Journal of Human Environment and Health Promotion

Print ISSN: 2476-5481 Online ISSN: 2476-549X

Assessment of the Quality of Effluent from the Zanjan Urban Wastewater Treatment Plant for Potential Reuse in Agricultural and Industrial Applications

Mohammad Reza Mehrasbi [a,*], **Mahsa Salimi** [a], **Ali Assadi** [a]

a. Department of Environmental Health, School of Public Health, Zanjan University of Medical Sciences, Zanjan, Iran.

***Corresponding author:** Department of Environmental Health, School of Public Health, Zanjan University of Medical Sciences, Zanjan, Iran. Postal Code: 4515786349. E-mail: zmehr@zums.ac.ir

A R T I C L E I N F O

Article type:
Original article

Article history:
Received: 25 June 2025
Revised: 4 August 2025
Accepted: 16 August 2025
Available online: 25 August 2025

https://doi.org/10.61882/jhehp.704

Keywords:

Urban sewage effluent
Reuse
Agricultural uses
Industrial uses

A B S T R A C T

Background: Every year, a significant amount of water is consumed worldwide and converted into wastewater. This wastewater can be reused by treating and transforming it into reliable and sustainable water resources for various purposes. The purpose of this study was to assess the viability of reusing the effluent from the Zanjan wastewater treatment plant for agricultural and industrial uses in Group 4.
Methods: In order to assess the quality of treated wastewater for agricultural and Group 4 industrial purposes, various parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and coliforms were measured. The results were then compared to the guidelines in Iran, and the quality of the effluent was ultimately interpreted using the Wilcox diagram.
Results: The findings showed that the treated wastewater met the required quality standards for both agricultural and industrial Group 4 uses, with no restrictions for reuse. The wastewater was classified in the Wilcox diagram as C_3S_1, indicating moderate quality for agricultural applications.
Conclusion: The average parameters measured in the wastewater fall within the acceptable ranges for agricultural irrigation and industrial use in Group 4. However, the utilization and reutilization of this wastewater necessitate careful planning and consideration of its environmental impacts. Through meticulous planning and effective wastewater management, substantial water resources can be accessed for industrial and agricultural purposes without incurring extra costs.

1. Introduction

The scarcity of water resources and increasing demand in many parts of the world have made water supply a constant challenge. As a result, overuse of groundwater has significantly reduced its levels in many areas, while climate change and pollution have led to excessive depletion of surface water in numerous countries (Akhoundi & Nazif, 2018). Water is considered one of the most essential factors for the development of human societies. Iran is one of the countries where providing water for various uses is considered a significant concern for sustainable development in the country (Ghaneian & Dehvari, 2019). Iran is situated in an arid and semi-arid region. Despite covering only about 1.1% of the world's land area, it has access to just 0.36% of the total water available globally (Hatami et al., 2018). The 50-year average long-term rainfall in Iran was approximately 250 mm. In the 2000-2001 water year, it reached 172.1 mm. In the 2020-2021 water year, it reached 137.5 mm, and in the 2023-2024 water year, it reached 234.5 mm (Iran Meteorological Organization, 2024). In 2001, total water consumption was 78 billion cubic meters, with the agricultural, industrial, and residential sectors accounting for 71.8, 1.2, and 5 billion cubic meters, respectively. However, by 2021, water consumption had increased to 92.7 billion cubic meters. The agricultural, industrial, and residential sectors accounted for 82, 2.4, and 8.3 billion cubic meters, respectively (Ministry of Energy, 2021).

The availability of water is quickly diminishing, while the number of water users in residential, commercial, industrial, and agricultural sectors is steadily rising worldwide (Faramarzi et al., 2010; Mishra et al., 2021; Vollmer &

How to cite: Mehrasbi, M. R., Salimi, M., & Assadi, A. (2025). Assessment of the Quality of Effluent from the Zanjan Urban Wastewater Treatment Plant for Potential Reuse in Agricultural and Industrial Applications. *J Hum Environ Health Promot*, *11*(4), 238-243.

