Vital Annex: International Journal of Novel Research in Advanced Sciences
ISSN: 2751-756X
Volume 04 Number 03 (2024)
https://innosci.org/IJNRAS

Article

Advancing Water Resource Management Through Wastewater Reuse: Assessing the Domestic and Industrial Suitability of Treated Effluent in Iraq

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Abstract: This research aimed to assess and compare the characteristics of treated wastewater at the Al Shatrh Sewage Treatment Plant (SSTP) against water quality diagnostic requirements in Iraq, Egypt, and the United States, for domestic and industrial uses, particularly for agricultural applications. The assessment methodology encompasses several tests performed on the effluent from a treatment facility over a period of six months. These tests provide an estimation of the hydrogen potential pH and the Total Dissolved Solids (TDS) concentration. Furthermore, the classification of chemical ingredients may lead to detrimental effects on plants, such as chlorine (Cl), contingent upon the results of the study. The results indicate that the pH and TDS levels of the treated wastewater released on all analysis dates are within the permissible limits established by the rules of Egypt, the United States, and Iraq. The projected concentrations of chlorine (Cl) at 55%, sulfate (SO_4) at 50%, phosphate (PO_4), limit PO_4, nitrate (NO_3), and ammonia (NH_3) in the treated wastewater of gushing discharge comply with Iraqi norms. Individually, 55%, 75%, 80%, 5%, and 45% do not accurately conform to the permitted range in Iraq.

Keywords: Al shatrh, Treated effluent, Water resource, Sewage validity, Wastewater reuse

Citation: Alewi, H. K. (2024). Advancing water resource management through wastewater reuse: Assessing the domestic and industrial suitability of treated effluent in Iraq. Vital Annex: International Journal of Novel Research in Advanced Sciences, 3(4), 160–170.

Received: 20th Jan 2025
Revised: 21th Jan 2025
Accepted: 5th Feb 2025
Published: 13th Feb 2025

1. Introduction

The substantial expansion of the global economy and population has rendered water a scarce resource, prompting water resource management specialists to underscore the imperative of reclaiming treated water from sewage treatment plants and ceasing water wastage as a crucial measure. Globally, there has been a predominant emphasis on water utilization for many reasons, including industrial, agricultural, and potable uses, particularly in dry areas or populations experiencing freshwater shortage or drought circumstances. [1,2]. Numerous studies have sought to comprehend the complex, multifarious processes associated with treatment strategies for different waste kinds. These studies provide valuable insights into the efficacy and efficiency of treatment procedures, highlighting the critical elements that affect treatment results. Comprehending these factors is crucial for improving wastewater treatment systems and guaranteeing adherence to regulatory standards and environmental criteria. By analyzing and presenting statistical data about treatment processes, researchers and practitioners may enhance the efficacy of treatment facilities, hence increasing water quality and promoting sustainable reuse methods.[3–6]. The concept of comprehensive network management for accurate distribution, treatment, and wastewater disposal emerged in the eighteenth century. rather than the traditional disposal into aquatic systems.[7,8]. The first frameworks of land application were hindered by pressure-induced and toxic overloading, together with inexperienced practices, resulting in significant environmental pollution. Urban development encroached into sewage treatment areas, resulting in the abandonment of several early large-scale water systems and sewage facilities in Europe. The unpleasant odour and concerns over the transfer of diseases, inappropriate use on land, and the discharge of untreated sewage into adjacent streams were significant issues, leading to the cessation of water systems using wastewater. [9,10] Concerns over the condition of watersheds and water supplies receiving substantial wastewater have renewed interest in wastewater reuse, especially in industrialized and developing countries facing increasing water resource demands. [11-13]. Societies in arid areas have shown a specific interest in using wastewater for their agricultural irrigation systems. Moreover, it was often perceived that the reutilization of wastewater in agriculture offers an efficient and relatively straightforward approach for the hygienic disposal of urban wastewater, therefore reducing waterway pollution. [14,15,16] Irrespective of its use in water systems, reclaimed wastewater may be utilized for groundwater recharge and other advantageous purposes.

These elements, along with fast urban expansion and the need to enhance rural production, made sewage farms attractive to the agricultural community and urban planners. [17,18] Land-based treatment of wastewater effluents may function as a natural and environmentally friendly approach for their final disposal. Domestic animals often congregate around or disturb the growing vegetation, which is a crucial component of the land clearance process. As the effluent traverses the root zone, inherent, compound, and physical processes that exceed the soil profile's capacity eliminate natural substances, suspended solids (SS), and soluble materials.

