Wastewater Quality Assessment at Amarah Sewage Treatment Plant: Implications for Agricultural Use and Environmental Safety

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ABSTRACT

This study examines the quality of treated wastewater from the Amarah Sewage Treatment Plant (ASTP) in Iraq for potential agricultural use and compares it to the water quality standards of Iraq, Egypt, and the USA. The effluent was analyzed over a five-month period for various parameters, including pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and concentrations of ions, such as chloride (Cl^-), sulfate (SO_4^{-2}), phosphate (PO_4^{3-}), nitrate (NO_3^-), and ammonia (NH_3). The findings showed that the pH and TDS measurements of the treated wastewater fell within the acceptable range, according to the regulations set by all three countries. The concentrations of Cl^-, SO_4^{-2}, PO_4^{3-}, NO_3^-, and NH_3 in the treated wastewater were also within the acceptable limits set by the Iraqi standards. However, chloride and sulfate levels occasionally exceed permissible thresholds. The treated wastewater from ASTP is generally suitable for the irrigation of certain crops, but it is important to implement a monitoring and control system to ensure consistent water quality. Finally, investments are needed to improve treatment processes and establish educational programs for farmers to enhance their understanding of proper wastewater usage. These measures are crucial for protecting public health and conserving water resources, particularly in regions facing water scarcity.

Keywords-Amarah; effluent treatment; sewage validity; substance components; wastewater reuse

I. INTRODUCTION

The significant growth in the global economy and population has led to water being considered a scarce commodity. Consequently, water resource management experts emphasize reclaiming treated water from sewage treatment facilities and reducing water waste. Globally, the primary focus has been on managing water consumption for various applications, including industrial processes, agricultural irrigation, and human consumption, particularly in water-scarce regions such as arid areas or communities facing freshwater shortages or drought conditions [1, 2]. Numerous studies have explored the intricate processes involved in treating different types of waste, providing insights into the effectiveness and efficiency of treatment processes and identifying the key variables that influence the outcomes. Understanding these variables is crucial for enhancing wastewater treatment systems and ensuring compliance with the regulatory standards and environmental requirements. By analyzing statistical data related to treatment processes, researchers and practitioners can improve the efficiency of treatment facilities, ultimately enhancing water quality and promoting sustainable reuse techniques [3-6]. The ideas of collection, treatment, and wastewater removal were advanced in the 19th century, when the use of soil as a treatment medium and wastewater as a source of supplements instead of conventional discharge into water bodies were supported [7]. From that point forward, land application has been a typical practice for the disposal of metropolitan wastewater, and numerous huge urban bases worldwide have applied their wastewater to land for over a century [8]. The initial systems for land application suffered from pressure-induced and toxic overloading as well as uncontrolled operations, resulting in significant environmental pollution. Urban advancement was infringed upon sewage ranch zones, leading to the abandonment of a significant number of early large water systems and sewage ranches in Europe. The awful smell and worry about the transmission of disorders, ill-advised application, and the release of raw sewage to nearby streams are also of extraordinary concern, prompting the discontinuance of water systems with wastewater [9, 10].

However, growing concerns about the quality of streams and water resources receiving large amounts of wastewater have attracted interest for wastewater reuse, particularly in industrialized and developing nations with a growing demand for water resources [11-13]. Countries in arid regions have shown particular interest in the utilization of wastewater in agricultural water systems. Furthermore, it is believed that reusing wastewater in farming provides an effective and relatively simple method for the clean removal of urban wastewater, thereby reducing waterway contamination [13, 14]. Regardless of its use in water systems, recovered wastewater can be used as groundwater energizer and contribute to other beneficial reuses.

