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ASSESSMENT OF GREY WATER DISPOSAL AND DIFFERENT TREATMENT OPTIONS FOR DOMIZ CAMP IN DUHOK CITY

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ABSTRACT

The objectives of this study are to characterize the grey water from Domiz refugee camp, to evaluate the impacts of grey water on the properties of soil, and to suggest different treatment options. Grey water produced in this camp is about 1380 m^3/d. The average grey water generation was estimated about 42 L/c.d. Grey water and soil samples were collected from stream channel at three different places. The results show concentrated grey water because of the water consumption was low inside the camp. Average Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total hardness, Calcium, Magnesium, Sodium, Potassium, Chloride, Sulfate, Nitrate, and phosphate values for the most polluted point were 1700, 1096, 540, 127, 65, 151, 29, 153, 232, 31 and 17 mg/L respectively. Impact of grey water on the properties of soil shows that Sodium Adsorption Ratio (SAR) values of soil samples increased compared to the control sample. Different treatment options were discussed for reusing the produced grey water. Because of the high level of TDS, availability of land, and low cost, construction wetland (CW) was selected as best option.

KEYWORDS: Grey water, Refugee Camp, Soil contamination, SAR, Grey water treatment.

1. INTRODUCTION

Duhok Governorate at 2012 hosts' large numbers of Syrian refugees escaped form hostilities in Syria. They were hosted in Domiz camp. The camp is located at the South-East of Duhok city with 42.89142378 36.78232231 GPS coordinates. It consists of two parts; Domiz I and Domiz II, the population of both parts is 33,209 (BRHA, 2017).

Based on the growing population changes, highly consumption of natural water resources increased, and relatively waste generation also increased. The need for searching new resources became subject of importance, one effectual method is to recycle and reuse waste water. Black Wastewater is well-defined as the waste produced from toilets, while grey water is defined as the waste produced from the kitchen (sink, dishwashers), bathtubs, showers, and wash basins. Because of highly chemical polluted contents, grey water from kitchens is defined as dark grey water or included in black water (Penn et al., 2011).

Grey water represents 50-80 % of the total waste, with lower contents of organic, nutrients, and pathogen in compared to black water, and it contains only 30% of organic and 9-20% of the nutrients (Smith & Bani-Melhem, 2012). Grey water composed round of 50-60 % water used in hand washing and bathing, it contains soap, shampoos, toothpaste, pathogenic micro-organisms may also be present, and it also contains body wastes such as hair, skin, body fats, and shaving waste. It is considered to be the least contaminated. Laundry grey water contributes in 25-35 % water used. It includes high concentrations of substances from detergents (including phosphorus, nitrogen, sodium, boron and surfactants), suspended solids, bleaches, non-biodegradable fibers from clothing, and possibly oils, paints and solvents. The COD is often high (Rodda et al., 2010). Finally kitchen contributes around 10-11 % of the total waste water (Rodda et al., 2010). Kitchen grey water includes food particles, high quantities of fats and oils, dish washing soaps, and can also contain drain cleaners and grease. Kitchen grey water may have pH from dishwashers, it's considered highly nutrient with highly concentrations of suspended solids content. Therefore, kitchen grey water could be dangerous to soils by changing its properties in the longer term and it is sometimes excluded from grey water stream unless treated (Morel, 2006; Rodda et al., 2010).

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World Health Organization (WHO) identified grey water as the biggest amount of the waste flow generated from families, it has lower nutrient and pathogen contents and can be used in crop irrigation, as well as can be help in fresh water demand reduction (WHO, 2006). Schaefer et al, (2004) defined the water reuse as using treated wastewater for useful purposes. Applications of reclaimed water include agricultural irrigation, non-potable urban and recreational reuse, and onsite grey water reuse (Schaefer et al., 2004).

