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Assessment of Sewerage System and Impacts of Wastewater on the Environment and Reusing in Erbil City

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ABSTRACT

This study provides a comprehensive assessment of the sewage system in the city of Erbil, Iraq, focusing on the wastewater's quality, quantity, and the environmental impact of untreated wastewater disposal. The city does not have a centralized wastewater treatment plant, although a design has already been approved. The study evaluates the current system by comparing existing data with previous research and highlighting the impact of lifestyle on wastewater characteristics in the region. The study highlights the dangers of reusing untreated wastewater for irrigation, which poses significant health and environmental risks, including groundwater contamination. Data was collected through site visits to various locations in the city of Erbil. The research discussed the current and potential impacts of wastewater on watercourses. It was found that the majority of wastewater in Erbil is discharged untreated into the environment, causing significant pollution problems. The total amount of produced wastewater and irrigated area is 257,184 m^3/day and 5,143,680 m^2/day respectively. In addition, the study concluded with recommendations for treatment processes suitable for the specific types of wastewater in Erbil. It emphasizes the importance of establishing a wastewater treatment plant to protect the environment in the area.

1. Introduction

Wastewater can originate from domestic/residential areas, industrial areas, commercial areas, surface runoff, landfill leachate, agricultural activities, infiltration and others (Aziz, 2019). In the current study, different types of wastewaters discharge to sewage system without any treatment except some of new residential areas like Cihan City and Italian-2 City etc. That means a certain rate of wastewater will percolate to groundwater. In many countries, groundwater is an essential water source for domestic, agricultural, and industrial use. In recent decades, demand for freshwater has risen sharply due to the rapid population growth and the fast development of industrialization (Gebrehiwot et al., 2011; Hawez et al., 2020). As a result of the insufficient amount of surface water, the demand for groundwater resources for drinking water, agriculture, and industrial purposes

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multiplied worldwide (Rajappa et al., 2011). Almost thirty percent of the world's population relies on groundwater resources to provide drinking water (Nickson et al., 2005). Groundwater forms 5 % to 7 % of the water resources in Iraq. Several villages, districts, and cities use groundwater as a main source of drinking water and agriculture purpose (Al-ansari et al., 2014). Groundwater has been used recently in the oil and gas sector in Kurdistan Region. Therefore, problems related to groundwater quality and management have to be given further consideration (Hawez et al., 2020). Another rate will evaporate, while the remaining flow of wastewater will discharge into the Greater Zab River, which poses a significant environmental concern. Consequently, industrial, agricultural and rural activities may result in pollution of water courses with elevated trace metal concentrations and implications for water supply and ecosystem functioning.

The disposal of wastewater into the Greater Zab River poses a significant environmental challenge. As wastewater flows are released, a portion of the water evaporates, while the remaining untreated wastewater enters the river system. This discharge risks contaminating the river, harming aquatic ecosystems, and affecting downstream water quality. Addressing this issue is crucial to prevent ecological degradation and ensure the health and safety of communities relying on the river for water resources.

Based on the literature, a gap in knowledge has been identified regarding the effectiveness of the current sewerage infrastructure in Erbil. Specifically, insufficient attention has been given to the lack of a specialized drainage system for storm water management, leading to flooding in residential areas and the discharge of untreated wastewater, which poses risks of groundwater contamination. The objectives of this study were: 1) to assess the shortcomings of Erbil's sewerage system, with particular focus on the interaction between surface runoff and wastewater, and 2) to examine the impact of storm water mixing with untreated wastewater on the environment and reusing of wastewater in Erbil City.

2. Materials and Methods

In the current research both quantitative and qualitative research methods were carried out. Site visits to the different locations in Erbil City were conducted. Interviews/Discussions with the related persons were carried out as well. The characteristics of Erbil municipal wastewater and some collected data were used in this work.

2.1. Study Area

The study area is located at the left side of Erbil-Mosul Main Road at Turaq, which is the main wastewater channel in Erbil City, Figure 1. Erbil municipal wastewater at Turaq commonly consists of wastewaters produces at residential areas like shops and super markets, restaurants, hotels and motels, car washing places, north industrial area, universities and schools, worship places, governmental and administration buildings, private sector houses and buildings, washings, infiltration, and losses of water supply system. Additionally, storm water is mixed with the municipal wastewater during rainy seasons and it dilutes the concentration of pollutants (Aziz, 2020).

