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Characteristics and Biodegradability of Automotive Services Wastewater Produced in Hamdan Industrial Zone/ Basrah Governorate, South of Iraq

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Abstract The characteristics of wastewater produced by automotive services, including its biodegradability, have not been studied extensively. However, without a firm base, this wastewater is usually treated by conventional biological treatment systems like that used to treat the wastewater generated from Hamdan Industrial Zone (HIZ) in Basrah governorate, south of Iraq. Thus, to justify a conventional treatment system application for reducing the environmental impact of automotive services wastewater, it is essential to characterize such wastewater. The study objective is to investigate the characteristics of the raw wastewater generated in the HIZ and identify its biodegradability measured in terms of biodegradability index which is the ratio of BOD_5 to COD. The study involved the analysis of different physiochemical parameters present in the wastewater. The study results revealed that the wastewater generated from the automotive services in HIZ can be characterized as oily, saline, organically polluted, slightly alkaline, and of strong strength. The automotive services wastewater was found to be not readily biodegradable since its biodegradability index values during the study period were below 0.5. The results showed that the major part of the non-biodegradable organics is particulate. Based on the detected wastewater characteristics, it was concluded that conventional treatment of automotive services wastewater needs to be upgraded by adding advanced oxidation and/or chemical precipitation processes for removing the non-biodegradable organics.

Keywords Automotive Services, Wastewater, Biodegradability Index, Hamdan Industrial Zone

1. Introduction

Knowing the characteristics and biodegradability of organically polluted wastewater, such as that produced from automotive service workshops, is critical in choosing its sustainable and appropriate treatment processes. To assess the characteristics and biodegradability of wastewater, two parameters are most commonly utilized: the biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD). The BOD_5, specifically, represents the quantity of dissolved oxygen required by aerobic bacteria to break down organic material over a period of five days at 20°C. The COD is measured through a chemical process involving wastewater sample digestion with acid at 150°C for 120 min under certain conditions [1]. The ratio of BOD_5 to COD represents the proportion of organic compounds in wastewater that is readily degradable. It indicates the biodegradability of wastewater and is called the "Biodegradability index" (BI) [2-4]. The BI value acts as an important index for evaluating the biological treatment system performance, where extremely low or high BI values can lead to reduced microbial diversity and result in lower pollutant removal efficiency [5]. When the BI value is 0.5 or higher, the wastewater is reflected as readily treatable through biological treatment methods. Conversely, if BI value drops to 0.3, it indicates the presence of toxic elements in the wastewater or the need for acclimated microorganisms to help in its stabilization [3].

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With a BOD/COD ratio below 0.3, biodegradation is not feasible since the waste inhibits bacterial metabolism due to its toxic or resistant characteristics, preventing biodegradation [6-9].

The COD indicates various organic contents can be differentiated based on biodegradation. The total COD can be divided into non-biodegradable and biodegradable COD. The non-biodegradable part includes soluble and particulate fractions. Soluble non-biodegradable COD (NBDSCOD) portion includes organic compounds that persist during biological treatment processes and it is released with the final effluent, while particulate non-biodegradable COD (NBDPCOD) gets trapped in the activated sludge, which is then removed through the excess sludge disposing system. When a high non-biodegradable fraction is present in wastewater, biological treatment is not an optimal choice.

Many researchers have investigated wastewater characteristics considering different parameters, including its biodegradability measured in terms of BI. Attioghe et al. [10] conducted a detailed investigation into the characteristics of raw wastewater sourced from various industries in Ghana including brewery, coca-cola, and abattoir industries. In their findings, they demonstrated the distinct nature and industrial processes' impact on wastewater composition and showed that the BI values for brewery, coca-cola, and abattoir wastewaters were 0.66, 0.35, and 0.23, respectively. Ghaly et al. [11] showed the low biodegradability of paper industry wastewater where the BI was 0.16. Abdallaa and Hammamb [7] investigated the wastewater biodegradability in eight municipal wastewater treatment plants (MWWTPs) located in Egypt and found that the BI values ranged from 0.3 to 0.96, highlighting the variability in BI values. They suggested that a constant ratio for BI cannot be assumed without consistent environmental conditions. Dahamsheh and Wedyan [12] showed that the wastewater produced from Al-Hussein bin Talal University in Jordan was highly biodegradable with BI values ranging from 0.6 to 0.95. Lakhlifi et al. [13] examined the biodegradability of raw MWW in Morocco and found that the BI was 0.49. Myszograj et al. [14] studied the characteristics of raw wastewater in five MWWTPs and one industrial WWTP and found that the BI for raw MWW varied in the range (0.38-0.67) and the BI for industrial wastewater was 0.71. Alramahi et al. [15] investigated the biodegradability of food processing wastewater in Hungary and found that the BI varied over the range (0.63-1) with an average value of 0.83. Al-Sulaiman et al. [8] investigated the biodegradability of MWW received by Al-Diwaniyah WWTP in Iraq and found that the BI was 0.69. Bader et al. [9] studied the biodegradability of wastewater originating from a power station located in Basrah Governorate, Iraq, and found that the BI varied over the range (0.33-0.89). Rudaru et al. [16] analyzed the wastewater collected from three MWWTPs in Romania and showed that the BI varied in the range (0.33-0.46), denoting insignificant BI variation. Lacalamita et al. [17] analyzed the wastewater of the laundry industry in France and indicated that this wastewater was biodegradable with BI values varying in the range (0.42-0.63).

