



Effects of pistachio processing wastewater on treatment efficiency of urban wastewater using activated sludge process

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Abstract

Background: In this study, the effect of wastewater produced by pistachio processing in processing terminals on wastewater treatment plants with activated sludge process was investigated.

Methods: The pilot of activated sludge was constructed at the laboratory scale similar to wastewater treatment plant in Kerman and it was investigated in different ratios of the wastewater of pistachio processing with urban wastewater and return sludge ratios of 50% and 75%. The best reactor efficiency in treating pistachio processing wastewater was obtained at a ratio of 5% with urban wastewater and return sludge of 50% plus 5 and 10% with urban wastewater and return sludge of 75%.

Results: The removal efficiency in the reactor in the aforementioned ratios was obtained to be 96.9%, 98%, and 96.2% for COD, 95.7%, 97.2%, and 93.3% for BOD₅, and 7.1%, 99%, and 96.97% for phenolic compounds, respectively. The removal efficiency of BOD₅ and COD reduced with the increase in the ratios of pistachio processing wastewater especially with the presence of phenolic compounds. The one-way analysis of variance (ANOVA) indicated that in the aforementioned ratios of pistachio processing wastewater with urban wastewater, the mean COD and BOD₅ in the output wastewater were significantly lower than the standards of Iranian environmental organization and guidelines of World Health Organization (WHO).

Conclusion: Activated sludge process is able to remove organic compounds of pistachio processing wastewater at a ratio of 5% and return sludge of 50% along with ratios of 5 and 10% and return sludge of 75% with urban wastewater with a high efficiency.

Keywords: Activated sludge process, Wastewater, Pistachio, Environment

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Introduction

Iran is the largest exporter of pistachio with production of over 220 000 tons/year. Kerman province is considered as one of the major producers of pistachio and its best type in the world (1).

Pistachio processing in terminals produces annually large amounts of wastes and wastewater resulting from peeling, washing, and separation stages whose characteristics differ from those of urban wastewater (2,3). Research has shown that the green peel of pistachio is rich in phenolic compounds which are a group of planned secondary metabolite (4).

Phenolic compounds have high solubility in water, thus,

they can be present in water resources. According to the classification by the United States Environmental Protection Agency (US EPA), phenolic compounds are regarded as primary contaminants which have a cumulative property for living creatures. Therefore, the wastewater of pistachio processing can cause serious problems due to loading high organic input into the receiving environment and wastewater treatment systems (5). Thus, it is necessary that these wastewaters are treated individually at the production site or if mixed with urban wastewater, they are pretreated appropriately (6). If there is no possibility for complete treatment, one can use adaptation method for pistachio wastewater with suitable



ratios, where it is discharged into the urban wastewater collection system such that it develops no problem for the biological treatment procedure. Khademi et al in Iran, investigated the quality and quantity of wastewater of pistachio processing terminals (7).

Electron oxidation process using graphite anode and examined electrocoagulation process using aluminum electrode planes investigated in the treatment of pistachio processing wastewater (8,9).

Furthermore, Bayar et al in Turkey, examined the effect of pH on the pretreatment of pistachio processing wastewater by electro-coagulation process (10).

As no research has been conducted so far on the adaptation of wastewater, the aim of this research was to investigate the possibility of discharging the pistachio processing wastewater into the urban wastewater network of urban wastewater treatment plants through activated sludge method.

Materials and Methods

This is an experimental and applied research, which was conducted in the pistachio harvesting season (September to October) during 2012 to 2014.

First, through field observations, the geographical position of all pistachio processing terminals located in Kerman city (20 units) was specified as census using GARMIN GPS76CSX device. To determine the quality of pistachio processing wastewater, sampling was done in 8 pistachio processing terminals and Samples were specified alphabetically (A-H). The quality of pistachio processing wastewater was determined in terms of BOD₅, COD, TSS,

total Phenolic compounds and pH (11).

In the next stage, the quality and efficiency of wastewater treatment plant of Kerman city were determined. To do so, compound sampling was performed on raw input wastewater of Kerman treatment plant and the output wastewater of chlorination basin and the efficiency of the treatment plant was determined. To examine the effect of pistachio processing wastewater on urban wastewater, activated sludge pilot was designed, constructed, and operated at the laboratory scale similar to the wastewater treatment plant of Kerman, Iran (Figure 1).