Harrison, 2021). Climate change, severe droughts, population growth, increasing demand, and poor management in recent decades have further highlighted the scarcity of freshwater resources worldwide (Jafari Shalamzari & Zhang, 2018; Khatibi & Arjjumend, 2019; Orimoloye et al., 2021; Procházka et al., 2018). Overexploitation of freshwater resources threatens food security and the overall well-being of humanity in many parts of the world (Al Hamedi et al., 2023; Falkenmark, 2013). Water scarcity is a problem that both developing and developed countries face, reflecting the complexity and unpredictability of the issue (Alsup & Alsup, 2021). It is predicted that by 2050, 3.6 billion people will not have access to adequate water (Aghababaei, 2020).

Reduced rainfall, shortages, and overexploitation of freshwater resources have made the management and use of unconventional waters a necessity for the country (Ghaneian & Dehvari, 2019; Kama et al., 2023; Procházka et al., 2018). Wastewater treatment and recycling are among the most important solutions in the current conditions of the country for developing water resources. It is also one of the most effective, sustainable, and always available factors that can reduce the pressure on the quantity of water resources (Farhadkhani et al., 2018; Heidarpour et al., 2007; Jeong et al., 2016; Khodabakhshi et al., 2022). Reusing wastewater not only creates new water resources and preserves existing water resources but also helps prevent environmental pollution (Orimoloye et al., 2021). The first regulations on wastewater reuse for agriculture and irrigation were established in California, USA, in 1918 (Angelakis et al., 2018; Olivieri et al., 2020; Shoushtarian & Negahban-Azar, 2020). World Health Organization (WHO) standards were published in 1973 (Jeong et al., 2016), followed by United State Environmental protection agency (USEPA) in 1980 and Food and Agriculture Organization (FAO) in 1987 (Shoushtarian & Negahban-Azar, 2020).

Wastewater can be utilized for various purposes such as urban, agricultural, recreational, environmental, industrial, and groundwater recharge (USEPA, 2012). Water used in industries is generally classified into four categories based on the required water quality and the amount of purification needed to achieve the desired quality. The fourth group of industrial waters includes water used in processes that are less sensitive than those in other groups. The main uses of water in this group include disposable and open-cycle cooling waters, surface washing water, water used in chemical industries for preparing adhesives, process water in petrochemicals, process water in cement factories, water used for transporting materials, irrigation, and water used in firefighting (Ministry of Energy, 2009).

In a study conducted in 2008, the performance of the Zanjan wastewater treatment plant was evaluated to assess the quality of the effluent for potential reuse in agricultural applications and discharge into receiving waters. The results of the study indicated that the activated sludge system utilized in the treatment plant was effective, producing effluent that met Standards for key parameters such as biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total suspended solids (TSS). As a result, the effluent was deemed suitable for agricultural reuse and discharge into receiving waters (Bagheri Ardebilian et al., 2011).

In a study conducted in 2011 to investigate the quality of wastewater from the Zanjan wastewater treatment plant, various parameters such as turbidity, pH, BOD_5, COD, TSS, and coliforms were measured. The results indicated that the wastewater met suitable conditions for agricultural use based on general indicators. However, in terms of bacteriology, the average data exceeded the environmental standard limit, indicating that the wastewater did not meet the required criteria (Gharibi & Akbarzadeh, 2014).

In a study conducted in 2011, the feasibility of using the effluent from the Zanjan treatment plant as water required by industries was assessed. The study evaluated the current degree of purification and compliance with environmental standards. The results indicated that the effluent fell into the third group of industrial waters. As a result, it was deemed suitable for use in cement industries without any restrictions. For petrochemical industries, the addition of a sand filter to remove additional TSS would make the effluent usable (Assadi et al., 2014).

