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Investigation of the Composition of Industrial, Domestic and Mixed Wastewater Samples in Baku Oil Refinery

Abstract

This study provided an analysis of the chemical and biological composition of the wastewater from the Baku Oil Refinery, named after H. Aliyev, in accordance with international standards and modern physicochemical methods. During the research, physical indicators of water (pH, electrical conductivity, TSS.density, TDS, salinity, odor), chemical indicators (carbonate, hydrocarbonate, chloride, sulfate,total hardness, calcium, magnesium and potassium + sodium ions, synthetic surfactants, phenols, OKT, OBT, Oil products) and microbiological indicators (The total number of coliform bacteria, E-coli, Total microbial count) were analyzed.

The study demonstrated that the chemical, physicochemical, and biological indicators of the water discharged from diverse sources (industrial, domestic, and mixed) that comprise the wastewater are distinct.

Keywords: *oil refinery, wastewater, organic and nonorganic components, physicochemical indicators, bacteriological parameters*

Introduction

The wastewater discharged from oil refineries presents a significant environmental hazard. It is estimated that the volume of wastewater may be 40% to 160% greater than the volume of processed oil (Coelho, Castro, Dezotu, Sam Anna, 2006, pp. 178-184).

In 2020 and 2021, SOCAR's Processing Complex refineries processed 5,874.9 and 6,657.7 thousand tons of crude oil, respectively. A large amount of water is used in the processing process (SOCAR-Haqqımızda-Hesabatlar-Socar rəqəmlərdə-Emal).

The volume of wastewater generated by the Baku Oil Refinery in 2021 was 7,952,773 m^3, including the volume of wastewater discharged without treatment, 316,630 m^3, of which 309,860 m^3 was directly discharged into the water environment. The efficacy of wastewater processing is contingent upon a number of factors, including the sophistication of the processing technology employed, the operational efficiency of the facilities in question, and the overall capacity of the wastewater system. The discharged wastewater has a complex composition, including toxic components, which has a significant adverse impact on marine biodiversity. It is therefore evident that an in-depth study of wastewater composition is of paramount importance in the context of environmental protection (ASTM D 7066, 2017).

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In this study, the chemical and biological composition of the wastewater from the Baku Oil Refinery, named after H. Aliyev, was provided in accordance with international standards and modern physico-chemical methods.

The objective of this study is to ascertain the initial composition of the wastewater generated by SOCAR's Baku Oil Refinery, named after H. Aliyev, and to investigate the potential for utilizing contemporary physical methods for the purification of this wastewater, with a view to removing toxic substances.

Material and methods

The chemical and physical chemical parameters of waste water are determined by modern international standard methodic (ISO.11923, 1997, pp. 3-8; Povarova, 2018).

Microbiological tests were conducted in the “Complex Research Laboratory” of the Ecology Department of the “Ecol Engineering Service Closed Joint Stock Company” by standard methods. The tests were carried out on heterotrophic bacteria, Escherichia coli and total coliform bacteria, as well as fecal coliform bacteria. The experiments were conducted using common microorganisms. The methods for separating and evaluating coliform bacteria and E. coli were performed in accordance with the guidelines set forth in the "MUK 4.2.1884-0403 (2004)" standard. The SimPlate for HPC, US EPA method was employed to analyse heterotrophic microorganisms.

Experimental results

The content of inorganic compounds, including the hydrocarbonate ion, chloride ion, total sodium, calcium ion, magnesium ion, sulfate ion, K+ +Na+ ion, minerality, and TDS indicators, as well as physicochemical indicators such as pH, electrical conductivity, salinity, odor, suspended particles, specific gravity parameters, and concentrations of chemical compounds, including synthetic surfactants, phenols, COD, BOD, oil products, and oils, were determined by chemical and physical-chemical methods based on ISO standards and UV spectroscopy. UV-absorption spectra were recorded in a VARIAN SCAN-50 (UV-Visible Spectrophotometer) spectrophotometer at a wavelength of λ=200-800 nm in a cuvette with a volume of 4 ml and a thickness of 1 cm. Mixed wastewater solutions were prepared by combining three parts of domestic wastewater with two parts of industrial wastewater. Table 1 presents the anion analysis of the initial industrial, domestic, and mixed wastewater samples (ISO.7875-1, 1996).

Table 1

Results of anion analysis of initial samples of industrial, domestic and mixed wastewater

Parameters	Unit of measure	Analysis results		
		Industrial wastewater	Domestic waste water	Mixed waste water
Carbonate ion, CO_3^{2-}	mg/l	28,8	12	18,72
Hydrocarbon ion HCO_3^-	mg/l	592,9	307,4	278,1
Chloride ion, Cl-	mg/l	752,1	248,8	194
Total hardness, Ca^{2+}+Mg^{2+}	mg ekv/l	10,2	7,74	6
Calcium ion, Ca^{2+}	mg/l	36,6	79	73,3
Magnesium ion, Mg^{2+}	mg/l	101,5	46	28,7
Sulfate ion, $SO^4{}_{2-}$	mg/l	847,9	208,7	195,7
K^++Na^+	mg/l	891,9	199,1	185,7
Minerality (TDS)	mg/l	3261,9	1108,7	980,2

The most prevalent anions in industrial wastewater are chloride, hydrocarbonate, sulfate, and K^++Na^+ ions. The presence of these anions results in elevated mineral values. The values of calcium, carbonate and total COD are comparatively low. A similar pattern is evident in the concentration of anions identified in domestic wastewater. The concentration of anions in industrial

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and domestic wastewater is higher, with the exception of the first wastewater sample, which contains a different calcium ion. Mixed wastewater samples were prepared by combining two volumes of industrial wastewater with three volumes of domestic wastewater. It is important to note that the observed values in the mixed wastewater do not satisfy the additivity conditions. This demonstrates that the dispersed components in the collected wastewater samples are not distributed in a proportional manner during the solidification process. Nevertheless, the parameters must be based on the mass of the wastewater to be treated (ISO.11923, 1997).