Studies have described the impacts of grey water reuse on irrigation area and its environmental impacts. Most of the studies indicated the increase of sodium and salinity in soil. Sodium content can be expressed by SAR that represents the proportion of sodium content to calcium and magnesium contents. High soil SAR and salinity values lead to decline the permeability of soil, deteriorate the soil structure, and decrease the crop yields because of osmotic and toxic effects. (Bouwer & Chaney, 1974; Halliwell et al., 2001; Oster, 1994; Oster & Shainberg, 2001; Quirk, 1994). Travis et al (2010) proposed that soil ability to absorb water could decrease due to the high oil and grease content of grey water. Gross et al (2005) indicated that accumulation of surfactants and salts in the soil occurred due to using of grey water for irrigation of arid loess soil for long term subsequently caused modifications in soil structure properties and toxicity to plants. Patterson (1994) reported that as low as SAR 3 the loss of soil permeability commenced. Pinto et al. (2010) showed that soil pH and EC were considerably raised up because of grey water irrigation compared to potable grey water. Nevertheless, the organic material in grey water could enhance crop production.

Water reuse for the 21 century consider a great challenge for many investigators in areas with arid or semi-arid climates .In Middle East and North Africa they have adopted many methods for treatment and reuse of grey water such as in Jordan, Israel, Iran, and Egypt(WHO, 2006; Smith & Bani-Melhem, 2012). In Canada studies have been conducted on simple technologies to treat grey water and reuse for toilets flush and irrigation of food crops. In California, US, there are three types of grey water that can be used to irrigate plants (Schaefer et al., 2004). First one is coming from washing machine's internal pumps to deliver the water to the garden and this system called Clothes Washer System. The second one is coming from Simple System; these systems supply less than 250 gallons a day and reuse water from the bathroom sink or shower, and the third one is coming from Complex System; these systems supply more than 250 gallons a day and rely on surge tanks, pumps, and filtration systems to recycle grey water (Ogoshi et al., 2001). Four criteria should be accomplished for reused grey water treatment: environmental acceptance, aesthetics, hygienic safety, and technical and cost effective practicability (Al-Hamaiedeh & Bino, 2010) use of grey water have been studied since the 1970s. Physical treatment was the first technologies reported for instance, membranes and filtration usually followed by disinfection. After that between 1980 and 1999, biological treatments were examined for example, aerated bioreactors, biological aerated filters, and rotating biological contactors. At the end of 1990s, advance technologies for grey water treatment reported for example, membrane bioreactor (MBR) as well as cheaper technologies for example, reed beds and ponds (Jefferson, Palmer, Jeffrey, Stuetz, & Judd, 2004).

Many technologies have been developed and used for grey water treatment and recycle, the choice of the proper technology is depend on several influences: the cost effective factor, the purpose of the water after treatment, and the requirements of operation and maintenances (Laine, 2001). Based on the type of treatment, the grey water recycling treatment can be classified as five categories: (a) Simple treatment; the grey water moves through two stages: first stage is sedimentation or coarse filtration to remove the large solids and the second stage is the disinfection (Al-Wabel, 2011; Hall et al., 1974; Hills et al., 2001). (b) Physical treatment; this treatment is separated into two different sub-categories; membranes and sand filters. Membranes remove the suspended solids and dissolved solids excellently however, remove the organics poorly. Sand filters either can be used alone (Itayama et al., 2006) or with activated carbon plus disinfection, or with disinfection only (Hypes et al., 1975). (c) Chemical Treatment; consist of two treatment processes. The first one is for laundry grey water treatment the steps are coagulation with aluminum, sand filter and granular activated carbon (Kujawa-Roeleveld & Zeeman, 2006; Šostar-Turk, et al., 2005). The second process used for treatment of grey water with low strength and consist of electro-

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coagulation followed by disinfection. (Lodge, 2003). (d) Biological treatment; consists of wide range processes for treatment grey water; fixed film reactors(Hall Jr et al., 1974; Nolde, 2000; Santala et al., 1998; Ward, 2000), biological aerated filters (Birks, 1998; Jenssen et al., 2005; Lodge, 2003); MBR (Hills et al., 2001; Liu, et al., 2005), rotating biological contactor (RBC)(Eriksson et al., 2007; Friedler, et al., 2005; Nolde, 2000), sequencing batch reactor (SBR)(Hernández et al., 2010; Shin et al., 1998), and anaerobic filters (Liu et al., 2005; Šostar-Turk et al., 2005). (e) Extensive treatment; this treatment include constructed wetlands for instance ponds and reed beds. Pre-treatment is used such as sedimentation to remove the large suspended solids in grey water besides the constructed wetlands followed by sand filter for more particles removal (Gross et al., 2007; Pidou, et al., 2007).

