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Municipal Wastewater Characterization and Natural Treatment Using Reed Beds

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Abstract

Domestic wastewater, if not correctly disposed of, is a cause of pollution for water-based bodies. The reed bed system is a sort of phytoremediation method used to remove toxins from the environment. This system has a high potential for application in the treatment of household wastewater (WW) because it has good performance as a whole, low operating and maintenance costs, and is not harmful to the environment. This research aimed to study characteristics variation of Grdarasha area WW (located in the left side of Erbil-Kirkuk main road) before and after reed beds. The reed bed system was proven to have a good efficiency in removing Chemical Oxygen Demand (COD) (15. 91-71. 07) %, Total Solid (TS) (8.33-50) %, Total volatile Solid (TVS) (18.8-50) %, and chloride (2.5 – 82.98%). In furtherance of transferring oxygen from the environment, the interplay between pollutant-plants-medium-microbes is critical in pollutant removal utilizing the reed bed technique.

Keywords: Erbil municipal wastewater (EMWW), Reed Beds, Treatment, Wastewater

Full length article **Corresponding Author*, e-mail: srwa_othman90@yahoo.com Doi # https://doi.org/10.62877/17-IJCBS-24-25-19-17

1. Introduction

For the sake of future generations, it is imperative to prevent ecosystem pollution from domestic wastewater (DWW), which is a major cause of pollution in water bodies [1]. However, because most treatment procedures include the use of chemicals and utilities, the expense of cleansing water bodies is rising. In order to solve this problem, low-cost, energy-efficient alternative home WW treatment technology is required; reed bed systems have recently received attention as a potential natural remedy [3]. In literature, researchers tried to treat WWs in Erbil City. Aziz and Ali [4] treated dairy and EMWWs by using biological trickling filter. Aziz and Ali [5] published a work on quality and treatment using different methods for WWs. Industrial WW and reusing were studied by Aziz et al. [6]. Oil refinery WW at Kawergosk arae treated by sequencing batch reactor and adsorption [7]. Firstly, moving bed biofilm reactor (MBBR), the sequencing batch reactor (SBR), and conventional activated sludge were designed for residential WW treatment and reusing in Erbil City [8]. Regarding treatment using Reed Beds application for municipal wastewater (MWW), Alsaad [9] worked on the treatment of MWW using engineering constructed Reed Bed (Sub Surface Flow) wetland system is going on for some time at the college of engineering\ Al-Nahrain University \ Baghdad. Also, Rahi and Faisal [10] investigated ability of using horizontal subsurface flow constructed wetland unit planted with Phragmites australis (common reeds) for MWW treatment of Al- Rustumia WWTP, Baghdad, Iraq as an alternative of conventional treatment methods. Furthermore, using a short-term batch reactor to treat actual home wastewater, Al-Ajalin et al. [11] evaluated the overall effectiveness of a pilot reed bed system planted with two native Malaysian plants, Scirpus grossus and Lepironia articulata. Furthermore, Sasirekha [12] demonstrated how to build a root zone bed and how this root zone treatment approach works well for removing a variety of pollutants. The outcomes for samples of raw and treated water were contrasted and talked about. For this reason, Omar [13] created wetlands systems with reed beds to handle household sewage in a variety of ways. Further, the system at Universiti Kebangsaan Malaysia (UKM) at Bukit Putri is highly helpful in removing micropollutants and nutrients from household sewage. Furthermore, Al-Ajalin [3] offered another method of treating the household WW in addition to providing a basic design of a phytoremediation reactor, particularly utilizing a reed bed system. The objectives of this study were to assess the overall efficacy of a pilot reed bed system for treating actual household wastewater in a brief batch experiment and to investigate the impact of treatment duration on the total amount of pollutants removed from the reed bed. The total effectiveness of the reed bed system's organic and nutrient removal from household wastewater is discussed in this research. The results that have been given might provide important information for the future field deployment of reed beds in treating residential WW.

2. Materials and Methods

2.1. Site description

2.1.1. Erbil municipal wastewater (EMWW)

The capital of Iraqi Kurdistan, home to almost two million people, is Erbil Governorate. Iraq's Erbil Province is located in the northeast. Its limits are located between latitude 35° 27′ N and 37° 24′ N and longitude 43° 15′ E and 45° 14′ E. EMWW originates from residential sewage, including WWs from bathrooms and kitchens, public business buildings and industrial zones, and storm water. The valley close to Turaq village, which is situated at 36° 10ʹ 14" N to 43° 56′ 12" E and 371 m above sea level, is where all WWs produced in Erbil City are dumped (Figures 1 and 2). The more than 50 km long effluent stream travels across a number of settlements and farmlands before emptying into the Greater Zab River. The quantity of discharged EMWW ranges from 0.85 m^3/sec to 1.7 m^3/sec [7].

