Using Vacuum Distillation Technique to Treat Waste Lubricating Oil and Evaluation its Efficiency by Chromatographic Methods

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Abstract

Today the world cares about recycles of industrial wastes in order to reduce the pollution in the environment and economic purposes. Waste lubricating oil is one of these residues that cause water, air and soil pollution when disposed of without treatment. In this work, vacuum distillation technique was applied to purify waste lubricating oil after primary treatments such as separation of water and filtration. Gas chromatography analysis was used to study the changes in chemical structures of the hydrocarbon fractions of treated lubricating oil and comparison them with those in fresh oil. The results showed that, the C_{10}-C_{15} hydrocarbon fraction is increased and the C_{20}-C_{25} is decreased for all type of hydrocarbon chemical structure after use of the lubricating oil. On the other hand, the comparison of hydrocarbon fraction of waste lubricating oil and gas oil showed that, there is close similarity between them according to the results of gas chromatography analysis.
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Keywords: Waste Lubricating Oil Treatment, Gas Chromatography Analysis, Vacuum Distillation.

Introduction

Mismanagement of used lubricating oil in Iraq is serious environmental problem because it is going directly into waterways, or pouring onto land, or being combustion in the air. So, it can save energy and avoid environmental pollution by recycled lubricating oil [1-2]. The main importance of lubricating oil is used to lubricate moving parts of internal combustion engines, it also cool the engine by carrying heat away from moving parts and inhibit corrosion [3]. Regeneration or refining are the main process that are applied on used lubricating oil to produce materials which can be alone used as base oil or fuel or blending with other substances [4-5]. Petroleum lubricating oil is composed of hydrocarbon compounds containing 15-50 carbon atoms per molecule in different arrangements which may divided into three grouping: paraffinic which have straight chains, naphthenic which have ring structures, and aromatic which have aromatic ring. The importance point is that the grouping of lubricating oil molecules are stable have wear out but it can be degrade or cleavage under friction or during usage [6].

After a period of use, the lubricating oil losses its lubricating properties because of the accumulation of contaminants such as gasoline, additives (detergents, dispersants, oxidation inhibitors, rust inhibitors, viscosity improvers), nitrogen and sulfur compounds, a broad range of aromatic and aliphatic hydrocarbons with chain lengths ranging from C_{15} to C_{50}, and metals such as lead, zinc, calcium, barium and magnesium. These contaminants arise from normal wear of engine components and from heating and oxidation of lubricating oil during engine operation [7-8]. Used oil may contain higher percentages of polycyclic aromatic hydrocarbons (PAHs) range from 34 to 190 times higher than those in fresh motor oil. Napththalene and acenaphthalenes were detected in used oil samples by Cotton et al. [9]. There are several papers concerned on the study the physical properties of the waste lubricating oil [10], but limited studies in the literature have assessed the chemical composition of automotive lubricating oils; however, many of these papers are dated and new oil manufacturing technologies, including the use of new additives, combined with different engine type sand operations will result in the production of new wastes. Waste lubricating oil characterization can be achieved using Fourier transform infrared (FTIR) [11], atomic absorption spectrometry (AAS) [12], Karl Fischer titration (KFT), malvern particle analyzer (MPA) as well as performing calorimetric and emission tests [13].

Gas chromatography is becoming increasingly important for accurately determining the concentrations of certain contaminants - particularly fuel and glycol in used oil samples [14-17]. While there is very little information regarding the chemical transformation about the chemical changes on the hydrocarbon compounds in oil itself. So, the aims of this study was to determine the hydrocarbon compounds that found in lubricating oil after usage and study the change that occurred in it by comparing with it in fresh lubricating oil as well as gas oil by using gas chromatography technique.

Materials and Methods

Materials

The tested sample of fresh generator lubricating oil was obtained from Shell company and applied in electrical generator machine type (400 kv) Perkin company for (150 hr) as recommended by supplied company. At the end of the determine time, the oil was drive out and collected from machine for treated and analysis. Gas oil was obtained from Aldora refinery. Chemicals such as hexane, heptan, octane, nonane (all ≥99% purity) were purchased from Fluka company and used as standards for identification of compounds in gas chromatography instrument.

Chromatographic System and Conditions

The compounds were analyzed by gas chromatograph Shimadzu 214 equipped with a split/splitter injector, a flame ionization detector (H_2 as fuel from hydrogen generator and air generator) and a SE 30 (3m×2 mm) column. The column temperature was 80-250ºc for 50 min rate 5 ºc /min. The injector temperature was 260ºc and detector temperature was 270ºc. The carrier gas (nitrogen ≥99 purity) was obtained from nitrogen generator from domanick henter company.

