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Investigating the feasibility of reusing the effluent from the urban sewage treatment plant (Case study: South Tehran treatment plant)

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Abstract

The current study was carried out with the aim of measuring the feasibility of reusing the effluent from the wastewater treatment plant in south Tehran. For this purpose, pH, BOD5, COD, NO_3^-, PO_4^{3-}, SO_4^{2-}, TDS, TSS, Turbidity, EC, fecal coliform and total coliform were investigated during 6 stages of sampling from the incoming wastewater and the outgoing wastewater from the treatment plant. The average pH, BOD5, COD, NO_3^-, PO_4^{3-}, SO_4^{2-}, TDS and TSS entering the treatment plant are 7.19, 211.4, 392, 68.8, 12.4, 464, 793.4, 217.8 mg/liter respectively, Turbidity 126.25 NTU, EC 1006.6 Micro mouse/cm, fecal coliform was 1200 MPN and total coliform was 1254 MPN, the highest organic load entering the treatment plant was in May and August 2020. The average total removal efficiency for pH, BOD5, COD, NO_3^-, PO_4^{3-}, SO_4^{2-}, TDS, TSS, which is equal to 6.9, 15, 31.16, 6.06, 2.99, 83, 465.13, 7.5 mg/L, respectively. Turbidity was 6.21 NTU, EC was 762.83 micro mouse/cm, fecal coliform was 8.75 MPN and total coliform was 63.5 MPN. By comparing the results of the quality parameters with the standards of the Environmental Protection Organization, it was found that the effluent of the treatment plant is in a favorable condition for discharge to surface water, absorbent wells and irrigation and agricultural uses, which indicates the correct operation of the treatment plant and compliance with the established rules and standards. Also, the efficiency of the sewage treatment system using the activated sludge method in this treatment plant is favorable.

Keywords: Wastewater treatment, reuse, physicochemical parameters, biological parameters, effluent

Introduction

Wastewater treatment has been evolving throughout history due to the increasing concentration of people in cities. As the pressure on water resources increases, there are concerns about how to find new sources that are able to balance supply and demand. In this context, one of the main possibilities to deal with water shortage is the rehabilitation of wastewater and its reuse (Salgot & Folch, 2018). The primary function of a wastewater treatment plant is to minimize the environmental impact of discharging untreated water into natural water systems. A wastewater treatment plant may also receive a source of effluent that performs tertiary treatment on treated wastewater that can be reused in non-potable applications (Meneses et al. 2010). Municipal wastewater reuse has become an important component of water resources management worldwide to address water scarcity issues and a valid mechanism to prevent drought-related problems (Jodar-Abellan et al. 2019; Michael-Kordatou et al. 2018). Water reuse is an inherent part of the natural water cycle because the discharge of effluent into watercourses and its dilution in the watercourse allows it to be indirectly reused downstream for urban, agricultural and industrial purposes (Iglesias et al. 2010). In addition, the more pressing need for a more sustainable society has led to new developments in wastewater management with the

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aim of recovering all resources in wastewater and even the perspective of on-site reuse in accordance with the new paradigm „circular economy“ (Sgroi et al. 2018). Water reuse can take many forms: potable or non-potable, direct or indirect, planned or unplanned. An example of unplanned indirect potable reuse is when a municipality takes water for use as potable water from a river that has a sewage discharge upstream (Oneby et al. 2010). Successful development of wastewater reuse is closely related to wastewater treatment plant installation, integrated water resources management, economic and financial analysis, and public acceptance. Since additional wastewater treatment beyond secondary treatment and the installation of pipeline networks are required for reuse, high cost is a very important issue in implementing wastewater reuse (Asano et al. 2007). Some studies analyzed the relationship between economic level and environmental pollution by environmental Kuznets curve (Grossman & Krueger, 1995). It has been found that after per capita GDP reaches a turning point, the degree of environmental degradation will decrease with an increase in GDP per capita. Similarly, there is likely to be a correlation between the level of water treatment and GDP per capita due to higher demand for water quality and water safety concerns. In addition, there can be other driving factors such as availability of water resources, technological development, environmental protection, public awareness, legal and political orientation, water tariff, inter-sectoral cooperation, etc. (Chen et al. 2017; Garcia-Cuerva et al. 2016; Liao et al. 2021; Po et al. 2003; Yi et al. 2011).

