L	600	300	100
6	TVS	mg/L	400	200	300
7	TnVS	mg/L	800	300	200
8	Salinity	PSU	0.71	0.38	0.39
9	Color	Pt.Co	2317	263	304
10	pH	-	7.15	7.09	6.36
11	Total acidity	mg/L	34	0	18
12	Total alkalinity	mg/L	532	264	256
13	Bicarbonate alkalinity	mg/L	532	264	256
14	Carbonate alkalinity	mg/L	0	0	0
15	Hydroxide alkalinity	mg/L	0	0	0
16	Total hardness	mg/L	148	213	224
17	Oil and grease	mg/L	0.1	0.7	0.5
18	DO	%	0	12.8	9.8
19	Chloride	mg/L	101.968	49.985	49.985
20	NH_3-N	mg/L	106.5	4.4	4.37
21	NO_2	mg/L	100	23	30
22	NO_3	mg/L	42.5	16.9	7.8
23	SO_4	mg/L	-	57	37
24	ORP	mV	-8.1	8.6	40.1
25	EC	µS/cm	1410	780	788
26	BOD_5	mg/L	185	30	22.5
27	COD	mg/L	314.76	60.56	48.26
28	BOD_5/COD	-	0.59	0.50	0.47
29	Phosphate	mg/L	10.45	2.75	1.65

Abstract

Direct discharge of blackwater (BW) without treatment to the natural environment causes problems for the environment. The present research aimed to characterize of disposed BW, municipal wastewater (MWW), BW mixed with MWW (BWMWW) and the soil at the BW disposal site in Erbil City, Kurdistan Region, Iraq. Additionally, the impact of BW disposal on the surrounded soil and MWW was studied. Suitable treatments and solutions for the BW disposal was presented as well. To check the effect of BW on the boarded MWW and the soil; BW, MWW, BW mixed with MWW (BWMWW), polluted soil, and clean soil samples were collected and analyzed. Samples of BW, MWW, and BWMWW were tested for 27 physical-chemical and biological quality parameters such as pH, solids, color, dissolved oxygen, five day biochemical oxygen demand , chemical oxygen demand , ammonia, oxidation-reduction potential (ORP), sulphate, oil and grease, phosphate, Most probable number (M.P.N.) of coliform, Thermo tolerant, M.P.N. E.Coli …etc. In contrast, soil samples were tested for 37 parameters, for instance pH, ORP, organic matter (OM), sulfite, Titanium, Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Gallium, Arsenic, Rubidium, Strontium, Yttrium, Zirconium, Molybdenum, Silver, Cadmium, Mercury, Lead, Thorium and Uranium. Statistically significant with high to very high positive correlations between parameters were obtained for both WW and soil samples. Results showed that direct disposal of BW resulted in increasing salinity in BWMWW and contaminated soil by 102.6 % and 200 %, respectively. While, BW disposal caused doubling of OM value in the polluted soil. Impact of the BW disposal on the surrounded soil was higher than the effect on the MWW.

Keywords Black water, greywater, pollution, soil, treatment, wastewater.

1. Introduction

Domestic wastewater includes two main types of wastewater: blackwater (BW) and greywater (GW). While, municipal wastewater (MWW) comprises of storm water, domestic, commercial, industrial, institution and washing WWs (Aziz and Ali, 2018). The amount and content of domestic wastewater can be varied considerably depending on the level of development and economic circumstances in which it is produced (Hammes et al., 2000). Boutin and Eme (2016) classified the domestic wastewater depending on their emission sources. They classified domestic wastewater to BW and GW. BW consists firstly yellow water which comes from urine and flush water, secondly brown water which comes from fecal matter and toilet paper/flush water and finally others which comes from cleaning activities and spillage. The GW consists firstly food and cleaning which comes from laundry and kitchen sink/dish washer and secondly personal care which consists bath and shower and wash basins (Boutin & Eme, 2016). There is a big difference between characteristics of BW and GW (Dixon et al. , 1999). GW is considerably less polluted than BW, making it an appealing option for on-site treatment and non-potable reuse such as garden irrigation and toilet flushing (Grossa et al., 2007). The GW is often contained valuable nutrients which gardening and irrigation need it, so consequently, there is no need to buy expensive mineral fertilizer (Imhof and Mühlemann, 2005). Additionally, GW can be treated by many different treatments such as filtration systems, upflow anaerobic sludge blanket digestion (UASB) or other treatments and then it can be reused for secondary household purposes like agriculture fields. But, BW has a different matter, it needs more intensive treatment even when produced in a small volume because it contains high organic load. In addition to nutrients and pathogens which causes a great risk of contamination (Sharma and Kazmi, 2015). The studies and researches recommended to separating the domestic wastewater into GW and BW to get an efficient system and prevent the contamination of GW. This separation will minimize the volume of fecal contaminated wastewater as well as reducing the cost of treatment (Abdel-