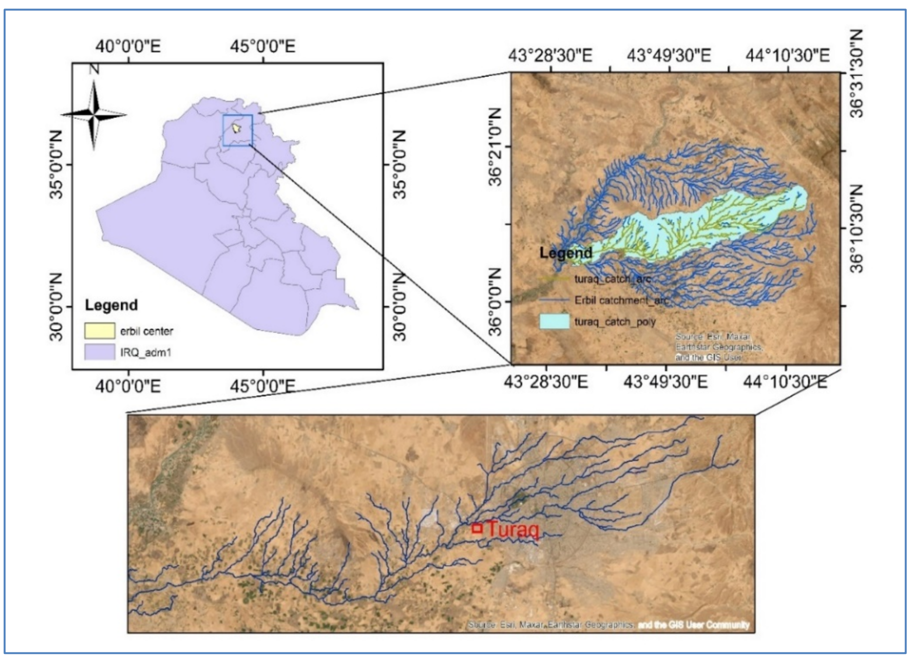

Figure 1. Location of study catchment area

2.2. Site Visiting to Erbil sewage wastewater locations

According to the current situation of the Erbil city sewage system and the directorate of Erbil sewage system, the main problems that occurred due to wastewaters include:

i) the amount of energy consumption that used to treat the wastewater,
ii) wastewater treatment plants also face the problem of a staffing shortage. Efficient and productive workers that are skilled in the business are necessary to properly treat wastewater, and
iii) the environmental footprint left by wastewater treatment plants is smaller and less impactful.

The present section describes the total of nine different site investigations of different positions in Erbil city that has the main problems of surface runoff of wastewaters comes from the various sources in that region. The main problems were clearly explained in the following configurations:

2.2.1. Shewasor Watershed (Kornish Road)

The Shewasur Watershed is located at the east of Erbil City Center, on the right side of the 120-meter main road along Kornish Road. The wastewater in this location is collected behind a designated green space, as illustrated in Figure 2. Some of this effluent contributes to surface water pollution when it flows off the ground. However, remaining wastewater seeps into the soil layers underneath, which could seriously contaminate the nearby groundwater. The region's ecosystem is seriously threatened by these two effects: groundwater contamination and surface water pollution.

Figure 2. Wastewater from Shewasor watershed on Kornish road

2.2.2. Roshanbiry Quarter

The wastewater from this site in Erbil city located near to 120 m-main road. As shown in Figure 3, the wastewater, which mainly comes from households or families, has been discharged into the natural environment without considering the harmful effects on the nature of the region and the health of the population.

Figure 3. Roshanbiry Quarter wastewater

2.2.3. Farmanbaran street

In Farmanbaran street shown in Figure 4 the wastewater was discharged directly into the closed environment without any treatment. In addition to the wastewater, the solid waste from the nearby houses was also removed and disposed of in a landfill. The high concentration of wastewater was to be analyzed during physical, chemical and biological treatment. In some cases, the wastewater was infiltrated through various layers below the ground surface and then discharged out through a well for the purpose of irrigation of an agricultural area.

2.2.4. Zaituna street

The same problem as aforementioned in Farmanbaran street was seen in the Zaituna street. As shown in Figure 5, the amount of wastewater can be seen as a stream inflow over the green geographical region. During long time of wastewater runoff, it may cause the outputting of an excess sludge. The recycling of sludge, containing useful organic matter and nutrients in agriculture is considered as the best solution. Some more modern treatment technologies are even able to reduce the burden of sludge by lowering its production.

