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Drainage water and its investment in agriculture in Muqdadiyah city

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Abstract : Water scarcity and the deterioration of water resources are among the most prominent challenges facing the agricultural sector in Iraq, particularly in resource-limited areas such as Muqdadiyah District in Diyala Governorate. With the continued decline in water revenues from traditional sources, the need to explore unconventional alternatives has emerged, including agricultural drainage water. This research aims to study the status of drainage water in Muqdadiyah City, in terms of its quantity, quality, and potential impact on agricultural production when reused after treatment or within certain standards. The research also discusses the environmental and economic aspects associated with the reinvestment of this water, with a focus on crops that tolerate high salinity levels and the use of appropriate irrigation methods. Preliminary results indicate the presence of significant quantities of drainage water, but its quality varies depending on the region and drainage source. Some samples show high levels of salts and heavy metals, requiring partial treatment or mixing with fresh water. With the adoption of modern agricultural technologies and rational water management, drainage water can contribute to alleviating the water crisis and achieving relative sustainability for local agriculture in Muqdadiyah.

Keywords: *Drainage water , agriculture , Muqdadiyah city, heavy metals*

مياه البزل واستثمارها في الزراعة في مدينة المقدادية

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المستخلص: يُعد شح المياه وتدهور الموارد المائية من أبرز التحديات التي تواجه القطاع الزراعي في العراق، ولا سيما في المناطق محدودة الموارد مثل قضاء المقدادية في محافظة ديالى. ومع استمرار انخفاض الإيرادات المائية من المصادر التقليدية، برزت الحاجة إلى البحث عن بدائل غير تقليدية، من بينها مياه البزل الزراعي.يهدف هذا البحث إلى دراسة واقع مياه البزل في مدينة المقدادية من حيث كميتها ونوعيتها وإمكانية الاستفادة منها في الإنتاج الزراعي عند إعادة استخدامها بعد المعالجة أو ضمن معايير محددة. كما يناقش البحث الجوانب البيئية والاقتصادية المرتبطة بإعادة استثمار هذه المياه، مع التركيز على المحاصيل المتحملة للملوحة العالية واستخدام طرائق الري المناسبة. تشير النتائج الأولية إلى وجود كميات ملحوظة من مياه البزل، إلا أن نوعيتها تختلف تبعاً للمنطقة ومصدر البزل. وقد أظهرت بعض العينات ارتفاعاً في تراكيز الأملاح والمعادن الثقيلة، الأمر الذي يتطلب معالجات جزئية أو خلطها بالمياه العذبة قبل استخدامها في الري. وفي ظل تبني التقنيات الزراعية الحديثة والإدارة الرشيدة للموارد المائية، يمكن لمياه البزل أن تسهم في التخفيف من أزمة المياه وتحقيق درجة من الاستدامة النسبية للزراعة المحلية في مدينة المقدادية.
الكلمات المفتاحية *: مياه البزل؛ الزراعة؛ مدينة المقدادية؛ المعادن الثقيلة.*