2.1.2. Grdarasha area

Grdarasha area is located in the left side of Erbil-Kirkuk main road, Figure 3. Latitude and longitude values for the WW collection sample were 36.097410 and 44.021029, respectively. The location is far from Erbil City center around 10 km. WW produces from residential area, washing and commercial places. In the rainy season, surface runoff mixes with the WW. Reed beds are available in the right side of Erbil-Kirkuk main road which participates in removal of pollutants in the WW.

2.2. Sampling process

The samples were collected in six periods from Grdarasha area as shown in figure 4 (20 October 2022, 30 October 2022, 13 November 2022, 7 December 2022, 28 December 2022 and 2 March 2023). The plastic containers used for collecting the samples were quickly filled and brought to the lab. Before they were used in the experiment, they were kept in a refrigerator at 4°C to stop biological activity and changes in their properties [9]. Eleven water-quality criteria were examined in the samples that were gathered. These were the parameters that were specified: temperature (°C), pH, electrical conductivity (EC) (µs/cm), total dissolved solids (TDS) (mg/L), chemical oxygen demand COD (mg/L), chloride (mg/L), total solids (TS) (mg/L), total volatile solids (TVS) (mg/L), total alkalinity (mg/L), total acidity (mg/L), and color (Pt.Co). Figure 5 illustrates the locations of the tests, which were carried out in the Civil Engineering Department's Sanitary and Environmental Engineering Laboratory at Salahaddin University in Erbil, Iraq.

2.3. Analytical methods

The American Public Health Association's Standard Procedures for the Examination of Water and WW were followed for all testing APHA [14]. A spectrophotometer (DR/3900 HACH) was used to quantify color (Pt.Co) and COD (mg/L). Atmospheric pressure (mmHg), pH, and temperature (°C) were measured using HANNA Multiparameter Meter (HI9829-00202). Wissenschaftlich-Technische Werkstœtten-LF-42 and HANNA Turbidity meter-LP 200 were used to quantify EC (µs/cm), respectively. Digital weighing devices, filter paper, and an oven muffle furnace were used for the TS, TDS, and TVS experiments.

3. Results and discussion

3.1. Characteristics of Municipal Wastewater

Table 1 illustrates characteristics of EMWW in Erbil City from 1994 to 2020. It can be seen from the table some wastewaters parameters, like BOD, COD, TSS, NH3, NO3, NO_2, PO_4, Mg, Cd, Cu, Zn, color, Pb, Mn, oil and grease, and phenols, surpassed the principles for removal of WW. Therefore, treatment techniques are necessary earlier removal to the herbal surroundings or blending with water sources. Published works discovered that various treatment strategies which include sequencing batch reactor, adsorption, lagoons, oxidation ditch, wetland, and trickling filter had been studied for remedy of WWs in Erbil City [15]. The chemical composition of MWW varies greatly from one location to the next. Even within a single location, the composition of wastewater changes over time. Organic material is the most significant EMWW pollutant. The average BOD_5 for all EMWW samples was higher than the waste disposal standards and classified as weak wastewater [7] whereas the average COD was approximately 80.75 mg/L in accordance with guidelines. According to Bapeer [16] EMWW can be identified as weak to moderate based on its BOD_5 and COD values. However, some seasonal and station-specific variations were observed. Physical characteristics of the EMWW, including pH, temperature, color, and turbidity, met Iraqi environmental standards. The biological activity rate is influenced by temperature and increases by approximately double for every 10°C rise in temperature. The kind and quantity of dissolved, suspended, and colloidal particles that is present in WW determines its color. A high degree of color indicates the amount of industrial discharges. The presence of suspended particles was shown to be correlated with varying EMWW turbidity levels [17].

3.2. Wastewater Samples Characteristics and Natural Treatment Using Reed Beds

The basic idea behind reed bed eco-technology is to encourage the natural decomposition of harmful substances in a given WW condition by activating microbial activities. This is owing to the unique properties of wetland plants, such as reeds, which can transmit significant amounts of air oxygen through their root systems, promoting an exceptional number and species variety of microbes to thrive near their roots. The key objective commonly expected from such a treatment process is that the quality of the discharged water is accepted and come across the local guidelines. Table 2 illustrates the Grdarasha area WW samples test results.