Figure 4. Wastewater near from Farmanbaran street

Figure 5. Wastewater near Zaituna street

2.2.5. Altun city

The creation of filtration and treatment facilities for sewage in the Altun City was done as a complex in Erbil. Inside the Altun city, there is a source of wastewater that moves through a number of box culverts and then enteres to a trapezoidal channel at the city itself. This system is old fashion collection of sewages of households that cause many problems since the sewages goes through the city, Figure 6.

Figure 6. Total wastewater inside the Altun City

2.2.6. Turaq area

The big source of Erbil wastewater is the Turaq wastewater, Figure 7. The region impacted by this effluent has a significant water concentration that resembles a long river with distinct upstream and downstream parts. The black water needs the primary and secondary processes of treatment so this huge amount of water can return to the environment. Due to population constantly increasing, municipal wastewater treatment plants need expanding their capabilities.

2.2.7. Cihan city

The domestic wastewater treatment plant for the Cihan city project is finished, Figure 8. There are many different types of waste in the household including; food waste, paper, glass, metals, plastics. Disease, air pollution, and environmental damage can result from domestic waste. Residential waste can be treated using landfills, energy-producing combustion, recycling, and composting. The same configuration was also designed for wastewater treatment system in Italy-2 city.

2.2.8. Bnaslawa District

In some zones, graywater is channeled via the sewage system or transported through unlined canals outside the Bnaslawa district in the south, Figure 9. Later, the channeled wastewater spreads in the environment or enters the Kornish valley. In the rainy season, graywater mixes with stormwater and the mixed wastewater enters the Kornish Valley. In some areas, there are sewer systems with different lengths and different concrete sewer sizes of 0.75 m, 0.9 m, 1.0 m and 1.2 m. In addition, in other zones, box sewers with dimensions of 1.0 m x 1.2 m, 1.5 m x 1.5 m, 2 m x 2 m and 2 m x 2.5 m

Figure 7. Erbil wastewater at Turaq area

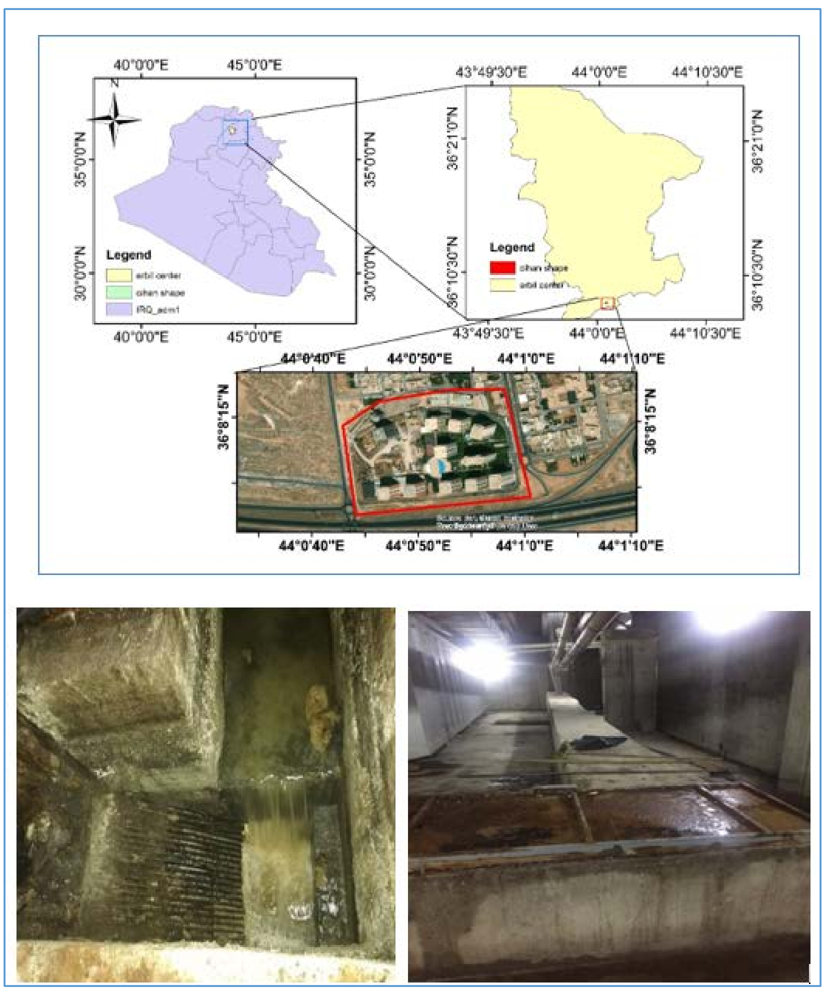

Figure 8. Wastewater treatment in Cihan city

Figure 9. Wastewater conveying by sewerage system and unlined channel

are available in different lengths. Black wastewater is normally treated in cesspools. About 2 % of black wastewater is illegally connected to the sewage system.