Hydrocarbon fractions have been estimated by GC in comparison with standard materials. The percentage of hydrocarbon fractions have been calculated by dividing the peak areas of fraction to the total areas of peaks of sample.

Experimental Procedures

The collected waste lubricating oil was poured into container and allowed to settle for 24 hr to remove water. The upper layer of the mixture was filtered. The filtrate was placed in the distillation flask and the heating was started under vacuum pressure (5 mmHg), collect the distillate at temperature ranging from 120-350ºc leaving residue in the distillation flask.

Results and Discussion

GC analysis of lubricating oil

Vacuum distillation treatment was applied in the purification of waste lubricating oil to determine the change in chemical composition of the waste lubricating oil and compare it with fresh lubricating oil and gas oil using gas chromatography technique.

In this study, it was concentrated on the light fraction of the hydrocarbon compounds which have carbon number 10-25 because it can be analyzed by GC-FID technique very simple. The GC–FID chromatogram of hydrocarbon compounds occurring in both the fresh and used lubricating oil as well as gas oil were expressed as broad bell-shaped curves from 0-50 min (Figs. 1A, 1B, 1C). The GC chromatogram of used oil Fig.(1A) revealed numerous new and more intense peaks fromC_{10}-C_{25} compared to those in fresh oil.

The degradation of hydrocarbon compounds of waste lubricating oil was evaluated by comparing the area percentage of the hydrocarbon compound with those of the fresh lubricating oil.

Here in, HC1 refers to n-paraffinic compounds (n-C_{10}-C_{25}) and HC2 refers to isoparaffinic, cyclic, and aromatic compounds (C_{10}-C_{25}).

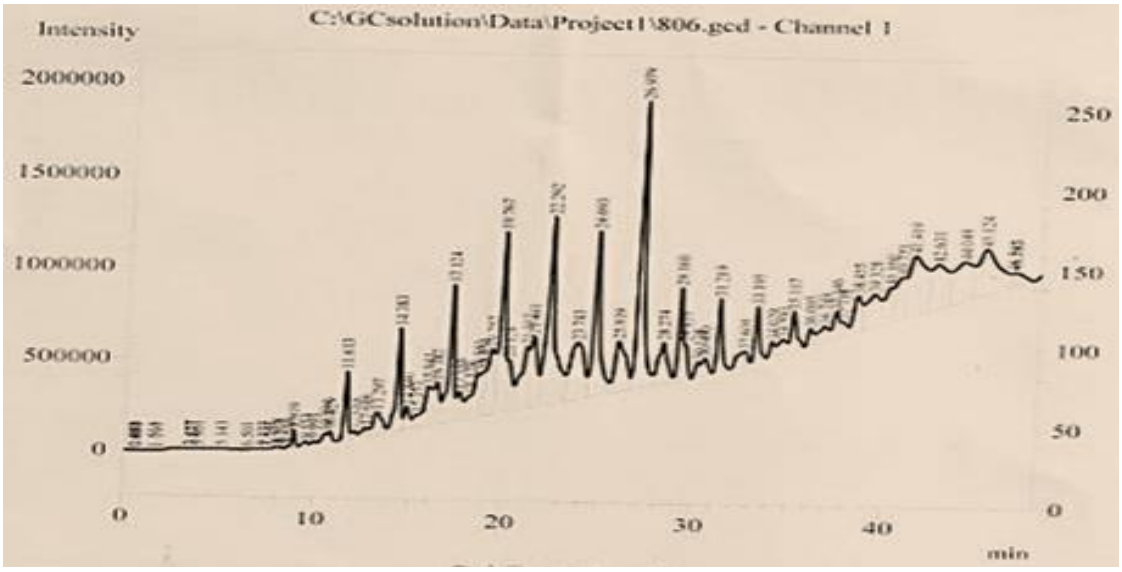


Fig.(1A): Chromatogram of waste lubricating oil.