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1.0 Introduction

Many agricultural areas in Iraq face significant challenges related to water scarcity and deteriorating water resources. Muqdadiya District, in Diyala Governorate, is one of the areas suffering from declining water levels and declining cultivated areas due to water scarcity, the policies of neighboring countries to cut off and dry up the sources of the Diyala River, drought, and climate change (De Wrachien et ,al ,2021) . Under these conditions, the need to explore unconventional alternatives to support the agricultural sector has emerged. One of the most prominent of these alternatives is "drainage water," which is water drained from agricultural lands due to over-irrigation or rising saline groundwater levels (Elnashar et al, 2023). Although drain water is considered relatively low-quality, it represents a water resource that can be exploited when treated or used in a thoughtful manner in agriculture, especially in areas experiencing a scarcity of fresh water. Hence, the importance of studying the potential for investing in drain water in agriculture within the city of Muqdadiya, highlighting the challenges facing this use, and its future prospects in supporting local food security. The agricultural sector in Muqdadiya suffers from a sharp decline in the amount of water available for irrigation, leading to a decline in agricultural production and threatening local food security (Hejase et al ,2021). Meanwhile, large quantities of drain water are wasted without being utilized, despite its potential to support agriculture if properly utilized. Available indicators do not record precise details about the first drainage project in the world. However, studies conducted by the Food and Agriculture Organization of the United Nations (FAO) indicate that drainage science is not as ancient as the knowledge of agriculture and irrigation, but it is not entirely recent (Freeman et al ,2022). The Greek historian Herodotus noted the use of drainage operations in the Nile Valley in (400) BC, indicating an ancient knowledge of this technology (Mishra et al ,2023). The drainage system spread more widely throughout the world in later periods, especially in humid areas that required open surface drainages. Drainage projects in the United Kingdom began at the beginning of the seventeenth century using open drainages, while vertical drainage appeared in the second half of the eighteenth century (Awogbemi and Von Kallon ,2022). Drainage witnessed significant development in the early nineteenth century when scientific applications began using clay pipes to construct covered drainages. These pipes later evolved from a horseshoe shape to a cylindrical shape. Concrete pipes were first used in the Netherlands in 1830, with a diameter of (5) cm and a length of (120) cm (Getahun et al ,2024). They were later modified to a diameter of (15) cm and a length of (60) cm due to difficulties in use. The twentieth century witnessed a significant expansion in the implementation of drainage networks around the world, and the Netherlands was at the forefront of countries interested in these projects, given that more than (50%) of its land lies below sea level (Al Hamedi et al ,2023). In Iraq, approximately (60%) of agricultural land suffers from problems of high groundwater levels and salinity (Zahoor and Mushtaq ,2023). Serious attention has begun to be paid to the problems of drainage and the reclamation of lands affected by salinity in recent decades, especially after the adoption of incorrect land exploitation methods and the absence of proper planning for irrigation networks, which exacerbated the problem of waterlogging and increased salinity (Pandit et al ,2021). Rising levels of saline groundwater have caused the degradation of agricultural land. The estimated rate of degradation of salinity-affected lands is approximately (1,000) dunums annually, with the total area of affected lands amounting to approximately (28) million dunums of the total arable land (Hernandez et al , 2024). The importance of drainage is not limited to draining excess water from the soil, but extends to improving the physical environment in the root zone, which enhances plant growth (Benyam et al, 2021). Drainage contributes to increasing soil porosity, allowing for better root aeration and gas exchange, which is crucial for plant health (Zhang and Koukou ,2023). Among the important benefits of drainage networks is reducing the phenomenon of "scalding," a common problem in hot regions during the summer (Christou et al ,2024). Irrigation without proper drainage leads to water stagnation, which exposes plants to damage due to high temperatures. Conversely, providing appropriate slopes and designing an effective drainage network contributes to reducing the effects of heat and improving agricultural productivity (Pomoni et al ,2023). Furthermore, the accumulation of water in basins and low-lying areas, due to the lack of good land slopes or inadequate surface drainage channels, creates suitable breeding grounds for disease-carrying insects, such as malaria-causing mosquitoes (Karanisa et al ,2022). Therefore, the design of effective drainage networks is essential, especially in rural areas that suffer from excess irrigation water accumulation. Another problem associated with the lack of adequate drainage is the excessive accumulation of moisture in the soil, especially in humid areas (Balasundram et al ,2023). This can lead to soil compaction, whether in grazing fields or on agricultural land where heavy equipment is used. Effective drainage in these cases is an ideal solution for reducing water pressure and improving soil arability (Alengebawy et al ,2024). Also, a high water table negatively affects soil temperature, especially in early spring, preventing sufficient temperatures for germination(Yrjälä et al ,2022). This can lead to seed rot before germination, while drained soils are warmer in such conditions, improving germination timing. Moreover, high groundwater levels contribute to the spread of plant diseases and are the primary cause of soil salinization in irrigated areas, where salts accumulate in the root zone and on the soil surface(Peng et al ,2023). Drainage networks also contribute to improving soil structure by reducing salt concentrations to acceptable levels and balancing the chemical elements within the soil, creating favorable conditions for plant growth (Basu et al ,2022). Furthermore, drains help reduce soil erosion by acting as barriers to long-distance flood flow. Therefore in this study the reality of drain water in the city of Muqdadiyah in terms of quantity and quality.To evaluate the potential for its use in agriculture from a technical and environmental perspective.