Shafy et al. 2009). The most common system that is used to treat the domestic wastewater is a septic tank because it is economical, the structure can be built by local materials such as brick and another important thing is no need electricity which is very important matter for developing countries (Sharma and Kazmi, 2015). In septic tank there are two important processes that happened: settling and partially digested settled sewage.

The Kurdistan Region of Iraq (KRI) is located in the north of Iraq. The sanitation system and sewerage management in the region are still under international standards. The KR has developed rapidly during the last decade. The latest revision of the UN World Urbanization Prospects estimated the Erbil's urban agglomeration 2019 population is 833,237, this estimation includes Erbil's population in addition to adjacent suburban areas (UN World Urbanization Prospects 2018). The main problem in the sanitation system in Erbil Cityis discharged wastewater and sewage directly into channels that end up in a field outside the City. In some cases, MWW is used directly for irrigation purposes which causes problems for the population, health and environment (Amin and Aziz 2005).

In general, the households in the Erbil City generally rely on cesspools or in some cases on septic tanks with cesspools to manage their BW. After some time, which could be ranged from months to few years, the collected BW will be drawn from these septic tanks or cesspool (which is under the houses) by vacuum trucks and discharged directly without any treatment in suburban areas outside the Erbil City. This will be leading to a very serious environmental problems and consequently affect citizens' health and it will act as an obstacle to achieving sustainable development. But the good thing is the BW separated from the other domestic wastewaters in each house, which can facilitate the treatment of this type of wastewater in the future.

Currently in Erbil City, there is no central wastewater treatment plant (WWTP) to treat the produced MWW in this city. So, the GW is mixed with storm water and discharged directly to the natural environment without any prior treatment and sometimes it used illegally by the farmers for irrigation purposes (Amin and Aziz 2005). On the other hand, BWs commonly collected in cesspools only. In some cases, septic tanks and cesspools are used. Due to the municipality regulation, houses, buildings, etc. should have septic tanks and cesspools. But, in most cases only cesspools are available.

A wide range of technologies is preceded by a sedimentation step as pre-treatment use of septic tanks, or screening are applied to reduce the number of particles and oil and grease (Friedler et al., 2005), then followed by a disinfection step as post treatment. For wastewater treatment and reuse, several biological processes can be used, such as rotary biological contactors (RBC), membrane bioreactors (MBR), constructed wetlands (CW), and sequencing batch reactors (SBR) (Li, 2009; Aziz et al., 2020). Various treatment technologies can be integrated according to the 'fit for purpose' concept. But, biological treatment is the key technology, nearly all types of wastewater show good biodegradability, sedimentation and filtration are applied as pre-treatment or post-treatment procedure (Gisi et al., 2015). In addition to the MBR process, most of the biological processes are followed by a filtration step and a disinfection step (UV or chlorination) to meet the non-potable reuse standards (Zhu et al., 2018). Constructed wetlands can be considered as the most environmentally friendly and cost-effective technology, even though they require a large space (Masi et al., 2010).

The objectives of the present work were to: 1) characterization of disposed BW, GW, and BW mixed with GW (BWMWW), 2) characterization of soil at the BW disposal site, 3) examine the impact of BW disposal on the surrounded soil and MWW, and 4) presenting suitable treatment and solutions for the BW disposal. So far, this kind of study on BW in Erbil City has not been published yet.