Regarding the previous studies conducted on wastewater generated from automotive services, Rubio and Zaneti [18] and Zaneti et al. [19] studied the treatment of vehicle wash wastewater and presented its characteristics. However, they performed their studies of wastewater samples collected from API oil separation system effluent. Thus, the presented characteristics cannot be compared with those of raw wastewater. Hashim and Zayadi [20] characterized the raw wastewater collected from three car wash stations and showed that they contained phosphate, total phosphate, oil and grease, TSS, and COD at average values of 10.2, 30.9, 85.0, 325.0, and 485.0 mg/l, respectively. Mujumdar et al. [21] investigated the treatment of the wastewater generated by car washing activities and they collected raw wastewater samples and analyzed them for pH, oil and grease, BOD, COD, total solids (TS), and total dissolved solids (TDS). They indicated that the value ranges of the considered parameters were: pH- (6.94-7.75), oil and grease- (42-310) mg/l, BOD- (55-68) mg/l, COD- (440-1200), TS- (440-2800) mg/l, and TDS- (100-520) mg/l. Irsan and Soeryamassoeka [22] presented a plan for a car wash treatment system employing biofilters and indicated that the wastewater was like that generated from domestic sources. Singru et al. [23] analyzed mixed raw automotive services wastewater collected from numerous stations for the toxicants (heavy metals, poly aromatic hydrocarbons, and Polychlorinated biphenyls) besides, pH, oil and grease, and COD. They showed that the pH, oil and grease, and COD were 7.45, 989 mg/l, and 78 mg/l, respectively. Lathaa et al. [24] analyzed the characteristics of raw wastewater collected from two car wash stations with the intent of comparing their treatment by adopting different approaches. The wastewater analysis results for the first and second stations were (in mg/l, excluding the pH); pH- 7 and 7.01, TSS- 140 and 590, TDS- 1220 and 930, COD- 5186 and 72240, BOD- 1150 and 1815, and oil and grease-380-2890. The results of this study highlight the uniqueness of automotive services

wastewater; although the stations are located in the same city, the difference in the values of the considered parameters was significant.

From the above review of previous studies concerning wastewater biodegradability and the characteristics of automotive wastewater, it can be shown that the biodegradability of automotive services wastewater has not been given attention and its characteristics are site specific. However, a conventional treatment system applying a biological treatment process is applied for treating such wastewater without a firm base for adopting this approach. Thus, to justify the application of a conventional treatment system for reducing the environmental impact of automotive services wastewater, it is important to characterize the automotive wastewater. The aim of this study is to investigate the characteristics and biodegradability of automotive services wastewater generated from Hamdan Industrial Zone in Basrah Governorate, south of Iraq.

2. Materials and Methods

2.1. *Description of Hamdan Industrial Zone*

Hamdan Industrial Zone (HIZ) is the main industrial zone in Basrah Governorate, southern Iraq, for automotive (cars, trucks, motorcycles, etc.) services. It is located 6 km from the Governorate center, Figure 1. Beside the automotive services, HIZ includes other industrial firms such as aluminum, wood, steel, gypsum board, construction blocks production factories, and water desalination plants adopting reverse osmosis systems. The estimated number of firms, workshops, and factories in HIZ is about 6000 [25]. Thus, it is considered as the center of industrial activities in Basrah Governorate [26].