In this study, we will evaluate the quality of wastewater from the Zanjan Wastewater Treatment Plant (ZWTP) to determine its suitability for reuse in agricultural and Group 4 industrial purposes. Water quality indicators will be compared to the guidelines in Iran for assessment. When comparing the output values of the parameters with their permissible limits in the guidelines, the quality of wastewater for agricultural uses is also determined based on the Wilcox diagram. Finally, according to FAO guidelines, potential irrigation issues are examined across various values of the parameters mentioned.

2. Materials and Methods

Zanjan Province is situated in the northwest of Iran (Figure 1), between 35°33' to 37°15' north latitude and 47°10' to 49°26' east longitude from the Greenwich meridian. The total area of Zanjan Province is 21,773 Km^2, with a population of 430,871 people in Zanjan City, the province′s center, according to statistics from 2016.

Figure 1. Map of Zanjan Province, Iran

ZWTP is located 5 km southwest of Zanjan city. Wastewater enters ZWTP by gravity. The existing ZWTP was put into operation as the first module in 2007 with a capacity of 125,000 people. Since 2017, work has been underway to upgrade the first module to accommodate 220,000 people by the target year 2019, with a flow rate of 40,000 cubic meters per day. This upgrade was completed and ready for operation by the end of the summer of 2019. A second module has been constructed for the target year 2022, with a total capacity of 410,000 people and a total flow rate of 75,000 cubic meters per day. The wastewater treatment process in the first module is an Extended Aeration Activated Sludge system, while in the second module, it is a sequencing batch reactor (SBR).

In this study, sampling of effluent from the ZWTP after the chlorination unit was conducted after the chlorination unit to determine the quality characteristics of the effluent over a 6-month period, from September 2023 to February 2024. After collection, the samples were transferred to the laboratory of the School of Public Health at Zanjan University of Medical Sciences.

The first step in investigating the reuse of effluent from the ZWTP is to determine water quality indicators. Therefore, to evaluate the quality of treated wastewater for agricultural purposes and Group 4 industrial uses, parameters such as electrical conductivity, BOD, COD, TSS, TDS, Na, Ca, Cd, Cl, Fe, Mg, Mn, SO_4, SiO_2, Pb, alkalinity, hardness, pH, turbidity, color, MPN and parasite eggs were measured and compared with estalished standards. All sampling conditions and tests were carried out according to the instructions outlined in the book "Standard Methods for Water and Wastewater Testing" (Rice & Bridgewater, 2012).

Excel software was used to analyze the data and draw graphs. Various standards for the use of wastewater in different fields have been established by international organizations such as WHO, FAO and USEPA. In Iran, the Environmental Protection Organization has set standards for the use of wastewater in agriculture and irrigation (IRNDOE Standard), while the Ministry of Energy has established guidelines for industrial uses (IRNMOE guideline). These standards will be considered in this study.

While comparing the output values of the parameters with their permissible limits according to guidelines, the quality of the effluent for agricultural use was also determined using the Wilcox diagram (Figure 2). This diagram is a common method for interpreting agricultural waters, based on electrical conductivity and the sodium absorption ratio (SAR). The horizontal axis represents electrical conductivity (EC) in µS/cm, while the vertical axis represents SAR. If the calcium, magnesium, and sodium levels in the water sample are known in terms of meq/l, the sodium absorption can be calculated using the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{1}{2}[ca^{2+}+Mg^{2+}]}}$$

In the Wilcox diagram, water is divided into 16 classes. Excellent quality water is in class C_1S_1, good water quality is in classes S_1C_2, S_2C_1, and S_2C_2. Moderate water quality is in classes S_3C_1, S_3C_2, S_2C_3, S_1C_3, S_3C_3, with the remaining classes indicating poor water quality. In these terms, S represents the sodium absorption ratio (SAR) and C represents the electrical conductivity (Wilcox, 1955).