[19,20] This research seeks to assess the properties of treated wastewater from the Al Shatra Sewage Treatment Plant (SSTP). We contrasted this with water quality criteria for agricultural use in three different countries. This endeavor is to address a notable deficiency in the literature about the use of treated water for applications in agriculture.

Novel Contributions

Even though there is a growing interest in using treated wastewater (TWW) for agricultural applications, there is still a significant gap in the literature covering the full evaluation of this practice. By thoroughly looking at the chemical and microbiological features of TWW from the Al Shatra sewage treatment plant (SSTP), this study aims to fill in the gaps in our knowledge by providing important new information about how safe and suitable TWW is for use in agriculture.

Study Area

The Al Shatra sewage plant, situated east of Al Shatra city Adjacent to the boundary of Dawaya city

is positioned at GPS coordinates 31°49'22"N latitude and 46°13'07"E longitude It has a treatment capacity of 9000 m3/d and covers an area of 20,000 m² (2 hectares) as shown in Figure 1.

Figure 1. Map of Al-Al Shatra Sewage Plant. Map data © Google. The scale displayed indicates that the horizontal distance represented is 300 meters, while the vertical distance is 1787 meters."

Criteria For The Quality Of Irrigation Water

Tables 1 and 2 [21] outline the water quality standards for agricultural use in Egypt. At the same time, Table 3 displays the classification of agricultural practices in the United States Standard for Water Quality [22, 23].

Table 1. Effluent Water Specification Of SSTP

<table>
<tr><th colspan="2">Treatment Degree / Parameter</th><th>Grade A</th><th>Grade B</th><th>Grade c</th></tr>
<tr><td rowspan="2">Max. attribute of the effluent</td><td>BOD ppm</td><td><20</td><td><60</td><td><400</td></tr>
<tr><td>T.S. S</td><td><20</td><td><50</td><td><250</td></tr>
<tr><td colspan="3">parameter</td><td colspan="2">Limit</td></tr>
<tr><td colspan="3">BOD</td><td colspan="2">< 40 ppm</td></tr>
<tr><td colspan="3">S. S</td><td colspan="2">mg/l < 60</td></tr>
<tr><td colspan="3">COD</td><td colspan="2">< 100 ppm</td></tr>
<tr><td colspan="3">PO4</td><td colspan="2">< 3ppm</td></tr>
<tr><td colspan="3">NO3</td><td colspan="2"><50 ppm</td></tr>
</table>

Table 2. Concentrations of chemical elements in wastewater treatment based on egyptian irrigation agriculture methods.

Component	max. Substance Level (mg/I)	max. Sh-term Substance Level (mg/I)
Cl	-	400
Ca	230	230
SO4	-	500
Mg	100	100
PO4	-	30
Na	230	230

Table 3. Quality Of Water For Agricultural Irrigation

Representation	Threshold Value
Acidity levels	4.4 – 9
Nitrate	-

2. Materials and Methods

A structured evaluation technique was used to determine the agricultural suitability of Al Shatra Sewage Treatment Plant (SSTP) treated wastewater. This research used a quantitative method and tracked six months of water quality data regarding pH, total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD5) along with chloride (Cl), sulfate (SO_4), phosphate (PO_4), nitrate (NO_3), and ammonia (NH_3) chemical constituents. The analysis of water samples happened during regular intervals through testing against international quality benchmarks established by Iraq, Egypt and the United States. The laboratory methods measured parameters' concentration levels accurately for complete evaluation against current regulatory thresholds. Statistical analysis tools processed the gathered results while the study assessed water quality variations across different time periods. The study conducted a comparison with the results published in previous research to establish context within the scientific field. An evaluation assessment considered possible harm from elevated element concentrations specifically chloride and sulfate because these elements threaten the health of both soil and harvested crops. The research evaluated periodic alterations of water quality indicators to establish their role in determining wastewater suitability. The used methodology produces reliable findings suitable for practical agricultural applications which advance the ongoing wastewater reuse discussion in water-scarce regions. The obtained result serves as foundation for developing policies that optimize wastewater treatment systems and establish irrigation safety protocols.

3. Results and Discussion

This study evaluates the effectiveness and results of employing treated wastewater in SSTP for agricultural applications.