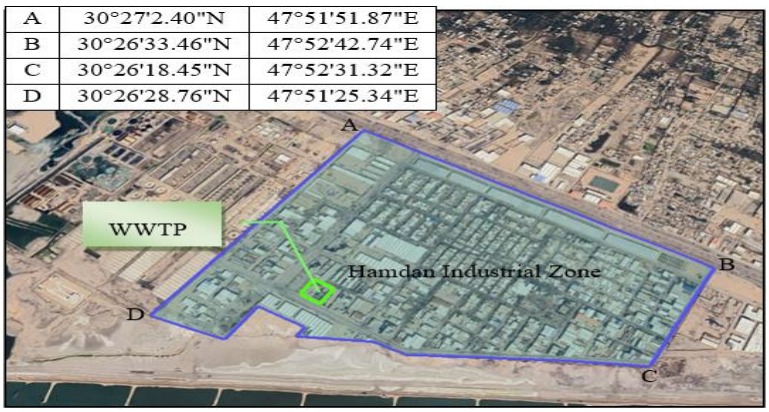


Figure 1. Location of Hamdan Industrial Zone. Map of HIZ: http://wikimapia.org/#lat=30.44305&lon=47.867775&z=15&l=0&m=b

HIZ was, recently, provided with a sewer system completed with a wastewater treatment plant, Figure 2. The plant employed a conventional treatment system adopting a sequence batch reactor (SBR) as a biological treatment system for removing the organic pollutants present in the wastewater. However, in accordance to unpublished data recorded by the lab of Basrah Sewerage Directorate, in less than three years, the plant malfunctioned in removing organic pollutants.

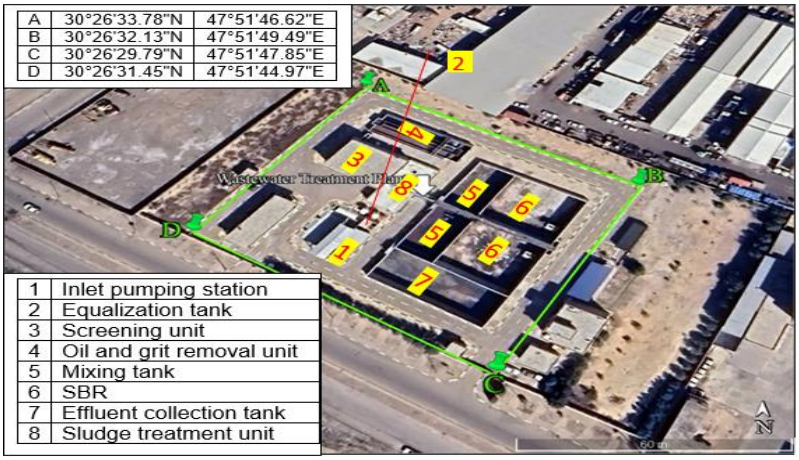


Figure 2. Location of WWTP in HIZ

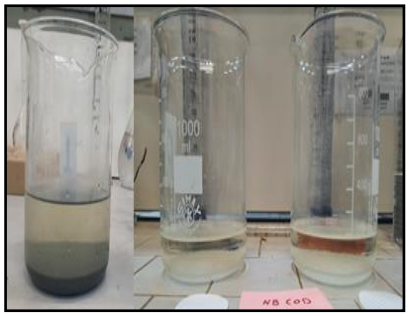
2.2. *Wastewater Sampling and Analysis*

The WWTP of HIZ incorporates an equalization tank at the plant head, Figure 2. A submersible pump was installed into the tank and used to lift the raw wastewater to an above ground tank. The wastewater samples were taken from the tank using glass containers. The samples were collected during the study period extended from 11/4/2024 to 13/7/2024. Some of these samples were used for the on-site measurement of dissolved oxygen (DO), pH, total dissolved solids (TDS), and temperature using a Hach HQ30D portable meter. The other samples were preserved at a temperature of about 4 °C and transported to the lab for analyzing the values of BOD_5, COD, oil and grease, total solids (TS), and non-biodegradable soluble chemical oxygen demand (NBSCOD). The BOD_5 and COD were measured by the BOD system Lovibond OxiDirect and DR 5000 UV-Vis Laboratory Spectrophotometer, respectively. The oil and grease and TS were measured in accordance to the standard methods 5520 B (partition-gravimetric method) and 2540 B, respectively [27].