These components, combined with the rapid urban expansion and the need to increase rural development, made sewage farms appealing to farming communities and city organizers [15]. Utilizing land for the treatment of wastewater effluents can be considered a natural and harmonious disposal method. Domestic animals tend to gather or brush developing vegetation, which forms an integral part of the land-based disposal system. As the effluent moves through the root zone, biological, chemical, and physical processes work to eliminate organic matter, suspended solids, and soluble materials [16-19]. The objective of this research was to assess the properties of treated wastewater from the Amarah Sewage Treatment Plant (ASTP). These characteristics were then compared with the agricultural water quality standards in Iraq, Egypt, and the USA. This investigation seeks to address a current gap in the scientific literature concerning the application of treated wastewater for agricultural purposes. This study aims to fill this gap by thoroughly analyzing the chemical and physical properties of treated wastewater from the ASTP. The research seeks to provide crucial insights into the safety and suitability of using treated wastewater in agriculture, thus expanding our understanding of this critical issue.

II. STUDY AREA

Figure 1 shows the Al-Amarah sewage plant, located west of Al Amarah city on the Al-Betera River, which is a branch of the Tigris River at the GPS coordinates 31°49'53.81"N latitude and 47°2'34.51"E longitude, has a capacity of 60,000 m^3/d, and an area of 180,000 m^2 of water treatment capacity.

Fig. 1. Map of the Al-Amarah Sewage Plant. Base map © GIS.

III. CRITERIA FOR IRRIGATION WATER QUALITY

Tables I-III outline the water quality standards for agricultural use in Egypt [20]. Table IV displays the classification of agricultural practices in the USA standard for water quality [21]. In Table I, Grade A is the highest level that can be achieved in treatment through the development of a secondary unit, which is used only in special cases because of its high cost. Grade B is a secondary treatment that is achievable from the established unit. Grade C is the treatment that results from the screening and primary units.

TABLE I. CLASSIFICATION OF WATER QUALITY

Parameter	Grade A	Grade B	Grade C
BOD (mg/l)l	<20	<60	<400
TSS.	<20	<50	<250

TABLE II. SPECIFICATIONS OF EFFLUENT WATER OF ASTP

Parameter	Limit
BOD	<40 mg/l
TSS.	<60 mg/l
COD	<100 mg/l
PO_4^{3-}	<3 mg/l
NO_3^-	<50 mg/l

TABLE III. CHEMICAL ELEMENT LEVELS IN WASTEWATER TREATMENT ACCORDING TO EGYPTIAN IRRIGATION PRACTICES FOR AGRICULTURAL

Ion	Maximum concentration (mg/l)	Maximum Sh-term concentration (mg/l)
Mg^{2+}	100	100
PO_4^{3-}	-	30
Cl^-	-	400
Ca^{2+}	230	230
Na^+	230	230
SO_4^{2-}	-	500

TABLE IV. QUALITY OF WATER FOR AGRICULTURAL IRRIGATION

Character	Threshold value
Acidity	4.4 – 9
Nitrate	-

IV. RESULTS AD DISCUSSION

This research presents an assessment of the outcomes of utilizing treated wastewater in ASTP for agricultural purposes.

A. Assessment of Raw Sewage Quality

The composition of the raw wastewater was evaluated by measuring the following quality parameters: pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and Biological Oxygen Demand (BOD5). The measurements of these parameters in both the influent and effluent wastewater over a five-month period are presented in Table V. By comparing these results and referencing American and Egyptian Standards (ECP 501-2005), crucial markers for sewage utilization in horticulture were identified. This study's data collection spanned five months, with the information in Table V being contrasted against the Egyptian and American standards. The results of the analysis are displayed in Figures

2-9. Figure 9 demonstrates that the TSS values for effluent-treated wastewater, considering all available data, fall within the acceptable range. The TDS readings of the treated sewage from all measurement data were within the highest acceptable limit. As depicted in Figure 2, the pH values of the flowing treated sewage, based on all measurement data, were within the acceptable limit.

B. Chemical Composition

The chemical composition of untreated and effluent wastewater in ASTP were assessed. The ions identified were chloride (Cl^-), sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3^-), and ammonia (NH_3(aq)). Table V details the concentrations of these ions in the treated sewage effluent collected over a five-month data collection period.