2.0 Research methodology

2.1 Spatial Boundaries and Temporal Boundaries

The research is limited to the city of Muqdadiyah, the center of the Muqdadiyah District in Diyala Governorate, at the intersection of latitude (=6 - 59 33) north and longitude (=42 - 56 44) east, given the water challenges it faces and the agricultural drainage networks containing quantities of drain water. The research covers the period between 2020 and 2025, as this represents a period that witnessed severe climate change and increasing water scarcity, which reinforces the importance of studying non-conventional water alternatives.

2.2 Types and Patterns of Drains in the City of Muqdadiyah

Repeated irrigation in arid environments is a major factor in the accumulation of salts in agricultural soils, even if the river water used has relatively low salinity. In the long term, these practices lead to salt deposition in the soil, contributing to the decline in its fertility. With continued irrigation without an effective system for draining excess water, the groundwater level inevitably rises, especially if the amount of water seeping, evaporating, or being consumed by plants is less than the amount of irrigation water entering the soil. Engineer William Wilcox, who played a prominent role in irrigation projects in Iraq at the beginning of the twentieth century, noted that Iraqi lands were once highly fertile, resembling lush gardens, but later became saline and barren. This is attributed to the lack of effective management of irrigation projects, in addition to the lack of effective drainage networks to dispose of excess water . Drainage systems in the city of Muqdadiyah are mostly open, while covered or lined drains are noticeably rare. This is attributed to several factors, most notably the low cost of construction. Open drains are quick to install, and easy to maintain and clean. Furthermore, constructing covered drains over long distances is complex and costly, which has led to the prevalence of open drains in most drainage projects within the study area. The primary objective of constructing drains, of all types, is to remove excess water from the soil to maintain an adequate groundwater level. This contributes to achieving a necessary balance between moisture and aeration in the root zone and limits the accumulation of harmful salts in agricultural soil, ensuring an ideal environment for plant growth . Among the most prominent types of drains deployed in the Muqdadiyah area are the following types as shown in table 1.

Table 1. Types and Lengths of Drains in the City of Muqdadiyah

Discharge Locations	Area Served (dunum)	Discharge (m^3/sec)	Length (km)	Number	Types of Drains
Discharging into Diyala River	1376	1.650	13.500	1	Main Drains 1-
Discharging into Diyala River	1257	0.500	13.500	1	(a) Al-Khailaniya
In Mahroot Al-Shamali	3018	0.550	13.500	1	(b) Al-Maadan
In Babilan Drain	3687	0.650	15.000	1	(c) Mein Al-Din
In Al-Aziya Drain	6144	1.200	21.000	1	(d) Baz Al-Shaakha
In Mahroot Drain	4442	0.600	21.000	1	(e) Al-Roz
In Northern Al-Roz Drain (Baladruz)	3466	0.550	7.500	1	(f) Babilan
—	—	—	—	—	(g) Northern Al-Roz

2.3 Field Drains

These are small drains constructed within irrigated fields and represent the first line of defense for removing excess water from plants. They lower the groundwater level to depths that are harmless to plants and contribute to improving aeration and root systems. The distance between each drain ranges between 50–100 meters.Their primary function is to collect wastewater from field drains and transport it to larger sub-drains. The distance between collector drains ranges from 500–600 meters, and they are constructed at depths ranging from 1.5–1.8 meters.
These drains transport water collected by the collector drains to larger sub-drains. These drains are typically constructed at depths ranging from 1.8–2 meters and are an important link in the agricultural drainage network.