2. Materials and Methods

2.1. Study area

BW is collected from Erbil City areas by tankers and discharge it near Azzah Village, Erbil City, since 2015. Drivers said that the BW disposal site was decided by the authority since 2015 (DEE, 2019). Figure 1 shows the BW discharge in this site. This site had been visited two times on 9th and 29th October 2019.

Figure 1. Direct disposal of BW to the Environment

The location of the BW disposal site is shown in Figure 2. The site is located 11 km far from Erbil City centre. E and N for the site are 43° 56′ 03″ and, 36° 06′ 54″, respectively. The site is 355 meters above sea level. Based on the interview made with tanker owners, they said every day around 100 tankers with an average capacity of 15000 L dispose BW to this site. The average number of trips per each tanker 2 trips/day. Total amount of BW=3 x 10^6 L/day = 3000 m^3/day.

It was noticed that disposed BW is mixed with the soil and the MWW channel that is coming from Erbil City as shown in Figures 1 and 3. In addition, residues from some refiners are disposed there as well.

Figure 2. Location of BW disposal site in Erbil City
(http://www.gosur.com/satellite/iraq_arbil_erbil/?lang=ar)

Figure 3. Mixing of BW with the soil and MWW

2.2. Data collection and analysis

BW, MWW, and BWMWW samples were collected according to (APHA, 2005). The BW samples were taken directly after disposal of the BW from the tankers on the land and before it mixed with the WW channel. Normally, the disposed BW was collected from natural pits on the ground and directly after disposal of the BW from the tankers. MWW samples were taking from the area (about 500 m) before the discharging area of the BW. BWMWW is taking from mixing zone which is the portion of water body close to a point source of BW discharge. The MWW channel is natural wide and shallow channel. The MWW and BWMWW samples were collected at depth approximately 30 to 40 cm under the top of the surface channel. The collected samples were transported immediately to the laboratory for the analysing physical, chemical and biological characteristics. The experiments were conducted in the Sanitary and Environmental Laboratory, College of Engineering, Salahaddin University-Erbil (SU-E) and laboratory of Ifraz 2 water treatment-plant, Directorate of Water-Erbil City.

The physical parameters included temperature, total solids (TS), , total dissolved solids (TDS), total volatile solids (TVS), color, oxidation-reduction potential (ORP), and salinity. The chemical parameters include pH, bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity, total hardness, oil and grease, dissolved oxygen (DO), chloride (Cl^-), ammonia-nitrogen (NH_3-N), nitrite (NO_2), nitrate (NO_3), sulfate (SO_4), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), BOD_5/COD, and phosphate. And finally, the biological characteristics includes most probable number (MPN) of Coliform, Thermo tolerant, and MPN of E. Coli.

Soil samples were collected around the BW disposal site (regarded as polluted sample) and a clean soil sample was collected inside College of Engineering, SU-E. The soil samples were taken at approximately 20 to 30 cm depth from the top surface of the land. Normally, the tankers discharge the BW at different locations of the specified disposal area. To avoid any mixing of the disposed BW with the land, clean soil samples (as control sample) were collected far from the BW disposal area. The tests for the soil samples were carried out in the Sanitary and Environmental Laboratory, College of Engineering, SU-E and laboratory of

Environmental Science Department, College of Science, SU-E. Collected soil samples were analyzed for pH, ORP, electrical conductivity (EC), TDS, salinity, temperature, calcium carbonate ($CaCO_3$), Cl^-, organic matter (OM), sulfite (SO_3), Potassium (K), Calcium (Ca), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Cupper (Cu), Zinc (Zn), Gallium (Ga), Arsenic (As), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium, formerly known as columbium (Nb), Molybdenum (Mo), Silver (Ag), Cadmium (Cd), Tin but Latin name is Stannum (Sn), Antimony but Latin name is Stibium (Sb), Mercury (Hg), Lead (Pb), Thorium (Th) and Uranium (U).