The NBSCOD in wastewater was measured following the method of biodegradation-coagulation [28, 29]. The method procedure includes subjecting the sample to six processes in sequence; aerobic biodegradation for 24 hours, sedimentation for one hour, rapid mixing, to accomplish coagulation by the addition of zinc sulfate and sodium hydroxide, for 1 minute, and slow mixing, to accomplish flocculation, for 5 minutes, sedimentation for 1 hour, and filtration using Whatman nylon filter discs of 0.45 μm pore size to remove the particulates. Then the COD was measured for the filtrate. The obtained COD value was recorded as NBSCOD. The non-biodegradable particulate COD (NBDPCOD) was determined by subtracting the values of BOD and NBDSCOD from the total COD value. Figure 3 illustrates the steps of NBSCOD measurement.

(a) Coagulation step

(b) Flocculation step



(c) Settling step

(d) Filtration step

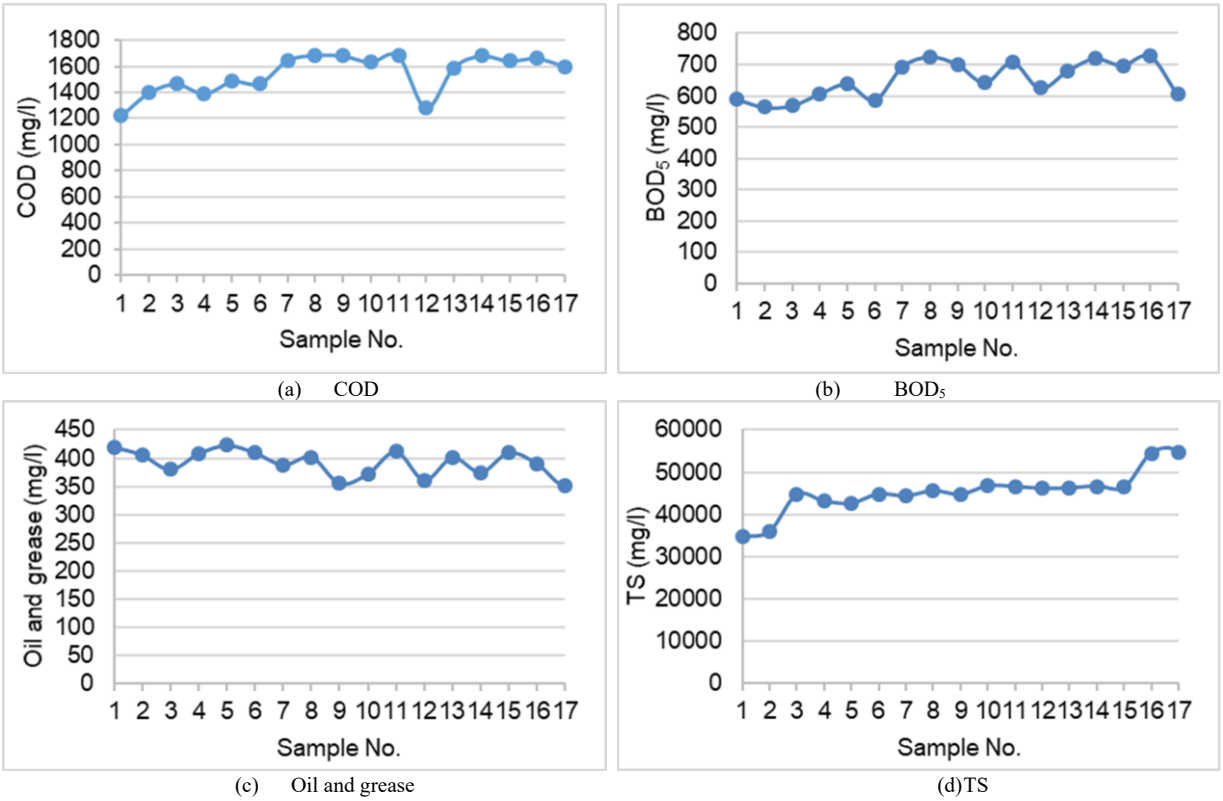
(e) Filtered samples (f) COD measurement apparatus