2.4 Main Drains

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These are open drains that collect and transport all agricultural drainage water collected in the drain network to the final outlet located outside agricultural lands. It's worth noting that any blockage or congestion in this network—due to the growth of plants such as reeds or papyrus—leads to rising wastewater levels, rendering the drains ineffective. Implementation of drainage projects in Muqdadiyah began in two phases. The first phase began in 1969, while the second phase began in 1982. Engineering designs and technical foundations were developed for the establishment of an integrated drainage network. Agricultural lands in the area were reclaimed to reduce soil salinity and improve soil productivity .

2.5 Topography and Surface Characteristics

Surface characteristics play an important role in the presence of thermal variations, and topography has a clear impact on the climate in general, and on temperature and humidity in particular. The city of Muqdadiyah is part of an alluvial plain, characterized by flat terrain and low elevations. The highest elevation is approximately (62) meters above sea level, located in the northern parts of the city. The lowest elevation is recorded in the western and southwestern parts, at approximately (54) meters, i.e., a difference of no more than (8) meters. As shown in Map (2), approximately (70)% of the city's area lies within an elevation range of (54) to (56) meters, while the remaining (30)% occupies elevations ranging between (54) and (58) meters.

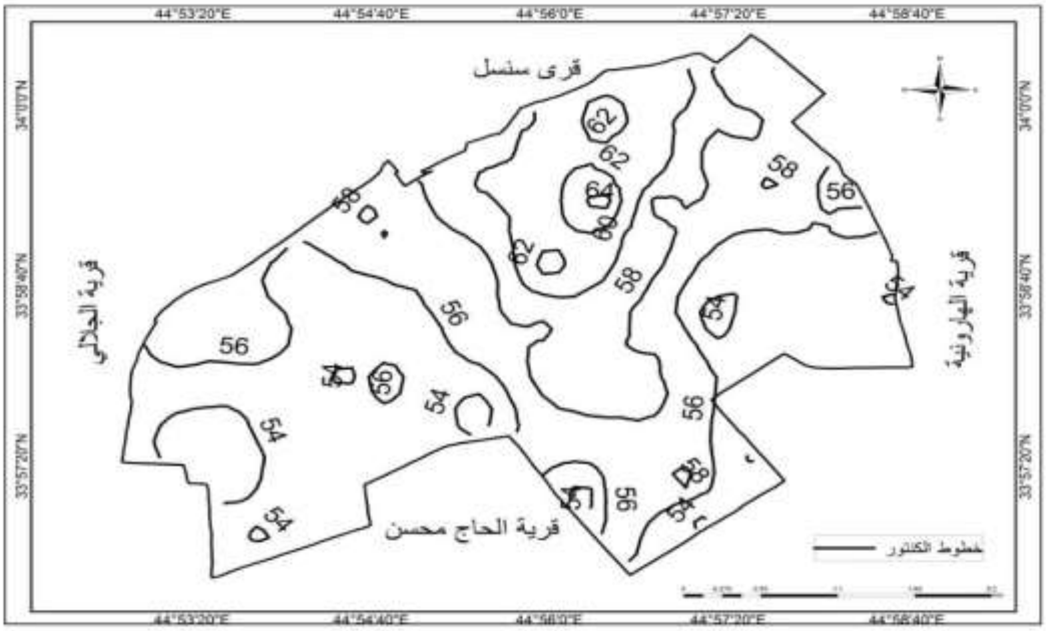

Figure 1. Contour lines of the city of Muqdadiyah

The small differences in elevation lead to limited variation in temperature rates, indicating that elevation is not a major factor in thermal variation within the city.

2.6 Climate

Climate is one of the most prominent factors directly affecting water resources, soil, and agricultural production. The city of Muqdadiyah lies within the arid and semi-arid zone, a region characterized by extremely hot and dry summers and cold, variable winters. Climatic conditions play a crucial role in determining the quality, quantity, and salinity of agricultural drainage water.