3. Results and Discussions

3.1. Impact of BW on MWW

The toilets have different flushing water system such as conventional, dual-flush toilets and water conserving toilets known as vacuum toilets. It was found that each type of toilet flushing system has different characteristics in terms of physical, chemical and biological properties. The reason behind this difference is the amount of flushing water. The conventional toilet flush using 9 L of water/flush, dual flush toilet using between 3 to 6 L water/flush, whereas vacuum toilet ranged between 0.5–1.2 L water/flush (Gao et al. 2019). In addition to the flushing water there is additional amount of water that used to wash after finish toilet. Accordingly, in general the approximate BW produced per person every day is ranged between 25-50 LPCD (Brears, 2019). Low flushing water consumption is helpful to achieve a low dilution of BW and an efficient process. That is why low-flush toilets or vacuum toilets are preferential for the collection of BW before anaerobic digestion (Wendland 2008).

This hole is regularly lined with stone, concrete or brick and received the BW and needs emptying at regular intervals, dependent upon the size of the tank, the number of people living at the property, and characteristics of the soil. Sometimes these holes allow waste seeping to the ground and it will be source of soil and groundwater pollution and consequently effect on human health and environment. The main problem in Erbil City there is no any kind of treatment for this wastewater. In general, the treatment in cesspool is very low and it could be considered as a primary settling tank where solids and liquids separate and also biological process will be there. The settling process happened via gravity and a primary colony of bacteria digested the organic waste (Brears, 2019). Anaerobic digestion is considered one of the oldest technologies that applied to treat wastewater. The main advantages of anaerobic digestion are biogas production and less amount of sludge production compared to aerobic treatment (Gao et al. 2019; Wendland 2008). Furthermore, it plays an important role in water management like reduce the consumption of high-quality drinking water, safe sanitation because the hazardous compounds in BW will not spread in the water cycle, production of biogas for domestics uses such as cooking, lighting ...etc. In addition, produce organic fertilizer that is used in agriculture field (Wendland, 2008)

As mentioned before one of the major health hazards in many countries is the lack of sewer system and an efficient WWTP, because of that the MWW and BW discharged directly to the environment. This work deals with investigation the physical, chemical and biological characteristics of BW, MWW and BWMWW and soil of the area near Azzah Village, Erbil City, . Table 1 shows the physical and chemical characteristics of BW, MWW and BWMWW for the collected samples.

Table 1. Physical and chemical characteristics of BW, MWW and BWMWW

No.	Parameters	Units	BW	MWW	BWMWW
1	Temperature	°C	21.10	21.39	22.08
2	TS	mg/L	1200	500	500
3	TDS	mg/L	600	300	100
4	TVS	mg/L	400	200	300
5	TnVS	mg/L	800	300	200
6	Salinity	PSU	0.71	0.38	0.39
7	Color	Pt.Co	2317	263	304
8	pH	-	7.15	7.09	6.36
9	Bicarbonate alkalinity	mg/L	532	264	256
10	Carbonate alkalinity	mg/L	0	0	0
11	Hydroxide alkalinity	mg/L	0	0	0
12	Total hardness	mg/L	148	213	224
13	Oil and grease	mg/L	0.1	0.7	0.5
14	DO	%	0	12.8	9.8
15	Chloride	mg/L	101.968	49.985	49.985
16	NH_3-N	mg/L	106.5	4.4	4.37
17	NO_2	mg/L	100	23	30
18	NO_3	mg/L	42.5	16.9	7.8
19	SO_4	mg/L	-	57	37
20	ORP	mV	-8.1	8.6	40.1
21	BOD_5	mg/L	185	30	22.5
22	COD	mg/L	314.76	60.56	48.26
23	BOD_5/COD	-	0.59	0.50	0.47
24	Phosphate	mg/L	10.45	2.75	1.65

Ambient temperature was varied from 18ºC to 34ºC during collection of the samples. The samples' temperatures were ranged between 21.1ºC to 22.08ºC. During sample collection period there was no rainfall. There are many factors effect on the water bodies temperature in that area such as water flow which associated with mixing of water and if there is slightly high temperature in the wastewater site may be due to high decomposition of the waste or shallow water bodies (Ongom et al., 2017).