The objectives of this study is to characterize the grey water discharged from the camp by regular monitoring a wide range of physical and chemical parameters, e.g. COD, TDS, pH, Electrical Conductivity (EC), Nitrate, Sulphate, Ca, Mg, Na, K, and Cl, to evaluate the impacts of grey water reuse on some soil physical and chemical properties, and to discuss and suggest different treatment options.

2. METHODOLOGY

2.1 Site selection

Domiz camp located at the north - east of IRAQ with 42.89142378 36.78232231 Global Positioning System (GPS) coordinates, and to south-east of Duhok city. The camp was selected as field of study. The camp hosted by 33,209 Syrian refugees. The daily grey water produced from the camp is estimated round to 1380 m3/d, based on 80 L/c.d water consumption. Domiz camp can be considered as a typical model for studying the grey water characterization and its impacts on the soil. Grey water is generated mainly from the hand wash, body wash, cloth wash and kitchen. Wastes drained directly to open conduits then collected and discharged to the nearby ground. The study relied on a program that to take samples from three field locations, starting with grey water upstream, the other two samples were collected downstream at 700 m, 300m intervals respectively, Figure 1 illustrate Domiz camp and field sample location.

2.2 Grey water sampling

Untreated grey water samples were collected, from stream flow that received grey water form Domiz camp, a total of fourteen (14) samples were collected during the study period. Six (6) samples were utilized for the grey water characterization; i.e. 3 samples per month; and were taken at distances shown in Figure 1 (B). The grey water samples were analyzed for physical and chemical characteristics, such as COD, TDS, pH, EC, hardness, alkalinity, Ca^{+2}, Mg^{+2},PO_4, Na^+, K^+, Cl^{-1}, NO_3^{+1}.

2.3 Soil sampling

Leachate is one of the main reason for soil pollution, consequently soil characterization be important to be investigated (Ramaiah and Krishnaiah, 2014). In this study soil samples were collected from grey water stream for months started from October 2016.

A total of 8 samples, three per each month with one sample considered as control soil sample which was taken from the ground nearby that received no grey water. The soil samples were taken from site locations shown in figure 1-B, at distances 0m, 700m, and 200m from the camp boundary, and at depth of 15 cm from the surface. Samples properly collected, labeled and transported to the laboratory. Soil samples were prepared by drying from air, sieving with 2 mm stainless steel sieve (Al-Hamaiedeh & Bino, 2010; Shin et al., 1998). After sample preparation, extraction of water is achieved in accordance with the modified standards test method (Ramaiah and Krishnaiah, 2014). Extraction of soil with water was done by mixing 10 gram soil with 100 ml distilled water (i.e. the soil-water ratio = 1/10), and shake in a mechanical shaker for 18 hrs (Ramaiah and Krishnaiah, 2014) (Al-Hamaiedeh & Bino, 2010; Shin et al., 1998). The surface water was decanting followed by centrifugal process, then all samples will be stored at 4°C before analyzing. The observed parameters were pH, EC, Ca^{+2}, Mg^{+2},PO_4, Na^+, K^+, Cl^{-1}, NO_3^{+1}, and the SAR.