The flow-diagram of the activated sludge pilot is shown in Figure 1, while the technical specifications of the reactor are provided in Table 1.

Next, the developed pilot was run using raw wastewater of Kerman city with a specific quality.

The efficiency of the activated sludge pilot in treating wastewater of pistachio processing G which had the worst quality, was determined. In the next stage, adaptation of wastewater of pistachio processing G with urban wastewater at return sludge ratios of 50% and 75% in the activated sludge pilot was conducted. This wastewater with different ratios (5%, 10%, 20%, 40%, 60%, and 80%) with Kerman raw wastewater whose quality had been already determined before entrance to the pilot, was examined. Storage tank was added to the activated sludge treatment system. The effect of different ratios of pistachio processing wastewater with urban wastewater on BOD₅, COD, total phenolic compounds of the output wastewater, mixed liquor suspended solids (MLSS) and sludge volume index (SVI) of activated sludge was determined at return

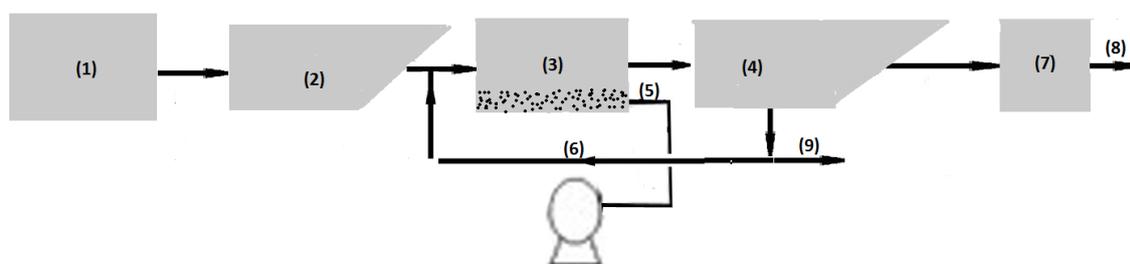


Figure 1. The flow diagram of the activated sludge pilot constructed for the research. 1) The tank for mixing pistachio and urban raw wastewater, 2) the primary sedimentation tank, 3) aeration tank 4) secondary sedimentation tank 5) air supply 6) return sludge 7) chlorination tank, 8) the output treated wastewater and 9) sludge discharge.

Table 1. The technical specifications of the activated sludge reactor design in the research

Unit	Shape	Length (cm)	Width (cm)	Height (cm)	Free Height (cm)	Volume (L)	Hydraulic Retention Time (h)
Primary sedimentation tank	Trapezoid	35	Surface (25) Bottom (10)	7	5	3	2
Aeration tank	Rectangular cube	40	25	10.5	5	10.5	7
Secondary sedimentation tank	Trapezoid	35	Surface (25) Bottom (10)	11	5	6	4

sludge ratios of 50 and 75% in three years, with the results being reported as mean.

The sampling methods and experiments were conducted according to the instruction of the *Standard Methods for the Examination of Water and Wastewater*, 20th edition (11). The concentration of phenolic compounds was determined according to Folin-Ciocalteu method (12). Absorption of the samples was measured by spectrophotometer at 765 nm versus control (12). This method was done for each of the standard solutions of gallic acid followed by plotting the calibration curve of concentration against absorption. The information obtained from the measured parameters in the output wastewater was compared with Iranian environmental standard for surface and agricultural waters. Data were analyzed by SPSS 16.

Results

The geographical position of the 20 pistachio processing terminals in Kerman city is shown in Figure 2.

Investigation of the status of discharges of the wastewater of pistachio processing terminals in Kerman city indicated that 85% of these terminals discharge their wastewater into absorption wells, 10% to agricultural lands, and 5% do the wastewater treatment incompletely. The distance between the 8 selected pistachio processing terminals and

urban wastewater lines was 10 m on average. The mean of the results obtained from determination of COD, BOD₅, total phenolic, total soluble solids (TSS), pH, and flow rate of raw wastewater of the selected pistachio processing terminals within the pistachio operation period is provided in Figure 3.

