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Original Article

Treated Wastewater Reuse for Agricultural Irrigation: A Case Study in Saveh City

Mokhtar Mahdavi[1,2*], Heshmatollah Ahmadi[3], Fatemeh Jalouli[1], Melika Memari[1], Mozhgan Farzmarzi[1], Ali Jamalvandi[2], Ali Torabi[3,4], Mokhtar Vaisi[5]

[1]Student Research Committee, Saveh University of Medical Sciences, Saveh, Iran
[2]Water and Wastewater Quality Monitoring and Control Center, Kermanshah Province Water and Wastewater Company, Kermanshah, Iran
[3]Human Resources and Research of Water and Wastewater Company of Kermanshah Province, Kermanshah, Iran
[4]Islamic Azad University of Kermanshah, Kermanshah, Iran
[5]Water and Wastewater Finance Department, Kermanshah Water and Wastewater Company, Kermanshah, Iran

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***Corresponding author:**
Mokhtar Mahdavi,
Email: Shamall6@yahoo.com

Abstract

Introduction: Using treated wastewater for farming irrigation is a strategic way to address water shortages. While it offers the benefit of providing nutrients to crops, its use poses health risks unless pathogens are sufficiently reduced to comply with safety standards. This study assessed the feasibility of reusing treated municipal wastewater from Saveh City, Iran, for agricultural purposes.

Methods: In a descriptive-analytical study, the samples were collected from the inlet and outlet of the Saveh wastewater treatment plant during spring and summer 2024. Physical, chemical, and biological parameters were analyzed according to the Standard Methods for the Examination of Water and Wastewater.

Results: The treated effluent complied with the Iranian agricultural standards for key physicochemical parameters, including pH, turbidity, chloride, and Chemical Oxygen Demand (COD). The Sodium Adsorption Ratio (SAR) was 5.28 and sodium percentage (Na%) was 53, indicating low sodium hazard and excellent water quality for irrigation. However, total and fecal coliform levels (26,000 and 6000 MPN/100 mL, respectively) exceeded permissible limits. The study calculated that the treated wastewater could irrigate approximately 194 hectares of wheat.

Conclusion: While the treated wastewater from Saveh is chemically suitable for agricultural reuse, its microbial quality requires enhancement through disinfection (e.g., UV, ozone) or additional treatment prior to use to ensure public health safety.

Keywords: Treated municipal wastewater, Agricultural irrigation, Wastewater reuse feasibility, Water scarcity solutions

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Introduction

Untreated wastewater contains pollutants that threaten health and the environment, affecting both farmers and their crops, and it can harm soil productivity. Properly managed treated wastewater irrigation is essential to avoid harm and provide benefits to farmers and society. In water-scarce countries, reusing treated wastewater is increasingly important. Although municipal wastewater is typically disinfected with chlorine, some pathogens resist this method, and chlorine can react with organic matter to form potentially carcinogenic compounds. In the last 20 years, treated wastewater reuse in agriculture has gained focus as a way to address water shortages. However, ensuring its safety and hygiene remains a challenge. Moreover, cultural resistance and limited public education about its safety hinder wider acceptance.[1,2] In arid and semi-arid regions where suitable water for drinking and agriculture is not always available, wastewater reuse can help manage water consumption.

A study on treated municipal wastewater in Mahdasht, Alborz province, found that a soil column covered with geotextile removed 67.7% of TSS, 77% of Chemical Oxygen Demand (COD), and 84.7% of Biological Oxygen Demand (BOD_5). Over time, the electrical conductivity and salinity of the outlet samples increased, while the outlet pH was generally lower than the inlet pH, though pH tended to rise at different soil depths.[3] In 2007, Zhao et al, in their study “Reducing Wastewater Pollutants Using Soil Columns on a Laboratory Scale," stated that the removal rate of organic matter is highest at half a meter from the soil surface.[4] Also, Dehghani et al studied treated wastewater from industrial parks for agricultural use and found that most parameters (TSS, SO_4, pH, and turbidity) were within Iran's environmental standards. However, COD and BOD_5 levels exceeded safe limits, indicating potential environmental risks if used for irrigation.[5] Jolaini et al studied Mashhad's water demand and wastewater output, projecting growth until 2035. They concluded that treated wastewater could help offset the reduced water available for agriculture due to increased demand for drinking and sanitation.[6] Masoudian et al found that public resistance to using treated wastewater in agriculture stems mainly from health concerns, distrust of authorities, and lack of awareness about treatment processes. Conversely, educating legislators on sustainable development and the economic and social benefits promotes their support for wastewater reuse projects.[7] In another study, Kolivand et al reported that a 50% filling percentage and 4-hour retention time are optimal for a moving bed biofilm reactor treating synthetic wastewater for irrigation. They also developed a regression model to estimate COD based on these factors.[8]