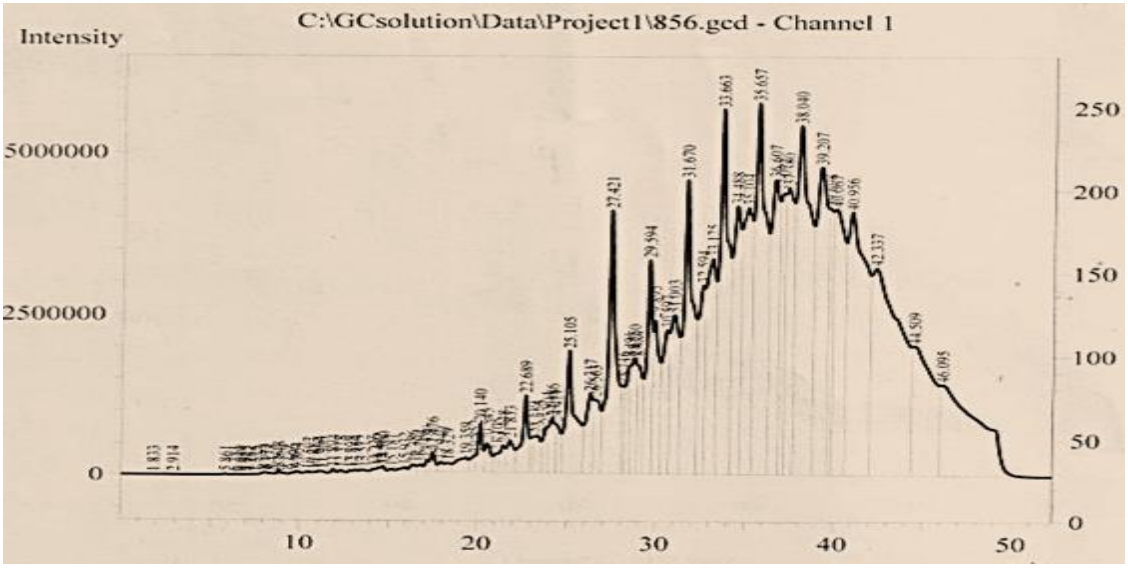


Fig.(1B): Chromatogram of fresh lubricating oil.

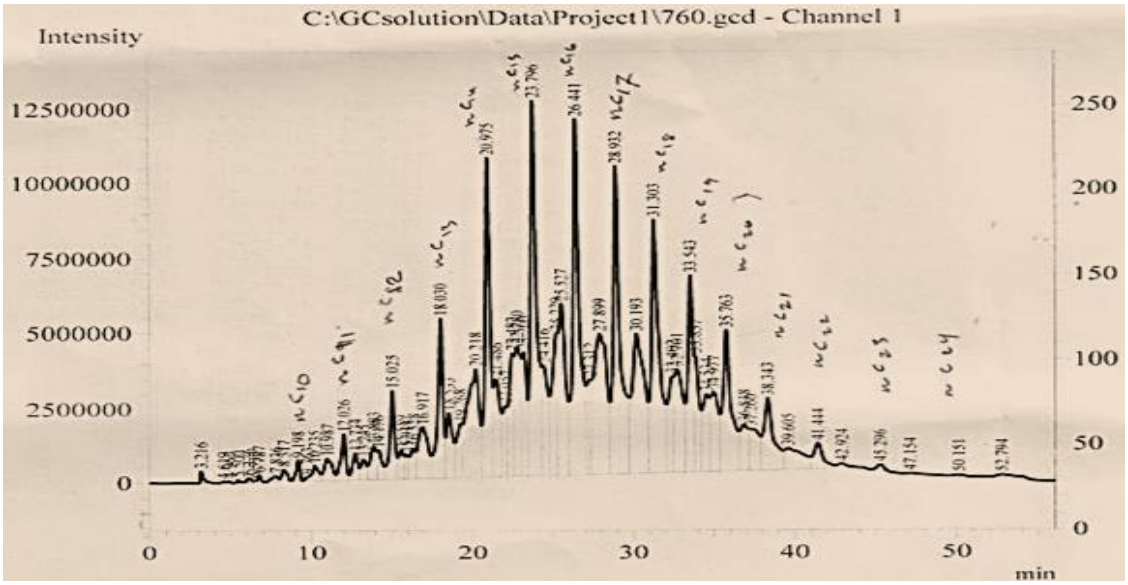
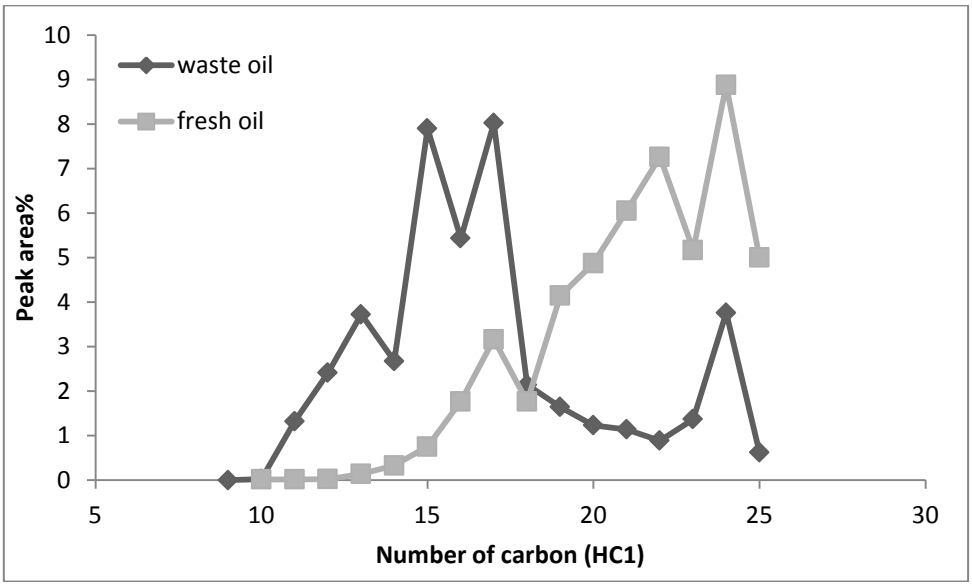