According to the obtained results, pistachio processing terminal G had the worst quality when compared with other terminals in terms of BOD₅, COD, TSS, total phenols and pH.

Examination of the quality of selected pistachio processing terminals during pistachio harvesting season in three years indicated that the mean concentration of the qualitative parameters of pistachio processing wastewater includes BOD₅ = 6106 mg/L, COD = 21570 mg/L, pH = 5.6, TSS = 682 mg/L and phenolic compounds = 4154 mg/L. The high TSS removal efficiency showed an efficient settling process.

The results obtained from investigation of the quality of the input raw wastewater into the Kerman treatment plant and its output wastewater as mean in three years (with a total of 6 samples for every parameter) along with the efficiency of Kerman treatment plant in the mentioned years are provided in Table 2.

According to the obtained results, the qualitative parameters of Kerman wastewater activated sludge

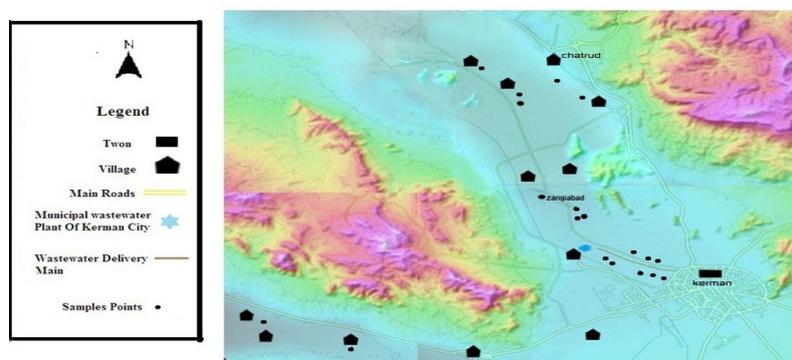


Figure 2. The geographical position of pistachio processing terminals in Kerman city.

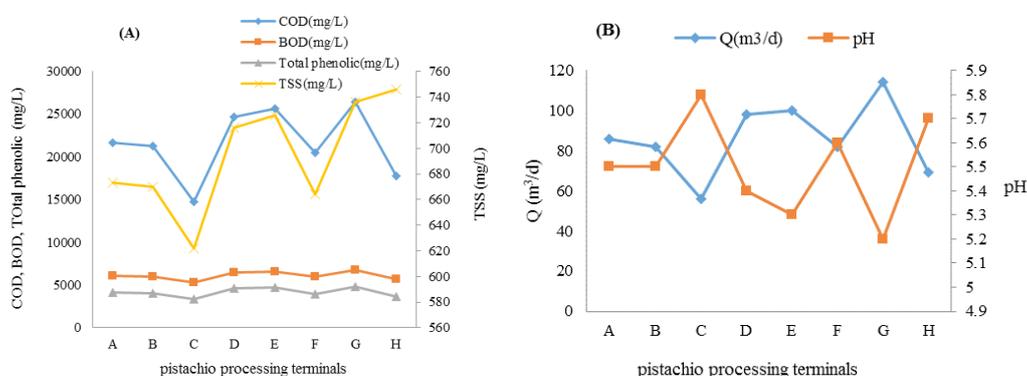


Figure 3. The mean values of BOD₅, COD, TSS, total phenolic compound (A), flow rate, pH (B) of the raw wastewater of pistachio processing terminals in Kerman city.

Table 2. The mean quality of the input raw wastewater and output wastewater of Kerman treatment plant in years 2012, 2013 and 2014 along with the efficiency of Kerman treatment plant

Parameters	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	pH	Phenol (mg/L)
Input raw wastewater	254.1±7.8	434.5±10.1	509.8±4.8	7.4±0.1	>0.1
Output wastewater	42±3.1	68.3±2.7	52.2±3.2	7.5±0.1	>0.1
Efficiency of Kerman treatment plant (%)	83.4	84.3	89.7	-	-

treatment plant in Kerman city is within the standard limits of Iranian environmental standards in the wastewater output for agricultural and irrigation purposes. Further, enhancement of the treatment plant's output qualitative parameters was observed in three years.

The mean values of the results obtained from implementation and operation of the activated sludge pilot with the raw wastewater of Kerman city at return sludge ratios of 50% and 75% in three years in pistachio harvesting season are provided in Tables 3 and 4.