Ambient temperature was varied from 10ºC to 35 ºC during collection of the samples. The samples' temperatures were ranged between 11ºC to 25ºC. It rained throughout of the sample time. The temperature of the water bodies in this region is influenced by a variety of variables, including water flow, which is connected to water mixing. If the temperature in the WW treatment area somewhat rises, it may be because of shallow waters or the intense decomposition of WW [18]. The most crucial operational water quality metric is pH, as is well known. Every sample had a pH in the range of 6.8 to 8. It is evident that the pH values increased after the reed beds, and these values—which range from 7.1 to 7.9—are higher than the neutral limit. The increase in pH value may be related to changes in the relationship between carbon dioxide, alkalinity, and pH due to algae consuming inorganic carbon dioxide from the underwater environment. In general, the pH value is still within irrigation water quality standards [6,19]. In addition, chloride concentration is between 16 to 94 mg/L and the removal percentage is (2.5 – 82.98%) after reed beds. Also, the physical characteristics such as pH, temperature and Chloride were remained within standard [15, 17, 20 and 21]. TS, TDS and TVS for the samples were ranged between 116 to 400 mg/L, 350 to 458 mg/L and 42 to 400 respectively, also the removal efficiency after reed beds are (8.33 – 50%), (9 – 16%) and (18.88 – 50%) separately. In some samples, solids increased due to the presence of clay particles, fine organic debris and other particles, as well as the presence of certain organisms such as plankton and algae. Furthermore, this research indicate that the salinity of the water samples are between 630-930.8 ms.cm-^{1} which is greater than the acceptable standards, generally, if the EC of irrigation water is below 0.7 dS.m^{-1}, it has not negative effect on the crop growth; when EC above 3 dS.m^{-1}, this can cause a severe damage for crop. The total alkalinity and total acidity for Grdarasha area samples are 200-296 mg/L and 20-104 mg/L respectively. It can be noticed from results of color for Grdarasha area samples were exceeded the WW disposal standards because of due to algae [20, 21] which is between 129 to 700 pt.Co; afterward, it is needs treatment prior disposal to the environment. Additionally, COD amounts ranged from 63 to 477 mg/L for samples from the Grdarasha region. High COD values indicate that WW contains common toxins and requires biological treatment. In addition, the COD removal efficiency after the reed bed is (15. 91-71. 07%), so the reed bed system meets treatment standards without operating costs. There is no electricity consumption. The reed bed system in the WW treatment process is the best. Because the mechanical process is less. That's beneficial from an economic perspective, then. The effluent water efficiency in the same samples is negative, indicating that there is more waste in the water after reed beds than there was before. This is because reed beds are influenced by a variety of factors, including their sensitivity to nutrient concentrations and toxic levels as well as their need for a steady supply of water. There's a chance of plant stress, signs of death, high temperatures, aphid damage, and vulnerability to nitrogen burn. The chances for developing negative micro-organisms and may lead to the accumulation of heavy metals in plants [22]. Furthermore, salt does build up in the test reed beds, particularly at the front side of the beds near the inlet where the bottom soil is located. This indicates that short circuiting is likely to occur, which means that there isn't any horizontal soil flow in this area. As a result, salt that is carried by water to the root zone will accumulate here and have an impact on the TDS and EC of the water that comes after reed beds. Additionally, a very large area is required to plant the reed beds. This therefore cannot be done for treatment plants where the available space is limited.