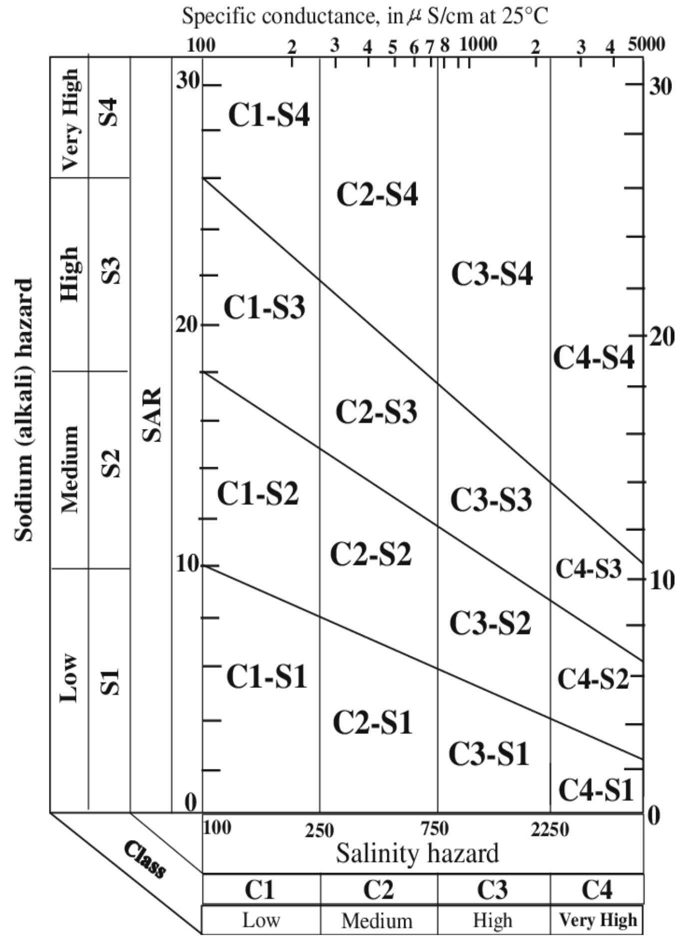

Figure 2. Wilcox diagram (Wilcox, 1955)

Table 1 presents the FAO guidelines for water quality for irrigation. It outlines potential irrigation issues associated with various parameter values. Electrical conductivity and total dissolved solids are used to determine water availability to crops, while electrical conductivity and SAR are used to assess water infiltration rate into the soil. Sodium and chlorine levels are evaluated for toxicity to sensitive crops in surface and sprinkler irrigation, and elements like nitrate and bicarbonate are considered for their impact on susceptible crops. The FAO guidelines also analyze the sensitivity of different agricultural products to water salinity (Ayers & Westcot, 1985).

3. Results and Discussion

The effluent from the ZWTP has been tested three times, and the average parameter values measured are shown in Table 2 to determine its suitability for use in agriculture compared to the IRNDOE Standard (Environmental Protection Agency of Iran, 2018).

According to Table 2, all measured parameters are within the standard range for reuse in agricultural uses. A sand filtration unit can be utilized to eliminate any potential parasite eggs.

Table 1. FAO guidelines for water quality for irrigation (Ayers & Westcot, 1985)

Possible Irrigation Problem		Units	Degree of Restriction on Use		
			None	Slight to Moderate	Severe
Salinity (Affects Crop Water Availability)					
EC_w		dS m^{-1}	<0.7	0.7-3	>3
(or)					
Total dissolved solids (TDS)		mg L^{-1}	<450	450-2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)					
SAR	=0-3 and EC		>0.7	0.7-0.2	<0.2
	=3-6		>1.2	1.2-0.3	<0.3
	=6-12		>1.9	1.9-0.5	<0.5
	=12-20		>2.9	2.9-1.3	<1.3
	=20-40		>5	5-2.9	<2.9
Specific Ion Toxicity (affects sensitive crops)					
Sodium (Na)					
Surface irrigation		SAR	<3	3-9	>9
Sprinkler irrigation		me L^{-1}	<3	>3	
Chloride (Cl)					
Surface irrigation		me L^{-1}	<4	4-10	>10
Sprinkler irrigation		me L^{-1}	<3	>3	
Boron (B)		mg L^{-1}	<0.7	0.7-3	>3
Trace Elements					
Miscellaneous Effects (affects susceptible crops)					
Nitrogen (NO_3-N)^2		mg L^{-1}	<5	5-30	>30
Bicarbonate (HCO3)		me L^{-1}	<1.5	1.5-8.5	>8.5
(overhead sprinkling only)					
pH				Normal Range 6.5-8.4	