The purpose of this study is to measure the feasibility of reusing the effluent of the sewage treatment plant in south Tehran in order to evaluate the environment and sustainability of reusing urban sewage. For this purpose, the physicochemical characteristics of the wastewater in the sewage treatment plant in south of Tehran were investigated. The results of this study were compared with the standards of Iran‘s Environmental Organization (IRNDOE) for draining surface water, draining into absorbent wells, and reusing wastewater for irrigation purposes in agriculture.

Data and Methods

This study is a descriptive-cross-sectional type and this research was carried out for 12 months from May 2020 to May 2021 on the southern refinery of Tehran. Currently, modules 1 to 6 have been put into operation, which are divided into two separate refineries under the titles of modules 1 to 4 and modules 5 and 6.

South Tehran sewage treatment plant

Sewage treatment plant in the south of Tehran, is located in Ray city, Shahid Avini highway, adjacent to Emadavar village. It is planned to treat a part of Tehran’s sewage in 8 modules. The four currently built modules, each of which covers a population equal to 525,000 people and can accept a flow equal to 450,000 cubic meters per day for treatment. The areas covered by this treatment plant are the wastewaters collected from the north and northeast of the city and are received from the two eastern and western entrances of the treatment plant. The land of the refinery has an area of 110 hectares and is located with a slope from north to south, from the level of 1035 to 1020. The wastewater treatment process type is activated sludge with nitrogen removal, and the treated wastewater will provide irrigation for agricultural lands in Varamin Plain.

Sampling

Sampling of the wastewater entering the treatment plant (in the waste collection unit) and its output effluent (after the chlorination unit) was done in 6 stages of sampling. Sampling months throughout the year were randomly selected. In this study, a total of 11 samples were collected and analyzed for 12 parameters, with 5 samples taken from the inlet and 6 from the outlet of the refinery. Care has been taken in collecting and storing wastewater samples so that they are not damaged or contaminated before reaching the laboratory. Polyethylene containers with a one-liter capacity were used for chemical tests, while sterilized sanded glass containers with a 300-milliliter capacity were employed for microbial tests. All tests were performed according to the methods provided in the standard method for water and sewage tests (Rice et al. 2017) and in the specialized water and sewage laboratory.

Effluent analysis

The studied parameteres such as pH, BOD5 (Biochemical Oxygen Demand for 5 days), COD (Chemical Oxygen Demand), NO_3 (Nitrate), SO_4 (Sulfate), PO_4 (Phosphate), TDS (Total Dissolved Solids), TSS (Total suspended solids), Turbidity, EC (Electrical Conductivity), fecal coliform and total coliform were analysed according to standard methods.

To measure the amount of sulfate. pH values were estimated with a pH meter using the electrical potential difference measurement method. BOD5 was measured with a BOD meter and incubator using the oxygen pressure potential difference method. COD value was measured with a photometer and heater using the absorption method at a specific wavelength.

Available phosphates and nitrates from the spectrophotometric device, respectively, with the turbidity measurement method and color spectrum absorption measurement at a specific wavelength, to measure TSS and TDS using a digital scale and filter paper using the weight difference measurement method, Turbidity with the turbidity meter device using the light diffraction method (Nephelometry), EC from the electrical conductivity meter with the method of measuring electrical conductivity and also for measuring the amount of fecal coliform and total coliform using incubator, heater and bain-marie, the most probable number of MPNs has been used.