Figure 3. Measurement of NBSCOD

3. Results and Discussion

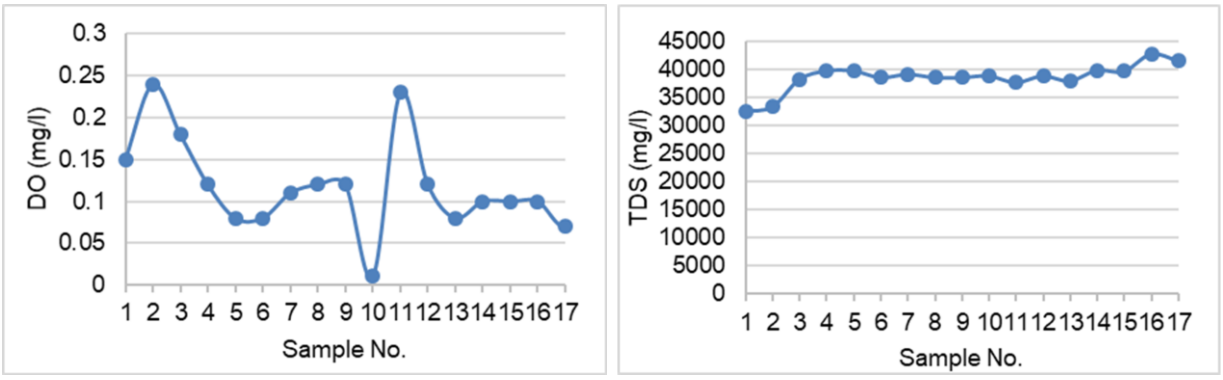
3.1. *Automotive Services Wastewater Characteristics*

The wastewater produced by the different facilities of HIZ has been analyzed for physicochemical parameters including COD, BOD_5, oil and grease, TS, DO, TDS, pH, and temperature. The variations of the measured parameters during the work period are shown in Figure 4. Statistical analysis results for the values of the measured parameters are presented in Table 1. From this table, it can be shown that the value ranges of the considered parameters were COD- (1220-1684) mg/l, BOD_5- (565-728) mg/l, oil and grease- (351-423) mg/l, TS- (351-423) mg/l, DO- (0.01-0.24) mg/l, TDS- (34670-54685) mg/l, pH- (7.01-8.30), and temperature- (23.5-35.1) °C.



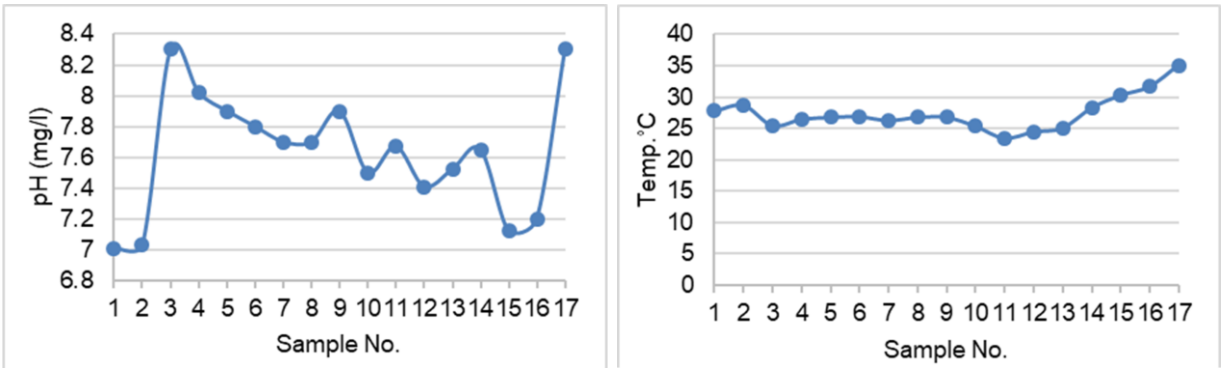
(a) COD (b) BOD_5

(c) Oil and grease (d)TS



(e) DO (f) TDS

Figure 4. Variations of physicochemical parameters in automotive services wastewater of HIZ



(g) pH (h) Temp.