3.3. Reusing of Treated Municipal Wastewater

WW reuse after proper treatment can successfully help resolve the emergency situations that may occur in areas with inadequate water resources. Industrial, municipal, and household drains can be recycled. Reuse is permitted, provided that complete environmental safety is ensured (without harm to the existing cultural plants, soil, and ecosystem), and that any health hazards to the local population are eliminated. This needs strict adherence to existing health and safety regulations and also current laws for agriculture and industry [23]. Generally, reusing MWW can be categorized as indirect and direct reuse. Direct reuse of treated WW for drinking water is not currently a viable option because of health risks. Indirect reuse is using treated WW after returning it to natural water sources (i.e. aquifer, lake, and river) for dilution and purification. It consists of natural buffers for further spatial and temporal separation of treatment [24]. Investigators described that Erbil City's WW became now no longer secure for all kinds of irrigation earlier than treatment. They found that EMWW is proper for cooked vegetables and for irrigating green area [19]. Also, Aziz et al. [6] investigated on fresh WW samples had been gathered from Yörüksüt Dairy Factory and Erbil Steel Company and evaluated for 21 water pleasant parameters like COD, BOD_5, TSS, etc. were surpassed the standards for removal of WW. Therefore, treatment methods are vital for the previous disposal of WW to the surroundings or the use for irrigation objectives. Assembled at the functions of the WWs, the treatment methods together with primary, secondary and tertiary have been examined. Also, the great of uncooked wastewater samplings and suggested handled business wastewater have been in comparison with the irrigation recommendations WHO [25] so it can be suitable for irrigation aim. Additionally, Aziz [15] aimed to study features variants of EMWW, suitable treatment the usage of separate methods, and the suitability of the handled WW for disposal to the herbal surroundings or use for irrigation objectives. Treatment of EMWW the usage of each number one gadgets and wetland brought about elimination performance of 94.75 %, 93.07 %, 89.47 %, 96.72 %, and 57.68 % for BOD_5, COD, NH_3-N, TSS and PO_4, respectively which results the disposed discharges features to be within WW criteria. Hence, handled EMWW may be used for cooked greens and watering inexperienced areas.

Table 1. Characteristics of EMWW from 1994 to 2020 [15].

No.	Parameter	Range	Standards
1	pH	6.1-8.85	6-9.5**
2	Temp. (ºC)	10-31.5	35**, 40*
3	EC (µs/cm)	284-2300	
4	T. Salts (mg/L)	236.8-1800	
5	TS (mg/L)	300-10000	
6	TSS (mg/L)	40-1800	60**, 35*
7	TDS (mg/L)	100-8200	
8	Turbidity (NTU)	0.41-1000	
9	Chloride (mg/L)	0.86-165	750 *
10	T. Acidity (mg/L)	0.18-60	
11	T. Hardness (mg/L)	120-590	
12	BOD_5 (mg/L)	6.3-304	40**
13	COD (mg/L)	12.2-901	100**
14	NH_3-N (mg/L)	0.004-11.4	Nil**, 1 *
15	NO_2-N (mg/L)	0.001-26	1 *
16	NO_3 –N (mg/L)	0.003-47	50**, 10*
17	SO_4 (mh/L)	0.008-1220	1500*
18	DO (mg/L)	0-10.4	
19	PO_4 (µg/L)	0.0015-6.97	3**
20	Na (%)	6.1-73	
21	SAR (%)	0.19-16	
22	Total coliform cell/100 ml X 10^5	0.34-380	
23	Na (mg/L)	0.38-62	
24	Ca (mg/L)	1..8-85	
25	Mg (mg/L)	0.1-30.8	0.5**
26	Cd (mg/L)	0- 46.73	0.01**
27	Cu (mg/L)	0-18.69	0.2**
28	Zn (mg/L)	0-76.92	0.2**
29	Pb (mg/L)	0-61.76	0.1**
30	TVS (mg/L)	100-300	
31	TnVS (mg/L)	100-600	
32	BOD_5/COD	0.487-0.830	
33	Color (Pt.Co,)	186-379	Nil **
34	Mn (mg/L)	1.3-4.6	0.2 **
35	TOC (mg/L	19-180	
36	Phenols (mg/L)	0.044-0.102	0.01-0.05**
37	Oil & grease (mg/L)	0.04-1.05	Nil*, 10 **
38	ORP (Mv)	-107.4 - (-33.2)	
39	Salinity	0.26-057	
40	T. Alkalinity (mg/L)	157.3-340	

41	Alkalinity (%)	8.93-40.15	
42	TVC Bacteria (Cfu/mL)	$110*10^5$-$176*10^5$	
43	Phytoplankton density (Cells/L)	21787.5	
44	Total Bacteria Count ($X10^8$)	0.002-0.74	
45	Total bacteria cell/L x $l0^5$	0.047-193	
46	Total fungi cells/L X 10^4	0.035-240	
47	Discharge (m^3/s)	0.85-5.56	