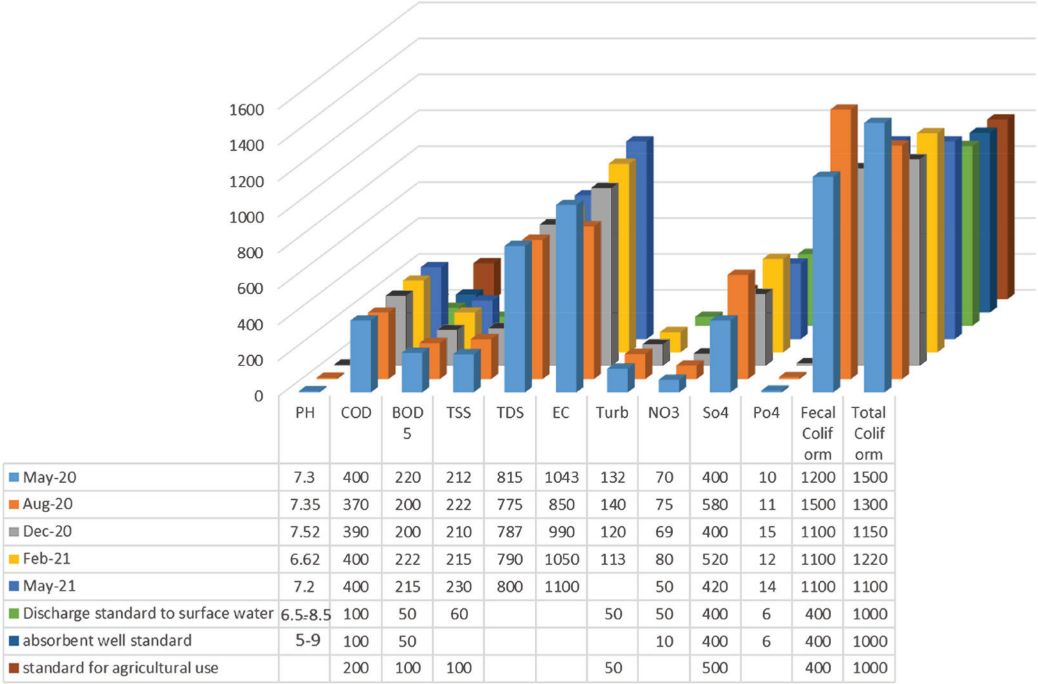
Results and Discussion

The total average quality of incoming and outgoing wastewater from the sewage treatment plant in South Tehran during one year of sampling is presented in Table 1. Based on the results, the average pH, BOD5, COD, NO_3^-, PO_4^{3-}, SO_4^{2-}, TDS, TSS entering the treatment plant were 7.19, 211.4, 392, 68.8, 12.4, 646, 793.4, 217.8 mg/liter respectively, Turbidity 126.25 NTU, EC 1006.6 micro mouse/cm, fecal coliform was 1200 MPN and total coliform was 1254 MPN, which was the highest organic load entering the treatment plant in the months of May and August 2020. The amount of COD, BOD5, TSS, TDS, EC, Turb, NO_3^-, PO_4^{3-}, SO_4^{2}, Fecal Coliform, and Total Coliform in the outgoing wastewater has been decreased by 92.1, 93, 96.6, 41.4, 24.2, 95.1, 91.2, 82.1, 75.9, 99.3 and 94.9 percent, respectively (Table 1).

Figures 1, 2, 3 and 4 show the comparison of the values and averages of the aforementioned qualitative parameters with the standards of the Iranian Environmental Organization for discharge to surface water, absorbent wells, and irrigation and agricultural uses.

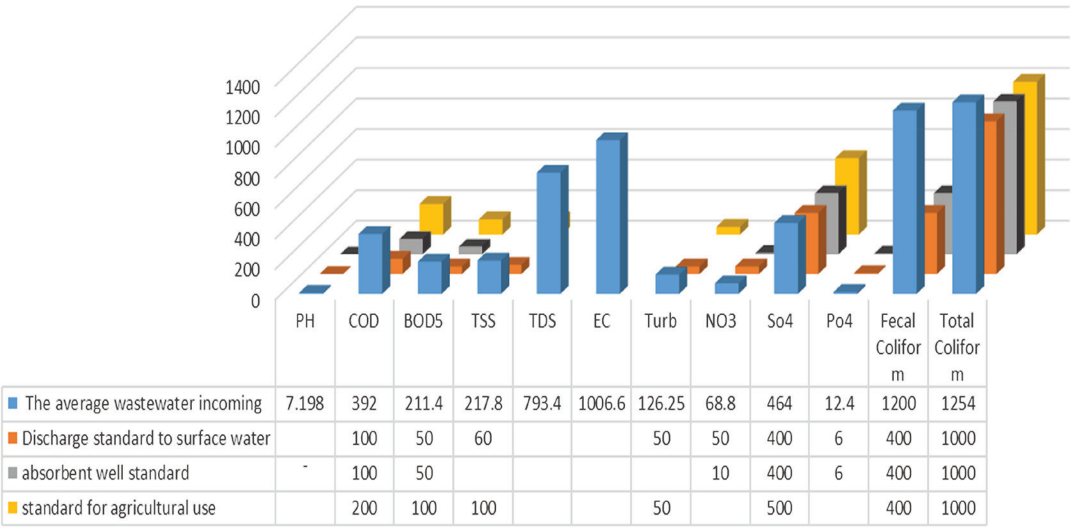
Table 1. The total average quality of incoming and outgoing wastewater of South Tehran wastewater treatment plant