Figure 4. continue

Table 1. Statistical analysis of automotive service wastewater composition

Parameter	Unit	Min	Max	Average	Standard deviation
COD	mg/l	1220	1684	1540	149.4
BOD		565	728	652	57.7
Oil and grease		351	423	392	22.8
TS		34670	54685	45169	4980.3
DO		0.01	0.24	0.12	0.06
TDS		32600	42800	38612	2465.5
pH	-	7.01	8.30	7.63	0.40
Temp.	°C	23.5	35.1	27.4	2.8

The results indicate that the wastewater generated from HIZ is oily, saline, and organically polluted. The presence of oil and organic pollutants in wastewater is due to the automotive services and sanitation facilities in the site. While, the high salinity (TDS) values can be considered a unique characteristic for such wastewater that may be present in only HIZ. That is because HIZ includes a number of private RO plants and these plants directly discharge their rejected untreated waters (brine) to the nearby sewer system, then, to the WWTP. The pH value range indicates that the wastewater is slightly alkaline and the temperature range is specific to the summer season during which raw wastewater samples were collected.

Using the wastewater characterization by strength presented by Metcalf and Eddy [3], Table 2 presents the

three levels of wastewater strength: weak, medium, and strong. Besides, it presents the average values of the measured wastewater parameters which are 1540, 652, 392, 45169, and 38612 mg/l for COD, BOD_5, oil and grease, TS, and TDS, respectively. Based on Table 2 data, the automotive service wastewater can be classified as strong strength.

Table 2. Classification of raw wastewater by strength

Parameter	Average value (present study)	Strength level (mg/l) [3]		
		Weak	Medium	Strong
COD	1540	250	430	800
BOD_5	652	110	190	350
Oil and grease	392	50	90	100
TS	45169	390	720	1230
TDS	38612	270	500	860

The relationship between BOD_5 and COD of raw automotive services wastewater is shown in Figure 5. This relationship can be represented by the following linear equation which has a correlation coefficient (R) of 0.78.

$$BOD_5 = 0.3031COD + 185.23 \quad (1)$$

3.2. *Biodegradability of Automotive Service Wastewater*

The biodegradability of raw wastewater generated from HIZ has been assessed using the biodegradability index (BI) and by measuring the concentrations of non-biodegradable soluble COD and non-biodegradable particulate COD (NBDSCOD and NBDPCOD). The BI results are shown in Figure 6. They reveal that the BI ranged from 0.38 to 0.49 with an average value of 0.42 and a standard deviation of 0.03. Since all the BI values were less than 0.5, the wastewater generated from the automotive services can be considered not easily biodegradable. This result highlights the necessity of upgrading the WWTP in HIZ by adding other treatment processes like advanced oxidation processes using ozone, UV, peroxide, .., etc.

The variation of NBDSCOD and NBDPCOD in raw automotive wastewater during the study period is shown in Figure 7. The values of NBDSCOD and NBDPCOD vary over the ranges (336-448) and (266-571) mg/l, respectively. Figure 7 illustrates that the soluble fraction of non-biodegradable COD may be greater or less than the particulate one. However, in 76.5% of the wastewater samples, the NBDPCOD fraction is greater than the NBDSCOD one. Thus, the major part of the non-biodegradable organics is particulate, which can be trapped within the activated sludge and removed from the main wastewater stream by the settling. Generally, a particle size distribution analysis is needed to decide whether these particulates can be settled with or without the need for chemical treatment by coagulation.

The correlation between BI and NBSCOD is depicted in Figure 8. The figure shows a reasonable relation between BI and NBSCOD where the BI decreases with the increase of NBSCOD.

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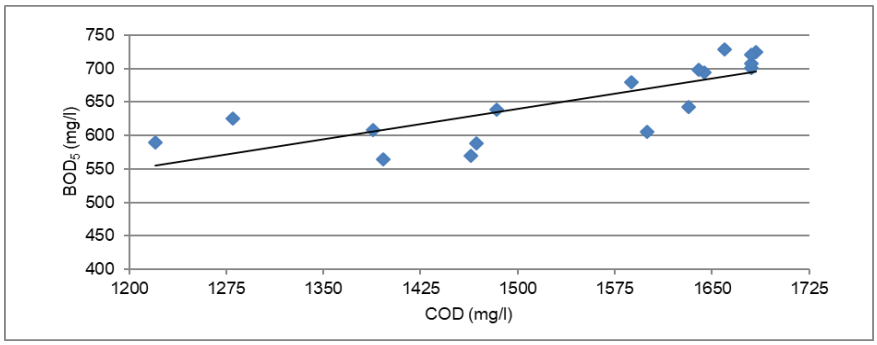