Table 2. Values of measured effluent parameters and the IRNDOE Standard for agriculture

Paramrter	Unit	effluent	agriculture
EC	µs/cm	1148 ± 9.89	-
BOD	mg/l	8.23 ± 0.1	100
COD	mg/l	67.6 ± 10.07	200
TSS	mg/l	37.26 ± 4.72	100
Na	mg/l	88.56 ± 7.82	-
Ca	mg/l	75.56 ± 2.65	-
Cd	ppb	2.27 ± 0.2	0.05
Cl	mg/l	118.11 ± 3.04	600
Fe	mg/l	0.118 ± 0.006	3
Mg	mg/l	16.51 ± 1.22	100
Mn	mg/l	0.032 ± 0.002	1
Pb	ppb	0.43 ± 0.07	1
SO_4	mg/l	136.43 ± 0.56	500
pH	-	8.17 ± 0.14	6-8.5
Turbidity	NTU	1.08 ± 0.11	50
Color	Pt-Co	<5	75
MPN	n/100 mL	153.3 ± 4.7	1000
parasite eggs (after sand filtration)	n/1 lit	ND	<1

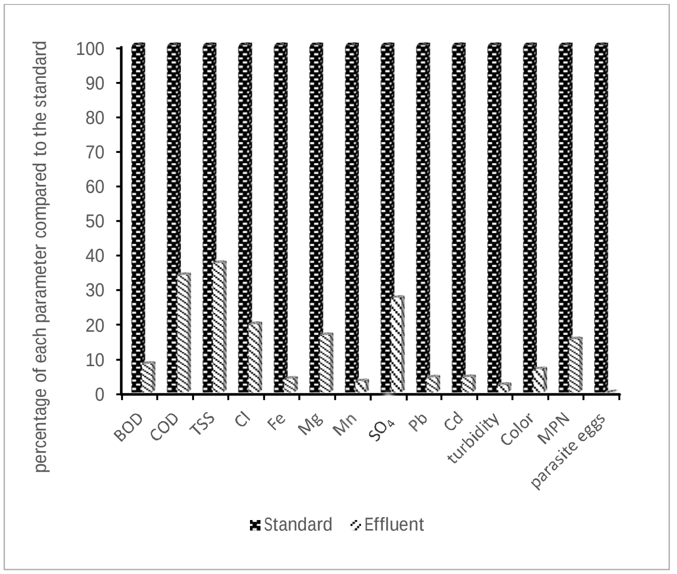

Figure 3. Comparison of ZWTP effluent and IRNDOE Standard for agriculture

Since the units of the parameters measured in this study were different, it was necessary to convert them to a common scale to draw a graph comparing the measured values to the standard. The graphs were plotted in percentage terms. In Figures 3 and 4, the standard level of each parameter was set at 100 percent, and the concentration of each parameter in the wastewater was calculated as a percentage compared to its standard level.

Figure 3 displays the levels of parameters measured in wastewater intended for agricultural reuse compared to the Iran Standard, as a percentage.

In the ZWTP, the electrical conductivity and SAR were 1148 µs/cm and 2.40, respectively. Therefore, according to the Wilcox diagram (Figure 2), the effluent falls into the C_3S_1 Class, which is considered a medium category. Table 3 displays the measurement results of the 6 parameters mentioned in Table 1, following the FAO guidelines for water quality for irrigation. According to the table, SAR and chlorine parameters in the effluent for surface irrigation fall within the range of having no effect, while the remaining parameters are within the range of having a slight to moderate effect on agricultural use.