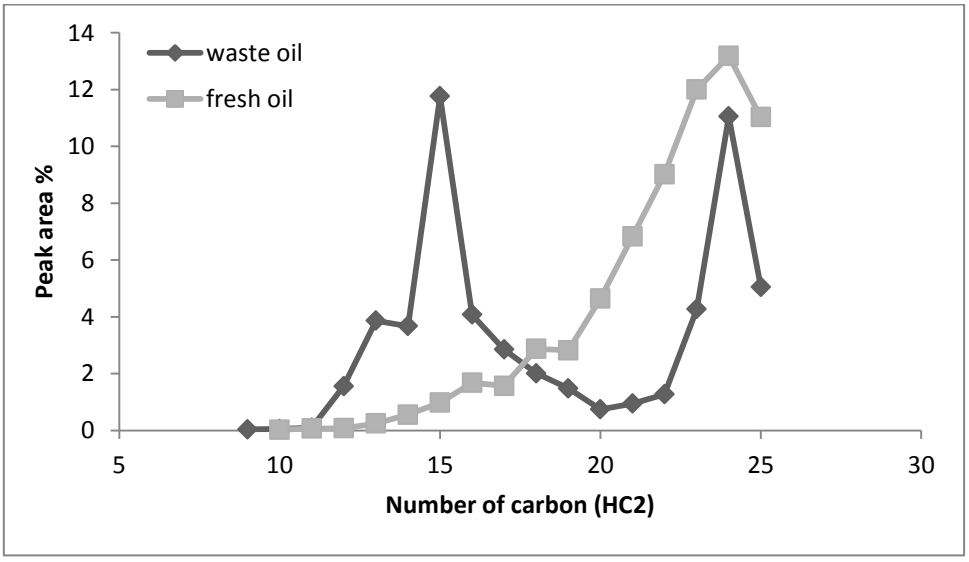
Fig.(1C): Chromatogram of gas oil.

Comparison of hydrocarbon compound of waste and fresh lubricating oil

Fig.(2A) shows the relation between the percentage of peak area for normal paraffinic compounds HC1 and the number of carbon atoms for both fresh and waste lubricating oil after vacuum distillation.



A



B

Fig.(2): Comparison of peak area between fresh and waste lubricating oil after vacuum distillation:(A) normal paraffinic compounds, (B) isoparaffinic, cyclic, and aromatic compounds.

As shown from Fig.(2A) of the appearance of the number of compounds have carbon atoms 10 and a clear increase up to 15. This is a result of the break-up and decomposition of hydrocarbon compounds which found in lubricating oils. Fig.(2B) shows the relation between the percentage of peak area for isoparaffinic, cyclic, and aromatic compounds HC2 with the number of carbon atoms for both fresh and waste lubricating oil after vacuum distillation. From the Fig.(2B), there is an increase in the concentration of hydrocarbon compounds which posses carbon atom number ranging from 11 to 16 and this is because of breakage and decomposition that occurs in long chain hydrocarbon fraction in the waste lubricating oil during usage.