1) Evaluation Of Untreated Wastewater Characteristics

An evaluation of the characteristics of crude wastewater was conducted. The parameters pH, TSS, TDS, and BOD5 are essential in defining the characteristics of untreated sewage. The results are presented in Table 4. We analyzed the findings and pinpointed essential metrics related to the application of sewage in horticultural practices. We employed both the American Standards and Egyptian Standards (ECP 501-2005) to accomplish this goal. The information-gathering program was conducted over a span of six months. The data presented in Table 4 highlights the differences between Egyptian and American norms. The results of the NSTP examination are presented in Figures 2-9. Figure 9 illustrates that the TSS estimations for effluent-treated wastewater, derived from all accessible data, align with the most suitable range.

The TDS estimations of the treated sewage emanating from all estimation information fall within the highest acceptable cutoff. As shown in Figure 8, the pH estimates of gushing-treated sewage, based on all estimation information, fall within the most suitable breaking point. as shown in Figure 2. Table 4 presents the pH and TDS results.

2) The Chemical Component

An analysis was conducted on the chemical composition of untreated sewage in SSTP, focusing on its presence in the effluent post-treatment. The primary components examined included chlorine (Cl), nitrate (NO3), phosphate (PO4), and sulfate (SO4). The concentrations of these elements in the treated sewage effluent are presented in Table 4, compiled from a six-month data collection period.

3) Comparison With Alternative Research

We compared the parameters tested in our study, such as pH, TSS, TDS, and chemical elements like Cl, SO4, and PO4, with findings from several recent studies that tackled related topics, including:

Al-Hazmi et al. (2023): Their research examines how treated wastewater affects soil microbial activity and consequent agricultural concerns. They reconsidered their studies. The consequences of hazardous metals, salts, organic contaminants, and infections were discussed. We examined substances such as chlorine (Cl), sulfate (SO_4), phosphate (PO_4), nitrate (NO_3), ammonia (NH_0), pH, and total dissolved solids (TDS). Both studies stressed the need to manage treated wastewater for agricultural reuse.[24].

Ibrahim et al. (2019): Ibrahim and his colleagues assessed the effluent quality from 22 wastewater treatment facilities in Jordan, using the Weighted Arithmetic Water Quality Index (WQI) to analyze chemical and microbiological parameters in accordance with Jordanian standards. Our research focused on a particular treatment plant (SSTP) in Iraq, and we compared the findings with those from Egypt, Iraq, and the United States, especially on agricultural applications. Both inquiries underscored the need for diligent oversight and possible interventions[25].

Rahimi et al. (2018): Rahimi and his colleagues concentrated on 39 characteristics of a specific treatment facility in Qom; they used the Wilcox diagram along with irrigation and agricultural usage indices to analyze the data. Their investigation indicated that the concentrations of total coliform (TC) and faecal coliform (FC) were markedly elevated, possibly endangering consumers if used in agriculture. Furthermore, the concentration of ammonium (NH) above permissible limits, raising concerns about the possibility for nitrate pollution of aquifers [26].

Dimane and El Hammoudani (2021) : exhibited divergent results in their own investigations. The Al-Hoceima WWTP demonstrated compliance with wastewater discharge regulations in Morocco. Their study indicated a reduction in BOD5, COD, TSS, and heavy metals, so illustrating the efficacy of the Al-Hoceima WWTP. Conversely, our investigation highlighted issues about the concentrations of chlorine (Cl), hydrogen potential pH, and total dissolved solids (TDS), underscoring the need for vigilant monitoring and potential remediation measures [27].

Upon assessing the findings in Table 4, it is evident that the attributes of treated wastewater from the SSTP mostly conform to the criteria established by both Egyptian and American regulations for agricultural reuse. The reported pH values, ranging from 6 to 9.5, are within the upper limit of the permissible range, favorable for certain crops that flourish in alkaline environments [28]. The observed ammonia levels exhibit variations correlated with seasonal fluctuations and the efficacy of the therapy. This aligns with the findings of Al-Hazmi et al. (2023), who likewise observed variations in ammonia levels associated with meteorological conditions. The elevated chloride and sulphate levels in certain months show the need of consistent monitoring, as noted in the literature (Rahimi et al., 2018), stressing the hazards linked to harmful salt buildup in agricultural soils. The systematic collection and analysis of these indicators may inform adaptive management techniques, assuring adherence to safety thresholds and optimum agricultural practices, thereby protecting both crop health and consumer safety.