As know the pH is the most important operational water-quality parameters. pH of all samples were ranged between 6.36 to 7.15. Commonly, the pH values were remaining with the irrigation water quality standards (Amin and Aziz 2005; Aziz et al., 2019). .

TS, and TDS for the samples were ranged between 500 to 1200 mg/L and 100 to 600 mg/L respectively. As mentioned before that BW was first collected in cesspool (sometimes septic tank and cesspool were used) under houses and stayed there for a long time (approximately 2-3 years) so it is very normal that BW will be digested anaerobically by bacteria, and finally contains clay particles, fine organic debris and other particulate matter and in addition to that the existence of some organisms such as plankton, algae.

The ratio of VS/TS is a measure of OM content, which was found relatively found low for BW is 0.33 and for MWW is 0.4. The low organic content is one of the main obstacles for the efficient anaerobic digestion in many countries, this happened due to the shortage of carbon sources in the influent and in addition to that the wide application of the biological nutrient removal process in wastewater treatment plants (Feng et al., 2013). But it can be noticed that the VS/TS for BWMWW is 0.6, which means high OM content and energy content.

The ORP determinations reflect the redox state of water. The microbial disinfection can be described or depend on ORP. In general, it can be noticed from Table 1 that the ORP for all samples were low. For BW was negative vale (-8.1mV), a negative value of ORP indicates that a substance is a reducing agent. The lower the reading, the more anti-oxidizing it is. Previous study shows that the decreasing of ORP can be happened with increasing of pH regardless of the oxidant concentration and type (such as chlorine, mono-chloramine, chlorine dioxide and oxygen) (James et al., 2004). For MWW and BWMWW were positive values of ORP 8.6 and 40.1 mV respectively, these values are means that MWW and BWMWW are an oxidizing agent.

Oil and grease) values were ranged from 0.1 to 0.7 mg/L. The reported data in “Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories” for oil and grease were less than 5 mg/L (Board, 1992)

Table 2 illustrates biological characteristics of BW, GW, and BWMWW samples. Results of M.P.N of Coliform, Thermo tolerant, and M.P.N. of E.Coli for the collected samples were unsatisfactory. Consequently, disinfection process is necessary to overcome microorganism's problems (Metcalf and Eddy, 2014).

In general, it can be observed that all the physical and chemical properties of BW is higher than both MWW and the BWMWW.

Table 2. Biological characteristics of BW, GW and BWMWW

No.	Parameters	BW	GW	BWMWW
1	M.P.N of Coliform	16/100 ml	16/100 ml	16/100 ml
2	Thermo tolerant	2.2/100 ml	2.2/100 ml	2.2/100 ml
3	M.P.N of E. Coli.	2.2/100 ml	2.2/100 ml	2.2/100 ml
	Results	Unsatisfactory	Unsatisfactory	Unsatisfactory

A comparison between BW characteristics in Erbil City and published data on BW are shown in Table 3. It is noticed that the TS, TDS, oil and grease, BOD_5, COD, phosphate, M.P.N. Coliform and M.P.N. E. Coli for raw BW samples of other studies had greater values than the BW of current study (Wendland, 2008; Abdel-Shafy et al., 2017; Wasielewski et al. 2017). High values of nitrate and nitrite in Erbil BW may be due to occurrence of nitrification/denitrification processes in the cesspools (Aziz et al. 2012; Metcalf and Eddy, 2014). It is very important to mention that there are two main types of toilets are using in Erbil City, these types are the western style toilet and squat (Eastern type) toilets. Squat toilets are most common type and the people in this area are using plenty of water when they go to the toilet because they consider it more hygienic than toilet paper. Because of this important reason, it is noticed when making a comparison between the characteristics of the BW that is discharged in area near Azzah Village, Erbil City and BW of vacuum toilets it was found that analyzed BW in this work is much lower concentrations than the BW of vacuum toilets due to high water consumed for flushing in the ordinary toilets and high-water consumption by people. It can be noticed that the raw BW's analysed concentrations of the other studies are much higher than the raw BW of Azzah Village because of low water demand for flushing in vacuum toilets.