High temperatures and increased evaporation rates lead to the concentration of salts in drainage water and a decrease in its quantity. Conversely, rainfall—in its various forms—contributes to reducing the salinity of drainage water and diluting the concentration of dissolved elements, leading to an increase in its quantity. Table (2) shows that the region enjoys high rates of actual sunshine hours, particularly during the summer. The annual average reached approximately (8.0) hours/day, with marked variation throughout the year. The highest average was recorded in June, at (10.5) hours/day. This is attributed to the length of daylight hours and the high angle of incidence of solar radiation, as the sun is nearly perpendicular to the Tropic of Cancer. In contrast, a significant decrease was observed in December, with the lowest rate reaching approximately It averages (5.4) hours per day. This decrease is attributed to the short daylight hours in winter and the low angle of solar radiation, with the sun positioned perpendicular to the Tropic of Capricorn. Table (2) shows that the annual average temperature in the region is approximately 22.6°C, with clear variation throughout the year. Temperatures begin to gradually rise during the summer months, reaching a peak in July at (35.9)°C, while their lowest levels are recorded in January, where they fall to approximately (10.1)°C. As for rainfall, the annual total amounted to approximately (77.05) mm, and its monthly distribution varies significantly, with the vast majority of it concentrated during an eight-month period extending from October to May. It is completely absent in June, July, August, and September, a period marked by marked drought. The climate in this region is hot and dry. High temperatures, an average annual wind speed of 1.3 m/s, and a relative humidity of approximately 47.8% contribute to increased rates of evaporation and transpiration, which total approximately 1,908 mm annually. This high rate leads to a water deficit estimated at approximately 1,739.06 mm, particularly concentrated during the summer months.

Table 2. Monthly averages of climatic elements for Khanaqin station for the period (2005 - 2023)

Month	Average Temperature (°C)	Sunshine Duration (hours/day)	Rainfall (mm)	Potential Evapotranspiration (mm)	Rainfall Deficit/Surplus (mm)	Humidity (%)	Wind (m/s)
October	25.9	7.5	12.2	176.6	-171.9	47.6	1.2
November	17.7	6.7	14.1	88.4	-74	59.8	1.0
December	12.1	5.4	25.0	42.2	-16.5	73.4	0.9
January	10.1	6.7	39.0	39.8	-9.4	76.8	1.2
February	11.9	6.2	27.8	52.9	-24.8	69.3	1.4
March	16.1	6.8	21.0	95.0	-73.6	60.8	1.9
April	22.1	7.4	17.3	161.6	-151.6	50.4	1.7
May	29.1	8.6	4.6	257.2	-254.3	36.8	1.6
June	33.5	10.5	-	392.0	-372.0	26.9	1.9
July	35.9	10.5	-	401.8	-384.8	24.8	1.8
August	35.7	10.2	-	379.2	-361.4	26.1	1.3
September	31.5	9.2	0.2	303.4	-286.3	29.1	1.7
Total	-	-	77.05	1908	-1739.06	-	-
Annual Average	22.6	8.0	-	-	-	47.8	1.3

This deficit in water balance exacerbates drought conditions and increases the demand for water for irrigation purposes, causing an increase in the amount of water lost through evaporation during irrigation. Consequently, the salinity of drainage water increases due to the lack of water in excess of the soil and plants' needs, which reduces the efficiency of salt drainage. Therefore, it is recommended not to use saline drainage water during the dry summer months to avoid the resulting agricultural and environmental damage.

3.0 Results and discussion

3.1 Al-Muqdadiyah City's Drainage Water and Its Suitability for Irrigation

Water quality and its physical, chemical, and biological properties are key indicators for determining the suitability of water for irrigation or other uses. Within this framework, a study was conducted to evaluate the quality of Al-Muqdadiyah City's drainage network water. This was accomplished by collecting (8) samples of drainage water from four selected locations, two samples from each location. These samples covered various parts of the drainage network in the region. Table (3) .