Zolfaghary used the Analytical Hierarchy Process to assess the feasibility of using urban wastewater for agriculture. Despite concerns about nitrate levels, microbial contamination, and aquifer vulnerability, cotton and rapeseed were identified as the most suitable crops for cultivation with wastewater in the study area.[9]

Mojiri's study found that using treated urban wastewater for agriculture is economically viable for dealing with water scarcity and supports agricultural development. Owing to its high salt and nutrient content, treated wastewater plays a unique role in food production.[10] Pirsaheb et al found that treated urban wastewater from the Olang Mashhad plant is a viable alternative to well water for irrigation. Its nutrient content can enhance agricultural productivity and reduce the need for chemical fertilizers.[11] A study in Qom evaluated treated wastewater for aquifer recharge and agriculture. The results showed that the effluent did not meet international and agricultural standards, making it unsuitable for farming without further review and management. Using this treated wastewater could pose health risks to farmers and workers.[12] Wastewater reuse offers benefits such as water conservation, reduced fertilizer use, and higher crop yields, but also poses risks including groundwater nitrate contamination, soil salinity, and health issues. Although the World Health Organization (WHO) has set standards, many countries struggle to meet them and cannot safely use treated wastewater. The main objective of this study was to quantitatively and qualitatively assess the treated wastewater of Saveh city based on various standards for agricultural use. As farmers in some cases already use this treated wastewater for irrigation, evaluating its quality is important to prevent risks to public health.

Materials and Methods

Study Area

The Saveh Wastewater Treatment Plant (WWTP), with a capacity of 35,000 m^3/day, accommodates a population of over 220,000 people. It was established to enhance the quality of life and health standards, prevent groundwater pollution, and optimize the use of treated wastewater for various applications. The presence of numerous factories has made Saveh one of the most attractive cities for migrants in Iran. The use of raw or treated wastewater remains a significant concern in this city, persisting despite extensive monitoring by the Saveh Health Department. The WWTP is located in southeastern Saveh, at geographical coordinates 444419.67 m longitude (X or E) and 3873654.69 m latitude (Y or N). Figure 1 shows the location of this facility.

Sampling

This descriptive, cross-sectional study was conducted during the spring and summer seasons. Sampling was performed on both raw and treated wastewater, with two sampling events spaced one month apart. Each event included two replicates, resulting in a total of 12 samples. The spring and summer seasons were selected because irrigation primarily occurs during this period.

Experimental Parameters

Following monthly sampling during the spring and summer seasons, the collected samples were transported to the laboratory of Saveh School of Health and Medical Sciences. Important parameters were analyzed according to Standard Methods for the Examination of Water and Wastewater.[13] The following parameters were measured: pH, color, turbidity, dissolved oxygen (DO), electrical conductivity (EC), COD, sodium, total dissolved solids (TDS), potassium, calcium, magnesium, total coliform (TC), and fecal coliform (FC).

- Turbidity: Measured using a HACH 2100 Q portable turbidimeter (nephelometric method).
- Color: Measured using a HACH DR6000 spectrophotometer (Method 120-Color 455 nm).
- pH: Measured using a HACH pH meter.
- COD: Measured using the vial method with a DR6000 spectrophotometer.
- Sodium and potassium were measured with a flame photometer.
- Total hardness, total alkalinity, calcium and magnesium measured by titration method.
- Microbiological Parameters (TC and FC): Determined based on the "Standard Methods for the Examination of Water and Wastewater."