The maximum pilot removal efficiency of BOD₅ and COD during three years, over 7 days of stability for return sludge ratio of 50% and 75% was obtained to be 90.9% and 99.9% along with 92.1% and 92.1%, respectively.

Comparison of the mean values of the results obtained from the efficiency of Kerman city wastewater treatment plant with activated sludge pilot efficiency at return sludge ratios of 50% and 75% in removal of BOD₅ of the input raw wastewater in three years revealed that Kerman wastewater treatment plant with an input BOD of 256.3±3.2 and output of 42.6±2.9 mg/L has BOD removal

efficiency of 83.3%. However, activated sludge pilot with the input BOD of 252.3 ± 2.2 mg/L and output of 22.8 ± 1.9 mg/L had a well efficiency of 90.9% with a return sludge ratio of 50% (Table 3). Furthermore, the efficiency of activated sludge pilot with the return sludge ratio of 75%, an input BOD of 260 ± 3.5 mg/L and output of 20.5 ± 1.9 mg/L, was obtained to be 92.1% (Table 4).

Comparison of the mean values of the results obtained from the efficiency of Kerman wastewater treatment plant with the efficiency of the activated sludge pilot at return sludge ratios of 50% and 75% in COD removal of the input raw wastewater in three years showed that Kerman city wastewater treatment plant with input COD of 434.5 ± 26.3 mg/L and output of 68.3 ± 10.3 mg/L had a COD removal efficiency of 84.3%. However, the activated sludge pilot with an input COD of 453.3 ± 3.1 mg/L and output of 39.3 ± 1.9 mg/L, had a removal efficiency of 90.9% with return sludge ratio of 50%. Further, the efficiency of activated sludge pilot with return sludge ratio of 75%, an input COD of 445.3 ± 3.9 mg/L and output of 35.1 ± 2 mg/L was obtained to be 92.1%. Increased

Table 3. The mean values of the results obtained from implementation and operation of activated sludge pilot with the raw wastewater of Kerman city at return sludge ratios of 50% in 3 years in pistachio harvesting season (early September until October)

Day	Q (mL/min)	HRT (h)	Input COD (mg/L)	Sewage COD (mg/L)	Removal efficiency (%)	Input BOD ₅ (mg/L)	Sewage BOD ₅ (mg/L)	Removal efficiency (%)
1	24	24	438.6±2.46	90.3±2.3	79.4	256±3.2	58.5±2.5	77.1
2	24	24	433±2.6	77.8±2.2	82	252±3.4	49.5±3.2	80.3
3	24	24	441±3	70.2±3	84	256.3±3.2	42.6±2.9	83.3
4	24	24	437±3	60.6±3.3	86.1	254±3	35.7±2.6	85.9
5	24	24	438±2.2	50.7±2.4	88.4	256.6±2.8	28.7±2.4	88.8
6	24	24	433±2.7	42.7±2.3	90.1	253±2.4	25.2±2.3	90
7	24	24	435.3±3.1	39.3±1.9	99.9	252.3±2.2	22.8±1.9	90.9

Table 4. The mean values of the results obtained from implementation and operation of activated sludge pilot with the raw wastewater of Kerman city at return sludge ratios of 75% in 3 years in pistachio harvesting season (early September until October)

Day	Q (mL/min)	HRT (h)	Input COD (mg/L)	Sewage COD (mg/L)	Removal efficiency (%)	Input BOD ₅ (mg/L)	Sewage BOD ₅ (mg/L)	Removal efficiency (%)
1	24	24	439.6±2.1	81.7±2.8	81.4	255.3±3	52.6±1.8	79.3
2	24	24	437.6±2.6	72±2.5	83.5	255±3.2	44.4±2.4	82.6
3	24	24	432.2±3.4	63.7±2.9	85.2	251±3	37.7±2.7	84.9
4	24	24	435.3±2.5	53.3±3.2	87.7	254±2.6	32±2.2	87.4
5	24	24	436.6±2.5	45.1±1.9	89.6	253.6±3.2	26.1±1.9	89.7
6	24	24	440.3±2	40.3±2.7	90.8	257±2.6	22.9±2.2	91
7	24	24	445.3±2.9	35.1±2	92.1	260±3.5	20.5±1.9	92.1

treatment during acidification was mainly a biological process, thus, the related enzymes played vital roles in the microbial metabolism. Sludge sedimentation is improved due to the release of intracellular polymers under anoxic and anaerobic conditions, which helps to bridge between biomass flocks to improve sedimentation.