C. Comparison with Other Studies

The present study compared the tested parameters with the findings of several recent investigations. For instance, authors in [22] evaluated the impact of treated wastewater on soil microbial activity and explored the challenges associated with its use in agriculture. They discussed the harmful effects of toxic metals, salts, organic pollutants, and pathogens. This study focused on chemicals, such as chloride (Cl-), sulfate (SO42-), phosphate (PO 43-), nitrate (NO_3-), and ammonia (NH_3), as well as pH and TDS. Both studies highlight the need for the careful management of treated wastewater for reuse in agriculture. M. N. Ibrahim examined the effluent quality of 22 wastewater treatment plants in Jordan using the Weighted Arithmetic Water Quality Index (WQI) approach to evaluate the chemical and microbiological parameters according to Jordanian specifications. In contrast, the current study concentrated on a specific treatment plant, ASTP, in Iraq. Both investigations indicate the need for vigilant monitoring and potential treatment [23]. Authors in [24] focused on 39 quality parameters of wastewater from a treatment plant in Qom. The Wilcox diagram, irrigation, and agricultural usage indexes were used to compare the results. Their study revealed that the levels of total coliforms and fecal coliforms were significantly high, potentially posing a risk to consumers if used in agriculture. Additionally, the concentration of ammonium (NH) exceeded the allowed limits, indicating concerns about the potential for nitrate contamination of aquifers. In [25], it was indicated that the Al-Hoceima wastewater treatment plant complies with Moroccan standards for wastewater discharge. That study revealed a reduction in BOD5, COD, TSS, and heavy metals, highlighting the efficacy of the plant. However, the present research identified issues with chloride (Cl-) levels, pH, and TDS, emphasizing the critical need for vigilant monitoring and potential additional treatment measures to ensure safe and sustainable wastewater reuse in agriculture.

When evaluating the results presented in Table V, the characteristics of the treated wastewater from ASTP generally align with the standards set by both Egyptian and American guidelines for agricultural reuse. The recorded pH levels were at the higher end of the acceptable spectrum, which is conducive for certain crops that thrive under alkaline conditions [26]. The measured ammonia levels also exhibited changes related to seasonal changes and treatment effectiveness.

TABLE V. QUALITY OF RAW SEWAGE EFFLUENT OF ASTP

pH				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
Max	**Min**			
9.5	6	7.49	7.69	January
9.5	6	8.5	8.3	February
9.5	6	6.74	6.78	August
9.5	6	9.1	9.5	September
9.5	6	8.1	8.49	October
Ammonia (NH_3)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
10		16.8	28.2	January
10		18.9	16.9	February
10		9.6	21.5	August
10		19	23	September
10		4.4	12.8	October
Chloride (Cl^-)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
600		611	624	January
600		1902	2285	February
600		1470	3144	August
600		962	1549	September
600		1436	1290	October
Nitrate (NO_3^-)				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
50		60	28	January
50		29	27	February
50		35	25.5	August
50		13.5	11	September
50		84	19.5	October
Phosphate (PO_4^{3-})				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
3		5.2	8.8	January
3		0	14.2	February
3		3.2	13.2	August
3		8.8	10.6	September
3		0.9	10.8	October
Sulphate (SO_4^{2-})				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
400		979	996	January
400		997	1036.1	February
400		996.6	798.7	August
400		599.5	623.8	September
400		634.9	579.8	October
TDS				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
_		4572	6082	January
_		5540	6124	February
_		5166	7504	August
_		3220	4284	September
_		3696	3732	October
TSS				
Effluent discharge standard		**Effluent**	**Influent**	**Month**
60		268	1830	January
60		326	712	February
60		300	830	August
60		0	298	September
60		92	180	October

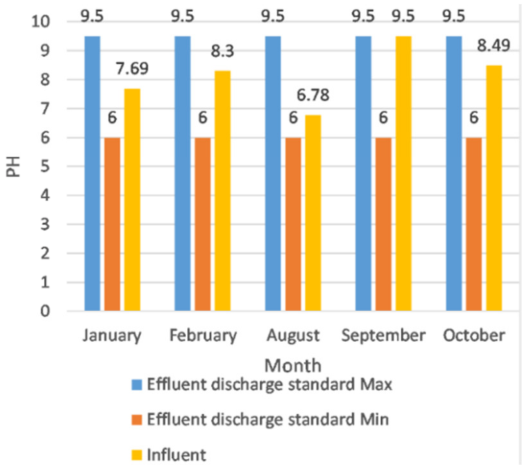

Fig. 2. pH of effluent and influent wastewater discharge compared to standards.