Furthermore, data analysis involved calculating measures of central tendency (mean), using statistical tables, and comparing results with established standards. Additionally, water quality indices such as the Sodium Adsorption Ratio (SAR) and percent sodium were evaluated.

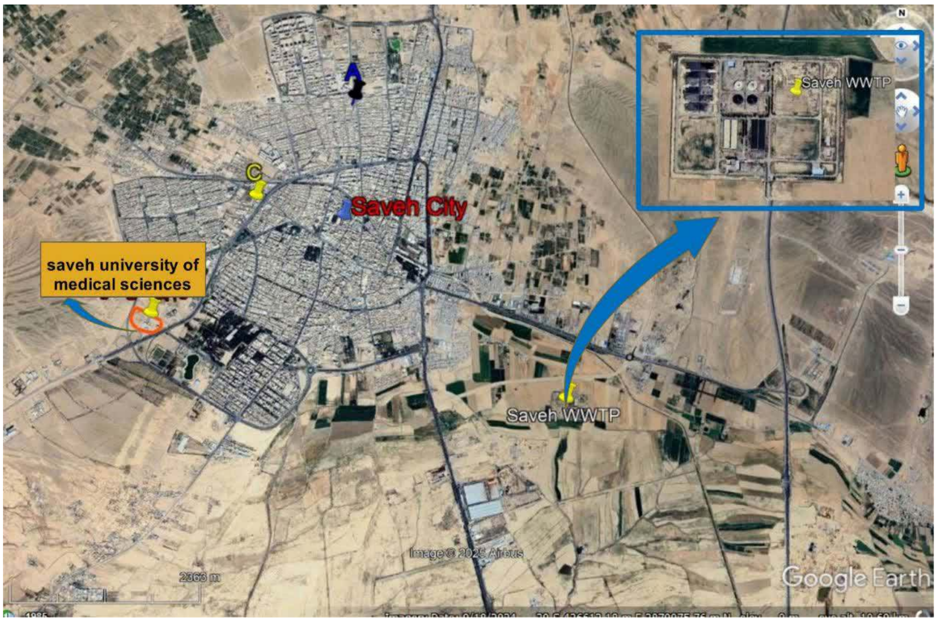

Figure 1. Location of the Saveh WWTP

Results and Discussion

The Quality of Raw and Treated Wastewater

Table 1 presents the characteristics of the raw influent and treated effluent from the Saveh Wastewater Treatment Plant.

In many developing countries, wastewater treatment and reuse are increasingly recognized as viable strategies to address water shortages and manage growing wastewater volumes. This is particularly crucial for nations in semi-arid and arid regions, where severe water scarcity and rising freshwater demands in agriculture and industry necessitate the use of treated wastewater as an alternative source.[14] Key physical characteristics of wastewater include turbidity, color, odor, electrical conductivity, and temperature. Chemically, wastewater contains various anions and cations that indicate nutrient levels and the extent of organic matter decomposition. Biologically, indicators such as total coliforms, fecal coliforms, and parasitic eggs are critical because of their pathogenic potential in treated effluent. These parameters collectively influence both the treatability of raw wastewater and the suitability of treated effluent for reuse in urban, agricultural, and industrial contexts. A summary of the most critical parameters has been presented in Table 2.[15,16] As this study has demonstrated, the treated wastewater from Saveh city meets the necessary standards for irrigation and agriculture in terms of pH (7), turbidity (72.4 NTU), and color (51 Pt. Co. units). The pH value, in particular, is within the compliant range, which is not only suitable for the growth of beneficial heterotrophic bacteria in biological treatment processes but also poses no adverse risk to soil health or plant development.[17]

Table 1. Characteristics of Raw and Treated Wastewater at the Saveh Wastewater Treatment Plant in 2024