According to the results obtained from comparison of efficiency of activated sludge pilot with the efficiency of Kerman wastewater treatment plant, the activated sludge pilot had a higher efficiency in COD, BOD₅ at return sludge ratios of 50% and 75%. In fact, all of the removed pollutants were assimilated and adsorbed on sludge.

The total mean of the results obtained from the investigation of the efficiency of activated sludge pilot in treating pistachio processing raw wastewater (processing terminal of pistachio G) of the two return sludge ratios of 50% and 75% in pistachio harvesting season from early September until October in three years are provided in Table 5.

The results obtained from determining the quality of raw wastewater of Kerman city and processing terminal of pistachio G before entrance to the pilot, have been mentioned as follows.

The mean concentration of BOD, COD, TSS, pH, and phenol of the raw wastewater of Kerman city in pistachio harvesting season in three years for entrance to the pilot

was obtained to be 254.1 ± 7.8 , 434.5 ± 10.1 , 509.8 ± 4.8 , 7.4 ± 0.1 , and >0.1 mg/L, respectively.

The mean concentration of BOD, COD, TSS, pH, and total phenolic compounds of the processing terminal of pistachio G in three years for entrance to the pilot was obtained to be 6791 ± 440 , 26405.3 ± 3266 , 736 ± 27 , 5.23 ± 0.25 , and $>4817.3 \pm 483$ mg/L, respectively.

The mean results obtained from adaptation of the raw wastewater of processing pistachio terminal G with urban wastewater at return sludge ratios of 50% and 75% along with the efficiency of activated sludge pilot in removal of BOD₅, COD, and total phenolic compounds in pistachio harvesting season in three years are provided in Figure 4. The mean of the results of effect of different ratios of pistachio processing wastewater and urban wastewater on MLSS and SVI of the activated sludge at return sludge ratios of 50 and 75% during three years is shown in Figure 5.

As can be observed in Figure 5, at ratios of 10%, 20%, 40%, 60%, 80%, and 100%, the pistachio processing wastewater with urban wastewater at return sludge ratio of 50%, due to decrease in the microorganisms of mixed liquid of the activated sludge, part of the input wastewater is outflowed as degraded from part of the aeration section of urban activated sludge. The increase in the SVI causes problem with sludge sedimentation. Further, decreased MLSS and

Table 5. The total mean of the results obtained from the investigation of the efficiency of activated sludge pilot in treating pistachio processing raw wastewater (processing terminal of pistachio G) at the two return sludge ratios of 50% and 75% in pistachio harvesting season from early September until October in 3 years

Pistachios raw sewage sludge with a ratio of 100% at return sludge ratios		50%	Efficiency (%)	75%	Efficiency (%)
BOD ₅ (mg/L)	Input	6741±2.7		6747±3.7	
	Output	5507±2	18.3	5282±3.3	21.7
COD (mg/L)	Input	26368±3.8		26379±3.7	
	Output	20110.6±2.8	23.7	19530.3±1.9	25.9
Total phenolic (mg/L)	Input	4756±3.3		4772±3.9	
	Output	3801.3±2.3	20	3662.1±2.6	23.2