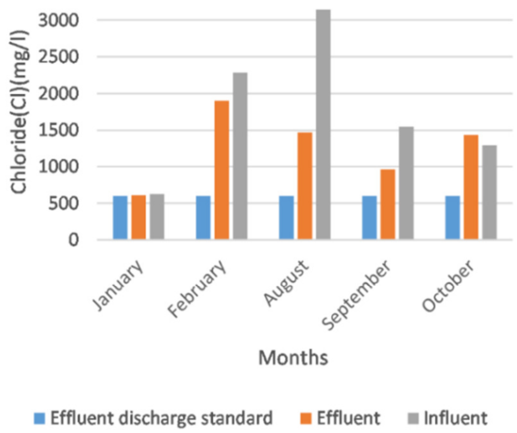

Fig. 3. Chloride (Cl^-) concentration in effluent and influent wastewater discharge compared to standards.

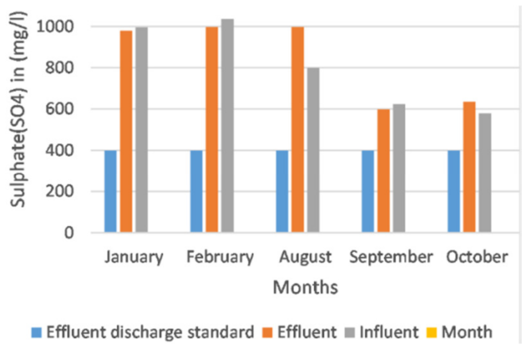

Fig. 4. Sulphate (SO_4^{2-}) concentration in effluent and influent wastewater discharges and compared to standards.

This is similar to the findings in [22] in which changes were observed in ammonia levels related to weather conditions. Additionally, chloride and sulfate levels exceeding standards in certain months underscore the importance of regular monitoring, as highlighted in the literature [24], emphasizing the risks associated with detrimental salt accumulation in agricultural soils. Regular collection and analysis of these parameters can promote adaptive management strategies, ensuring consistent compliance with safety thresholds and optimal usage in agricultural practices, thereby safeguarding both crop health and consumer safety.

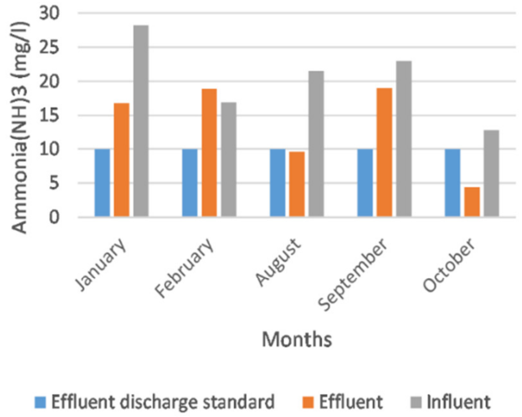

Fig. 5. Ammonia (NH_3) concentration in effluent and influent wastewater discharges and compared to standards.

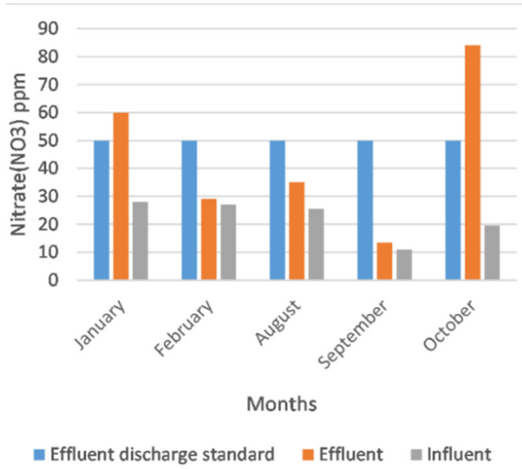

Fig. 6. Nitrate (NO_3^-) concentration in effluent and influent wastewater discharges and compared to standards.