The physico-chemical results of the primary water sample of industrial, domestic and mixed waste water are given in table 2.

Table 2

Physico-chemical indicators of primary sample water of industrial, domestic and mixed waste water

Parameters	**Unit of measure**	**Analysis results**		
		Industrial wastewater	**Domestic waste water**	**Mixed waste water**
pH		9,47	7,66	7,38
Electrical conductivity	μS/sm	4600	1678	1572
Salinity	$^{0}/_{00}$	2,4	0,7	1,38
The smell	ball	5	3	4
TSS	mg/l	39	47	42
Density	g/sm^3	1,0025	1,0024	1,0024

The physico-chemical parameters of wastewater samples collected from different sources vary depending on the specific characteristics of the wastewater in question. In the case of industrial wastewater, the pH, electrical conductivity and salinity values are typically higher. However, the concentration of suspended particles in domestic wastewater is higher than that observed in industrial wastewater. The specific gravity values determined for the three wastewater samples were identical, equating to 1.0025 mg/l. Table 3 presents the principal chemical analysis indicators for industrial, domestic, and mixed waste (ISO.7875-1, 1996).

Table 3

Indicators of preliminary chemical analysis of industrial, domestic and mixed wastewater

Parameters	**Unit of measure**	**Analysis results**		
		Industrial wastewater	**Domestic waste water**	**Mixed waste water**
Synthetic surfactants	mg/l	1,291	0,530	0,8
Phenols	mg/l	0,496	0,144	0.3
COD	mg/l	26,4	3,2	12,5
BOD	mg/l	17,95	2,176	4.24
Oil products and oils	mg/l	43,47	17,84	14,14

The chemical components of industrial wastewater are more expensive than those of domestic waste due to the greater number of chemical compounds created during the processing of industrial waste. The table below presents the results of a biochemical analysis of household and mixed wastewater samples.

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Table 4.

Coliform bacteria in domestic and mixed wastewater samples, *E. coli*, total bacteria count (22°C), total bacteria count (37°C)

Bacteriological parameters	Unit	Industrial wastewater	Domestic waste	Mixed waste water
The total number of coliform bacteria	CFU/100 ml	<1	1	<1
E-coli	CFU/100 ml	<1	<1	<1
Total microbial count (22 ℃)	CFU/1 ml	800	2200	2000
Total microbial count (37℃)	CFU/ml	633	1835	1670

The biochemical analyses of the industrial, domestic, and mixed wastewater solutions from the H. Aliyev Oil Refinery demonstrated a reduction in the levels of total coliform bacteria, E. coli, total microbial number (22°C), and total microbial number (37°C). The initial composition of the domestic wastewater demonstrated that the total microbial number (22°C) and total microbial number (37°C) were 800 and 633 colony-forming units (CFU) per millilitre, respectively. In the other study, it was determined that the quantity of heterotrophic bacteria and other microorganisms present in samples obtained from seawater and domestic tap water sources within the Hovsan coastal region of the Caspian Sea may exceed the established norm (Mammadova, Gurbanov, Guliyeva, 2024; Akhmedzadeh, Gulieva, Mamedova, Guseynova, Panakhova, Gurbanov, 2019; Washington State Department of Health. Coliform Bacteria in Drinking Water; Common coliform bacteria in water, 2023).

The results of the analysis indicate that the highest indicators are consistent with those typically observed in industrial wastewater. The parameters of the mixed wastewater are consistent with the average values of the parameters corresponding to the concentrations of mixed industrial and domestic waters (ISO 6059, 1984).

Of the various types of water pollution, petroleum products represent the most significant hazard. They have a detrimental impact on human health, disrupt the ecological balance of aquatic ecosystems and cause damage to agricultural practices. Such substances may be present in a liquid in a dissolved state, in the form of an emulsion, or in the form of a sorbet (EPA 420.1, 1978).

With regard to inorganic compounds, the toxicity of a given substance is primarily determined by the redox properties of the cations and anions that constitute its composition. Inorganic cations that are practically non-toxic (Na^+, K^+, Cs^+, Sr^+) are characterized by a strong negative redox potential, which results in their ions being weak oxidising agents (ISO 6222, 1999).

Conclusion

The concentration of the principal components in the wastewater of the Baku Oil Refinery named after H. Aliyev was determined in accordance with international standards. The results demonstrated that the chemical, physico-chemical and biological indicators of the water discharged from disparate sources (industrial, domestic and mixed) that comprise the wastewater are disparate. It is therefore essential to take these factors into account when selecting appropriate cleaning technologies.

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