Table 3. Comparison of ZWTP effluent and FAO guidelines

Parameter	Effluent	None	Slight to Moderate	Severe
EC (ds/m)	1.14	<0.7	0.7-3	>3
TDS (mg/L)	607.6	<450	450-2000	>2000
SAR(meq/L) Surface Irrigation	2.40	<3	3-9	>9
SAR(meq/L) Sprinkler Irrigation	2.40	<3	>3	-
Cl (meq/L) Surface Irrigation	3.33	<4	4-10	>10
Cl (meq/L) Sprinkler Irrigation	3.33	<3	>3	-
NO_3 (mg/L)	28.14	<5	5-30	>30
HCO_3 (meq/L)	3.11	<1.5	1.5-8.5	>8.5

The average values of the measured parameters are shown in Table 4 to determine their suitability for Group 4 industrial uses compared to the IRNMOE guideline (Ministry of Energy, 2009).

Table 4. Quality of ZWTP effluent for industrial uses, Group 4

Parametre	Effluent	IRNMOE guideline
pH	8.17 ± 0.14	5-10
COD (mg/l)	67.6 ± 10.07	0-75
TSS (mg/l)	37.26 ± 4.72	0-100
TDS (mg/l)	607.6 ± 9.39	0-1000
Cl (mg/l)	118.11 ± 3.04	0-500
SO_4 (mg/l)	136.43 ± 0.56	0-500
Fe (mg/l)	0.118 ± 0.006	0-1
Mn (mg/l)	0.032 ± 0.002	0-1
SiO_2 (mg/l)	24.12 ± 1.33	0-50
Alkalinity (mg/l CaCO3)	156 ± 6.48	0-500
Hardness (mg/l CaCO3)	256.66 ± 8.67	0-500

In Figure 4, the results of the ZWTP effluent are compared against the IRNMOE guidelines for Group 4 industrial uses, presented as percentages.

Based on the measurements of various parameters and the IRNMOE guidelines for Group 4 industries (Figure 4), all parameter values in the effluent from the ZWTP comply with the Group 4 industry guideline, indicating that no further treatment is necessary.

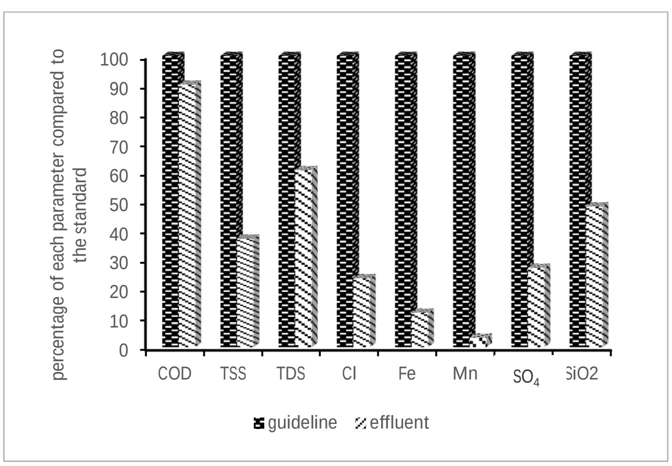

Figure 4. Comparison of ZWTP effluent and Group 4 industries

4. Conclusion

In this study, the quality parameters of the effluent from the ZWTP were measured and compared to the relevant guidelines in Iran to assess its suitability for agricultural and industrial use in Group 4. The results showed that the quality of the wastewater meets the standards for agricultural consumption and Group 4 according to the guidelines in Iran. Additionally, the Wilcox diagram classified the effluent from the ZWTP as C_3S_1, indicating it is in the medium class.

Overall, it can be concluded that utilizing treated effluent from urban treatment plants to replace conventional water resources in agriculture and industries can significantly benefit valuable water resources and have positive economic and environmental impacts. However, careful planning and consideration of environmental impacts are necessary for its use and reuse.