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

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

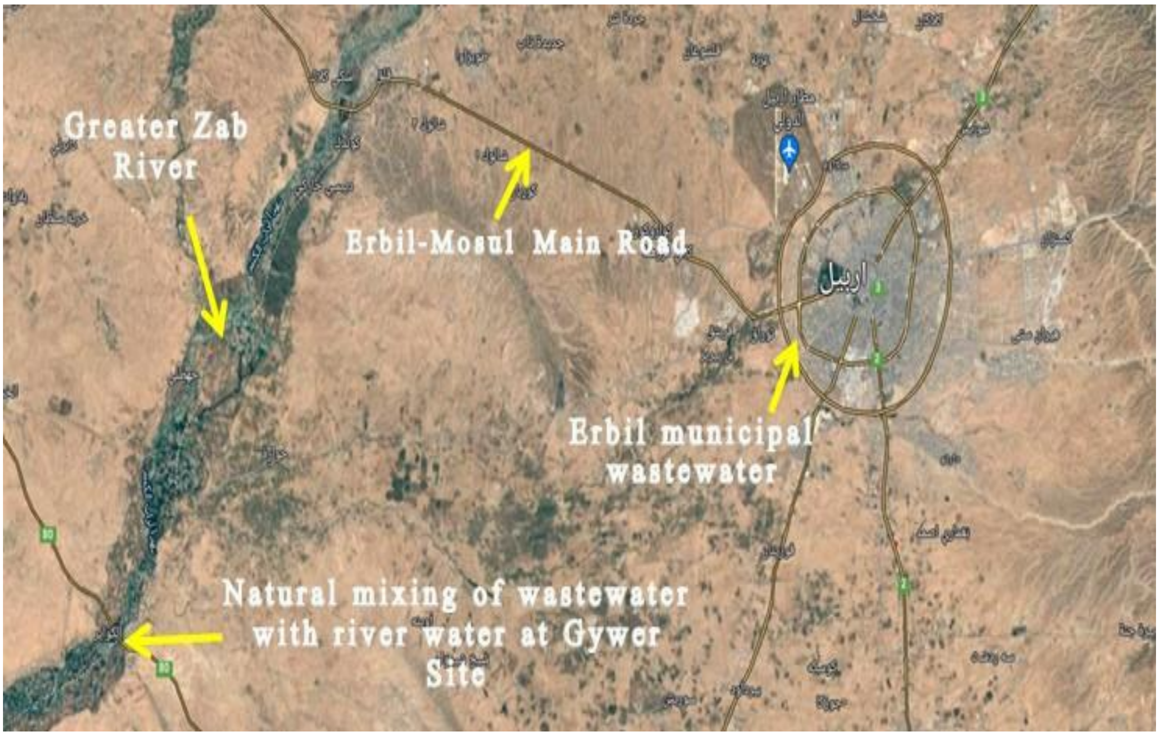

Figure 1. Satellite image (https://www.google.iq/maps/@36.1593852,43.8110409,38506m/data=!3m1!1e3

Table 2. Characteristics of WW at Grdarasha area in Erbil City

Date		20/10/2022			30/10/2022			13/11/2022		
Parameter	**Unit**	Grdarasha Discharge channel	Grdarasha after Reed beds	Removal Efficiency (%)	Grdarasha Discharge channel	Grdarasha after Reed beds	Removal Efficiency (%)	Grdarasha Discharge channel	Grdarasha after Reed beds	Removal Efficiency (%)
Atmosphere temp	C̊	37	37		31	31		27	27	
Wastewater Temperature	C̊	25	25		23	23		19.2	20.3	
pH		6.8	7.1		7.5	7.9		8	7.6	
EC	ms/cm	751	755	-0.53	798	930.8	-16.64	890	836	6.07
TDS	mg/L	376	378	-0.53	396	458	-15.66	439	420	4.33
COD	mg/L	477	232	51.36	96	63	34.38	280	81	71.07
Chloride	mg/L	79	55	30.38	72	82	-13.89	88	80	9.09
TS	mg/L	400	300	25.00	300	275	8.33	246	212	13.82
Volatile S	mg/L	100	50	50.00	84	67	20.24	70	42	40.00
T. Alkalinity	mg/L	224	280	-25.00	268	284	-5.97	296	208	29.73
T.Acidity	mg/L	88	64	27.27	104	56	46.15	72	48	33.33
Color	Pt.Co	209	129	38.28	393	175	55.47	148	700	-372.97