Table 3. Comparison of BW characteristics with the other studies

No.	Parameters	Units	BW Characteristics			
			Current work	Hussein I. Abdel-Shafy et al. (2017)	Wendland (2008)	Wasielewski et al. (2017)
1	Temperature	°C	21.10	10 - 35		
2	Turbidity	FTU/NTU	439.83	152.3		
3	TS	mg/L	1200		6530	
4	TDS	mg/L	600	841		
5	pH	-	7.15	7.16 - 8.1	7.7	6.7 -8.6
6	Oil & grease	mg/L	0.1	51.5 – 75.3		
7	NH_3-N	mg/L	106.5	3.7 – 9.3		
8	NO_2	mg/L	100	0.01– 0.06		
9	NO_3	mg/L	42.5	0.1 – 0.22		
10	BOD_5	mg/L	185	420 – 1420		3750–7424
11	COD	mg/L	314.76	835 – 1680	8060	3350- 25800
12	Phosphate	mg/L	10.45	17.9 – 35.4	9	
13	M.P.N of coliform		16/100 ml	$2.1x10^9$- $1.7x10^{10}$		
14	M.P.N of E. Coli.		2.2/100 ml		$9.1x10^7$ (Total Coli $1.3 x 10^8$)	

3.2. Impact of BW disposal on the surrounded soil

The characteristics of contaminated soil (which is taken from the BW disposal site) and normal soil (which is taken from the Engineering college, SU-E) are shown in Table 4. Analysis of soil samples revealed that values of the following parameters pH, ORP, EC, TDS, Salinity, Cl^-, OM, Ca, Cr, Mn, Cu, Ga, As, Zr, Mo, Sn, Sb, and Pb in the soil surrounded BW disposal area were higher than the normal (clean) soil sample. Additionally, it was notices there is no trace of Co, Nb, Hg, Th, and U for the both samples. So, it was clear from the results that disposal of BW to the environment without any treatment is increasing contamination of the surrounded soil. The percentage of OM in the polluted and normal soil samples were 6.1% and 2.1% respectively; it was clear that organic substances in the BW increased the OM in the contaminated soil. Mojiri et al. (2013) provided by their experiments that the application of wastewater caused increasing in many substances like EC, Cl, and OM.

But it was found that the contaminated soil has less values for other minerals such as SO_3, K, Ti, V, Mn, Fe, Ni, Zn, Rb, Sr, Y, Ag, and Cd than clean soil. This is could be happened because the BW stay long time in the cesspool so these chemicals are seepage to the soil around cesspool or septic tank. Table 4 shows the values of these chemical substances and minerals. Generally, heavy metals are more bioavailable for plant uptake at lower pH levels; therefore, the pH of sewage sludge is an important consideration for metal-toxicity potential to plants. Several researchers have shown that metal sorption by soils increased with increasing pH, OM, cation exchange capacity, and the contents of iron and manganese oxides. However, there is a lack of information concerning the adsorption of sludge borne heavy metals on different soils (Singh et al., 2011). Aziz and Maulood (2015) reported that Erbil landfill leachate affected on the surrounded soil and increased some paraments such as pH, Cl, EC, total salts, OM and SO_4 in the polluted soil.

Table 4. The analysis of contaminated soil and normal soil

No.	Test	Units	Contaminated Soil	Normal Soil
1	pH		7.06	7.01
2	ORP	mV	49.9	40.5
3	EC	µS/cm	423	207
4	TDS	mg/L	212	103
5	Salinity	PSU	0.20	0.10
6	Temperature	°C	21.96	22.18
7	$CaCO_3$	mg/L	1.0	1.1