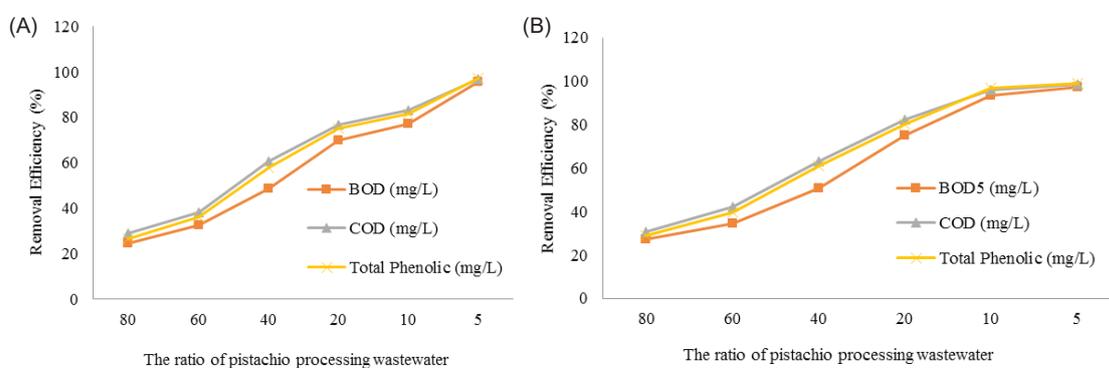


Figure 4. The mean results obtained from the adaptation of the raw wastewater of processing pistachio with urban wastewater at return sludge ratios of 50% (A) and 75% (B) along with the efficiency of activated sludge pilot in removal of BOD₅, COD, total phenolic in pistachio harvesting season in three years.

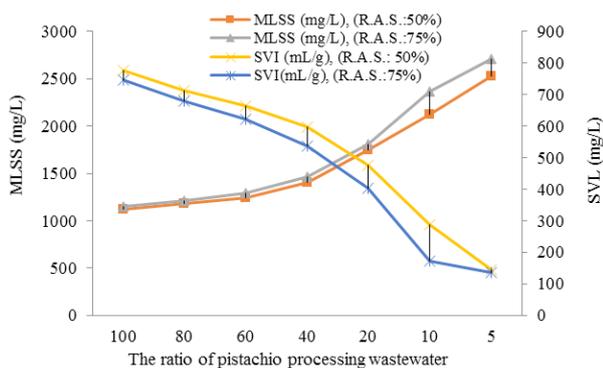


Figure 5. The mean of changes in MLSS and SVI of the activated sludge at different ratios of pistachio processing wastewater at return sludge ratios of 50% and 75% during pistachio harvesting season in 3 years..

sludge sedimentation were observed.

The standards of wastewaters output set by Iranian Environmental Protection Agency (13), US EPA (6), and the guidelines of World Health Organization (WHO) (14) in terms of allowable limits of BOD₅, COD, pH, and TSS, are provided in Table 6.

Discussion

The findings imply that the high ratio of COD and BOD of pistachio processing wastewater with primary contaminant qualitative characteristics (phenolic compounds) had a high toxicity for the environment (15-17).

The removal efficiency of COD and BOD₅ with pistachio processing wastewater ratios of 20%, 10%, 5%, 40%, 60%, 80%, and 100%, respectively, with urban wastewater and return sludge ratios of 50% and 75% revealed that at the ratio of 5% and return sludge of 50% and 75% along with 10% pistachio processing wastewater with the return sludge of 75%, it had a high efficiency in removing the parameters of BOD and COD. The presence of high nitrogen and carbon inorganic compounds in the pistachio terminal sewage system, with 75% sludge return ratio can be further removed. Because more sludge return rates, it increases the availability of organisms to nutrients which represents the production of interstitial organic compounds. On the other hand, the increase in the microbial mass of the system due to an increase in the organic matter and the increase in the cellular residence time with constant intake, will reduce the consumption

rate of the substrate and increase the removal efficiency. Sawyer and Anderson in the United States managed to dilute the wastewater of an alcohol production unit up to 1% using urban wastewater collection system and a dripped two-stage filtration system with a return ratio of 1:3 and an organic loading of 0.95 kg BOD/m³/d, they reduced the value of BOD from 485 mg/L to 25 mg/L (18). Burnett in the United States diluted the wastewater of an alcohol production unit with a COD of 90 000 mg/L and BOD of 25 000-300 000 mg/L up to 10% using urban wastewater and following neutralization, using a dripped filter with an organic loading of 4.8-6.1 kg COD/m³/d and return ratio of 0.5, and achieved a COD removal of 40% (19). Costa Reis and Sant'Anna in Brazil removed COD from the wastewater of an alcohol unit diluted by up to 10% in a floating bed reactor with a retention time of 10-15 hours by up to 80% (20). The effect of dilution on wastewater in these studies showed congruence with pistachio processing wastewater research.