Parameters	Raw wastewater	Treated wastewater	Iranian standard for wastewater disposal
Turbidity (NTU)	165	4.72	50
True color (Pt. Co. units)	498	51	75
Electrical conductivity (μs/cm)	4004	3610	-
Total dissolved solids (mg/L)	2131	1900	-
pH	7.59	7.04	6-8.5
Total Hardness (mg/L as $CaCO_3$)	462	434	-
Alkalinity (mg/L as $CaCO_3$)	411	451	-
Sulfate (mg/L)	450	420	-
Chloride (mg/L)	659	533	600
Calcium (mg/L)	125	115	-
Magnesium (mg/L)	52	49	100
Sodium (mg/L)	280	265	-
Potassium (mg/L)	27	22	-
Sludge Volume (mL/L)	2.5	0	-
COD (mg/L)	320	120	-
Dissolved Oxygen (mg/L)	1.5	2.5	2
Total Coliforms (MPN/100 mL)	-	26000	1000
Fecal Coliforms (MPN/100 mL)	-	6000	400

The water in Saveh is naturally brackish, exhibiting elevated levels of total dissolved solids (TDS) and electrical conductivity (EC), approximately 1900 mg/L and 3610 μS/cm, respectively. Although no specific regulatory standards currently exist for these parameters, their high values are notable. TDS encompasses a variety of anions and cations and can significantly influence the assessment of other indicators, such as the SAR. According to the guidelines proposed by Ayers, the reuse of treated effluent from the Saveh municipal wastewater treatment plant is considered unrestricted with respect to EC. However, it is subject to moderate restrictions regarding TDS concentration. This suggests that prolonged use of the treated effluent may negatively affect soil permeability. Nonetheless, this impact can be mitigated through

Table 2. Some Important Qualitative Characteristics of Wastewater to Consider for Reuse in Effluent

Constituent	Reason for importance
Suspended solids	Suspended solids can lead to sludge deposits and anaerobic conditions when untreated wastewater is discharged into the aquatic environment.
Biodegradable organic matter	It is mainly composed of proteins, carbohydrates and fats and is usually measured in terms of BOD and COD. Its biological stability can lead to oxygen depletion and septic conditions.
Pathogenic agents	Infectious diseases can be transmitted by pathogenic organisms present in wastewater.
Nutrients	Nitrogen, phosphorus and carbon are essential nutrients for growth, but discharging them in excess in the aquatic environment will cause undesirable growth of aquatic organisms. Also, excessive discharge in the terrestrial environment will cause groundwater pollution.
Priority pollutants	Organic and inorganic compounds that are known based on their carcinogenicity, mutagenicity, teratogenicity or acute toxicity, some of which can be detected in wastewater.
Persistent organic matter	These materials tend to be resistant to conventional wastewater treatment methods (agricultural pesticides, phenols, surfactants, etc.).
Heavy metals	Heavy metals are usually added to wastewater as a result of commercial and industrial activities and are very dangerous to human health.
Soluble minerals	Inorganic compounds such as calcium, sodium, and sulfates, which must be removed if wastewater is reused, especially for agricultural or industrial purposes, because they can have a destructive effect on plants, soil, or sediment and corrosion.

appropriate management strategies, including the application of soil and water quality amendments and the implementation of best agricultural practices.[18]

The organic load of wastewater is commonly assessed using parameters such as BOD and COD. In the present study, the COD of the treated effluent was measured at 120 mg/L, which is below the permissible limit of 200 mg/L, thereby indicating compliance with regulatory standards for treated wastewater in Saveh. Baanu et al reported that the application of treated wastewater with a COD concentration of approximately 34 mg/L did not present any adverse effects when used for agricultural purposes.[19] Similarly, Anbir et al, in their study titled "Evaluation of the Quality of Treated Effluent from the Ekbatan Urban Wastewater Treatment Plant for Use in Agricultural Lands and Green Spaces," recorded BOD and COD removal efficiencies of 97 and 95%, respectively. The findings of the present study confirm the claim that wastewater treatment and reuse may be regarded as one of the most important solutions toward optimal management of water resources under the current conditions in Iran to meet part of the growing water demand.[20]