Authors' Contributions

Mohammad Reza Mehrasbi: methodology; validation and study design; and supervision of the study. **Mahsa Salimi:** material preparation; data collection; experiments; and formal analysis. **Ali Assadi:** design and formal analysis; writing the fisrt draft of the paper. All authors reviewed and approved the final manuscript.

Funding

This work was funded by Zanjan University of Medical Science.

Conflicts of Interest

The authors declare that they have no competing interests.

Acknowledgments

The authors would like to thank the Zanjan University of Medical Sciences, Zanjan, Iran, for their support.

Ethical considerations

This study received approval from the Ethics Committee of Zanjan University of Medical Science. (Code: IR.ZUMS.BLC.1401.025).

Using artificial intelligence

The website, editmyenglish.com, was used to edit the English text.

References

Aghababaei, N. (2020). Feasibility of reuse of wastewater Tafresh's municipal sewage treatment plant in agriculture. *Iranian Journal of Irrigation and Drainage*, *13*(6), 1774-1782.

Akhoundi, A., & Nazif, S. (2018). Sustainability assessment of wastewater reuse alternatives using the evidential reasoning approach. *Journal of Cleaner Production*, *195*, 1350-1376.

Alsup, K., & Alsup, K. E. (2021). *Sustainable water treatment systems: A direct potable proposal.* Honors College Theses. https://digitalcommons.murraystate.edu/honorstheses/89

Angelakis, A. N., Asano, T., Bahri, A., Jimenez, B. E., & Tchobanoglous, G. (2018). Water reuse: From ancient to modern times and the future. *Frontiers in Environmental Science*, *6*, 26.

Assadi, A., Hassani, A. H., Babaloo, N., & Javid, A. (2014). *Feasibility study on the reuse of wastewater from the Zanjan city wastewater treatment plant for industrial purposes.* 16th National Conference on Environmental Health. https://civilica.com/doc/237519/

Ayers, R. S., & Westcot, D. W. (1985). *Water quality for agriculture*. Food and Agriculture Organization of the United Nations.

Bagheri Ardebilian, P., Sadeghi, H., Nabaii, A., & Bagheri Ardebilian, M. (2011). Assessment of wastewater treatment plant efficiency: A case study in Zanjan. *Journal of Health and Hygiene, 1*(3), 67-75.

Environmental Protection Agency of Iran. (2018). *Treated wastewater output standard.* http://www.environmentalhealth.ir/Water-and-Wastewater-Standards

Falkenmark, M. (2013). Growing water scarcity in agriculture: Future challenge to global water security. *Philosophical Transactions of the Royal Society A, 371*(2002), 20120410.

Faramarzi, M., Yang, H., Mousavi, J., Schulin, R., Binder, C. R., & Abbaspour, K. C. (2010). Analysis of intra-country virtual water trade strategy to alleviate water scarcity in Iran. *Hydrology and Earth System Sciences*, *14*(8), 1417-1433.

Farhadkhani, M., Nikaeen, M., Yadegarfar, G., Hatamzadeh, M., Pourmohammadbagher, H., Sahbaei, Z., & Rahmani, H. R. (2018). Effects of irrigation with secondary treated wastewater on physicochemical and microbial properties of soil and produce safety in a semi-arid area. *Water Research*, *144*, 356-364.

Ghaneian, M. T., & Dehvari, M. (2019). *Guideline for application of reclaimed water in agriculture*. Tehran University Of Medical Science.

Gharibi, H., & Akbarzadeh, A. (2014). *Improving the process of the Zanjan city wastewater treatment plant to enhance the quality of the effluent for agricultural use.* The Second National Conference on Water Recycling: A Principled Strategy for Managing the Water Crisis. https://civilica.com/doc/338098

Hasan Al Hamedi, F., Kandhan, K., Liu, Y., Ren, M., Jaleel, A., & Alyafei, M. A. M. (2023). Wastewater irrigation: A promising way for future sustainable agriculture and food security in the United Arab Emirates. *Water*, *15*(12), 2284.