Galaieri et al in Tehran, evaluated the volume parameters of inoculation of the activated sludge, pH, and initial concentration in removing wastewater's phenol using discontinuous activated sludge system. They indicated that an aqueous solution containing 600 ppm phenol following 35 hours and 5 mL of inoculation volume of the activated sludge with a pH of 7, had the greatest phenol removal (21).

The best state for sludge sedimentation occurred at 5% of pistachio processing wastewater in the pilot of urban activated sludge with a return sludge ratio of 50%. With increase of the return sludge ratio from 50% to 75%, improvement of the performance of mixed liquid microorganisms and sedimentation of the sludge were observed. In this state, the ratio of pistachio processing wastewater treatment enhanced from 5% to 10%.

Nikazar et al in Tehran, compared the performance of sequencing batch reactor (SBR) for removing phenol at different concentrations. The greatest phenol removal efficiency was obtained to be 99.99% and the highest value of MLSS was 3801 mg/L in the reactor with a concentration of 150 mg/L (22). Elevation of the removal efficiency at the optimal concentration in these studies is in line with the present study.

At higher ratios of pistachio processing wastewater, the majority of microorganisms present in the reactor enter death phase, where the mentioned parameters of the

Table 6. The standard of Iranian Environmental Protection Agency, US Environmental Protection Agency and the guidelines of World Health Organization for the output of wastewaters

Entry	Parameter	Iranian Environmental Protection Agency (13)		Guidelines of WHO (14)	US EPA (6)
		Discharges to surface water	Agriculture and irrigation use		
1	BOD ₅ (mg/L)	30	100	100	30
2	COD (mg/L)	60	200	200	120
3	TSS (mg/L)	40	100	100	5
4	pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.4

output wastewater along with MLSS and SVI parameters increase and move towards unfavorable values. Further, the output wastewater of the reactor was not able to meet the standards of Iranian EPA along with the guidelines of WHO for discharging into surface waters and agricultural lands (13,14).

Takdastan et al in Tabriz, investigated the degree of degradation of para nitrophenol using aerobic biological method in an activated sludge batch reactor, such that by the injection of 100 mg/L para nitrophenol into the reactor, COD reduced from 772 to 193 mg/L, and the COD removal efficiency reached 75%. MLSS concentration increased slightly from 1290 to 1446 mg/L. The SOUR value was obtained to be 31 mgO₂/h.gVSS, SVI reduced to below 48 mL/g and the concentration of para nitrophenol in the output wastewater and the sludge were obtained as 63 and 0.09 mg/L, respectively. With injection of 150 mg/L para nitrophenol into the reactor, COD and the concentration of para nitrophenol of the output wastewater increased and the biological treatment system was disrupted (23). Shoukahi et al indicated that the Pearson coefficient between MLSS concentration and the phenol removal efficiency has a direct relationship, where its correlation has been significant with 100% confidence (24). According to their investigation, the effect of elevation of concentration on the reactor efficiency is in accordance with this study.

Conclusion

If properly managed and guided, activated sludge process is able to remove organic compounds from pistachio processing wastewater at a ratio of 5% and return sludge of 50% along with ratios of 5% and 10% and return sludge of 75% with urban wastewater with a high efficiency. However, at higher ratios, it does not have the required efficiency and the pistachio processing wastewater should be treated before being discharged into the urban wastewater system. Discharge of the wastewater of pistachio processing terminals without specific treatment or without using adaptation method to the urban wastewater by the activated sludge method is prohibited. It is suggested that at pistachio processing terminals close to wastewater collection system, provided that the aim is to use urban wastewater system, pistachio processing wastewater should be discharged through adaptation method with the city's wastewater collection system. In cases where there is no urban wastewater collection system around the pistachio processing terminal, independent wastewater treatment method is recommended. It is better to treat these wastewaters in accumulation complexes and through either biological or chemical methods.

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Ethical issues

It is hereby declared that this work and the obtained results are the original experimental work of the authors and it has neither been published, nor is under review in another journal, and it is not being submitted for publication in any other journals.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

FK carried out the experiments. MM supervised the project, developed the theory and performed the computations. KY assisted to write the manuscript and analyze the results. AN assisted to write the paper. MT and MAH approved this project and assisted to fund of the project by Water and Wastewater Engineering Company of Kerman province.

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