Chloride is among the key ions that can contribute to plant toxicity when present in elevated concentrations.[21] Based on environmental regulations, the maximum permissible chloride concentration for irrigation is less than 600 mg/L. In this study, the chloride concentration in the treated effluent from Saveh was measured at 533 mg/L, which falls within the limit set by the Environmental Protection Agency. However, according to guidelines from the Food and Agriculture Organization (FAO), this level exceeds the range for good-quality irrigation water (70–140 mg/L), making the effluent unsuitable for chloride-sensitive crops. In a related study, Bahrami et al found that chloride levels in treated wastewater from the Shiraz municipal facility remained within acceptable limits for agricultural irrigation.[22] In a study by Panahi et al, which investigated the impact of the use of urban wastewater on groundwater quality in Northern Isfahan, the chloride level in the effluent exceeded the standard limit.[23] The magnesium concentration in the effluent from the Saveh municipal wastewater treatment plant was measured at 49 mg/L, which is below the irrigation water standard threshold of 100 mg/L. This indicates that the magnesium content does not pose significant risks for agricultural use. This finding is consistent with that of Mohammadi Moghaddam et al[24] who reported a magnesium concentration of 19 mg/L in the effluent from the Isfahan municipal wastewater treatment plant, further supporting the suitability of treated wastewater in this regard.

It is important to note that under high pH conditions (above 8 to 9), increased concentrations of bicarbonate and carbonate ions can lead to calcium precipitation and a reduction in exchangeable calcium in the soil. This process may subsequently elevate soil sodium levels, potentially affecting soil structure and fertility.[25] However, this concern does not apply in the present case, as the pH of the treated wastewater in Saveh was neutral at 7.

Microbial quality is another critical parameter in assessing the suitability of treated effluent for reuse. For the Saveh municipal wastewater treatment plant, the total coliform and fecal coliform counts were recorded at 26,000 and 6,000 MPN/100 mL, respectively. These values substantially exceed permissible limits for agricultural irrigation, indicating potential health and environmental risks. These findings are consistent with other studies in Iran. Panahi et al, in their evaluation of effluent quality in northeast Isfahan, reported that while most physicochemical parameters met standards, elevated levels of total coliforms, parasite eggs, and detergents in some samples limited its safe agricultural use.[23] Besides, a study by Nasseri et al, which investigated the effect of the use of *Treated Wastewater from Ardabil Wastewater Treatment Plant for agricultural aims,* reported that total and fecal coliform concentrations in the treated effluent exceeded the recommended limits established by the Iranian Environmental Protection Agency for agricultural reuse. As a result, the study emphasized the need for additional chlorination prior to effluent discharge. Moreover, considering the average concentrations of fecal coliforms and intestinal nematode eggs, and in accordance with WHO guidelines, the use of this effluent for irrigating crops consumed raw is not considered safe or permissible.[26]

A study conducted by Razaghi Khamsi et al reported that total and fecal coliform levels in the wastewater from Firoozabad exceeded the permissible limits established by Iranian standards, rendering the effluent unsuitable for agricultural irrigation without further treatment.[27] Similar findings have been reported in other studies, indicating that the average total and fecal coliform counts in treated wastewater from the examined locations do not meet national microbial quality standards.[28]

As far as agricultural reuse is concerned, the type of crop, edible versus non-edible, plays a critical role in determining the applicable microbial standards and the required level of wastewater treatment. According to existing guidelines, wastewater intended for the irrigation of edible crops must undergo both primary and secondary treatment.[29] Therefore, if the effluent from the present study is to be used for irrigating edible crops, additional treatment will be required. This can be achieved through methods such as ultraviolet (UV) disinfection, effluent storage in retention tanks, and filtration systems, all of which are effective in improving the microbial quality of treated wastewater.[30] Table 2 shows some of the qualitative characteristics of wastewater that should be considered for effluent reuse.

Standards for Effluent and Reuse of Treated Wastewater

Table 3 shows the standards set by the Iranian Environmental Protection Agency for the use of treated wastewater in agricultural and green space applications. This table examines important qualitative parameters.