Parameter	Average inflow wastewater	Average effluent output
pH	7.2	6.93
COD	392	31.16
BOD5	211.4	15
TSS	217.8	7.5
TDS	793.4	465.13
EC	1006.6	762.83
Turb	126.25	6.21
NO_3^-	68.8	6.07
SO_4^{2-}	464	83
PO_4^{3-}	12.4	2.99
Fecal Coliform	1200	8.75
Total Coliform	1254	63.5



	PH	COD	BOD 5	TSS	TDS	EC	Turb	NO3	So4	Po4	Fecal Coliform	Total Coliform
■ May-20	7.3	400	220	212	815	1043	132	70	400	10	1200	1500
■ Aug-20	7.35	370	200	222	775	850	140	75	580	11	1500	1300
■ Dec-20	7.52	390	200	210	787	990	120	69	400	15	1100	1150
■ Feb-21	6.62	400	222	215	790	1050	113	80	520	12	1100	1220
■ May-21	7.2	400	215	230	800	1100		50	420	14	1100	1100
■ Discharge standard to surface water	6.5-8.5	100	50	60			50	50	400	6	400	1000
■ absorbent well standard	5-9	100	50					10	400	6	400	1000
■ standard for agricultural use		200	100	100			50		500		400	1000

Figure 1. Incoming wastewater of South Tehran treatment plant



	PH	COD	BOD5	TSS	TDS	EC	Turb	NO3	So4	Po4	Fecal Coliform	Total Coliform
■ The average wastewater incoming	7.198	392	211.4	217.8	793.4	1006.6	126.25	68.8	464	12.4	1200	1254
■ Discharge standard to surface water		100	50	60			50	50	400	6	400	1000
■ absorbent well standard	-	100	50					10	400	6	400	1000
■ standard for agricultural use		200	100	100			50		500		400	1000