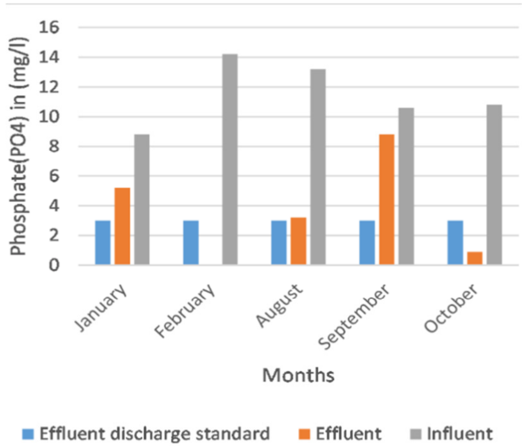

Fig. 7. Phosphate (PO_4^{3-}) concentration in effluent and influent wastewater discharges and compared to standards.

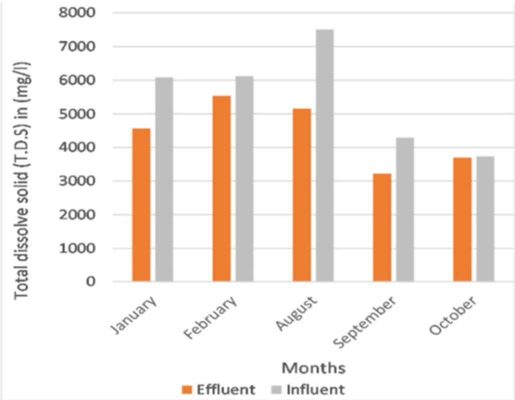

Fig. 8. TDS concentration in effluent and influent wastewater discharges.

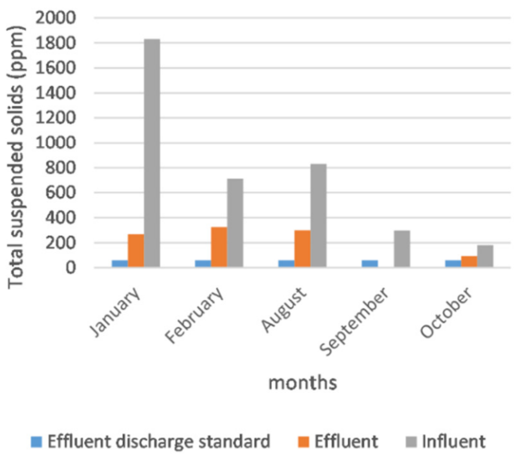

Fig. 9. TSS concentration concentration in effluent and influent wastewater discharges and compared to standards.

V. CONCLUSIONS

The results indicated that for treated wastewater, the pH, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS) measurements fell within acceptable and logical limits. Consequently, the processed wastewater from the Amarah Sewage Treatment Plant (ASTP) could be used for the irrigation of certain crops in agricultural applications. The analysis carried out in this study revealed that approximately 55% of the Cl^- measurements surpassed acceptable thresholds, 50% of the SO_4^{2-} values exceeded permissible levels, and 80% of the PO_4^{3-} readings were within acceptable ranges. The treated wastewater exhibited TDS, pH, ammonia, PO_4^{3-}, and NO_3^- concentrations within the acceptable range of the Iraqi standards. Based on these findings, this paper suggests implementing a monitoring and control system for wastewater treatment to ensure safe outcomes in the agriculture and other sectors. This system should include regular testing for sulfate and chloride concentrations simultaneously to address this issue when their concentrations exceed the acceptable limits. This study also strongly urges relevant authorities to follow the example of countries that have invested significantly in improving treatment processes. This initiative would enhance wastewater quality while conserving water resources, considering the current supply shortage and increasing demand. Finally, it is crucial to establish educational programs to improve farmers' understanding of proper wastewater usage, as they play a direct role in protecting public health and preserving the environment.

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