Disposing Standards	Range	2/3/2023			28/12/2022			7/12/2022		
		Removal Efficiency (%)	Grdarasha after Reed beds	Grdarasha Discharge channel	Removal Efficiency (%)	Grdarasha after Reed beds	Grdarasha Discharge channel	Removal Efficiency (%)	Grdarasha after Reed beds	Grdarasha Discharge channel
	18-37		17	15.8		18	18		22	22
35*, 40**	25-Nov		15.8	17.1		11	11		16.2	17.3
6-9.5*	6.8-8		7.7	7.5		7.85	8		7.2	6.8
	630-930.8	7.68	793	859	9.31	760	838	-4.17	825	792
	350-458	9.22	394	434	16.47	350	419	-4.56	413	395
100*	63-477	32.83	266	396	37.82	120	193	15.95	216	257
750**	16-94	82.98	16	94	2.50	78	80	2.86	68	70
	116-400	18.88	116	143	50.00	200	400	18.60	315	387
	42-400	18.88	116	143	-33.33	400	300	5.81	81	86
	200-296	12.50	140	160	0.00	280	280	-32.00	264	200
	20-104	52.00	12	25	0.00	20	20	12.50	28	32
Nil*	129-700	-72.70	1050	608	-159.43	454	175	71.67	170	600

Date: December 9, 2020

Date: March 2, 2021

Figure 2. EMWW main channel at Tooraq Area

Figure 3. WW sample collection at Grdarasha area

Figure 4. Grdarasha area WW and Reed beds

Figure 5. Sanitary and Environmental Engineering Laboratory, Civil Engineering Department, College of Engineering, Salahaddin- University-Erbil, Iraq

3.4. Irrigation of Agriculture Lands and Economical Study

It has proven more effective to use advanced irrigation generation rather than reduce off-site water quantity and quality problems. On an agricultural level, it may significantly improve water-use performance. However, a number of criteria will determine if generator adoption will result in significant water cost reductions for nonfarm and in-stream usage. The efficiency of generation in achieving environmental goals has significant consequences for local water regulations. Since agriculture is mostly carried out on small farms, it is a low-input, low-output system with little use of technology, which results in poor crop yields and financial profits. Crop yields are additionally hampered by the low quality of currently available agrochemicals, their overuse, and the paucity of organic fertilizers. Furthermore, low production is a result of most farmers having insufficient technical knowledge and farm equipment that is outdated [26]. Due to its heavy reliance on irrigation water, agriculture is one of the industry's most negatively impacted by droughts. Drought, for instance, destroyed about 40% of Iraq's agricultural in 2008 and 2009, while over 50% of Ninewa and Erbil's cropland suffered damage. The amount of farmed area that needs irrigation for wheat alone increased by 33% between 2000 and 2010, which made the threat of drought much more real [27]. In order to meet the nation's water demands in a sustainable manner, the Ministry of Water Resources established an aggressive approach in 2014. Even with Iraq's growing population, if this policy is properly executed, freshwater consumption will fall by 24.5% by 2035. The agriculture sector's reduced use of freshwater is mostly responsible for this decline. In order to reach an overall irrigation efficiency of 60%, the strategy calls for novel cropping patterns and crop combinations based on agroclimatic zones, as well as advances in on-farm water usage efficiency to 70%, conveyance efficiency to 90%, and operational efficiency to 95%. The sector's surface water use would drop by more than 30% between 2015 and 2035 if those gains were realized [27]. In the Kurdistan Region of Iraq, the Kurdistan Regional Government's (KRG) Ministry of Agriculture and Water Resources sets sectorial policies and strategies and develops additional water resources. Water and sewerage infrastructure in the region is the responsibility of the KRG's Ministry of Municipalities and Tourism [28].

4. Conclusions

According to the results of the trial, contaminants such as COD, TDS, TSS, and chlorides were considerably eliminated from household and WW samples in the reed beds following treatment. The control bed's pollution elimination capacity is effective. Reed Bed has been shown to be quite dependable in treating WW, particularly from household sources. A good reed bed design will provide a higher threat to achieve better pollution elimination efficiency by giving a higher herbal oxygen alternative. The planted reed bed system presented a removal of pollutant up to (8.33-50) % for TS, (18.8-50) % for TVS, (15. 91-71. 07) % for COD, and (2.5 – 82.98%) chloride, from the initial concentration. The inclusion of plants had a major effect when most parameters were removed. The outcomes were compared to the standard therapy. It has been observed that root zone treatment may be used independently for a small-scale unit or as an addition to a traditional treatment system for comprehensive WW treatment.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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