Figure 2. The average wastewater incoming of South Tehran treatment plant

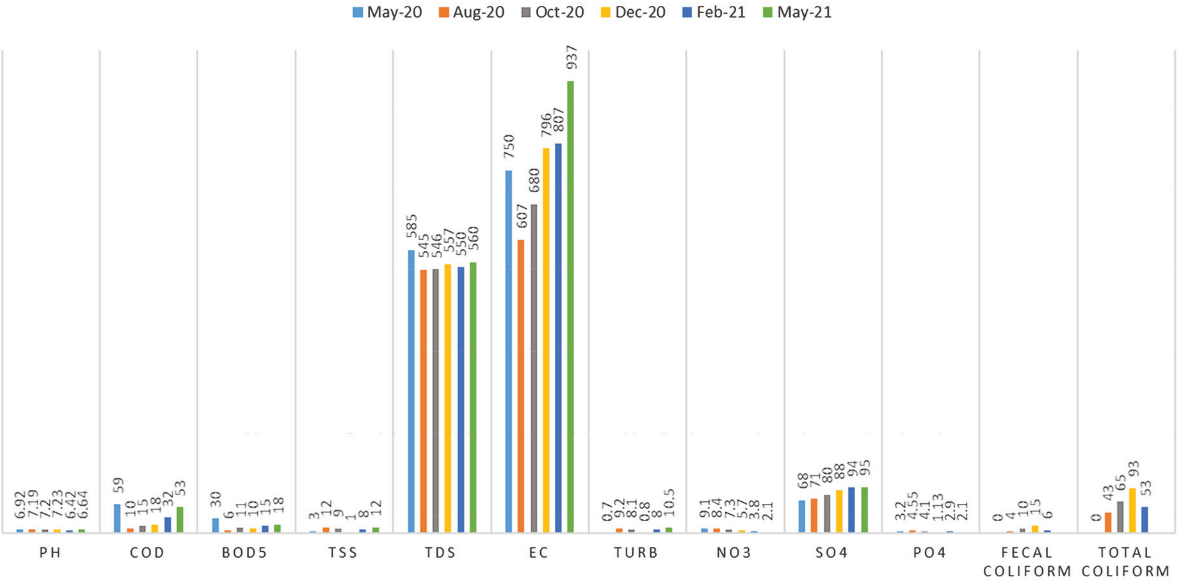


Figure 3. The effluent of South Tehran treatment plant

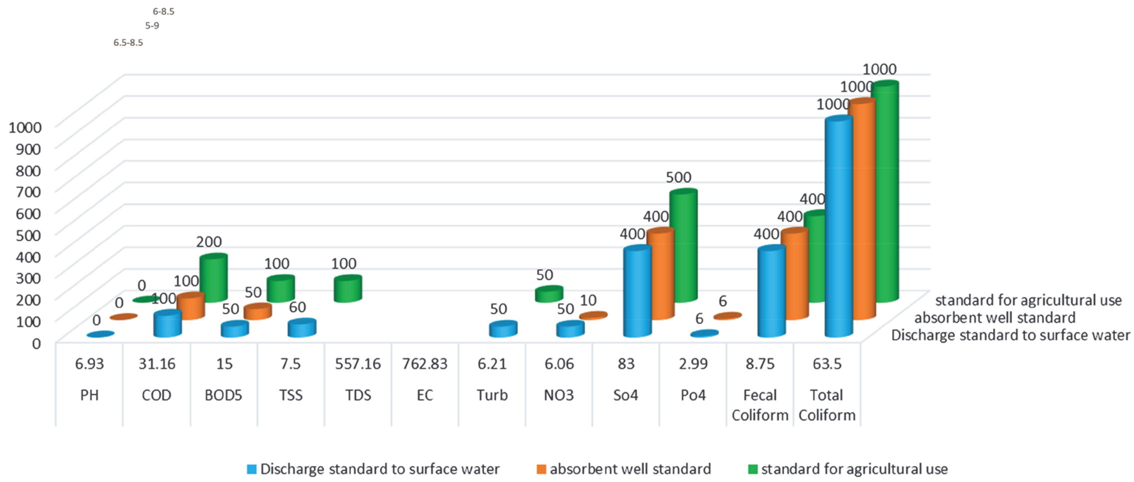


Figure 4. The average effluent of South Tehran treatment plant

According to the results presented in Table 1, the average pH of the wastewater entering the treatment plant (7.198), COD (392 mg/liter), BOD5 (211.4 mg/liter), TSS (217.8 mg/liter), TDS (793.4 mg/L), EC (1006.6 µm/cm), Turbidity (126.25 NTU), NO_3^- (68.8 mg/L), SO_4^{2-}(464 mg/L), PO_4^{3-}(12.4 mg/liter) and fecal coliform (1200 MPN) and total coliform (1254 MPN) belong to the group of wastewaters with medium pollution intensity in terms of pollution during the one-year study period. As can be seen in Figure 3 and 4, the value of the examined parameters of the effluent at different times (from May 2020 to May 2021) and compared with the standard of the Iranian Environmental Organization is as follows:

Acidity (pH)

The average pH value is 6.92, the highest value of which corresponds to December 2020 with a value of 7.23 and the lowest value corresponds to May 2021 with a value of 6.64. According to the standard table, the permissible pH limit for discharge to surface water is 6.5-8.5, discharge to absorbent wells is 5-9, and for agricultural and irrigation purposes is 6-8.5. According to the findings of Odjadjare and Okoh (2010), treated municipal wastewater in South Africa was within the permissible pH range. In a study by Dalvi et al. (2021), the pH of wastewater inside the photobioreactor exceeded 9 except for winter and hydraulic retention time of 1 day in summer. According to a study by Chaimaa et al. (2022), the average pH values are between 7.7 and 7.8, and the average hydrogen potential difference between the dry and wet seasons is usually small. This indicates that there is no seasonal effect on pH. In a study by Onchiri et al. (2021), it was found that the changes especially in the pH values of wastewater are different between the two seasons.

Chemical Oxygen Demand (COD)

The average amount of COD is 31.16 mg/liter, the highest amount of which is related to May 2020 with an amount of 59 mg/liter and the lowest amount is related to August 2020 with an amount of 10 mg/liter. Based on the standard, the COD limit is 100 mg/l for transfer to surface water, 100 mg/l for discharge to absorbent wells, and 200 mg/l for agricultural and irrigation purposes. According to a study by Hamaidi and Djeribi (2022), the COD of wastewater released in different areas of Annaba city (Northeastern Algeria) increased during the seasons, which is not consistent with the present study. Also, in a study by Cecconet et al. (2022), observed COD removal efficiency was in the range of 60–69%. Since treated wastewater with a COD value of less than 12 mg/liter can be used to irrigate edible crops, irrigate parks and schoolyards, dishwashers, and flush toilet tanks (Zahmatkesh et al. 2022), therefore, August 2020 wastewater have been suitable.