Table 4. SSTP'S Raw Sewage Effluent Quality

Ammonia (NH)3				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
10		***16.0***	***26.8***	**January**
10		***18.0***	***16.1***	**February**
10		***14.5***	***15.2***	**March**
10		***9.1***	***20.4***	**Jun**
10		***18.1***	***21.9***	**September**
10		***4.2***	***12.2***	**October**
pH				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
Max	**Min**			
9.5	6	6.9	7.1	**January**
9.5	6	7.8	7.6	**February**
9.5	6	6.4	6.6	**March**
9.5	6	6.8	6.8	**Jun**

9.5	6	9.2	9.6	**September**
9.5	6	8.2	8.6	**October**
Phosphate (PO4)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
3		***5.7***	***9.7***	**January**
3		***4.6***	***15.6***	**February**
3		***4.0***	***13.6***	***March***
3		***3.5***	***14.5***	**Jun**
3		***9.7***	***11.7***	**September**
3		***1.0***	***11.9***	**October**
Chloride (Cl				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
600		562	574	**January**
600		1750	2102	**February**
600		1647	2171	**March**
600		1352	2892	**Jun**
600		885	1425	**September**
600		1321	1187	**October**
Nitrate (NO3)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
50		57	27	**January**
50		28	26	**February**
50		31	26	**March**
50		33	24	**Jun**
50		13	10	**September**
50		80	19	**October**
Total suspended solids				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
60		294.8	2013	**January**
60		358.6	783.2	**February**
60		344.3	1025.2	**March**
60		330	913	**Jun**
60		157.3	327.8	**September**
60		101.2	198	**October**
Sulphate (SO4)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
400		969.2	986.0	**January**
400		987.0	1025.7	**February**
400		982.1	1065.4	**March**
400		986.6	790.7	**Jun**
400		593.5	617.6	**September**
400		628.6	574.0	**October**
Total dissolve solid (T.D.S)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
_		4617.7	6142.8	**January**
_		5595.4	6185.2	**February**
_		5676.2	6213.5	**March**
_		5217.7	7579.0	**Jun**
_		3252.2	4326.8	**September**
_		3733.0	3769.3	**October**

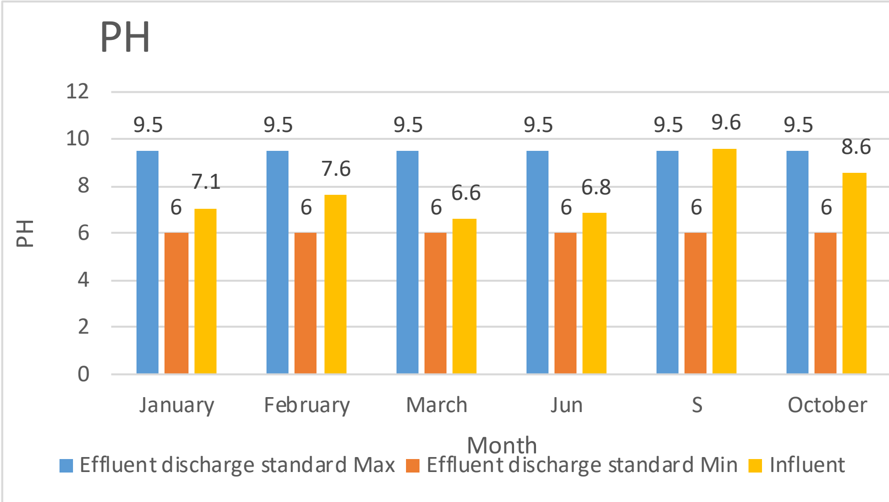

Figure 2. pH comparison of effluent and influent wastewater discharges and standard