The first sample was taken in January 2025, while the second sample was collected in July of the same year, with the aim of comparing water quality between the winter and summer seasons. The study focused on analyzing a number of physical and chemical elements and compounds that directly affect plant growth, as shown in Table 3.

Table 3. Laboratory Test Results for Sewage Water in Al-Muqdadiyah City in 2025

No.	Location	Month	T.D.S (mg/L)	EC (mS/cm)	pH	Cations (mg/L)			Anions (mg/L)		
						Ca	Mg	Na	Cl	SO_4	NO_3
1	Al-Jazeera	December	1858	3.9	7.4	30.9	47.8	48.5	29.2	193	3.6
		July	1970	5.2	8.1	38.7	49.2	55.3	34.3	213	5.8
2	Al-Shakha Village	December	1948	4.0	7.5	31.1	46.9	47.7	28.8	202	3.6
		July	2011	5.2	8.2	39.0	49.7	52.2	34.9	217	5.1
3	Al-Muhandisin	December	1903	3.8	7.2	31.8	48.9	46.9	30.1	196	3.9
		July	1990	5.4	7.7	43.4	49.3	51.2	34.4	216	5.4
4	Barsheta	December	1884	4.4	7.6	32.4	47.2	48.7	28.3	198	3.6
		July	1989	6.0	8.0	40.6	49.6	54.6	33.8	219	5.7

For comparison, to determine the suitability of Muqdadiyah's drainage water and determine its potential use for irrigation, local standards were adopted, including the Islamic Educational, Scientific and Cultural Organization (ISESCO) classification . There appears to be spatial and temporal variation in the physicochemical values of elements and compounds, and their relationship to suitability for agricultural uses, as follows:

3.2 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) refer to organic and inorganic substances present in water in the form of ions or suspended particles. Increased concentrations of these salts negatively affect plants, as they impede water absorption through the roots and affect the pore size of the soil, altering its water and air content. Furthermore, some components of these salts may contain elements that are toxic to plants. According to the data . TDS values in the study area's drain water vary spatially and temporally. The lowest value was recorded in the Al-Jazeera drain during January, reaching 1858 mg/L, while the highest value was recorded in the Al-Shakha village drain during July, reaching 2011 mg/L. According to the Islamic Educational, Scientific and Cultural Organization (ISESCO) standard,. some of these values—especially those below 2000 mg/L are suitable for use in irrigating field crops.

3.3 Electrical Conductivity (EC)

Electrical conductivity is one of the primary indicators for measuring salinity concentration in water, as these concentrations increase with rising temperatures. Referring to Table (3), the EC values in the studied drain water ranged between 3.8 and 4.4 mmol/cm in January and rose to 5.2 and 6.0 mmol/cm in July.

When comparing these values with the ISESCO classification, it is noted that salinity levels are high, and this water is not recommended for irrigation, especially for summer crops. However, this water can be used during the winter season, provided that a rotation system is implemented with fresh, low-salinity water. Through study and fieldwork, it was found that the variation in salt concentrations between regions is primarily due to the varying amounts of rainfall during the winter season. This rainfall affects water infiltration into irrigation and drainage canals. Low temperatures and low evaporation also contribute to varying salinity levels. In addition, poor water management and incorrect agricultural practices, such as inappropriate plowing times and depth, soil and crop types, and the timing, quality, and quantities of chemical fertilizers added, exacerbate the problem. It was also observed that some farmers create irregular crossings over drains, and some have even leveled them and converted them into agricultural land. This has led to the neglect of these drains, the cessation of their maintenance, the growth of reeds and papyrus within them, and the accumulation of sediment, which impedes water flow and contributes to increased salinity levels. Interviews with a number of farmers also revealed that they follow a fallow system without adhering to the agricultural cycle and are expanding summer farming without adhering to the Agriculture Directorate's plan regarding crop types and planting dates. The Muqdadiyah District Council in Diyala warned of an environmental disaster threatening the residents of the city of Muqdadiyah, as a result of the diversion of sewage into drainage projects for agricultural land. These drainages, which were established decades ago to drain agricultural land water and reduce groundwater levels, have in recent years become a source of pollution due to the dumping of solid waste and manhole waste into them without legal deterrent, posing a threat to public health and water resources.