2.4 Analytical methods

The grey water samples and the water extracted from the soil samples were analyzed for different physical and chemical parameters according to Standard Methods for the examination water and waste water (APHA, 2005; Mzini & Winter, 2015). Concentrations of COD were estimated by using 5220 C Closed Reflux titrimetric method. TDS using method 2540 C

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using drying method at 180 °C, total hardness and alkalinity were measured use methods 2320 (*#29) and 2340 (*#31) method described in the standard methods edition 22. Na^+ and K^+ were analyzed using atomic adsorption spectrophotometer (model HF 931401). While NO_3^{+1} and $SO_4^=$ concentration measured by using spectrophotometer (model CECL 9000). pH and EC were analyzed by using HANNA (model HF 931401) and conductivity meter (model JENWAY 4310). The methods were used to measure the average values during the research period

Equation 1 used to calculate the SAR values (Travis et al., 2010) the units of sodium, calcium, and magnesium should be in (meq/kg):

$$SAR = \frac{[Na]^+}{\sqrt{\frac{[Ca]^{2+}[Mg]^{2+}}{2}}} \dots\dots\dots\dots\dots . Eq\ (1)$$

3. RESULTS AND DISCUSSION

3.1. Grey water characterization

3.1.1 Quantity of grey water

The expected average grey water production in Domiz camp by different sources was 42 L/c.d (1380 m^3/d) depending on 33,209 population; 80 L/c.d of clean water to be supplied and according to 80% to be converted to wastewater (Finley et al., 2009) and then 65% from the wastewater to be converted to grey water (Shamabadi et al., 2015, Siggins et al., 2016). This production rate was lower than the European communities production rate which are ranged between 66 and 274 L/c.d. (Fittschen & Niemczynowicz, 1997; Jefferson et al., 2004; Palmquist & Hanæus, 2005) and the values in Arizona, USA (75.7-132.5 (L/c.d) (Shamabadi et al., 2015). However, it was higher than the reported production rate for Um Alquttain, Mafraq area in Jordan (15 L/c.d.) (Halalsheh et al., 2008).

3.1.2 Quality of grey water

Average concentrations of some chemical characteristics found in grey water and a comparison with literature are presented in Table 1. Grey water was found to have a neutral pH with increased TDS, COD, magnesium and nitrate values compared with most of literature. However the concentrations of different cations such as sodium, and potassium were in accordance with the previously performed research studies. Average COD, TDS, Total hardness, Calcium, Magnesium, Sodium, Potassium, Chloride, Sulfate, Nitrate, and phosphate values for the most polluted point were 1700, 1096, 540, 127, 65, 151, 29, 153, 232, 31, and 17 mg/L respectively.

The COD values reported by Halalsheh et al., (2008) and Al-Hamaiedeh & Bino, (2010) exceeded those observed in the current study because these studies were conducted in Jordan subsequently the low grey water generation rate was responsible for producing high COD. Abdel-Shafy et al., (2014a) reported higher values of Calcium, Magnesium, and Sodium compared with the values reported in the current study. In addition, significantly high concentration of sulfate was reported by Rodda et al., (2011). The grey water was sourced from different countries, as illustrated in Table 1. Most of the reported characteristics values for grey water in this study were reduced along the stream. For example, the COD values reported for points 1, 2, and 3 were 1700, 1250, and 1050 mg/L respectively.

Table 2 shows the permissible level for different countries standards in irrigation and by comparing with the characteristics in Table 1, the grey water in current study is not allowed to be used for any kind of irrigation according to Iraqi standards and other mentioned standards as well. The average values of COD, potassium, phosphate and magnesium for grey water are more than the permissible level of Iraqi standards. Besides, the chloride value is more than the allowed level according to the Iranian standard. In conclusion, the quantity and quality of grey water were varied due to the collection sources of grey water (Abdel-Shafy et al., 2014b) and the activities involved in its production (Li et al., 2009).

3.2 Effects of grey water on soil

Using the grey water for any type of land application probably will cause negative environmental effects (Muanda & Lagardien, 2008). Analysis was conducted for the water extracted from the collected soil samples. Table 3 shows the chemical parameters measured. Average EC, pH, nitrate, phosphate, potassium, chloride, calcium, magnesium, and sodium values for the most polluted points were 675 µs/cm, 8.22, 36, 2.18, 21, 32, 54, 25, and 22 mg/L respectively. Chemical parameter values were considerably higher for all grey water exposed soil samples than control soil samples. Chemical parameters indicated some degree of variability along the stream, in general the faraway the samples the higher the values for all parameters except for

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calcium it was decreasing with distance. Also, the values of chloride and magnesium declined again in point 3 sampling as shown in Table 3.