Biological Oxygen Demand (BOD5)

The average amount of BOD5 of the effluent is 15 mg/liter, the highest value of which is in May 2020 with the amount of 30 mg/liter and the lowest value is in August 2020 with the amount of 6 mg/liter. The limit of BOD5 defined according to the standard for transfer to surface water is 50 mg/liter, discharge to absorbent wells is 100 mg/liter, and agricultural and irrigation uses are 100 mg/liter. According to a study by Robles et al. (2020), the municipal effluent COD remained below the effluent discharge limit and reached COD removal above 90%. In a study by Rahi et al. (2020), a significant increase ($p< 0.05$) was observed for electrical conductivity (EC), total dissolved solids (TDS), nitrate-nitrogen (NO_3^--N) and sulfate (SO_4^{2-}) of effluent compared to raw sewage.

Total Suspended Solids (TSS)

The average amount of TSS of the effluent is 7.5 mg/liter, the highest value of which is 12 mg/liter in May and August 2020, and the lowest value is 1 mg/liter in December 2020.

The permissible limit of TSS for transfer to surface water is 60 mg/liter, discharge to absorbent wells is not specified, and agricultural and irrigation uses are 100 mg/liter. According to a study by Hamaidi and Djeribi (2022), the maximum amount of suspended solids in wastewater (1700 mg/liter) was observed in winter. Also, in a study by Cecconet et al. (2022) observed TSS removal efficiency was in the range of 63–73%.

Total Dissolved Solids (TDS)

The average amount of TDS of the output effluent is 557.16 mg/liter, the highest amount of which is related to May 2020 with the amount of 585 and the lowest amount is related to the August 2020 with the amount of 545 mg/liter. The permissible limit of TDS for transfer to surface water is interpreted with Note 1 under the standard table (Discharge with a concentration higher than the amount specified in the table will be allowed if the effluent does not increase the concentration of chloride, sulfate and soluble substances of the receiving source by more than one percent within a radius of 200 meters), Discharge to absorbent wells is explained with Note No. 2 that discharge with a concentration higher than the amount specified in the table will be allowed if the increase of chloride, sulfate and soluble substances in the outgoing effluent is not more than 10% compared to the water consumed. However, there are no limits or notes for agricultural and irrigation purposes. After investigations and questions and answers from the executive agents, it was found that the provisions of the notes are observed. According to a study by Custodio et al. (2021), total dissolved solids (TDS) increased in urban areas where frequent domestic and industrial wastewater discharges occur. These results are consistent with the results of El-Tohamy et al. (2018). Based on this, urban, agricultural and industrial effluents increase TDS concentration.

Electrical conductivity of water (EC)

The average value of EC is 762.83 micromouse/cm, the highest value of which is related to May 2021 with a value of 937 micromouse/cm and the lowest value is related to August 2020 with a value of 607 micromouse/cm. According to the standard table of the Iranian Environmental Protection Organization, the permissible limit of EC for transfer to surface water, discharge to absorbent wells, and agricultural and irrigation uses is not specified. According to a study by Hamaidi and Djeribi (2022), conductivity decreased in winter. The significant decrease in conductivity in winter compared to the standard is due to the fact that the sampling was done on the days of increased levels of mineral salts without rain. Other seasons showed a very significant increase in conductivity values, which was explained by the mineralization of organic matter by the microbial group, along with a slight increase in summer due to high temperature (a determining factor). Therefore, high conductivity values are explained by the presence of a large number of mineral salts (Samia, 2014).

Turbidity

The average level of turbidity is 6.21 NTU, the highest value of which is related to May 2021 with a value of 10.5 NTU and the lowest value is related to May 2020 with a value of 0.7 NTU. According to the standard table of the Iranian Environmental Protection Organization, the permissible limit of turbidity for transfer to surface water is 50 NTU, discharge to absorbent wells is not specified, and agricultural and irrigation uses are 50 NTU. According to a study by Custodio et al. (2021) who studied the water quality of the Cunas River in rural and urban areas in the central region of Peru. It was found that the average value of turbidity ranged from 3.92 (2019) to 5.85 NTU (2018) and in some other areas from 6.82 (2017) to 12.68 NTU (2019), which indicated the significant effect of the spatial coefficient ($p>0.05$). In the same study, the W test showed that 85% of the sections presented turbidity values that exceeded the water quality standard (5NTU).