3. Results and Discussions

3.1. Quality of Wastewater in Erbil City

Life style, season, sewerage system, climate, and areas (or zones) had effect on the quality of the wastewater. Previous research has concluded that Erbil's wastewater is unsuitable for irrigation in all cases. For instance, (Aziz et al., 2019) specifically stated that Erbil's wastewater should not be used directly for irrigation purposes. Mainly, the treatment of Erbil municipal wastewater using various systems may lead to decrease of contaminants such as; organic matter, suspended solids, nitrogen compounds etc. As a result, treated wastewater can be used for the irrigation purpose. The produced wastewater from Bnaslawa district can be considered as weak wastewater and can be treated in wetlands and aerated lagoons (Aziz, 2024). Erbil municipal wastewater has been observed to be (weak/low to medium) wastewater type according to Aziz, (2020) and this found BOD5 values of (6.3 mg/L to 304 mg/L) for EMWW Erbil municipal waste water which is in agreement with published data. Lower COD values were reported in a number of South Korean Wastewater Treatment Plants by Choi et al. (2017). Similarly, lower BOD_5, COD, TSS, PO_4, NO_3-N, and NO_2-N for two municipal wastewater treatment plants in Indonesia. On the other hand, lower BOD_5, COD, NO_3-N, NO_2-N, and turbidity values for MWW Municipal waste water in there WWTPs Waste water treatment plants in Malysia (Aziz, 2020). The literature highlights variations in wastewater quality across different countries, emphasizing the importance of considering these differences when designing a centralized wastewater treatment plant for Erbil. Understanding these variations is crucial, as it helps ensure that treatment processes are tailored to address the specific characteristics and contaminants present in Erbil's wastewater, leading to more effective and efficient treatment solutions.

Fluctuations were noticed in the Erbil municipal wastewater quality and time had not great effect on EMWW characteristics. The causes of increasing discharge may refer to increase in human generation, leakage in water distribution system, expansion of size of the city and sewerage system, and additional storm water. It should be considered that the mixing of storm water and municipal wastewater caused the dilution of Erbil municipal wastewater, especially during rainy seasons.

The study also observed that the biological problems are available in EMWW; for these reasons both (treatment and disinfection) processes are necessary. In spite of this, the nutrients such as (organic matter, nitrogen compounds, and phosphate) are present in Erbil municipal wastewater, which can be used for agriculture and irrigation purposes. Also, heavy metals such as (Cd, Cu, Zn, and Pb) were found in Erbil municipal wastewater that exceeded the standard limitations of Wastewater discharge that needs extra treatments (Aziz, 2020). Usually, Disinfection process is required to eliminate biological problems. Based on the existence of oil and grease, PO_4, Mg, and Ca values for Erbil municipal wastewater, reclaimed Erbil municipal wastewater can be used for irrigation according to the standards., the details of the Erbil wastewater characteristics are tabulated from Table (1 to 3) (Aziz, 2020). Additionally, Characteristics of Ashty City wastewater are given in Table 4.

Table 1
Characteristics of Erbil Erbil municipal wastewater -Part 1 (Aziz, 2020)

Parameters	Range	Standards
pH	6.1-8.85	6-9.5*
Temp.(C)	10-31.5	35*,40**
EC(μs/cm)	284-2,300	
T.Salts(mg/L)	236.8-1,800	
TS(mg/L)	300-10,000	

Table 1 Continued
Characteristics of Erbil Erbil municipal wastewater - Part 1 (Aziz, 2020)

Parameters	Range	Standards
TSS (mg/l)	40-1,800	60*, 35**
TDS (mg/l)	100-8,200	
Turbidity(NTU)	0.41-1,000	
chloride	0.86-165	
T.Acidity(mg/L)	0.18-60	750**
T.Hardness(mg/L)	120-590	

*: Iraqi Environmental Standard (2011) (Aziz, 2020).
**: Environmental protection regulations (EPA) (2003) (Aziz, 2020).