8	Cl^-	mg/ L	45.092	11.273
9	OM	%	6.1	2.8
10	SO_3	%	0.515	0.943
11	K	mg/kg DW*	6569.924	14835.310
12	Ca	mg/kg DW	150817.5	116449.3
13	Ti	mg/kg DW	3699.272	3899.313
14	V	mg/kg DW	9.1915	132.5399
15	Cr	mg/kg DW	349.698	197.335
16	Mn	mg/kg DW	687.207	760.431
17	Fe	mg/kg DW	24650.95	34632.11
18	Co	mg/kg DW	0	0
19	Ni	mg/kg DW	130.481	220.710
20	Cu	mg/kg DW	109.662	26.226
21	Zn	mg/kg DW	47.321	58.536
22	Ga	mg/kg DW	11.662	6.315
23	As	mg/kg DW	8.973	4.019
24	Rb	mg/kg DW	32.245	44.850
25	Sr	mg/kg DW	214.509	249.404
26	Y	mg/kg DW	15.434	19.343
27	Zr	mg/kg DW	55.758	30.813
28	Nb	mg/kg DW	0	0
29	Mo	mg/kg DW	8.109	7.800
30	Ag	mg/kg DW	9.804	17.177
31	Cd	mg/kg DW	1.520	2.457
32	Sn	mg/kg DW	15.399	0
33	Sb	mg/kg DW	18.810	0.153
34	Hg	mg/kg DW	0	0
35	Pb	mg/kg DW	16.400	7.810
36	Th	mg/kg DW	0	0
37	U	mg/kg DW	0	0

* DW means dry weight

3.3. BW treatment methods

It can be noticed from results that color, NH_3-N, NO_3, NO_2, BOD_5, and COD for the BW samples were exceeded the wastewater disposal standards (EPA, 2003; Iraqi Environmental Standards, 2011; Aziz, 2020); Subsequently, the BW in Erbil City needs treatment prior disposal to the environment. Additionally, BW commonly impacted negatively on the MWW and increased the pollutants. On the other hand, biodegradability ratio (i.e. BOD_5/COD) for the BW, MWW and BWMWW samples generally were close to and greater than 0.5; this mean that the biological treatment processes are efficient for treatment of BW, MWW and BWMWW in Erbil City (Aziz et al. 2012; Aziz and Ali 2018). Collected BW sample contained nitrogen compounds, OM, and phosphate. This mean that all nutrients were not removed in cesspools and septic tanks and it acts as normal fertilizer.

To remove solids, OM and nutrients, raw wastewater must be subjected to physical, chemical, and biological processes. Specific treatment stages such as preliminary and primary, secondary and tertiary or advanced treatment of wastewater must be used (Metcalf and Eddy, 2014; Aziz et al., 2019)

Many studies were used for treated BW and GW anaerobically in a laboratory scale. One of the studies applied upflow anaerobic sludge blanket (UASB)-septic tank to treat concentrated BW under two different temperatures 15 and 25 ^{o}C. It was found that the removal efficiency of total COD was 61% and 74% (Kujawa-Roeleveld et al., 2005).

The other study applied also UASB–septic tank system to recover methane gas. In their work, the researchers added kitchen waste to BW to double the biogas production during the anaerobic treatment. Post-treatment of the effluent is providing recovery of phosphorus and removal of remaining COD and nitrogen. The total amount of energy saving by the new proposed sanitation concept was 200 MJ/p/year (Zeeman et al., 2008).

In Egypt, it was found that the combination of UASB and constructed wetlands were an effective system to treat BW and GW. The overall removal efficiency of COD, BOD and total suspended solids for GW were 87.7%, 89.5% and 94% and for BW were 94.2%, 95.6% and 94.9%, respectively (Abdel-Shafy et al., 2009).

Halalsheh et al. (2008) mentioned in their study about the importance of separate gray water from BW and then treated separately by low cost on-site treatment which does not exceed 300 US$/family. After treated it can be reused to irrigation their olive trees that planted their houses. The study examined three treatment systems which are: septic tank followed by intermittent sand filter; the second system was septic tank followed by wetlands; and the last one was UASB-hybrid reactor. The last system is differing from the conventional UASB reactor by the introduction of filtering media at the settling zone of the reactor. It was found that UASB-hybrid reactor would be the best option for house on-site treatment in the studied area (Halalsheh et al., 2008).

All the previous studies were carried on in the laboratory, but Sharma and Kazmi (2015) were carried out their study on the actual field in India. The study was onsite treatment of source- separated black water by applied modified septic tank followed by an anaerobic filter within the same unit (Sharma and Kazmi, 2015).