Wastewater production is inevitable, as it is an inseparable part of the value chain in all aspects of human activity.[30] Global annual wastewater production is estimated at approximately 380 billion cubic meters (some estimates range from 360 to 380 billion m^3), and roughly 20 million hectares of agricultural land are irrigated with contaminated (often untreated) wastewater. Approximately one-tenth of the world's irrigated crops are watered with raw, untreated wastewater. Farmers in parts of Asia (e.g., China, Pakistan, India) and Africa (e.g., Kenya, Morocco, Ethiopia, Ghana) often prefer undiluted wastewater because it supplies nutrients and is cheaper than alternative water sources.[32, 33] An important portion of wastewater is relatively clean and, with proper treatment, can be safely reused—representing one of the most straightforward solutions to water scarcity.[34] Treated wastewaters can be applied for drinking water preparation, agricultural irrigation, road and sidewalk cleaning, outdoor dust control, car washing, toilet flushing, park and sports field irrigation, street washing, cemetery maintenance, vehicle washing, and firefighting. Such reuse typically requires advanced treatment methods, such as coagulation and flocculation combined with filtration, or oxidation processes.[35]

Reusing wastewater for irrigation offers agronomic benefits due to its nutrient content (e.g., nitrogen), but it also carries risks from potentially toxic metals and other contaminants that can harm plants and human health. While nutrients like nitrogen are essential for plant growth, excessive concentrations can disrupt normal development, increase susceptibility to pests and diseases, and ultimately reduce crop yields. Therefore, policy and regulatory decisions regarding the treatment level and agricultural application of wastewater must carefully balance costs, risks, and benefits.[36]

Table 3. Iranian Environmental Protection Agency Standards for Discharging Treated Wastewater for Agricultural and Green Space Use[31]

Row	Pollutants	Unit (mg/L)	Row	Pollutants	Unit (mg/L)	Row	Pollutants	Unit (mg/L)
1	Total Suspended Solids (TSS)	100	18	Arsenic (As)	0.1	35	Mercury (Hg)	negligible
2	Total Dissolved Solids (TDS)	-	19	Bromium (Br)	1	36	Lithium (Li)	2.5
3	BOD5	100	20	Barium (Ba)	1	37	Magnesium (Mg)	100
4	COD	200	21	Beryllium (Be)	0.5	38	Manganese (Mn)	1
5	Settlement able Solids (SS)	-	22	Calcium (Ca)	-	39	Molybdenum (Mo)	0.01
6	Dissolved Oxygen (DO (Min)	2	23	Cadmium (Cd)	0.05	40	Nickel (Ni)	2
7	pH Range	6-8.5	24	Free chlorine (Cl)	0.2	41	Ammonium (NH_4^+)	-
8	Parasite Eggs	*	25	Chloride (Cl^-)	600	42	Nitrite (NO_2^-)	-
9	Detergent, ABS	0.5	26	Formaldehyde	1	43	Nitrate (NO_3^-)	-
10	Color (Color Unit)	75	27	Phenol	1	44	Phosphate (PO_4)	-
11	Turbidity (Turbidity Unit)	50	28	Cyanide (CN)	0.1	45	Lead (Pb)	1
12	Radioactive Substances (Picocuries)	0	29	Cobalt (Co)	0.5	46	Selenium (Se)	0.1
13	Fat Oil	10	30	Chromium (Cr^{6+})	1	47	Sulfide (S^{2-})	3
14	Total Coliforms (per 100 mL)	400	31	Chromium (Cr^{3+})	2	48	Sulfite (SO_3^{2-})	1
15	Fecal Coliforms (per 100 mL)	1000	32	Copper (Cu)	0.2	49	Sulfate (SO_4^{2-})	500
16	Silver (Ag)	0.1	33	Fluoride (F)	2	50	Vanadium (V)	-
17	Aluminum (Al)	5	34	Iron (Fe)	3	51	Zinc (Zn)	2

* The number of parasite eggs (nematodes) in treated wastewater, if used to irrigate crops that are consumed raw, should not exceed one per liter.

Recent studies indicate that treated wastewater is used for crop irrigation in various countries, provided that relevant standards are met. Examples include the following approximate percentages of total wastewater reused (often largely for irrigation): Brazil (0.1%), Mexico (5%), Japan (7%), Australia (14%), Spain (22%), Saudi Arabia (34%), Pakistan (44%), the United States (46%), Kuwait (63%), and occupied Palestine (86%).[37] Ofori et al demonstrated that membrane-treated wastewater reused for agricultural irrigation improved carrot plant growth and increased soil nutrient content. These findings suggest that appropriately treated wastewater can enhance agricultural productivity while reducing reliance on freshwater resources. Nevertheless, to mitigate microbial risks, disinfection methods such as ultraviolet (UV) irradiation or ozone treatment are recommended, as they effectively reduce pathogen levels and produce fewer toxic byproducts, thereby minimizing the potential for secondary crop contamination.[38]