Table 2
Characteristics of Erbil municipal wastewater - Part 2 (Aziz, 2020)

Parameters	Range	Standards
BOD_5 (mg/L)	6.3-304	40*
COD (mg/L)	12.2-901	100*
NH_3–N (mg/L)	0.004-11.4	Nil*, 1 **
NO_2–N (mg/L)	0.001-26	1 **
NO_3–N (mg/L)	0.003-47	50*, 10**
SO4 (mh/L)	0.008-1220	1500**
DO (mg/L)	0-10.4	
PO_4 (µg/L)	0.0015-6.97	3*
Na (%)	6.1-73	
SAR (%)	0.19-16	
Total coliform cell/100 ml X 105	0.34-380	

*: Iraqi Environmental Standard (2011) (Aziz, 2020)
**: Environmental Protection Regulations (EPA) (2003) (Aziz, 2020)

Table 3
Characteristics of Erbil municipal wastewater - Part 3 (Aziz, 2020)

Parameter	Value	Range	Standard
Na (mg/L)	30.6 - 32.1 0.38 - 2.3 62	0.38 - 62	
Ca (mg/L)	5.4 - 6.4 1.8 - 4.8 85	1.8 - 85	
Mg (mg/L)	2.8 - 3.4 0.1 - 0.42 30.8	0.1 - 30.8	0.5*
Cd (mg/L)	0 - 46.73	0 - 46.73	0.01*
Cu (mg/L)	0 - 18.69	0 - 18.69	0.2*
Zn (mg/L)	0 - 76.92	0 - 76.92	0.2*
Pb (mg/L)	0 - 61.76	0 - 61.76	0.1*
TVS (mg/L)	206.8 100 - 300	100 - 300	
TnVS (mg/L)	227.9 100 - 600	100 - 600	
BOD_5/COD	0.487-0.830	0.487 - 0.830	
Color (Pt.Co,)	186 - 379	186 - 379	Nil *
Mn (mg/L)	1.3 - 4.6	1.3 - 4.6	0.2
TOC (mg/L	19 - 180	19 - 180	
Phenols (mg/L)	0.044 - 0.102	0.044 - 0.102	0.01 - 0.05*
Oil & grease (mg/L)	0.04 - 1.05	0.04 - 1.05	Nil*, 10 **
ORP (Mv)	-74.2	-107.4 - (-33.2)	
Salinity	0.26 - 057	0.26 - 057	
T. Alkalinity (mg/L)	260 - 340 157.3 - 236 206 301	157.3 - 340	
Alkalinity (%)	17.67 - 19.11 8.93 - 40.15	8.93 - 40.15	
TVC Bacteria (Cfu/mL)	$110 \cdot 10^5$- $176 \cdot 10^5$	$110 \cdot 10^5$- $176 \cdot 10^5$	

Table 3 Continued
Characteristics of Erbil municipal wastewater - Part 3 (Aziz, 2020)

Parameter	Value	Range	Standard
Phytoplankton density	21,787.5	21,787.5	
Total Bacteria Count (X10^8)	0.002 - 0.74	0.002 - 0.74	
Total bacteria cell/L x l0^5	0.047 - 77 0.87 - 193	0.047 - 193	
Total fungi cells/L X 10^4	0.49 - 107.5 0.035 - 240	0.035 - 240	
Discharge (m^3/s)	0.85 - 1.7 1.23 - 2.61 1.696 - 3.582 5.56	0.85 - 5.56	

*: Iraqi Environmental Standard (2011) (Aziz, 2020)
**: Environmental protection regulations (EPA) (2003) (Aziz, 2020)

Table 4
Ashty City WW characteristics (Aziz et al., 2020)

No.	Parameter	Unit	Value 25 Feb. 2018	Value 27 March 2018	Disposing standards
1	pH		8.2	8.6	6.5 - 9.6*
2	Temperature	°C	14	14.9	<35*, 40**
3	EC	µs/cm	500	417.2	
4	Turbidity	FTU	18	20	
5	Total Acidity	mg/L	20	20	
6	Total Alkalinity	mg/L	200	212	
7	Total Hardness	mg/L	116	136	
8	Chloride	mg/L	26	24	750 **
9	Colour	Pt. Co	157	103	Nil *
10	Total salts	mg/L	300	267	
11	Total solids	mg/L	300	600	
12	TDS	mg/L	100	200	
13	Total Suspended Solids	mg/L	200	200	60*, 35**
14	Total non-volatile solids	mg/L	200	500	
15	Total non-volatile solids	mg/L	100	100	
16	BOD_5	mg/L	100	95	<40*
17	COD	mg/L	200	196	<100*
18	BOD_5/COD		0.5	0.48	
19	ORP	mv	-111.2	-131.3	
20	Ammonia	mg/L	7	7.2	Nil*, 1 **
21	DO	mg/L	5.6	5.3	
22	Nitrate (NO_3-N)	mg/L	4.1	3.5	50*, 10**
23	Nitrite (NO_2-N)	mg/L	8	9	1 **