Coliform

Fecal coliform (FC) indices are commonly used to assess microbial or fecal contamination in surface water (Xu et al. 2022). The average amount of fecal coliform and the total coliform of the output effluent was 8.75 and 63.5 MPN, respectively, the highest value of which corresponds to December 2020 with 15 and 93 MPN, respectively, and the lowest value corresponds to May 2020 with values less than 3 MPN. The permissible limit of fecal coliform and total coliform for transfer to surface water, discharge to absorbent wells and agricultural and irrigation purposes is 400 MPN and 1000 MPN. As a result, in terms of microbial load, the effluent of the refinery can be reused for agricultural and irrigation purposes, discharging into surface water and absorption wells. The results of Xu et al. (2022) showed that there are significant monthly changes in FC concentration and its concentrations in May to August were significantly higher than other months. The annual concentration in the entire basin increased slowly from 2008 to 2018.

Nitrate (NO_3^-)

Nitrates in various water and wastewater streams have caused concerns due to severe effects on human and animal health (Ghafari et al. 2008). The average level of NO_3^- in the effluent is 6.06 mg/liter. Its highest amount is related to May 2020 with the amount of 9.1 mg/liter and the lowest amount is related to May 2021 with the amount of 2.1 mg/liter. The permissible limit of NO_3^- for transfer to surface water is 50 mg/l, for transfer to absorbing wells is 10 mg/l, and for agricultural and irrigation purposes, the permissible limit is not specified. According to a study by Nuhoglu et al. (2002) and Han et al. (2020), nitrate-containing wastewater has negative effects on the aquatic environment and human health, and as a result leads to eutrophication of the water body and increases the risks of methemoglobinemia, non-Hodgkin's lymphoma, and heart diseases.

Sulfate (SO_4^{2-})

Sulfate is usually present in domestic wastewater in the concentration range of 20 to 60 mg/L (Moussa et al. 2006). The average amount of SO_4^{2-} is 83 mg/liter. Its highest amount is related to May 2021 with an amount of 95 mg and the lowest amount is related to May 2020 with an amount of 71 mg/liter. The permissible limit of SO_4^{2-} is 400 mg/liter for transfer to surface water, 400 mg/liter for transfer to absorption wells, and 500 mg/liter for agricultural and irrigation purposes.

Phosphate (PO_4^{3-})

When it comes to wastewater treatment, phosphate is of particular importance due to its dominant role in eutrophication in freshwater systems (Schindler

& Vallentyne, 2008). The source of phosphate is sewage, domestic drains and urban runoff containing waste and other organic matter (Tomar & Suthar, 2011; Xing et al. 2010). The results of the present study showed that the average amount of PO_4^{3-} is 2.99 mg/liter. Its highest value is related to August 2020 with a rate of 4.55 and the lowest value is related to December 2020 with a rate of 1.13. The permissible limit of PO_4^{3-} for discharging into the surface waters and discharging into the absorbent well is 6 mg/liter and the permissible limit of PO_4^{3-} for the transfer for agricultural and irrigation use, the permissible limit is not specified. In a study by Edokpayi et al. (2015), the treatment was based on biological filter. The concentration of phosphate as phosphorus (P) (1.572-4.836 mg/L) was lower than the concentration of nitrate as nitrogen (N) in the effluent during the sampling periods. The wastewater treatment plant showed P reduction efficiency only for the months of May (24%) and June (5%). This finding showed that the wastewater treatment plant was effective in reducing phosphate ions from wastewater to some extent. A high concentration of phosphate causes eutrophication as an acceleration of algae growth, which leads to a decrease in dissolved oxygen and the loss of some forms of life in water (Correll, 1998; Roelofs et al. 1984; United Nations Environment Programme, 2010). DWAF (1996) stated that phosphate concentrations greater than 5 µg/L can cause unwanted algal growth in surface waters. Considering that the amount of phosphate after treatment in this study is more than this amount, So the presence of algae in surface water is not unexpected.

Conclusion

The comparison of the results of the quality parameters with the standards of the Environmental Protection Organization showed that the effluent of the refinery is in a favorable condition for discharge to surface water, absorbent wells and irrigation and agricultural uses, which indicates the correct operation of the refinery and compliance with the established rules and standards. In addition to sufficient performance to remove physical and chemical pollutants, this system has also been effective in removing total coliform and fecal coliform.

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