3.4 Statistical Analysis

Statistical Package for the Social Sciences (SPSS) version 26 was applied for the statistical analysis. Tables 5 illustrates correlations for BW, MWW, and BWMWW

There is a statistically significant and high positive correlation between BW and MWW scores, $r (22) = 0.738$, and $p < 0.01$. Which $r^2 = 0.545$, equal to 54.5% of the variance in BW scores is associated with the variance in MWW scores (i.e. only 45.5% of the variance in BW scores are not associated with the variance in MWW scores) $df = n - 2$. On the other hand, there is a statistically significant and high positive correlation between BW and BWMWW scores, $r (22) = 0.745$, and $p < 0.01$. Which $r^2 = 0.555$, equal to 55.5 % of the variance in BW scores is associated with the variance in BWMWW scores (i.e only 44.5 % of the variance in BW scores are not associated with the variance in BWMWW scores) df = n -2 and n=24. Additionally, there is a statistically significant and very high positive correlation between BWMWW and MWW scores, r (22) = 0.927 and p< 0.01. Which r^2 = 0.859, equal to 85.9 % of the variance in BWMWW scores is associated with the variance in MWW scores (i.e only 44.1 % of the variance in BWMWW scores are not associated with the variance in MWW scores) df = n -2 and n=24.

Table 5. Correlations for BW, MWW and BWMWW

		BW	MWW	BWMWW
BW	Pearson Correlation	1	0.738**	0.745**
	Sig. (2-tailed)		0.000	0.000
MWW	Pearson Correlation	0.738**	1	0.927**
	Sig. (2-tailed)	0.000		0.000
BWMWW	Pearson Correlation	0.745**	0.927**	1
	Sig. (2-tailed)	0.000	0.000	
**. Correlation is significant at the 0.01 level (2-tailed).				

Salinity is a measure of the content of salts in water or soil. Salinity was chosen for prediction of WW and soil contamination by the BW, because salinity represent the total available salts and it is good indicator for pollution. Forecasted salinity for the BWMWW is given in equation 1.

Salinty for BWMWW = 1.026 *Salinity for MWW (1)

Table 6 shows correlations for contaminated and normal soils. There is a statistically significant and very high positive correlation between contaminated soil and normal soil scores with r (35) = 0.989 and p < 0.01. Which r^2= 0.978, equal to 97.8 % of the variance in contaminated soil scores is associated with the variance in normal soil scores (i.e only 2.2 % of the variance in contaminated soil scores are not associated with the variance in normal soil scores) df = n -2, and n = 37. Equations 2 and 3 present the prediction of soil contamination by BW.

Salinity for Contaminated soil = 2 * Salinity for normal soil (2)

OM for contaminated soil = 2.179 * OM for normal soil (3)

It can be noticed that BW caused contamination of soil and resulted in approximately doubling of salinity and OM values in the contaminated soil.

Table 6. Correlations for contaminated and normal soils

		Contaminated Soil	Normal Soil
Contaminated Soil	Pearson Correlation	1	0.989**
	Sig. (2-tailed)		0.000
	No.	37	37
Normal Soil	Pearson Correlation	0.989**	1
	Sig. (2-tailed)	0.000	
	No.	37	37

**. Correlation is significant at the 0.01 level (2-tailed).

4. Conclusions

Based on the current research it was found that even the BW in Erbil City is diluted and not concentrated wastewater; But, all its physical and chemical properties are higher than both MWW and the BWMWW. Consequently, this kind of wastewater is commonly impacted negatively on the MWW and increased the pollutants to the nature of disposal site which means contaminated the soil in the surrounded area of the BW disposal site. Additionally, it was found that since there is no special treatment so all the nutrients were not removed and it acts as a good organic fertilizer for agriculture, if it processed scientifically. This study suggested a biological treatment processes are efficient to treat BW, MWW and BWMWW.

Results revealed that direct disposal of the BW caused increasing salinity in BWMWW and contaminated soil by 102.6 % and 200 %, respectively. While, OM was commonly doubled in the polluted soil as well.Statistically significant and high to very high positive correlations between parameters were achieved for both WW and soil samples. Effect of the BW discharge on the surrounded soil was greater than the influence on the MWW.

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