*: Iraqi Environmental Standards (2011) (Aziz, 2020)
**: Environmental protection regulations (EPA) (2003) (Aziz, 2020)

3.2. Evaluation of Erbil sewerage system

3.2.1. Overview

Sewerage system from Erbil city conveys both sewage and stormwater into the downstream valleys of Erbil, eventually flowing into the Greater-Zab River. The city lacks a centralized wastewater treatment plant. According to the study by Mahmood (2020) the sewer network system extends to a length of 24 km. In general, the sewer network is composed of sewer lines, manholes, and inlets. First, sewer lines include both box and pipe lines of various sizes and construction materials. These materials range from ordinary concrete and reinforced concrete to different kinds of plastics, polyethylene, steel, cast iron, and ductile iron. The sizes of the box and pipe sewer lines vary, starting form a 20 cm diameter and going up to 3m by 3m for box sewers. Typically, smaller sewer lines are referred to as branches, larger ones as main sewers, and those in between as sub-mains. Second, manholes are built into both box and pipe sewer lines for purposes such as maintenance, and for facilitating bends and connections. Finally, inlets are used to collect wastewater. The sewer networks function entirely by gravity, hence the term "gravity sewer network", which is one of the oldest and most common types worldwide. Concerning the types of wastewaters, it generally includes stormwater and graywater, which are collected and transported by the sewer system to the drainage point (Ameen and Aziz, 2024a).

3.2.2. Septic tank and Cesspools

Cesspools and septic tanks are generally used for managing blackwater in Erbil City. Houses typically rely on cesspools, while both cesspools and septic tanks are utilized for schools, mosques, markets, and similar establishments. This practice has led to ground water issues, such as contamination with nitrate and nitrite. Recently, in response to new local government regulations, some compact units and small-scale wastewater treatment plants have been built, such as in Italy city 2 and Cihan city etc. Some of these facilities reuse treated wastewater for irrigation, particularly for landscaping and green zones (Ameen and Aziz, 2024a; 2024b). Additionally, the Ministry of Municipality plans to build a large-scale central wastewater treatment plant in Turaq valley. Currently, the groundwater table has significantly decreased as Erbil has developed rapidly, with a corresponding rise in population and water demand. The government is now focusing on the sewage system for reuse purposes and as an additional water source.

Blackwater from toilets is generally disposed to the cesspools in Erbil City. This cesspool is regularly lined with stone, concrete or brick and received the BW Blackwater 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 happens via gravity and a primary colony of bacteria digests the organic waste. Anaerobic digestion is considered one of the oldest technologies applied to treat wastewater. The main advantages of anaerobic digestion are biogas production and less amount of sludge production compared to aerobic treatment. Furthermore, it plays an important role in water management like reducing the consumption of high-quality drinking water, safe sanitation since the hazardous compounds in blackwater will not spread in the water cycle, production of biogas for domestics uses such as cooking, lighting ...etc. In addition, it produces organic fertilizer that is used in agriculture field. One of the major health hazards in many countries is the lack of sewer system and an efficient wastewater treatment plant, therefore the municipal wastewater and blackwater discharged directly to the environment (Alrawi et al., 2021)

3.2.3. Separate and Combine Systems

In sanitary engineering, the sewerage network is mainly divided into two types, namely a separate system and a combined system. Both types collect all types of wastewaters, i.e. rainwater, graywater and blackwater, as well as industrial and commercial wastewater. Consequently, household and other types of connections cannot be effectively implemented due to the lack of sewer branches throughout the area. This situation leads to several issues, including health risks from pathogen exposure, persistent odor problems, and the need for frequent municipal cleaning. Ideally, stormwater should flow into designated inlets, while houses and other structures should be properly connected to the sewer network to prevent these problems.