The collected soil samples were alkaline including the control samples but the alkalinities in the grey water exposed samples were higher than the control soil samples and these results were compatible with the results observed by (Siggins et al., 2016). The EC values in the grey water exposed soil samples were three folds higher than the control soil samples and this results were well-matched with what (Rodda et al., 2011) have reported, they have found that the EC values for soil samples irrigated with grey water were four fold increase compared with EC values of tap water irrigation soil sample. Moreover, Pinto et al. (2010) have indicated that using tap water instead of grey water for irrigation may prevent the soil from EC and pH increasing. On the other hand, Al-Hamaiedeh & Bino, (2010) have observed EC values for soil irrigated with treated grey water higher than the results of current study and it was specifically 1550 and 1830 µs/cm after 1 and 2 years of irrigation respectively compared to 523, 675, and 670 µs/cm for points 1, 2, and 3 respectively for current study.

The reported values of sodium were significantly higher than the control samples and this is owing to the use of cleaning products by the refuges inside the camp which contains high level of sodium (Mohamed et al., 2013; Revitt et al., 2011). Furthermore, Gross et al., (2005); Travis, et al., (2010) have reported that high level of sodium will cause soil hydrophobicity and impact the soil structure negatively as well as impact the capacity of the soil to support plant growth. The SAR values were calculated according to equation 1. These calculated values were higher significantly in the grey water exposed soil samples than in the control soil samples as shown in Table 3. Al-Hamaiedeh & Bino, (2010) have found that the SAR value for soil samples irrigated with treated grey water is 3.04 and it was comparable with the values of current study.

According to the Iraqi standards (IME, 2012) the allowable SAR value for irrigation is 6. Besides, Mace and Amrhein, (2001) have reported that SAR value of 5 have adversative effects on soil structure. Consequently, the SAR values for grey water collected samples were calculated. The observed values were 2.8, 2.9, and 2.69 for points 1, 2, and 3 respectively. Subsequently, these values would not be expected to have any negative effects to the irrigation.

3.3. Treatment options and suggestions

The grey water for the current study has a medium to high strength according to the characteristics in Table 1 consequently the physical and chemical treatment alone will not be sufficient enough then biological treatment will be necessary. Anaerobic biological treatment for grey water is not suitable because of the low efficiency removal for organic material and surfactants. On the other hand, the aerobic treatment for grey water can remove the biodegradable organic material very efficiently (Li et al., 2009). A number of biological treatments have been used for grey water treatment. For example, SBR (Hernández Leal et al., 2010; Shin et al., 1998), MBR (Lesjean & Gnirss, 2006; Merz et al., 2007), RBC (Eriksson et al., 2007; Friedler et al., 2005; Nolde, 2000), and CWs (Gross et al., 2007; Li et al., 2004). The MBR technology can be considered as an attractive application for grey water reuse, specifically in urban domestic houses due to high organic loading rate, excellent removal efficiency, stable effluent quality, low sludge production and small footprint (Lazarova et al., 2003). On the other hand, MBR is not the suitable treatment option for the current study because it require high investment and operational cost as well as advanced technical support (Lesjean & Gnirss, 2006; Merz et al., 2007; Paris & Schlapp, 2010; Winward et al., 2008). The strength of grey water in current study can be considered between medium and high therefore it can be treated by the SBR technology to meet the desired reuse standards. The SBR technology has several advantages such as: aeration tank and secondary settling tank can be obtained in a single vessel; capital cost savings by eliminating one tank and other equipment; flexible operation and control; essential nitrogen phosphorus removal capability;, and minimal footprint (EPA, 1999; Gerardi, 2011; Wang et al., 2009). Subsequently, SBR is appropriate for grey water treatment in current study nevertheless it needs nonstop power supply to guarantee suitable dissolved oxygen concentration as well as highly skilled operators (Dalahmeh et al., 2009; Lamine et al., 2007). Another technology for treating grey water is the construction wetlands. It is considered as the most cost effective technology for grey water treatment specifically in term of operation and maintenance as well as it is environmentally friendly