In a study by Baanu et al, who compared the quality of irrigation water from treated wastewater and groundwater, it was found that irrigation with treated wastewater reduced overall water requirements and fertilization costs. In some cases, a blend of treated wastewater and groundwater can be effectively used for irrigation.[19]

Libutti et al found that although the physicochemical characteristics of wastewater satisfied Italian irrigation reuse standards, only advanced-treated effluent met microbial safety requirements, since total coliform concentrations in secondary-treated wastewater exceeded allowable limits. This emphasizes the need for advanced treatment to ensure safe agricultural reuse.[39]

Long-term use of wastewater for irrigation can cause heavy metals to accumulate in agricultural soils, leading to contamination and greater uptake by crops. This can negatively affect both food quality and food safety. Consumption of crops contaminated with heavy metals poses serious health risks, including nutrient depletion, impaired immune function, delayed fetal development, cognitive deficits, malnutrition, and an elevated risk of upper gastrointestinal cancers.[40] Their high water solubility enhances toxicity, and even trace concentrations can cause serious threats to human health, because the body lacks effective mechanisms for their elimination.[41]

Soil serves as a natural filter, adsorbing heavy metals from wastewater through various physicochemical processes. However, sustained pollutant loading combined with fluctuations in soil pH can diminish this attenuation capacity, potentially resulting in the mobilization and leaching of soluble heavy metal species into groundwater. In contrast to conspicuous pollutants such as plastic debris, heavy metals are imperceptible to the naked eye, yet they present substantial risks to both environmental integrity and human health.[42] Given the profound implications of heavy metal contamination for soil quality and the safety of agricultural produce, rigorous monitoring of their concentrations in treated wastewater destined for irrigation is important. Although the present study was unable to quantify heavy metal levels in the treated municipal wastewater of Saveh owing to budgetary constraints, addressing this analytical gap through future investigations remains essential.

Effect of Evaluating the SAR

To calculate the SAR index and sodium content for determining the quality of water used in agriculture, equations 1 and 2 were used:

$$SAR = \frac{Na^{+}}{\left(\frac{Ca^{2+} + mg^{2+}}{2}\right)^{0.5}} \qquad (1)$$

$$Na^{+}(\%) = \frac{Na^{+}}{Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}} \times 100 \qquad (2)$$

In these equations, the units for magnesium, calcium, and sodium are mill equivalents per liter (meq/L). The results for these two indices are shown in Table 4.

Tables 5 and 6 provide interpretations of the SAR index and %Na values.

One of the most important impacts of agricultural effluent on the environment is the increase in soil salinity, which can reduce productivity in the long term.[44] This parameter affects osmotic properties, limiting the ability of plants to absorb water.

Sodium concentration is a key parameter in evaluating the suitability of water for irrigation. High sodium levels can promote soil alkalinity, leading to structural degradation and reduced soil permeability. Irrigation with sodium-rich water is also of concern because sodium can be taken up by plant roots, transported to aerial tissues, and accumulate in leaves, where it may cause physiological damage.[45] Salinity influences plant performance through several mechanisms:

1. Osmotic effects, resulting from the overall salt concentration in the soil solution.
2. Specific ion toxicity, caused by elevated concentrations of particular ions.
3. Soil particle dispersion, associated with particle dispersion under conditions of low salinity and high sodium content.
4. As salinity increases in the root zone, plants need to

Table 4. SAR Index and Sodium Content in Raw and Treated Wastewater in Saveh City

Index	Raw wastewater entering the treatment plant	Wastewater treatment plant effluent
SAR	5.3	5.28
Na^{+}(%)	51.9	53

Table 5. Guidelines for Interpreting the SAR Index[43]

Sodium hazard for soil	SAR level (meq/L)
Low	0-10
Medium	10-18
High	18-26
Very high	>26

Table 6. Irrigation Water Criteria by FAO[44]

Water quality	Na %	EC	SAR
Excellent	<20	<250	<10
Good	20-40	250-750	10-18
Acceptable	40-60	750-2000	18-26
Suspicious	60-80	2000-3000	>26
Unsuitable	>80	>3000	-