3.2.4. Current Situation

The current sewage system in Erbil remains incomplete. The city lacks a wastewater treatment plant, and the system is neither fully combined nor separate. It operates as a stormwater sewer system, which is inadequate for a city of Erbil's size. Additionally, the network has several well points that become problematic during heavy rains, such as in Gilkand quarter near Langa Bazar, 100 m street near Akar oil station, Tayrawa near Bayz interaction, and under the Saydawa bridge. Some sections of the sewer system are completely or nearly blocked, particularly in areas like downtown, Shekh Alla, Badawa, Setaqan, and some parts of 30 m street. The entire sewage system also suffers from a lack of maintenance, including in manholes and inlets. Currently, untreated sewage is sometimes used for irrigation during the summer season, transported by tankers.

Finally, the sewer network in Erbil is primarily a gravity sewer system, with the majority consisting of pipe sewers and a smaller portion made up of box sewers. Concrete, both ordinary and reinforced, is the most commonly used construction material, followed by plastic and polyethylene, with steel and iron being used to a lesser extent. Polyethylene is currently the preferred material in sewage projects due to its advantages, though it also has drawbacks. Topography plays a crucial role in the system, as the slope directly influences the velocity within the sewer lines, affecting sedimentation. Proper household connections or connections from any structure to the sewer network are essential to avoid the issues mentioned earlier. Additionally, wastewater can be reused for various purposes, which supports surface and subsurface water sources as part of the water supply system (Ameen and Aziz, 2024a; 2024b).

3.3. Quantity of Wastewater

Quantity of municipal wastewater in the main channel at Turaq area from 2001 to 2020 varies between 0.85 m^3/s to 5.56 m^3/s (Aziz, 2020). Expected total amount of produced wastewater in Erbil City can be calculated as follow:

No. of Population in Erbil City in 2020 = 846,000 Capita (Ismael and Aziz, 2024a)

Water supply per capita = 380 LPCD (Ismael and Aziz, 2024a)

80 % of water supply becomes wastewater.

Total quantity of wastewater = 846,000 Capita x 380 LPC x 0.8 = 257,184,000 L/day = 257184 m^3/day

Suppose each square meter needs 20 L for irrigation,

Irrigated area = 257,184,000 L/day ÷ 20 L/m^2 = 12,859,200 m^2/day = 5143. 68 donums/day = 5,143,680 m^2/day

3.4. Impact of the Wastewater on the Environment

Municipal solid waste (MSW) disposal systems include open dumping, sanitary landfill, composting, and incineration. Sanitary landfill is the best public MSW disposal technique because of easy disposal method, low budget, and landscape-restoring effect on holes from mineral workings. However, the production of highly contaminated landfill leachate is a chief shortcoming of this technique. Gas and inert solids comprise other products of landfills. Leachates may contain large quantities of organic pollutants, nitrogen compounds (e.g., ammonia), suspended solids, heavy metals, inorganic salts, phenols, and phosphorus (Maulood and Aziz, 2016). According to the Erbil sewerage system, the surface runoff of storm rainfall mixes with wastewater. The lack of a special designed drainage system dependent on the quantities of water coming from rainstorms means that manholes are unable to draw rain quantities and some of residential areas will be flooded. Thus, the current wastewater management system in Erbil is inadequate, as untreated wastewater from various sources is discharged directly into the sewage system, leading to potential groundwater contamination. Alrawi et al. (2021) stated that direct disposal of the blackwater to the environment caused pollution for the municipal wastewater and the surrounded soil.

3.5. Reusing

Wastewater reuse afterward appropriate treatment can positively help resolve the emergency situations that may occur in areas with inadequate water resources. Industrial, municipal, and household wastewaters can be reused. Reusing is allowed, provided that complete environmental safety is guaranteed and that any health hazards to the local population are removed. This requires strict compliance with existing health and safety regulations and with agricultural and industrial legislation. When reusing municipal wastewater, a general distinction is made between indirect and direct reuse. Direct reuse of treated wastewater for drinking water is not currently a practical option because of health risks and availability of water resources in the selected area. Indirect reuse is applied when the treated wastewater is used for dilution and purification after being returned to normal water sources. It includes natural buffers for further spatial and temporal separation of treatment (Ismael and Aziz, 2024b; Ismael et al., 2024). The authors described that Erbil City's wastewater is no longer safe for all kinds of irrigation before treatment. They found that Erbil municipal wastewater is suitable for cooked vegetables and irrigation of green areas. Treatment techniques are vital for the earlier disposal of wastewater to the surroundings or the use for irrigation purposes. In the functions of wastewater, the treatment processes were studied along with primary, secondary and tertiary treatment. Additionally, municipal wastewater with appropriate treatment, the practice of separate approaches and the suitability of treated wastewater for disposal to the plant environment or use for irrigation purposes were investigated (Ismael and Aziz, 2024b; Ismael et al., 2024).