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technology. However, the suspended solids and microorganisms removal efficiency are not so high consequently it requires a post treatment such as filtration and / or disinfection to be within the recycling standards of grey water (Li et al., 2009). On the other hand, CWs has some disadvantages such as large footprint, and release of bad odors because of anaerobic decomposition in the deep parts of CWs (Dalahmeh et al., 2012; Dallas et al., 2004; Li et al., 2009; Torrens et al., 2009). Therefore, it is not appropriate to be used in the urban areas. Furthermore, Halalsheh et al (2008) pointed out that high evapo-transpiration rate during summer may occur due to the large area required by wetlands subsequently it may lead to a zero effluent from the system.

Based on the previous discussion we would like to recommend two options for grey water treatment in Domiz camp, one is for long term period and another for short term period. If the Syrian refugee camp is going to stay for long time then we recommend using the SBR application although it will be more costly specifically for the maintenance and operation. Regarding this option the grey water needs to be prepared for the biological treatment so we recommend using bar screen firstly to retain the coarse solids found in grey water then to use a small grit chamber to remove the heavier inorganic materials with specific gravity more than 2.65. Afterward to use an equalization basin to uniform the daily variation of grey water flow rate as well as to homogenize it subsequently the resulting grey water will be pumped to primary settling tank then the grey water will be ready to be applied to SBR for biological treatment finally a chlorination will be used for disinfection after that the quality of the effluent can meet the Iraqi standard as shown in Table 2 to be reused for irrigation. Another option we would like to recommend is to use the CW if the Syrian refugee camp is going to stay temporarily for a short time. This option requires low investment costs and simplicity of operation and maintenance. We recommend a pre-treatment for the grey water before the application of CW. The pre-treatment will include flowing the grey water through a screen to retain the coarse solids found in grey water then it will be transferred to a septic tank to remove a portion of biochemical oxygen demand and total suspended solids subsequently it will be applied to the CW finally a chlorination will be used for disinfection. In case this system is applied, the quality of the effluent will meet the Iraqi standard also as shown in Table 2 to be reused for irrigation. Finally, Because of the high level of TDS, availability of land, and low cost, CW is the best option.

4. CONCLUSION

The expected grey water generation in Domiz camp was 1380 m^3/d with average production per person of 42 litters. Grey water was found to have a neutral pH with increased TDS, COD, magnesium and nitrate values compared with most of literature. However the concentrations of different compounds such as sodium, and potassium were in accordance with the previously performed research studies. The average values of COD, potassium, phosphate and magnesium for grey water are more than the permissible level of Iraqi standards. Chemical parameter values were considerably higher for all grey water exposed soil samples than control soil samples. SBR application was recommended for long term period and CW was selected for short term option because of the availability of land and low cost.

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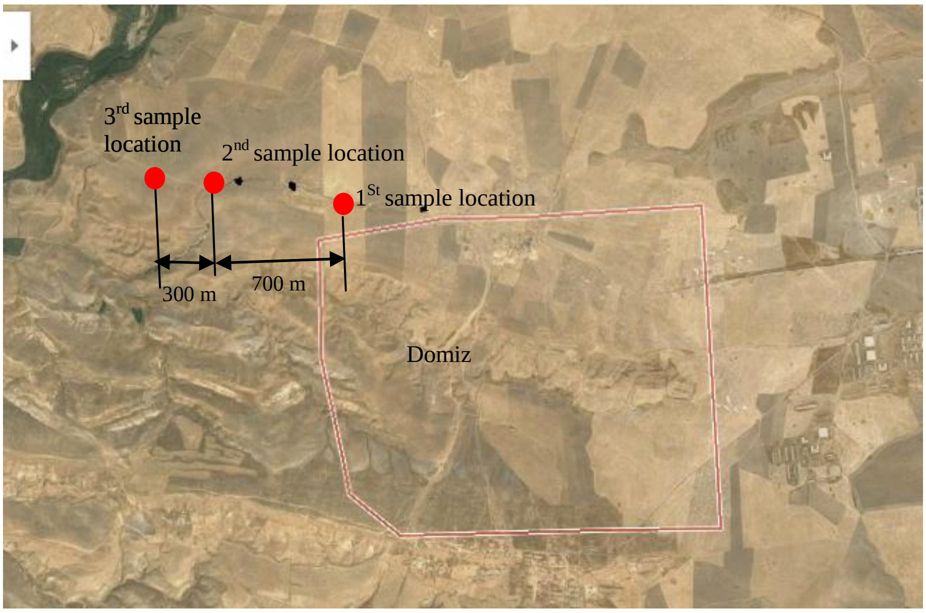
(A)