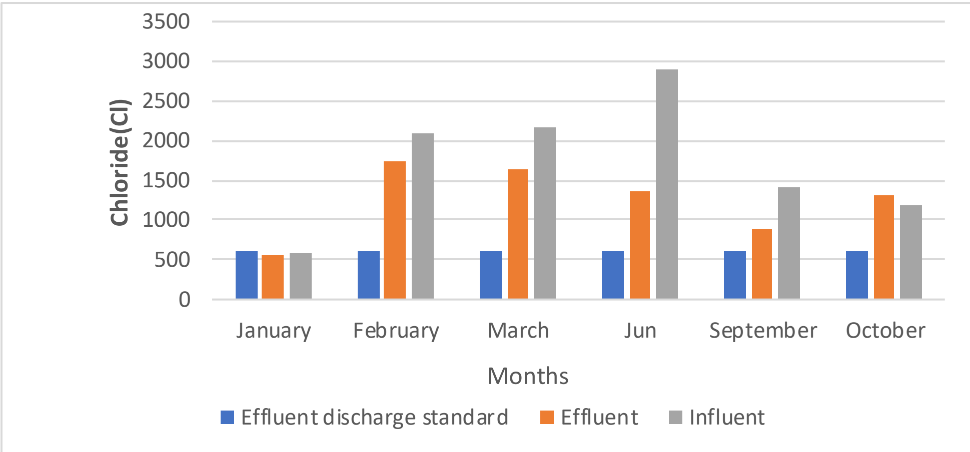

Figure 3. Chloride (Cl) comparison of effluent and influent wastewater discharges and standard

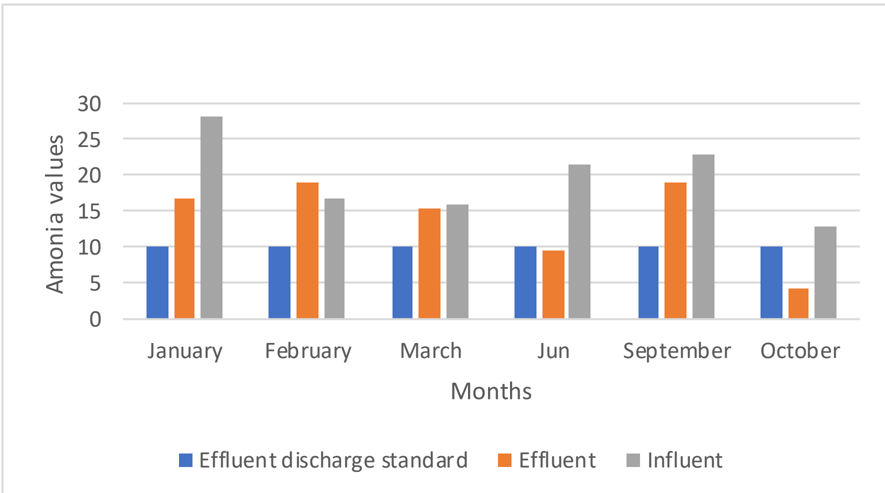

Figure 4. Ammonia (NH)3 Comparison of effluent and influent wastewater discharges and standard

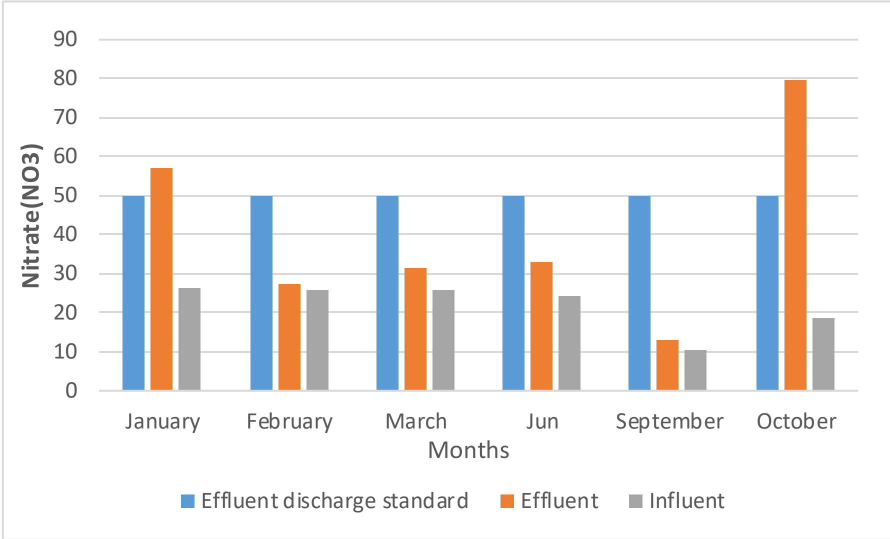

Figure 5. Nitrate (NO3) comparison of effluent and influent wastewater discharges and standard