4. Conclusions

The absence of a centralized wastewater treatment plant has led to significant environmental challenges, including groundwater contamination and inadequate sewage management. The sewage system, which functions primarily as a gravity sewer system, is incomplete and inadequately equipped to meet the city's needs, especially during heavy rainfall. In addition, the improper use of untreated wastewater for irrigation poses serious health and environmental risks. The study highlights the need for improved sewage infrastructure, including proper household connections, the construction of a large-scale wastewater treatment plant, and the adaptation of sustainable wastewater reuse practices to support water resources. The condition of the sewerage infrastructure was assessed, and areas in need of improvement were identified. The quality and quantity of wastewater was thoroughly analyzed, highlighting the main issues related to treatment and potential risks. In addition, the possibilities for wastewater reuse were investigated, highlighting opportunities for sustainable water management. It was found that urgent actions and improvements are needed to improve the efficiency, safety and sustainability of Erbil's wastewater system. The total wastewater volume and irrigated area are 257,184 m^3/day and 5,143,680 m^2/day respectively.

Based on the findings, several measures are recommended to address the critical problems in Erbil's sewage system. A centralized wastewater treatment plant should be built to mitigate the environmental problems, including groundwater pollution. Proper household connections need to be established to ensure full integration of the gravity sewer network. Sustainable wastewater reuse practices also need to be introduced to reduce dependence on untreated wastewater for irrigation.

These measures should be prioritized to improve the city's wastewater management system, especially in light of rapid population growth and development. By implementing these recommendations, environmental protection and public health in Erbil can be ensured in the long term. It is important to consider the following points for future study:

- Construction of a large centralized wastewater treatment plant for the city of Erbil,
- Use of sulfate-resistant cement for concrete and increased use of polyethylene (PE) and glass fiber reinforced plastic (GRP) pipes,
- Increasing the safety factor for the capacity and dimensioning of sewer pipes and boxes, which means that they function very well during floods or rainy days, especially in spring and winter,
- The layout of the sewer pipes is also an important natural valley that must be taken into account during planning and construction,
- Continuous maintenance of the sewers is important to ensure that they do not clog and function well at all times, Compact units to be built for each type of project, as well as the installation of strainers and grease interceptors (FOG), e.g. in restaurants,
- Avoid deep excavations for wastewater pipes and use other alternatives.

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Procena kanalizacionog sistema i uticaja otpadnih voda na životnu sredinu i njihovo ponovno korišćenje u gradu Erbil

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INFORMACIJE O RADU

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Ekološki rizik
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Kvalitet i količina
Kanalizacioni sistem
Otpadne vode

I Z V O D

Ova studija pruža sveobuhvatnu procenu kanalizacionog sistema u gradu Erbil, Irak, sa fokusom na kvalitet i količinu otpadnih voda, kao i na uticaj ispuštanja neprečišćenih otpadnih voda na životnu sredinu. Grad nema centralizovanu fabriku za prečišćavanje otpadnih voda, iako je njen projekat već odobren. Studija procenjuje trenutni sistem poređenjem postojećih podataka sa prethodnim istraživanjima, naglašavajući uticaj načina života na karakteristike otpadnih voda u regionu. U radu se ističu opasnosti od ponovnog korišćenja neprečišćenih otpadnih voda za navodnjavanje, koje predstavlja značajne zdravstvene i ekološke rizike, uključujući kontaminaciju podzemnih voda. Podaci su prikupljeni kroz posete različitim lokacijama u gradu Erbil. Istraživanje razmatra trenutne i potencijalne uticaje otpadnih voda na vodotoke. Utvrđeno je da se većina otpadnih voda u Erbilu ispušta neprečišćena u životnu sredinu, uzrokujući ozbiljne probleme sa zagađenjem. Ukupna količina proizvedene otpadne vode i navodnjavane površine iznosi 257184 m^3/dan i 5143680 m^2/dan. Pored toga, u radu se nalazi i preporuka za procese prečišćavanja koji su pogodni za specifične vrste otpadnih voda u Erbilu. Naglašava se važnost uspostavljanja fabrike za prečišćavanje otpadnih voda radi zaštite životne sredine u ovom području.