Hatami, T., Nadali, A., Roshanaei, G., & Shokoohi, R. (2018). Feasibility of reuse of effluent from the extended aeration process of wastewater treatment plant in the Bojnoord city for agricultural and irrigation uses. *Pajouhan Scientific Journal*, *16*(3), 20-28.

Heidarpour, M., Mostafazadeh-Fard, B., Koupai, J. A., & Malekian, R. (2007). The effects of treated wastewater on soil chemical properties using subsurface and surface irrigation methods. *Agricultural Water Management*, *90*(1-2), 87-94.

Iran Meteorological Organization. (2024). *Trends in annual precipitation changes in the last 50 years across the country.* https://www.irimo.ir/

Jafari Shalamzari, M., & Zhang, W. (2018). Assessing water scarcity using the Water Poverty Index (WPI) in Golestan province of Iran. *Water*, *10*(8), 1079.

Jeong, H., Kim, H., & Jang, T. (2016). Irrigation water quality standards for indirect wastewater reuse in agriculture: A contribution toward sustainable wastewater reuse in South Korea. *Water*, *8*(4), 169.

Kama, R., Song, J., Liu, Y., Hamani, A. K. M., Zhao, S., & Li, Z. (2023). Water availability and status of wastewater treatment and agriculture reuse in China: A review. *Agronomy*, *13*(5), 1187.

Khatibi, S., & Arjjumend, H. (2019). Water crisis in making in Iran. *Grassroots Journal of Natural Resources*, *2*(3), 45-54.

Khodabakhshi, A., Mohammadi-Moghadam, F., Motaghi, K., & Bagherzadeh, F. (2022). Investigating the feasibility of reuse of effluent from wastewater treatment plant in Borujen City, Iran, for agricultural and irrigation uses. *Journal of Health System Research*, *18*(1), 66-74.

Ministry of Energy. (2009). *Guidelines for quality lassification of raw water, effluent, and reused water for industrial and recreational use.* https://www.bhrc.ac.ir/Portals/8/PropertyAgent/1567/Files/1814/Code462.pdf

Ministry of Energy. (2021). *The amount of excessive water extraction in different years.* https://new.moe.gov.ir/fa-IR/isn.moe.gov/5749/Articles/view/15574/492/-140IR/isn.moe.gov/5749/Articles/view/15574/492/-140

Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. (2021). Water security in a changing environment: Concept, challenges and solutions. *Water*, *13*(4), 490.

Olivieri, A. W., Pecson, B., Crook, J., & Hultquist, R. (2020). California water reuse-Past, present and future perspectives. In R. Singh, A. Kumar, & S. Sinha, *Advances in chemical pollution, environmental management and protection* (pp. 65-111). Elsevier.

Orimoloye, I. R., Belle, J. A., Olusola, A. O., Busayo, E. T., & Ololade, O. O. (2021). Spatial assessment of drought disasters, vulnerability, severity and water shortages: A potential drought disaster mitigation strategy. *Natural Hazards*, *105*(3), 2735-2754.

Procházka, P., Hönig, V., Maitah, M., Pljučarská, I., & Kleindienst, J. (2018). Evaluation of water scarcity in selected countries of the Middle East. *Water*, *10*(10), 1482.

Rice, E. W., & Bridgewater, L. (2012). *Standard methods for the examination of water and wastewater*. American Public Health Association.

Shoushtarian, F., & Negahban-Azar, M. (2020). Worldwide regulations and guidelines for agricultural water reuse: a critical review. *Water*, *12*(4), 971.

USEPA. (2012). *Guidelines for water reuse.* https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf

Vollmer, D., & Harrison, I. J. (2021). $H_2O \neq CO_2$: Framing and responding to the global water crisis. *Environmental Research Letters*, *16*(1), 011005.

Wilcox, L. V. (1955). *Classification and use of irrigation waters*. U. S. Department of Agriculture.