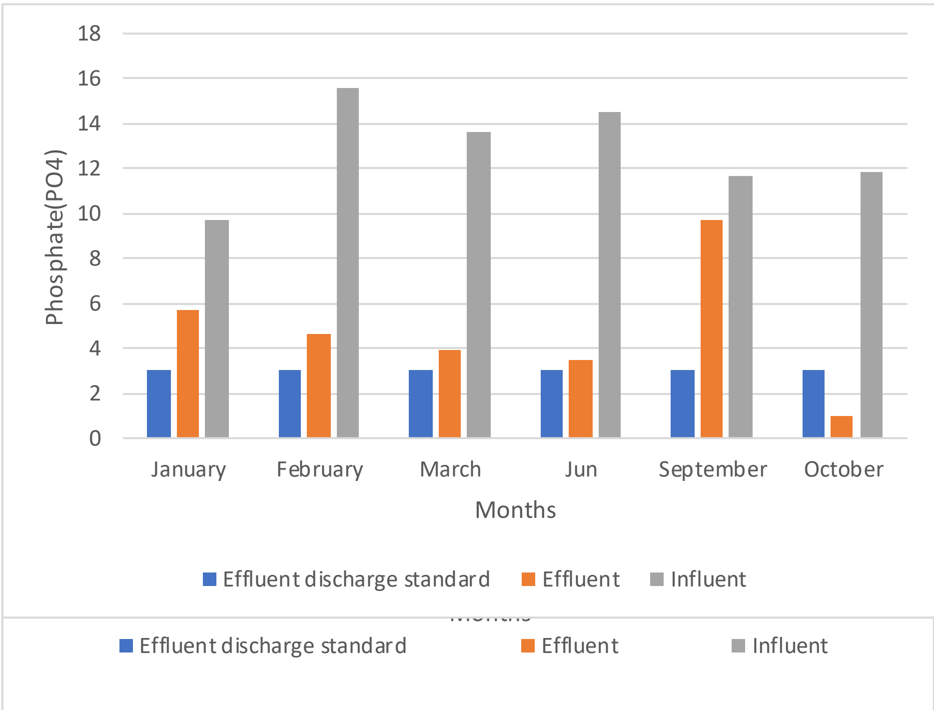

Figure 6. Phosphate (PO4) comparison of effluent and influent wastewater discharges and standard

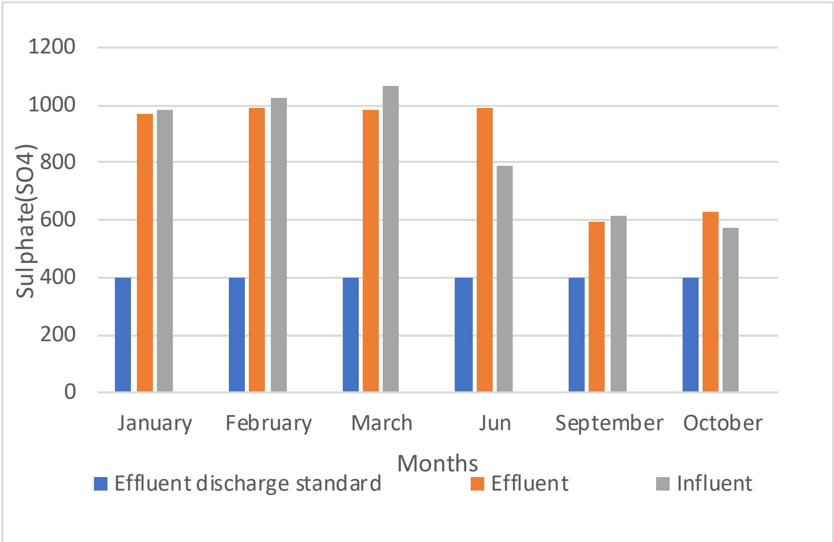

Figure 7. Sulphate (SO4) comparison of effluent and influent wastewater discharges and standard