Table 7. Water Required for the Growth of Certain Agricultural Crops

Crop	Water requirement, mm during the growing period	Growing period, days	Amount of land that can be irrigated with Saveh wastewater, hectares
Wheat	480	120	875
Sugarcane	1800	200	648
Cotton	620	200	1129
Sunflower	875	120	2916

> invest additional energy to extract water from the soil through osmotic adjustment. This reduces the energy available for growth and biomass production.[16]

One of the commonly used indicators for evaluating sodium-related hazards in irrigation water is the SAR. Based on the calculated values, the SAR of treated municipal wastewater in Saveh City was 5.28. According to established guidelines, this value corresponds to a low sodium hazard for agricultural soils and indicates excellent irrigation water quality.

Another key parameter for evaluating sodium-related risks in irrigation water is the Sodium Percentage (Na%). Sodium ions can exchange with cations in clay minerals, reducing soil porosity and impairing the movement of air and water within the soil matrix. Monitoring this parameter is essential for agricultural land management, as prolonged irrigation with sodium-rich water can degrade soil structure and quality.[46] In this study, the Na% for treated municipal wastewater in Saveh City was calculated as 53, which—according to relevant standards—indicates that the water is permissible for agricultural use. These findings align with those of Mohammadi Moghaddam et al[24] who, in a feasibility study on reusing treated municipal wastewater in Isfahan, reported a SAR of 2.62 and a Na% of 39.7%.

Based on the observations reported by Safa et al the treated wastewater from Kerman City's wastewater treatment plant had low to moderate restrictions in terms of the sodium index.[47] Bedbabis et al concluded that irrigation with treated wastewater leads to sodium accumulation in the soil after 5 and 10 years, but it is not a serious issue.[48] These results are also consistent with a study comparing the quality of treated wastewater from the Olang Wastewater Treatment Plant in Mashhad with well water for irrigation.[11]

Evaluation of Water Requirements for Crop Cultivation

Table 7 shows the amount of water required for irrigating crops such as wheat, sugarcane, and cotton.[49, 50]

Based on the results, most physicochemical parameters of the treated wastewater from Saveh City meet the criteria for agricultural irrigation, with the exception of microbial quality. Therefore, it is recommended that prior to reuse for agricultural purposes or other urban applications—such as dust suppression, street washing, vehicle washing, irrigation of parks, cemeteries, and green spaces, flushing public toilets, sports field maintenance, and firefighting—the treated effluent undergo appropriate disinfection. Methods such as chlorination, ultraviolet (UV) irradiation, or ozonation should be applied to the treated wastewater from the Saveh municipal wastewater treatment plant to ensure microbial safety before utilization.

Conclusion

Based on the findings of this study, the treated wastewater from Saveh City generally meets the required standards for physicochemical parameters relevant to agricultural irrigation, with a low sodium hazard (SAR = 5.28, Na% = 53) and excellent quality in terms of salinity risk. However, the microbial quality, particularly total and fecal coliform counts, exceeds the permissible limits, posing significant health risks for agricultural reuse without further intervention. Therefore, disinfection processes such as chlorination, ultraviolet (UV) irradiation, or ozonation are essential prior to its application in irrigation. Additionally, advanced treatment methods like coagulation and filtration could further enhance effluent quality. It is recommended that future studies investigate the concentration of heavy metals in the treated wastewater, as this study could not assess them due to budgetary constraints. Such research is crucial for a comprehensive risk assessment and long-term sustainable reuse in agriculture.

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Authors' Contribution

Conceptualization: Mokhtar Mahdavi.
Formal Analysis: Mokhtar Mahdavi.
Investigation: Heshmatollah Ahmadi.
Methodology: Fatemeh Jalouli, Melika Memari.
Project Administration: Mokhtar Mahdavi.
Supervision: Mozhgan Farzmarzi.
Writing–Original Draft: Ali Jamalvandi.
Writing–Review & Editing: Ali Torabi, Mokhtar Vaisi.

Competing Interests

The authors declared no conflict of interest.

Ethical Approval

There were no ethical considerations to be considered in this research.

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