(B)

Fig. (1): (A) Domiz camp location, (B) Field sample location.

Table (1): Physical and chemical characteristics of Domiz grey water in (mg/L)

Parameter	Source			(Rose, Sun, Gerba, & Sinclair, 1991)[a]	(Eriksson, Auffarth, Eilersen, Henze, & Ledin, 2003)[b]	(H. I. Abdel-Shafy, Al-Sulaiman, & Mansour, 2014a)[c]	(Rodda et al., 2011)[d]	(Al-Hamaiedeh & Bino, 2010)[e]	(Halalsheh et al., 2008)[e]
	Point 1	Point 2	Point 3						
pH	7.2	7.27	7.26	6.54	7.6-8.6	6.71	8.1	7.2	6.35
EC (µs/cm)	1712	1601	1535		267	688		1830	1830
COD, mg/L	1700	1250	1050	76.3	77-240	392	280-310	1712	2568
TDS, mg/L	1096	1025	982			509.8			
Total hardness, mg/L	519	535	540						
Calcium, mg/L	121	127	109		99-100	290.3	8.3		
Magnesium, mg/L	53	47	65		20.8-23	105.6	7.5		
Sodium, mg/L	147	151	144		44.7-98.5	320.9	188		
Potassium, mg/L	29	24	24		5.9-7.4		31		
Chloride, mg/L	153	128	114						
Sulfate, mg/L	232	197	190	158			576		89
Nitrate, mg/L	31	22	22	9.3		0.4	88	0.64	
Phosphate (PO_4) , mg/L	17	14	6	9			40		

a: Arizona U.S.A., b: Denmark, c: Egypt, d: South Africa, e: Jordan

Table (2): Permissible level for different countries standards for recycled water used in irrigation.

Parameter	Iraqi standards for treated wastewater in irrigation (IME, 2012)	Iranian standards for recycled water in irrigation of green spaces (Shamabadi et al., 2015)	Jordanian standards (Halalsheh et al., 2008)		
			Cooked vegetables Category A	Tree crops Category B	Fodder crops Category C
pH	4-8.6	6.5-8.4	6-9	6-9	6-9
EC (µs/cm)		700			
TDS, mg/L	2500	450	1500	1500	1500
COD, mg/L	40		100	500	500
BOD_5, mg/L	10	30	20	200	300
Calcium, mg/L	400				
Magnesium, mg/L	60				
Sodium, mg/L	230	70			
Potassium, mg/L	20				
Chloride, mg/L		100			
Nitrate, mg/L	50				
Phosphate (PO_4) , mg/L	12	50	30	30	30

Table (3): The impact of grey water on soil properties.

Parameter	Source			Control sample
	Point 1	Point 2	Point 3	
pH	8.13	8.14	8.22	8.11
EC (µs/cm)	523	675	670	217
Nitrate, mg/L	13	21	36	7
Phosphate (PO_4) , mg/L	0.54	0.96	2.18	0.12
Potassium, mg/L	4.8	13	21	3
Chloride, mg/L	26	32	28	22
Calcium, mg/L	54	48	36	35
Magnesium, mg/L	20	25	18	13
Sodium, mg/L	14	20	22	5
SAR	1.31	1.84	2.36	0.58