As a result, the data presented is summarized in Table (1) which showed that the change percentage of HC1 and HC2 of hydrocarbon compounds of waste lubricating oil as compared with the fresh one, it was observed that the increasing of C_{10}-C_{15} fraction at about 10 times and decreasing of C_{15}-C_{20} fraction at quarter for HC1and half for HC2, while the C_{20}-C_{25} fraction stay stable as comparing between waste and fresh lubricating oil.

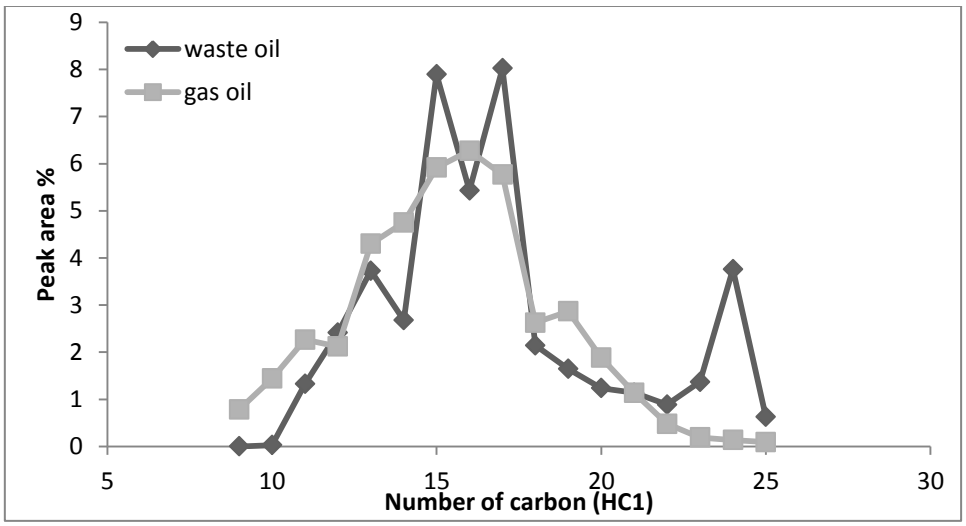
Table (1)
HC1 percentage of waste and fresh lubricating oil.

Hydrocarbon Fraction	HC1 fresh oil %	HC1 waste oil %	HC2 fresh oil %	HC2 waste oil %
C_{10}-C_{15}	1.293	18.066	1.949	21.008
C_{15}-C_{20}	15.720	18.749	13.590	11.158
C_{20}-C_{25}	32.362	7.783	52.070	22.070

Comparison of hydrocarbon compound of waste lubricating oil and gas oil

Figures (3A, 3B) show the relation between the number of carbon atoms for both gas oil and treated waste lubricating oil and the percentage of peak area for normal paraffinic compounds HC1 and isoparaffinic, cyclic, and aromatic compounds HC2 respectively.

As is clear from Fig.(3), there is close similarity of the quality and quantity of hydrocarbon compounds between waste lubricating oil and gas oil.



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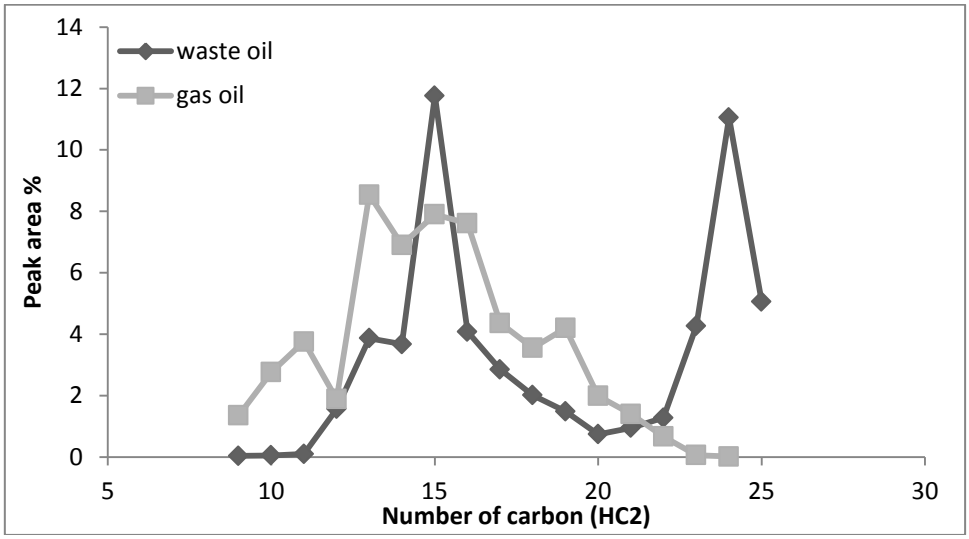

B

Fig.(3): Comparison of peak area between gas oil and waste lubricating oil after vacuum distillation:(A) normal paraffinic compounds, (B) isoparaffinic, cyclic, and aromatic compounds.