Table 4. Water suitability for irrigation according to the classification of the Islamic Educational, Scientific and Cultural Organization (ISESCO)

Symbol	Chemical Parameter	Unit	Maximum Allowed Limit	Classification / Remarks
T.D.S	Total Dissolved Solids	mg/L	2000	Suitable for irrigation of crops
EC	Electrical Conductivity	mS/cm	4	Suitable for irrigation of some crops
Ca	Calcium	mg/L	20%	Low effect on plant growth
Mg	Magnesium	mg/L	50%	Moderate effect on sensitive crops
Na	Sodium	mg/L	50%	Medium sodium water
Cl	Chloride	mg/L	30%	Acceptable for some plants
SO_4	Sulfate	mg/L	220	Low effect on plant growth
pH	Acidity / Alkalinity	mg/L	8.5	Slightly basic effect

NO_3	Nitrate	mg/L	10	Suitable for irrigation of crops

3.4 Direct Use of Drainage Water
In this method, a chemical analysis of the drainage water to be reused in agriculture must be performed. If it does not contain high concentrations of salts or toxic ions, it can be used. However, if it does contain high concentrations, it requires the cultivation of tolerant crops or the availability of highly permeable soil . A programmable control system has been designed and programmed to determine the suitability of drainage water for irrigation without the need for chemical tests. This is done by installing sensors immersed in the drainage water, which feed the system with information related to the salinity level. Based on this data, the system issues an executive order to operate or stop the water extraction and drainage station. Given the possibility of installing this system in remote locations far from electrical power sources, its design relies on solar energy.

3.5 Mixing Drainage Water with Fresh Water
If a fresh water source is available near the drainage water, a water mixing system can be adopted, whereby a portion of the fresh water is mixed with the drainage water. This method is effective in providing larger quantities of irrigation water, contributing to the expansion of agricultural land and increased agricultural productivity as shown in figure 2.

Figure 2. Transforming Muqdadiyah drains into sewage canals

4.0 Conclusion
The study revealed the influence of natural factors, including surface topography and climatic factors, on the quality and quantity of drain water. It was found that the slope of the surface played a prominent role in shaping the drainage network within the Bani Saad district, which helped accurately determine the geographical extent of this network. Laboratory testing results for selected samples of sewage water revealed spatial and temporal variations in the concentrations of elements and chemical compounds within the studied areas. High levels of some elements were observed in certain locations, while low levels were observed in others. This variation is attributed to the variation in the amount of irrigation water discharged from agricultural lands, the nature of the lands in terms of soil salinity and mineral composition, as well as the type of fertilizers and pesticides used. The sewage water in Muqdadiyah is of limited suitability for irrigation. It can be used to irrigate crops that tolerate varying degrees of salinity, using alternating irrigation systems or mixing this water with freshwater sources. Effective soil washing and water drainage procedures should also be implemented to ensure the elimination of

salt accumulations, thus achieving sustainable agricultural use. Raise awareness among farmers and promote the use of modern irrigation technologies. This should be done by implementing awareness-raising campaigns to raise awareness of the importance of water conservation and encouraging farmers to use modern irrigation methods. It is also proposed to provide financial facilities and bank loans to enable them to purchase modern agricultural equipment and machinery. Alternatively, the Agricultural Bank or relevant official bodies could import and sell this equipment at subsidized prices to facilitate its acquisition. Improving water use efficiency in the agricultural sector. This is achieved by relying on water quotas for actual crop production, in addition to developing and breeding improved plant varieties characterized by low water consumption and their ability to withstand high salinity. This contributes to rationalizing the use of water resources without impacting agricultural production.

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