Figure 5. Relationship between BOD_5 and COD

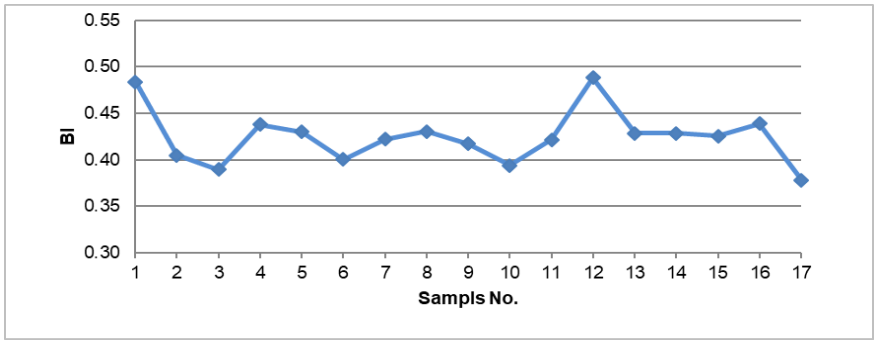

Figure 6. BI variation of automotive services wastewater

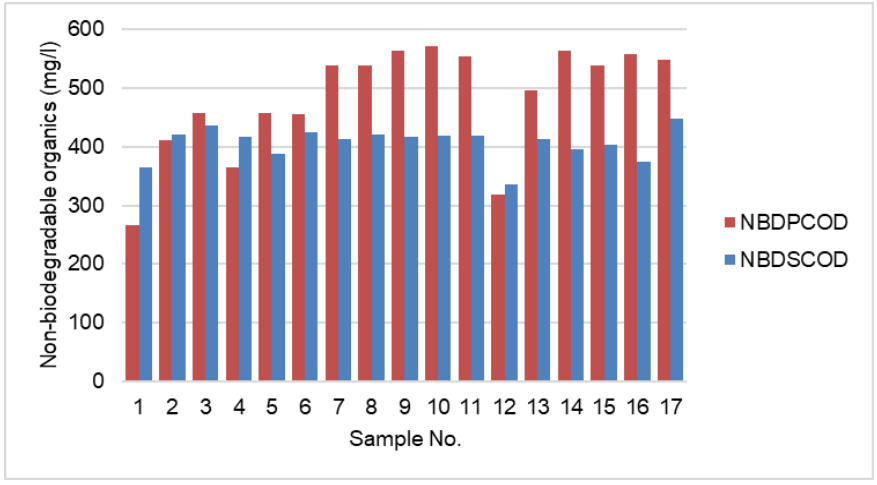

Figure 7. Soluble and particulate non-biodegradable COD

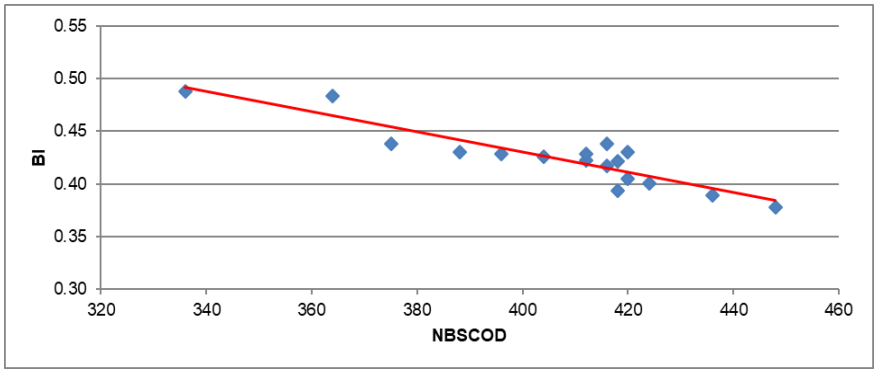

Figure 8. BI versus the NBSCOD

4. Conclusions

The wastewater generated from automotive services in HIZ can be characterized to be oily, saline, organically polluted, slightly alkaline, and of strong strength. It has biodegradability index values that vary in the range (0.38 to 0.49) and thus it is not easily biodegradable. The values of NBDSCOD and NBDPCOD in the raw wastewater vary over the ranges (336-448) and (266-571) mg/l, respectively. The study results revealed that the major part of the non-biodegradable organics that may be removed by the settling is particulate.

Generally, the conventional treatment of automotive service wastewater by biological processes is not sufficient and it is necessary to incorporate an advanced oxidation process and/or chemical precipitation for removing the non-biodegradable organics.

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Conflicts of Interest: The authors declare no conflict of interest

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