Table (2) showed that, the change percentage of HC1 and HC2 of hydrocarbon compounds of waste lubricating oil and gas oil.

Table (2)
HC1and HC2 percentage of waste lubricating oil and gas oil.

Hydrocarbon Fraction	HC1 diesel fuel %	HC1 waste oil %	HC2 diesel fuel %	HC2 waste oil %
C_{10}-C_{15}	20.876	18.066	33.107	21.008
C_{15}-C_{20}	19.419	18.749	21.739	11.158
C_{20}-C_{25}	2.031	7.783	2.142	22.070

Comparison of hydrocarbon compound of HC1 and HC2 of waste lubricating oil

An interesting observation from Fig.(4) and Table (3) is that, the used lubricating oil contain close percentage of HC1 and HC2 for both C_{10}-C_{15} and C_{15}-C_{20} fractions while there is large difference for C_{20}-C_{25} fraction.

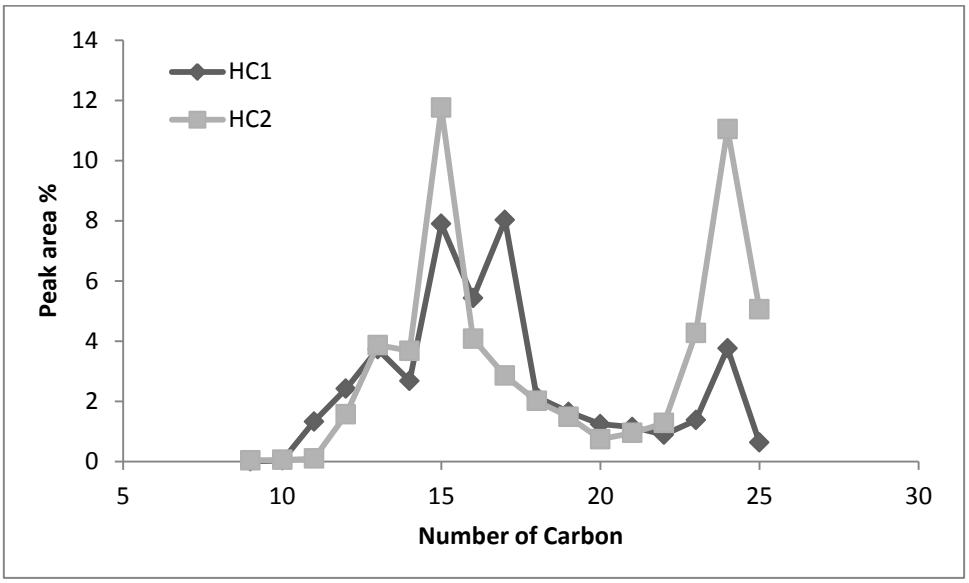

Fig.(4): Comparison of peak area between normal paraffinic compounds and isoparaffinic, cyclic, and aromatic compounds of waste lubricating oil after vacuum distillation.

As a result, the data presented is summarized in Table (3) which showed that the change percentage of HC1 and HC2 of hydrocarbon compounds of waste lubricating oil.

Table (3)
HC1 and HC2 percentage in waste lubricating oil.

Hydrocarbon Fraction	HC1 %	HC2 %
C_{10}-C_{15}	18.066	21.008
C_{15}-C_{20}	18.749	11.158
C_{20}-C_{25}	7.783	22.070

Conclusions

The usage of lubricating oils in machines running on the decomposition and break the chains of straight, branched, cyclic, and aromatic hydrocarbon compounds to the compounds have smaller molecular weights than those that found in fresh lubricating oil. The treatment of waste lubricating oils by using vacuum distillation is an effective method to remove impurities and produce hydrocarbon compounds which was similar to those that found in gas oil in chemical structure. So, the treated waste lubricating oil may be used as fuel alone or blending with another fuel.

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