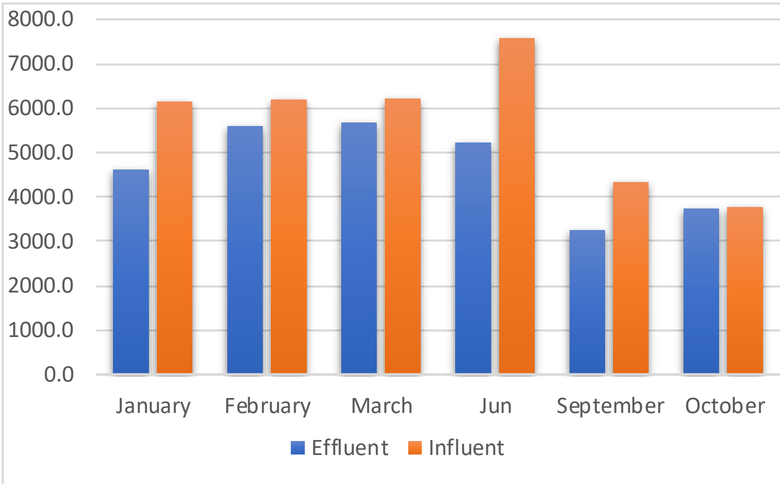

Figure 8. Total dissolve solid (T.D.S) comparison of effluent and influent wastewater discharges

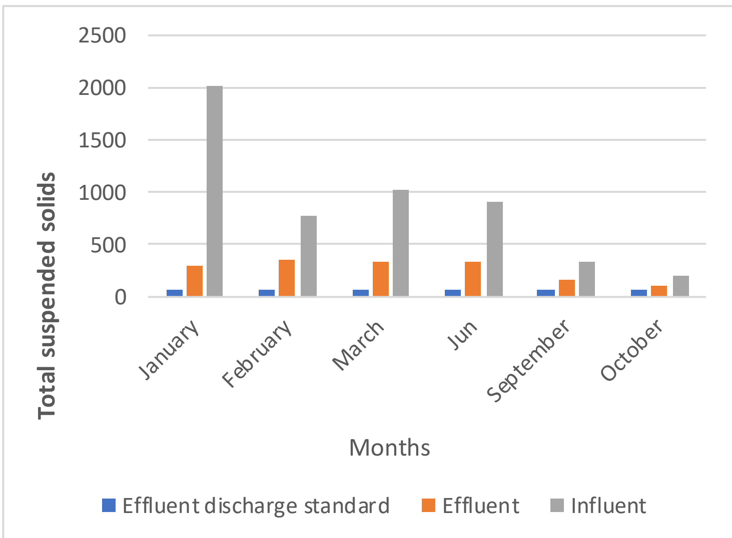

Figure 9. Total suspended solids (T.S.S) comparison of effluent and influent wastewater discharges and standard

4. Conclusion

The study results indicate that the pH, T.S.S., and T.D.S. measurements of the treated wastewater fall between the extreme and acceptable range based on all evaluated data. Consequently, the treated water of the SSTP may not suitable for some domestic purposes such drinking water because of the fluctuating in the concentration of ammonia ,nitrate, and TSS .However we may use this treated wastewater for irrigating to certain crops during agricultural operations especially corps that are more affected by higher chloride (Cl) and sulfate (SO_4) levels such Barley, Sugar Beet, Sorghum, Wheat, Cotton, and Atriplex. The use of the treated wastewater will advance the quantity of water required for agriculture and domestic. Integrating treated wastewater along with the other water resources in multiple uses will be important and crucial, especially if we consider the existing supply shortage. In the same context, the treated wastewater could be vital in conserving the water resources from being wasted in the secondary activities which could alternatively use the treated water, such as landscape and garden irrigation, toilet flushing, laundry and car washing, as well as industrial processes and cooling systems. the use of the treated water could be reduce waste that could happen for hundreds of cubic meters of fresh water, Additionally, we assess the concentrations of Cl, SO4, and PO4 as follows: Approximately 55% of the Cl estimates are above the allowed limits; 50% of the SO4 values exceed the permissible range; and 80% of the PO4 readings fall within the acceptable range. The treated wastewater from Iraq discharges estimated levels of total dissolved solids (T.D.S.), pH, ammonia (PO4), and nitrogen (NO3) that fall within the permissible range. In light of the present findings, we advocate for the establishment of a program to monitor and regulate wastewater treatment to ensure safe results in agriculture and other industries. This program must include simultaneous testing for sulfate and chloride concentrations to rectify about half of the readings that exceed permissible limits. Moreover, we highly advocate that the relevant authorities replicate the initiatives of countries that have significantly invested in improving treatment protocols. This program would enhance wastewater quality while preserving water resources, given the existing supply deficit and increasing water demand. It is essential to develop educational initiatives to improve farmers' understanding of appropriate wastewater use since this directly protects public health and promotes environmental conservation.

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